Semi-nomadic pastoralism and the conservation of biodiversity in the Richtersveld National Park, SOUTH AFRICA

by

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Thesis presented for the Degree of
DOCTOR OF PHILOSOPHY
in the Department of Botany
UNIVERSITY OF CAPE TOWN

March 2004

Disclaimer

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

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H.H.Hendricks (Date)

Acknowledgements

The most important source of assistance throughout this study has been that provided by my supervisors and I wish to thank them wholeheartedly for their guidance;

Peter Novellie who invited me to participate in an embryonic two year research project initiated by him on the management of the Richtersveld National Park. This project later evolved into a study on the possible coexistence of livestock farming and biodiversity conservation, which ultimately developed into this thesis. I must also thank him for his continuous support throughout the study period as this study would not have happened without his valued advice and boundless enthusiasm.

William Bond has been a great teacher and mentor. He provided an invaluable source of insights into the interface between ecological dynamics and social dimensions. William's broad knowledge assisted me to see the crux of a problem.

Jeremy Midgley has provided an enormous character to this study. His open-minded intellectual questioning brought a lot of coherence in an apparent cosmopolitan study of this nature.

I am greatly indebted to Timm Hoffman who was part of this team that designed this study during the initial stages into a fine contribution to our knowledge of communal rangelands in South Africa. Richard Knight also took a formidable interest in this study. During the study period I spent in total of one semester working with the Bureau of Land Management in the United States of America, and thanks are due to the Department of Interior for making this possible. The great problem solving mind of Benjamin Clark (Oregon State University) has helped me to overcome the numerous stumbling blocks of livestock movement tracking. Trimble (USA) kindly made a GPS toolkit available for resource mapping and movement tracking. Dick Williams (CSIRO, Australia), Norbert Jürgens and Timm Hoffman made valuable comments on an earlier draft paper of Chapter 8 while Philip Desmet refereed the paper on diet selection (Chapter 7). Peter Scogings and anonymous referee made valuable comments on an earlier draft paper of Chapter 6. I received invaluable advice from Mike Knight on population ecology. I am also very grateful to Hugo Bezuidenhout and Graham Williamson who assisted me in identifying various plant species and communities. I would like to thank Christo Smith with whom I have had long discussions about recommended agricultural practices. I am also thankful to many of my friends who took an interest in my work and provided encouragement; Susi Vetter, Philip Desmet, Ivor James, Doug Johnson, Bruce Anderson, Simon Todd, Norman Harris, Kenneth Buk and Lita Webley. Ashia Petersen shared the high and low moments during this study. A special "thank you" is due to Koos Jossob, Johannes Domrogh and Rufus Hein who helped me to collect field data.

The pastoralists, their families and herders in the Richtersveld National Park endured the intrusion into their lives with good grace and unfailing courtesy. They gave me a place to sleep, shared a plate of food and allowed me to herd their animals.

The project was financially supported by the WWF-SA. A special 'thank you' to the South African National Parks for providing a platform to complete my study.

A deep appreciation of the loving-yet-critical support of my family. My family was always there to give me moral support, a room of my own when visiting UCT and took a strong interest in the progress of my research study.

Finally, my twin daughters (Celeste and Celine) endured my long absence in the field or in front of a computer with good grace and humour. I am privileged to have a supportive wife such as Elnarie .... I didn't have to die to see an angel!

Abstract

The thesis presented here is about traditional semi-nomadic pastoralism and the conservation of biodiversity in a semi-arid South African National Park. The aim was to help improve farmer livelihoods without compromising the unique biodiversity of the area, especially the succulent plants. The thesis sets out to analyse the dynamics of pastoral activities with the Richtersveld National Park (RNP), focussing on the relationship between pastoralism and livelihoods; the impact of grazing on vegetation biodiversity; and a synthesis of these in order to suggest management strategies to minimise conflicts between pastoralists and conservation interests, both of whom have a stake in the future management of the park.

It is currently argued by rangeland theory that by lowering the size of a herd, the productivity of individual animals will increase and that this smaller herd size will conserve rangeland. So, in theory, reduced herd sizes would be beneficial to biodiversity conservation and herd performance. In common with most of pastoral Africa, de-stocking is difficult to implement in the RNP because it is unpopular and there is no clear agreement on which of the 20-odd pastoralists should be reducing their herd size. So how does herd size of a pastoralist influence (a) herd performance and pastoralist livelihood, and (b) biodiversity conservation?

Chapter 1 frames the problem between semi-nomadic pastoralism and biodiversity conservation, using the Richtersveld National Park case study, and so asks what chance is there for a sustainable coexistence between livestock farming and the conservation of biological diversity in communal rangelands?

Chapter 2 describes the physical and ecological aspects of the RNP, including the semi-nomadic pastoral system of the Nama people.

Chapter 3 attempts to understand the management of the RNP in the overall context of its management history, livestock population patterns and the importance of livestock in the household economy of pastoralists. Both literature reviews and Participatory Rural Appraisal (PRA) techniques were used to determine the historical profile of the RNP. Livestock

populations were counted four times a year (January, April, July and October) between 1995 and 2002. During these visits, pastoralists were interviewed on herd offtake and mortality. Data concerning household meat consumption and monetary income/expenditure were not based on accurate records, but on pastoralists' estimates. Total stock numbers for the RNP (ca. 4 500 SSU) never exceeded the set carrying capacity of 6 600 SSU during the study period; goat populations exceeded sheep and cattle by far. Herd number increased from 13 in 1995 to 18 in 2002. The mean herd size recorded was 391 animals. The average income from stock sales was ca. R750 per month compared to pastoralists monthly expenditure of ca. R2 000. Pastoralists slaughtered about two animals per month.

Chapter 4 examines the regulatory effect of rainfall on stock numbers, and how herd size and pastoralist interventions and skills impact on livestock performance. The analyses in this chapter are based on the data set collected in Chapter 3. Here, I address the question whether herd size matters for herd performance; specifically if an increase in herd performance is achieved with smaller herd sizes, if small herds have a higher risk of complete extirpation than larger herds and if herd performance is a function of various production objectives. I found that total stock numbers were regulated by annual rainfall, usually a lag effect of 1-2 years. This study found little relationship between herd size and herd performance, or herd size and density dependent stock losses and recovery rates during a two year drought. Smaller herds have a higher risk of disappearing than larger herds during a severe drought. Herd size manipulation is not an effective intervention for pastoralist livelihood and biodiversity conservation in the RNP

Chapter 5 assess the seasonal movement patterns and daily foraging activities of livestock, making use of both GPS and telemetry data collection techniques. The second part of the chapter quantifies the potential impacts of herd movement on conservation-worthy sites. Seasonal herd movements were characterised by regular treks of approximately 10km between the Upland Succulent Karoo veld ('buiteveld') in the winter and the Orange River pastures in the summer. The average foraging range was 2.5km, ca. 1 900 ha available grazing area. Goats and sheep walked much more quickly in the morning (ca. 1km/hr) than in the afternoon (ca. 0.5km/hr). During these seasonal movements and daily foraging activities, livestock foraged a large proportion (ca. 60%) of areas with special conservation importance between 1995 and

2001. A few stock posts (ca. 10) were located within the conservation-worthy sites.

Chapter 6 explores why pastoralists do what they do in the RNP. This study includes their herd production objectives, stock ownership patterns, and local knowledge about factors influencing herd size. movement from one stock post to another and the underlying motives for decision-making. Here, I used a suite of PRA techniques to collect the relevant data. I found that the traditional pastoral system is witnessing some changes. This is based on my suggestions that people begin to rely more heavily on remittances sent by relatives or allowances from government, the Nama language is mainly spoken by the older people still speak the Nama language make common use of it, animals are also hardly kept for ceremonial (sacrificial) purposes anymore, and the fact that the average pastoralist in this study was older than 50 years and the majority of pastoralists made use of 'hobby farming'. The herd production objectives varied between pastoralists, not all were trying to increase production. Pastoralists followed different approaches to track available resource.

Chapter 7 determines the diet selection of goats with a focus on diet composition, plant growth forms, principal and preferred food plants in comparison with the conservation status of food plants. This study includes five-minute feeding observations during the winter rainfall period between 1997 and 1998. I found that goats exploited a wide array of food plants both in terms of species composition (ca. 90 species) and growth form (ca. 10 different types). Only four of these species eaten had Red Data List status while the rest of the species were considered to be of low conservation priority.

Chapter 8 investigates the effects of livestock foraging activities on the plant species richness and composition along a foraging intensity gradient. Here, I mainly hypothesised that livestock grazing reduce the diversity of plants closer to the stock post and highest plant species richness should be associated with low stocking densities from smaller herd sizes. Evidence for comparable transects analysis were established between small (<300 animals), medium (between 300-500 animals) and large herds (>500 animals). Foraging intensity gradients existed at distances away from stock posts. Distance from the stock post was characterised by the lowest plant species richness and diversity near the stock posts. I found that plants able to endure the effects of heavy grazing occurred near stock posts where declines in palatable plant species, assumingly sensitive to heavy grazing and trampling, were recorded. Grazing increased vegetation patchiness closer to the stock post. However, the degree to which the change in species composition occurred did not depend on stocking densities, suggesting that herd size was not a major determinant of the amount of biodiversity loss. Just the sustained use of an area leads to biodiversity loss and hence, the effect of actual herd size on vegetation remains unclear.

Chapter 9 synthesis all the above information and makes suggestions in refining resource management strategies for the RNP. In the context of this study, I conclude that it is unlikely that lower stocking densities will increase herd performance or promote biodiversity conservation. The route to improve livelihoods may owe more to assistance to pastoralists than attempts to reduce herd size. To the extent that herd size does matter, the optimum herd size in the RNP may be ca. 400 animals for maximum sustained yield. I recommended zonal land use plans and a ban on the establishment of new stock posts as the most effective compromise between the pastoralists and conservation objectives.

Contents

Chapter 1
Introduction

Conservation today is about forming a bridge between humans and the environment in a long term and sustainable way. This thesis is about semi-nomadic pastoralism and biodiversity conservation in a protected area in South Africa. The Richtersveld National Park (RNP), where this study was conducted, is located in an arid karoo shrubland renowned for its high biological diversity of plants and animals, and levels of endemism. The central focus of the RNP is to maintain its unique plant diversity, especially succulent plants. However, the RNP forms past of the Richtersveld communal rangelands which traditionally have been used for livestock production. The RNP is home to a group of pastoralists making a living, although not exclusively, from their livestock. The total number of livestock that can be kept in the RNP has been set under contractual agreement as the upper limit (6 600 SSU) that the RNP rangeland can support. Conflict is inevitable under these circumstances, so what chance is there of a sustainable coexistence between livestock farming and biodiversity conservation?

1.1 The issue of biodiversity and its conservation

The definition of biodiversity (Gaston 1996) is fraught with contestations and uncertainty (Bowman 1993; Guyer & Richards 1996), and continues to generate more heat than light. Generally, biodiversity is an abbreviated form of the term biological diversity, which infers a diversity of plants and animals at different spatial and temporal scales. It has also been variously described as 'the wealth of life on earth', 'the diversity of life' and 'the variety of living organisms and the ecological complexes in which they occur' (Brown 1998). Scott *et al.* (1995) defined biodiversity as the richness, abundance and variability of plant and animal species and communities and the ecological processes that link them with one another and with soil, air and water.

Popular perception often sees the promotion of biodiversity as a matter of saving species, but in reality species exist only as part of ecosystems and cannot survive unless their ecosystems are conserved along with as much as possible of the diversity they contain (Martinez 1996). Excellent summaries of the issues involved in maintaining biodiversity were provided by Hudson (1991), Scott *et al.* (1995), Soulé & Wilcox (1980) and Wilson (1985 & 1992), while Noss

(1990) discussed the compositional, structural and functional aspects of biodiversity in general terms.

Southern Africa has the richest flora in the world for its area (Cowling *et al.* 1989). Both Tanzania, South Africa and Madagascar are classified among the 25 most biodiverse countries. South Africa ranks sixth in the world for the size of its flora; a considerable number of plant species (>75%) are endemic to the region (Cowling & Hilton-Taylor 1997). It has a variety of biomes including Mediterranean-type, arid, alpine and tropical environments. Within these biomes there is a high species diversity and endemism such as is found in the Cape Floristic Region (Figure 1.1).

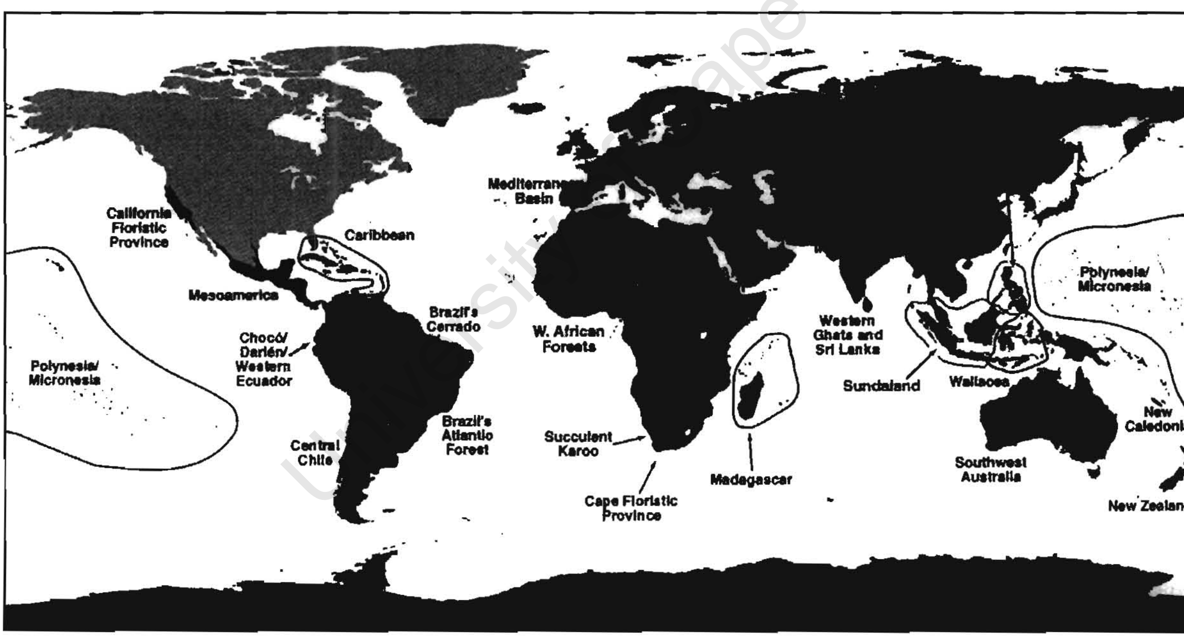


Figure 1.1. The 25 biodiversity hotspots in the world according to Myers *et al.* (2000).

Other hotspots of biodiversity, emphasising their importance and threatened status, are the Succulent Karoo biome (Hilton-Taylor 1996), the grasslands and shrublands of the Maloti-Drakensberg mountains, the moist grasslands of the interior and the northeast coastal wetlands and woodlands. Not only do these biodiversity elements represent an important component of the human life-support system, but they are important potential assets as valuable genetic resources or as a basis for a profitable tourist industry. Namaqualand, arguably the richest desert in the world (Myers *et al.* 2000), contains a diverse flora and fauna with exceptionally high levels of endemism. The succulent plant species richness is especially useful in terms of biodiversity conservation; in addition to their unique adaptations to arid areas, their fragility and economic use in pharmaceutical industries (Cunningham 1989), succulents of the region comprise nearly 10% of the world's succulent flora (Cowling & Pierce 1999).

Biodiversity is a critical yet frequently undervalued component of our natural environment (Pearce & Moran 1994); currently ca. 6% surface area of South Africa is allocated for the protection of biodiversity resources in formally protected areas (10% conforms to IUCN recommendations). Siegfried (1989) and Lombard *et al.* (1995) found that the existing reserve network in South Africa provides a remarkably good species coverage despite the *ad hoc* and arbitrary manner originally used to proclaim protected areas. Biodiversity loss is the key motive behind most conservation efforts (Frankel & Soulé 1981). There is a world-wide concern at the extent to which biodiversity is being lost, especially habitat destruction among mammal and bird diversity (May 1992). A projection suggested that between 10% and 40% of plant and animals may be extinct in 50 years (Wilson 1988). Here, I do not deliberately attempt to ignore the critical awareness around the biodiversity debates against bias toward ideological persuasion (several authors, such as Lomborg, have contested these predictions).

Biodiversity conservation goals are unlikely to be achieved if not pursued within the broader framework of sustainable development. At the political level, South Africa (and many other countries) endorses numerous international conservation treaties and conventions. At the same time, as a society undergoing democratisation, this country is confronted with the challenge of ensuring that the current and potential benefits derived from protected areas are more equitably distributed throughout society than in the past. This has required a paradigm shift from that of 'conservation cannot be practised unless indigenous people are removed' to the recognition that conservation cannot be guaranteed in the long term unless it has the support of the local people (Cock & Koch 1991). In fact, nowadays, it is often neither politically feasible nor ethically justifiable to exclude local people from conservation matters such as protected area management. This compels conservation objectives to be increasingly integrated with social and economic strategies (Ghimire & Pimbert 1997). As a result, conservation strategies nowadays seek significant roles in supporting social and economic development at a local level (Botha 2003). For example, the current Working for Water Programme (Van Wilgen *et al.* 2002) contributes significantly to levering economic and social benefits and reducing the direct costs of conservation (Sandwith 2002). The Programme, which was developed to control invasive alien plants and provide social improvement, contributes towards promoting social equity through training for economically marginalised people and job creation. At the same time it maximises an ecosystem service, the delivery of water, and also protects biodiversity. Community Based Natural Resource Management has been the new wave of conservation in the last few decades (Cock & Fig 2002), with projects such as CAMPFIRE in Zimbabwe developing as new models for how to involve local communities in the management of natural resources (Madzudzo 1996).

1.2 Rangelands and protected areas

Rangelands constitute by far the majority of the land surface of South Africa (Botha 2003; Hoffman *et al.* 1999). Today, many of the National Parks comprise parts of old farms previously used as rangelands (Magome & Murombedzi 2003). Indigenous African mammals have been introduced in most parts of these areas. However, the RNP is very unusual in that it remains under the use of pastoralists for domestic livestock grazing. The original inhabitants remain within the RNP and a committee comprising of park officials, community members and a representatives of the pastoralists reviews RNP management decisions. This has made it clear that we can no longer rely on easy traditional yardsticks, such as recommended agricultural stocking rates, to meet the survival needs of rural communities and simultaneously retain representative conservation areas with threatened ecosystems in rangelands. Managing land use in these rangelands is imperative socially, economically and ecologically if we are to retain those ecological characteristics needing to be conserved.

The motive for the establishment of protected areas has been to conserve natural ecosystems and biodiversity in the face of increasing utilisation and destruction of the environment by humans (McNeely & Pitt 1985). Biodiversity conservation should assume top priority (Ehrlich 1988; McNeely 1992; Myers 1979; Wilson 1988). In developing countries protected areas for conservation have often meant displacement of rural communities. The view commonly portrayed is that poor people have access to fewer (often marginalised) resources under communally-owned tenurial arrangements and are forced to over-exploit these resources to maintain their standard of living (Avoka 2002; Jolly 1994; Scherr 2000). The management philosophy emphasized that the public good was best served through the protection of natural resources, even if this meant the displacement of local communities (Ghimire & Pimbert 1997). By and large, the concept and practice related to environmental protection were based on the ideological principles and techniques of recommended agricultural practices on rangelands of mainly the commercial sector.

The communal rangelands are viewed as overgrazed, degraded, unproductive and overstocked (Lamprey 1983). When compared with commercial farming areas, communal grazing in South Africa is also perceived as unsustainable (de Bruyn *et al.* 1998) and the degradation of natural resources is viewed as a result of poor management practices (see Vetter 2003 for a review of the current debate about degradation in communal rangelands). These views raised concern about the ecological sustainability of communally grazed rangelands.

However, Sullivan & Rohde (2002) critically reviewed the current economic and ecological assumptions of existing debates on communal rangelands and suggested that a range of factors are central issues in the assessment of ecological sustainability of rangelands. Perhaps, the most basic flaw in ecological sustainability lies in the concept of carrying capacity as applied to arid and semi-arid rangelands (Behnke *et al.* 1993; Illius & O'Conner 1999). The idea of carrying capacity implies that the environment is capable of supporting a set number of grazing animals, and by implication a certain maximum sustainable yield for offtake. When stocking levels are maintained below carrying capacity (i.e. maintain sustainable livestock production), there will be unused resources (Tainton *et al.* 1980); above carrying capacity will result in environmental damage (Hardin 1968). A shortcoming of the carrying capacity concept is that it is often regarded as a static assessment, while it should be seen as varying in space and over time. Rangelands are temporally variable, mainly as a result of seasonal and inter-annual variation in rainfall, and this results in variation in both forage availability and quality (Danckwerts & Tainton 1996). Rangeland environments are thus 'patchy', and pastoralists make use of this patchiness to sustain high stocking rates in communal areas (Ellis & Swift 1988; Scoones 1989). Mobility of herds is central to this strategy (Smith 1992), which Sandford (1983) has characterised as tracking feed supplies in time and space or 'opportunism'. Understanding the influence and diverse consequences of livestock grazing on communal rangelands is therefore a complex process. The notion that subsistence agriculture on communal land is synonymous with poverty and range degradation has also been questioned (Boonzaier *et al.* 1990). Behnke & Scoones (1992), Ellis & Swift (1988), Ward *et al.* (1998) and Rohde *et al.* (1999) also inferred that there is no obvious relationship between communal rangeland management and natural resource degradation.

1.3 Communal rangelands and ecological sustainability

Communal rangelands make up 13% of the land surface of South Africa (Scogings *et al.* 1999). These rangelands are characterised by an 'open access' system; animal production on land where the tenure system provides access to rangeland to all members of the community holding the land (de Bruyn *et al.* 1998). Grazing on communal rangelands is important for livestock products (such as meat and milk). Land under communal tenure is home to a quarter of South Africa's population (Scogings *et al.* 1999). Many of the households also depend on rangeland resources to supply them with fuelwood (Shackleton 1993; Solomon 2000), medicinal plants (Cunningham 1985) and construction material (Evans 2001; Liengme 1983). Land use in the Richtersveld is close to an 'open access' system in that any land within the RNP can be utilised by any of the pastoralists. However, there is an upper limit on the stock numbers and the number of pastoralists.

Understanding the underlying mechanisms of vegetation and animal dynamics in arid and semi-arid rangelands has been an area of much debate, especially over the last decade or so (Briske *et al.* 2003; Desta & Coppock 2002; Ellis & Swift 1988; Illius & O'Connor 1999; Sullivan 1996; Sullivan & Rohde 2002; Vetter 2003). Vegetation and herbivore dynamics on rangelands are conceptually related to two (primarily opposing) theories; equilibrium and non-equilibrium paradigms.

At a population level, it is suggested that herd performance varies primarily as a function of herd size. This is demonstrated by the Jones & Sandland (1974) model which is based on the theory of logistic population growth. It is assumed that the 'ecological carrying capacity' (N_{max})

of the rangeland is maintained at the point when herd size stays constant (in other words, births equal deaths and there is zero weight gain). The maximised production (N_{opt}) is at half of this herd size, beyond which the addition of more animals leads to a decrease in herd performance. Therefore, the common recommendation is to reduce herd size to about half N_{max} for maximum offtake.

At the plant community level, the rangeland succession model (derived from the Clementsian succession model for range condition and trend analysis, *sensu* Dyksterhuis 1949) is based on the assumption of optimum production between the pioneer and climax stage and stocking rate is the main determinant of vegetation composition. Too high stocking rates will lead to a reduction in veld production while too low stocking rates will have similar effects. Vegetation change follows a linear progression in time through an orderly and predictable series of successional stages until a climax community stage is reached, with flexible movement backwards and forwards along the continuum (Stafford Smith & Pickup 1993). Its associated metaphor 'the balance of nature' depicts that the impact of grazing would drive the system away from the climax state, and with the reduction or elimination of grazing the system would naturally progress to the climax stage (Behnke & Scoones 1993). Any landscape, according to the equilibrium theory, has a certain carrying capacity (Fritz & Duncan 1994), and a negative feedback between animal numbers and the availability of forage will produce a stable equilibrium between animal and plant populations (Bell 1985; Caughley 1979). A key assumption is that conditions for plant growth are relatively constant and, therefore, animal populations are regulated by increased competition for food resources in a density-dependent manner. as herbivore populations grow, they exert negative, density-dependent feedback on their own productive performance. Intermediate stocking rates are, therefore, recommended for optimum veld production (O'Connor & Roux 1995).

Unlike commercial farmers, pastoralists in communal areas are not beef producers. These pastoralists have different objectives, which generally lead to preference for maximising total animal numbers (N_{max}) and not N_{opt}. The view that plants and animals exist in some sort of equilibrium has also been criticised for its inapplicability to the event driven nature of arid and semi-arid rangelands (Ellis *et al.* 1993; Ellis & Swift 1988; Westoby *et al.* 1989). Herd production may also vary more with, for example, rainfall than with herd size (e.g. Fynn & O'Connor 2000), so that reducing stocking rate is not an effective tool for increasing production. A key factor in whether rainfall variability could control herbivore populations is drought frequency (Ellis *et al.* 1993) which poses another challenge to rangeland ecologists examining the population stability of grazing animals (Coppock 1993). The non-equilibrium paradigm proposes that climate (i.e. rainfall) variability plays the major role in keeping herbivore numbers below a density at which they could negatively affect themselves or influence the environment in many pastoral areas of Africa (Ellis & Swift 1988; Pickett & Ostfeld 1995; Scoones 1994).

It is suggested that the succession of plant community is not linear because vegetation change is not stocking rate dependent (Westoby 1989). Besides the suggestion that some systems never reach the perceived climax state (Stafford Smith & Pickup 1993), the removal of grazing does not necessarily lead to a plant community undergoing succession towards a more preferred state (Westoby *et al.* 1989). Secondly, animals are only food limited in severe droughts when herds experience much death and there is likely to be enough food after the drought. A higher frequency of drought reduces the chance that herbivore numbers will steadily grow and increases the chance that the forage base will be dominated by unstable annuals adapted to aridity. In areas that experience low and highly variable rainfall, the effective carrying capacity (and hence stock numbers) fluctuates considerably between years when drought frequencies are high, and variation in the inter- and intra-annual rainfall are large (Ellis & Swift 1988). This is because repeated mortalities during droughts followed by slow herd recovery keep livestock densities below equilibrium. Only in severe drought extended over several years will the vegetation be affected by livestock grazing, but this vegetation recovers quickly when the droughts ends. For this reason, it has been argued that grazing by animals should have no effect on the plant production and hence, the reduction of stock numbers on heavily degraded lands is not seen as a worthwhile intervention in arid and semi-arid regions (Ellis & Swift 1988).

Illius & O'Connor (1999) opposed this argument and suggested that animal numbers do have an impact on resources, even if the effect is minimal and not evenly distributed throughout the landscape. They argue that animal numbers are regulated in a density-dependent manner by the limited forage available for use in the dry season, with numbers being virtually uncoupled from resources elsewhere in the system. The paradigm also does not account for the maintenance of stock numbers during the dry season by artificial water provision, forage supplements and 'key resource' areas. When evaluating if land use by grazing induced changes, one emerging view is that non-equilibrium systems may pertain more to highly arid environments, while equilibrium features may prevail more in semi-arid and sub-humid zones (Coppock 1993; Ellis *et al.* 1993; also see Sullivan & Rohde 2002). Studies that analysed the movement responses of grazing animals in a seasonally varying environment for pastoralism (Coppock *et al.* 1986; Goldstein *et al.* 1990; McCabe & Ellis 1987; Pratt *et al.* 1986) and wild ungulates (Inglis 1976; Williamson *et al.* 1988) have suggested grazing systems in which plant and animal dynamics are largely independent of one another. However, ecosystems at equilibrium and non-equilibrium are not distinguished on the basis of unique processes or functions, but rather by the evaluation of system dynamics at various temporal and spatial scales. Rangelands ecologists proposed that equilibrium and non-equilibrium are extremes along a continuum and the transition between the two states can occur in both directions, although not with the same ease or triggered by the same process (Illius & O'Connor 1999; Milton & Hoffman 1994; Westoby *et al.* 1989). Briske *et al.* (2003) and Coppock (1993) suggested that many grazing systems in Africa encompass elements of both equilibrium and non-equilibrium states.

1.4 Richtersveld National Park case study

The Richtersveld National Park (RNP) is located in the semi-arid northwestern corner of South Africa and forms a significant part of the under-conserved Succulent Karoo biome (Table 1.1). It is considered to be unique with respect to the high diversity of dwarf, endemic succulent plants (Cowling *et al.* 1999). More than 30% of the succulents in the Richtersveld flora are listed in the Red Data list of Hilton-Taylor (1996). The only colonies of *Lithops herrei* (Williamson 1995) and *Amaryllis paradisicola* (Williamson 2000a) have been recorded inside the RNP. Three species (*Pectinaria articulata* subsp. *borealis*, *Stapelia neronis* and *Quaqua pruinosa*) are extremely rare and so far also only recorded from single mountain peaks in the RNP (Williamson 2000b). The endangered *Aloe pillansii*, endemic to the Richtersveld, is on the brink of extinction with only a third of its current population formally protected in the RNP.

Table 1.1 Total surface area (ha) of the biogeographic areas in the Succulent Karoo biome conserved in formally protected areas.

District / Region	Protected area	Total area (ha)	% Area of Succulent Karoo biome
Namaqualand	Richtersveld National Park	162 445	1.983
	Namaqua National Park	55 000	0.671
	Helskloof Nature Reserve	10 900	0.133
	Goegap Nature Reserve	15 000	0.183
	Moedverloor farm protected area	7 000	0.085
Hantam Karoo	Tankwa Karoo National Park	18 664	0.228
	Akkerndam Nature Reserve	2 750	0.034
	Gannabos Heritage Site	300	0.004
	TOTAL	272 059	3.321

At the same time the RNP also forms part of the Richtersveld communal rangeland. RNP is the only complete Contractual National Park in South Africa (Chapter 2) and the South African National Parks pays rent to the Nama people who own the land and have the right to use it for their own purposes (mainly livestock grazing). The RNP rangeland is managed for goat and sheep farming as well as biodiversity conservation under a contractual agreement between the South African National Parks and the Nama people of the Richtersveld. The original inhabitants remain within the RNP. The RNP is home to a group of pastoralists making a living, although not exclusively, from their livestock. The total number of livestock that can be kept in the RNP has been set under contractual agreement as the upper limit (6 600 SSU) that the RNP rangeland can support. A committee comprising of park officials, community members and a representatives of the pastoralists reviews RNP management decisions.

The objectives of the pastoralists may not be mutually compatible with those of conservation because herbivores are generally thought to have great impacts on ecosystems, especially biodiversity (Hilton-Taylor 1994), species composition (Shackleton 1998; Todd & Hoffman 1999), plant productivity (Palmer *et al.* 1990) and soil erosion (Hoffman *et al.* 1999). It has also been suggested that high stocking rates decrease plant diversity (Fynn & O'Connor 2000; O'Connor & Roux 1995). Range managers are able to manipulate the impacts on the vegetation through stocking rate.

However, in arid environments with very high climatic variability, such as experienced by the RNP, stocking rate may have minimal effects on the vegetation dynamics as argued by Ellis & Swift (1988). The reduction in animal numbers might also influence the well being of the pastoralists in the RNP (standard rangeland theory). The problem is how to accommodate these apparently conflicting aims in the RNP. More importantly, can the conservation and pastoralist objectives be mutually compatible given the high degree of aridity and predominance of fragile, succulent plants? The challenge is to manage the area in such a way as to maximise the socio-economic development of livestock production without compromising the conservation of its biological diversity.

1.5 Study objectives

The thesis set out to explore aspects of the livestock enterprise which influence pastoral livelihoods and the impacts of grazing on the vegetation in the RNP in order to suggest relevant management strategies for this protected area. The findings of this study could be used as a guide for policy makers to minimise conflict between the pastoralists and the maintenance of biodiversity in the Succulent Karoo biome region in other part of the Namaqualand magisterial district.

Based on the total animal numbers and how they vary, an understanding of the relationship between rainfall, herd size and productivity was obtained as an approach to a possible rational carrying capacity that could benefit the pastoralists. The implications of such relationships are that pastoralists can be advised as to what potential herd size could be ideal for maximised useable offtake and minimised farming costs. To relate livestock grazing to biodiversity conservation, I evaluated the grazing influence of different herd sizes on the vegetation of the RNP based on diet selection, conservation-worthy sites and plant species diversity.

The thesis is organised as follows:

Chapter 2. To describe the physical and ecological aspects of the RNP, including pastoralism.

Chapter 3. To determine the history of livestock management, and to show how total stock numbers vary over time on the basis of livestock demography and its importance in household economy of pastoralists.

Chapter 4. To examine the regulatory effect of rainfall on stock numbers and how herd size and pastoralist interventions and skills impact on livestock performance (kidding, offtake, mortality and production).

Chapter 5. (a) To assess the seasonal movement patterns and daily foraging activities of livestock; and (b) quantify the potential impacts of herd movement on conservation-worthy sites (i.e. locations with rare, threatened and significant populations of endemic plant species) for potential biodiversity conservation strategies.

Chapter 6. To determine why pastoralists do what they do; including their production objectives, stock ownership patterns, and local knowledge about factors influencing herd size, movement from one stock post to another and the underlying reasons for decision-making.

Chapter 7. To determine the diet selection of goats with a focus on diet composition, plant growth forms, principal and preferred food plants, and the conservation status of food plants.

Chapter 8. To determine the effects of livestock foraging activities on plant species richness and composition along a foraging intensity gradient.

Chapter 9. To synthesise all the above information and make suggestions in refining management strategies in terms of 'better farming' for both people and plants.

Chapter 2

Study Area

2.1 Locality

The RNP is located (28^0 15' S; 17^0 10' E) in the semi-arid region of the Namaqualand magisterial district in the northwestern part of the Northern Cape Province (South Africa), immediately south of the Orange River which marks the international border with Namibia (Figure 2.1). The RNP covers a total area of 162 445 ha and forms part of the Richtersveld communal rangelands (513 919 ha).

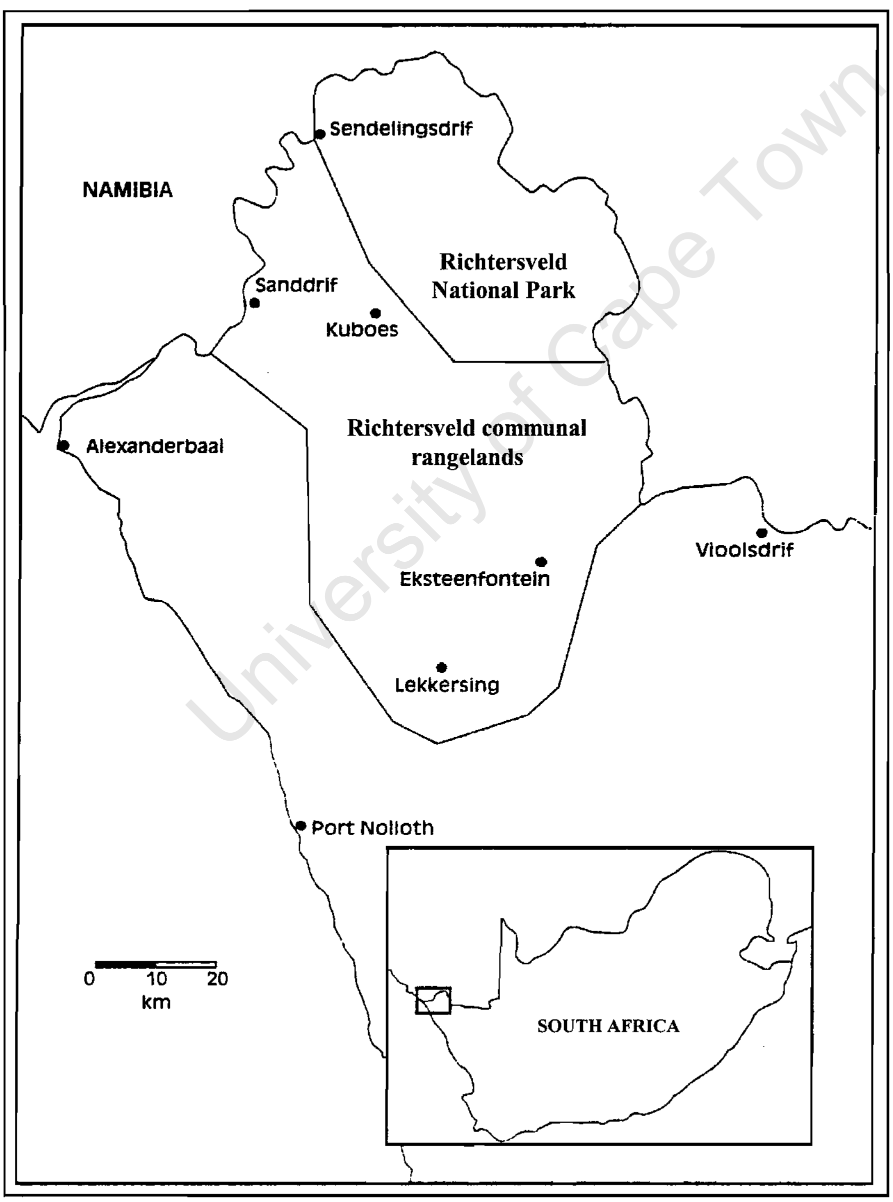


Figure 2.1. The location of the RNP in the Richtersveld communal rangelands, South Africa.

2.2 Topography

Richtersveld is regarded as remote, inhospitable and the only true mountain desert in South Africa (Van der Walt 1992). The RNP consists mostly of extremely mountainous terrain with large altitudinal changes over very short distances (Figure 2.2). Labyrinths of deep gorges and ravines meander out into dry river beds, and eventually towards the Orange River. The highest point of the RNP is in the Vandersterr Mountain (1 337 metres above sea level) while areas along the Orange River lie below the 300 metre contour. Four major land types can be identified in the RNP: (a) the Orange River and adjacent flood plains, (b) gently undulating plains, (c) rolling hills, and (d) rugged mountains. There are mainly three plains in the RNP; Koeroegabvlakte, Springbokvlakte and Rooilepel.

2.3 Geology

The geology of the RNP and immediate surroundings is underlain by rocks belonging to formations that vary in age from some of the oldest known to the youngest in South Africa. Cowling *et al.* (1999) outlined characteristics of the bioregions in Namaqualand (Table 2.1). The rocks cover a time span of 2 billion years in geological history and constitute a wide variety of rock types including volcanic, igneous and sedimentary rocks as well as their metamorphic equivalents. According to Beukes (1997), the oldest rocks are the 2000 million-year old volcanic-sedimentary rocks of the Orange River Group, which are subdivided in the Richtersveld area into two major geological units: the basal De Hoop Subgroup and the Rosyntjieberg Formation. The De Hoop Subgroup represents the remains of an ancient northwest-southeast trending belt of island volcanoes, comprising large, irregular bodies of metafelsic and metamafic volcanics and give rise to the scenic mountains in the east and northeast of the RNP. The De Hoop Subgroup is overlain by the younger Rosyntjie Formation, comprising mainly metasedimentary rocks, forming the 1 100m high backbone of the Richtersveld in the south of the RNP.

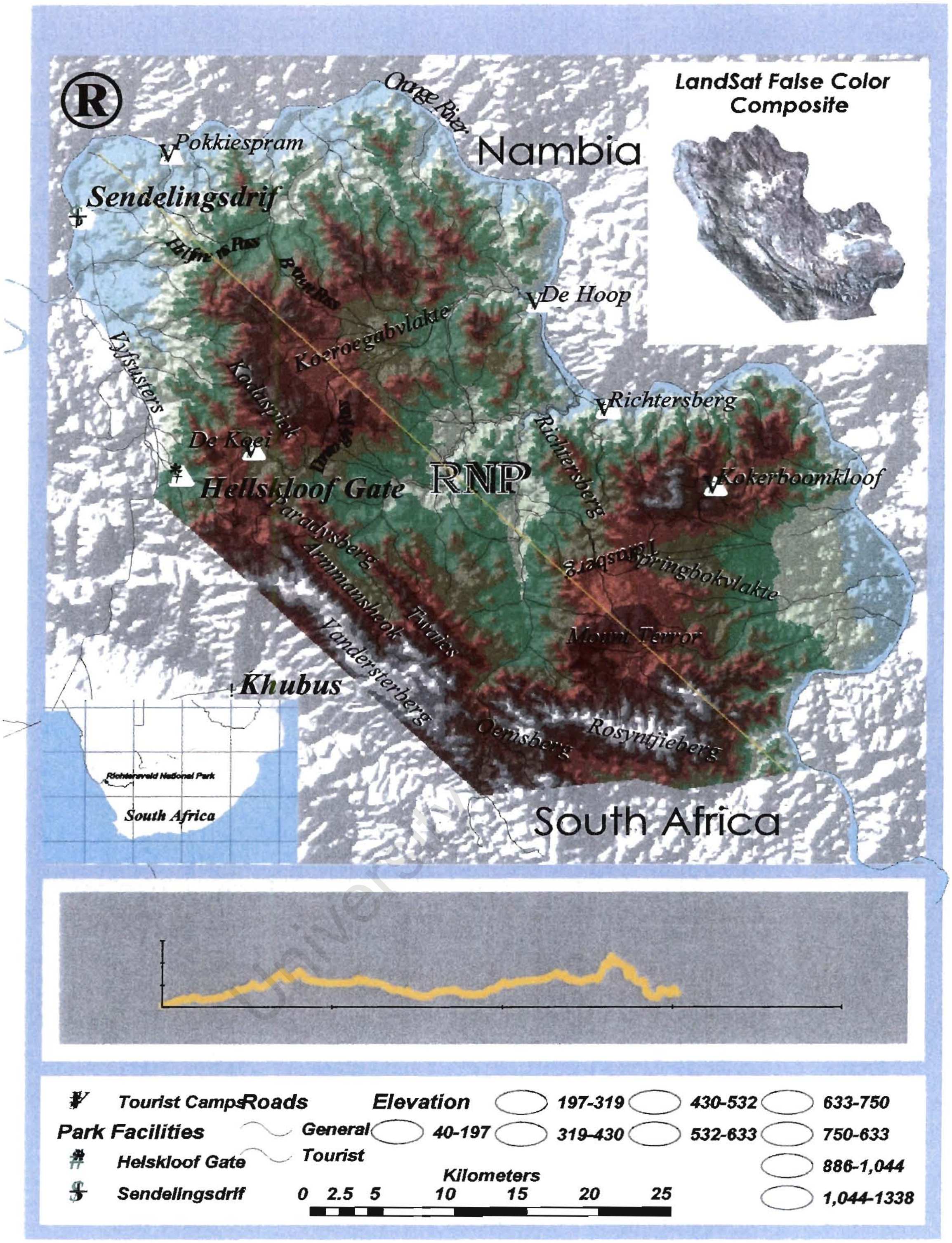


Figure 2.2. The topography of the RNP with the names of places mentioned in text.

Table 2.1. Characteristics of bioregions in Namaqualand (after Hilton-Taylor 1996). (Source: Cowling *et al.* 1999). ND = No data.

Bioregion	Area (km^2)[1]	Rainfall (mm.yr^{-1})	Geology	Major vegetation types: Acocks (1953)	Major vegetation types: Low & Rebelo (1996)
Southern Namib Desert	1 208	20-60	Recent-Tertiary sands; gravel plains; sheared and folded sediments of the Pan African Belt	Strandveld; Succulent Karoo	Strandveld; Succulent Karoo; Lowland Succulent Karoo
Richtersveld (Gariep Centre)	7 235	30-300	Sheared and folded sediments of the Pan African Belt; granite-gneiss intrusions	Namaqualand Broken Veld; Succulent Karoo; Western Mountain Karoo	Lowland Succulent Karoo; Upland Succulent Karoo; North-western Mountain Renosterveld
Hardeveld (Namaqualand Rocky Hills)	19 229	100-200	Granite-gneiss of the Namaqualand Metamorphic Province	Succulent Karoo; Namaqualand Broken Veld	Lowland Succulent Karoo; Upland North-western Mountain Renosterveld
Kamiesberg	1 211	100-200	Granite-gneiss of the Namaqualand Metamorphic Province	Namaqualand Broken Veld; Mountain Renoster Fynbos	Upland Succulent Karoo; North-western Mountain Renosterveld; Mountain Fynbos
Sandveld	11 676	50-150	Recent-Tertiary sands	Strandveld Succulent Karoo	Strandveld Succulent Karoo; Sandplain Fynbos
Knersvlakte (Vanrhynsdorp Centre)	9 549	100-200	Pan African Belt sediments; Recent-Tertiary sands	Succulent Karoo; Strandveld	Lowland Succulent Karoo; Strandveld Succulent Karoo; Sandplain Fynbos

[1] Excludes areas of bioregions (Gariep and Southern Namib Desert) in Namibia.

2.4 Climate

The RNP is located in an area where two major climate systems meet. The warm temperate winter rainfall region is mainly experienced from the central mountain range westwards while the subtropical summer rainfall region is found to the east (Van Jaarsveld 1993) with higher temperatures and low humidity (Jürgens 1986).

The climate is arid (aridity is caused by the southern subtropical high-pressure (anticyclone) belt (Desmet & Cowling 1999). The mean annual rainfall is 72 mm, but varied between 52 mm and 154 mm over the last seven years. The annual rainfall also varied from approximately 66 mm on lowlands to 124 mm in mountains. The largest proportion of the Richtersveld region receives winter rainfall in the form of soft, gentle rains - usually from late April to September with peaks in May, July and September for all weather stations. The rest of the region, mostly located along the Orange River to the east of the RNP, receives summer rainfall (October-April) in the form of thunder-showers which last for very short periods. With the exception of July, the highest mean monthly rainfall did not exceed 10 mm. Until recently, the Richtersveld never experienced a year without rain. Moisture also comes in the form of western fogs, especially during the summer mornings, rolling in from the cold Atlantic Ocean seaboard which is cooled by the Benguela Current (Williamson 1995). Desmet & Cowling (1999) showed that fog, as a source of moisture for plant growth along the west coast, is more reliable in terms of frequency and predictability of occurrence than rainfall (Plate 2.1).

Rainfall variability, expressed as the co-efficient of variation (*cv*), follows a similar trend to rainfall for the karoo. It decreases from east to west and from south to north (Desmet & Cowling 1999). The rainfall *cv* for all the weather stations in the Richtersveld region was 50%. This rainfall variability decreased slightly (45%) when only those weather stations in the RNP were considered. Generally, rainfall decreases from south to north and from west to east. When the rainfall *cv* for the RNP is compared between stations in the Nama (summer rain) and Succulent (winter rain) karoo regions, the rainfall in the Succulent karoo on average is 1.15 times more reliable than corresponding rainfall in the Nama karoo (Desmet & Cowling 1999). The average temperature varies between 25°C during January and 14°C in June. Temperatures can easily rise above 50°C in the summer and plunge to freezing point on winter nights. The mean maximum temperature rapidly declines from April to June followed by a gradual increase to a maximum in February. The decline in maximum temperatures could possibly be a result of the influence that the wind has, as it could carry advective heat from warmer areas or as a result of adiabatically heated air in the form of bergwinds. The RNP is characterised by relatively high windspeeds, overall ranging from an average of 7km/hr in January to 4km/hr in June.

Plate 2.1

A. The occurrence of fog (i.e. 'malmokkie'). **B**. Precipitation from fog on the leaves of *Aloe pearsonnii*

2.5 Water

The RNP has a total of 14 animal watering points, which include borehole windpumps, temporary springs, rock reservoirs, seepages and the Orange River. Natural springs are found in the higher mountainous regions while most granite potholes act as natural water catchments scattered around the lower lying mountainous areas. There are mainly two perennial rivers in the RNP; the Orange River and the upper stretches of the Gannakouriep River. The Orange River winds through wild gorges with towering cliffs crowding its banks.

2.6 Vegetation

The Richtersveld, in general, is regarded as one of the world's richest succulent areas (Cowling & Roux 1987; Cowling *et al.* 1999; Hilton-Taylor & Le Roux 1989; Jürgens 1985; Rutherford & Westfall 1986; von Willert *et al.* 1992). This apparent wealth is due to the large variety of geological formations, rugged relief and diverse soils, which brings about an unusual number of habitats with great difference in moisture condensation, sunlight exposure and temperature (Van der Walt 1992). Basically, moisture availability is least on plains and highest on the mountain summits. The southwest facing slopes are protected and often have a higher density of plants than the drier, lower plant-covered north and northeast slopes. The vegetation of the Richtersveld has been described by Powrie (1992), Van der Walt (1991) and Willis (1992), while Cowling *et al.* (1999) gave an overview of this unique winter-rainfall desert ecosystem.

The RNP is located in the strongly winter-rainfall part of southern Africa's Succulent Karoo biome (Milton *et al.* 1997; Rutherford & Westfall 1986) which is recognised as the Namaqualand-Namib Domain of the Succulent Karoo floristic region (Jürgens 1991). The Southern Karoo Domain (non-seasonal rainfall) makes up the rest of the Karoo region (Cowling *et al.* 1999). The vegetation of the RNP has evolved within a water-stressed environment and is thus mainly succulent, comprising more than 700 species of herbs, shrubs and trees, geophytes and annuals (Williamson 2000b). The vegetation is typical to the Upland Succulent Karoo (Low & Rebelo 1996) and associated with mainly the larger families (Mesembryanthemaceae, Asteraceae, Crassulaceae, Geraniaceae, Euphorbiaceae ad Asclepiadaceae)(Cowling *et al.* 1999).

A magnificent variety of dwarf shrubs with water-storing leaves occur in the western portion of the RNP while its eastern portion is associated with arid flora. Van Jaarsveld (1981) divided the vegetation into two main units: (1) mesophytic vegetation along the Orange River, sandy drainage lines and plains, and (2) xerophytic vegetation for the rest of the park. Acocks (1988) divided the xerophytic vegetation into Succulent-Karoo vegetation (Acocks veld type no. 31) found in the western region of the RNP, the Namaqualand Broken veld (Acocks veld type no. 33) to the north, where a rain shadow coupled with high temperatures are responsible for sparse vegetation, and the Mountain-Karoo vegetation type (Acocks veld type no. 28) found in the southeastern areas. More recently, Williamson (2000a) described a floristic-vegetation study of the RNP according to eight zones; (1) Orange River littoral and ephemeral, (2) quartz outcrops and pebbly pavements, (3) low altitude sand-grit, (4) sandy upper reaches of rivers, alluvial fans and sandy plateaux, (5) submontane zone comprising low mountains and incised gorges, (6) mountane zone, (7) mountain summits above 900 metres and (8) gorges (mainly protected moisture traps with high plant diversity).

Owing to higher rainfall (up to 300-400mm) and better soil development than the Lowland Succulent Karoo (Low & Rebelo 1996), plant communities of the Upland Succulent Karoo are more closed and have greater structural diversity (Cowling *et al.* 1999). The most unusual floral elements are concentrated in gorges, foothills and on the higher condensation mountain peaks. Members of the Mesembryanthemaceae or 'vygies' as well as of the succulent and deciduous Asteraceae are prominent in the leaf succulent-dominated vegetation (Plate 2.2). Many of the plants, some of them endemic to the RNP, also belong to the family Aizoaceae with genera such as *Conophytum*, *Lithops*, *Cheiridopsis*, *Cephalophyllum* and *Ruschia*. Asclepiadaceae is well represented by the following genera, *Hoodia*, *Trichocaulon* and *Stapelia*. Geophytes (*Gethyllis*, *Trachyandra*, *Amaryllis* and *Bulbine*) also occur in the RNP.

Trees are present in patches of evergreen thicket. For example, *Euclea pseudebenus*, *Tamarix usneoides*, *Combretum erythrophyllum*, *Salix mucronata*, *Rhus pendulina*, *Ziziphus mucronata* and *Acacia karroo* dominate the alluvium banks of the Orange River (Plate 2.3). Shrubs such as *Sisyndite spartea*, *Phragmites australis*, *Gomphostigma virgatum* and *Ectadium virgatum* var. *virgatum* also occur along the Orange River. The most common trees found on plains include *Acacia erioloba*, *Maerua schinzii*, *Parkinsonia africana*, *Euclea pseudebenus*, *Schotia afra* var. *angustifolia* and *Adenolobus gariepensis*. Some of the endemic plants include

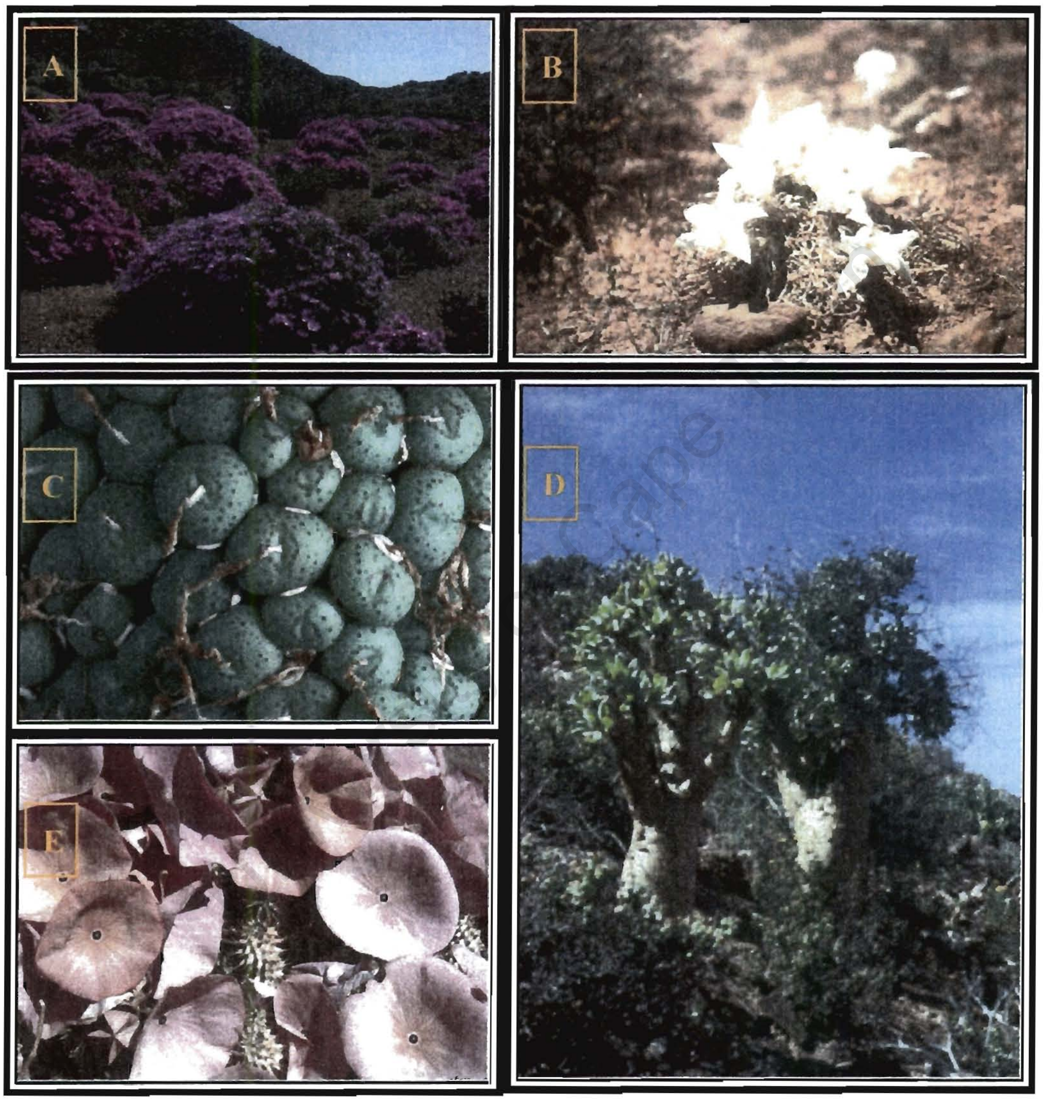


Plate 2.2

A. *Ruschia* shrubs below Koeroegabvlakte. **B**. *Gethyllis namaquensis* in flower. **C**. Old inflorescence stalks between the fused leaves of *Conophytum gratum*. **D**. The dwarf succulent treelet *Tylecodon paniculatus*. **E**. Giant succulent stapeliad *Hoodia gordonii*.

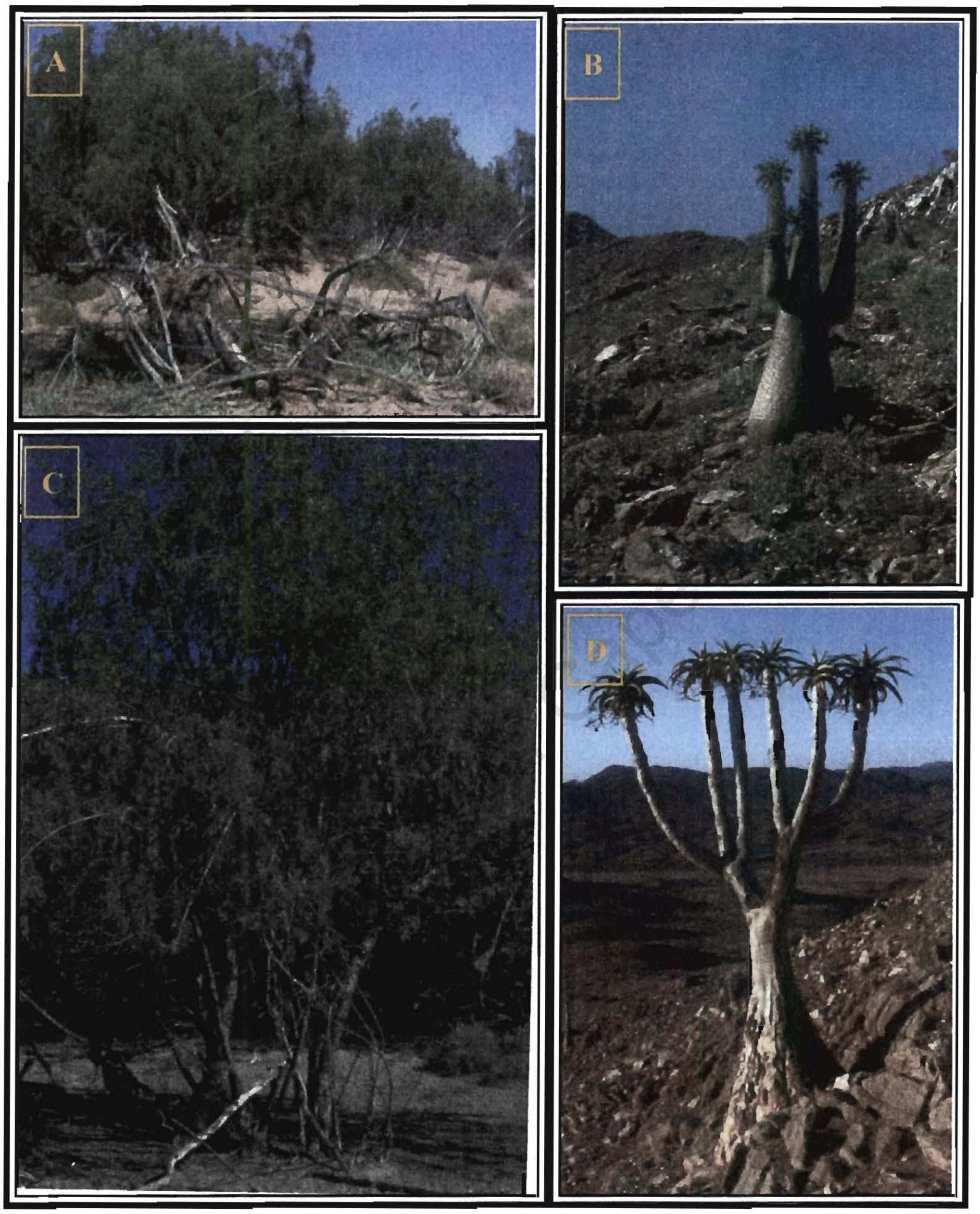


Plate 2.3

A. Ebony tree (*Euclea pseudobenus*) grows up to 4m high and well distributed in the National Park. **B**. The charismatic *Pachypodium namaquanum*. **C**. The forage plant *Ziziphus mucronata*. **D**. *Aloe pillansii* is endemic to the northwestern region of South Africa scattered individuals of arborescent aloes, such as *Aloe pillansii*, and the charismatic *Pachypodium namaquanum* (Midgley *et al.* 1997). After a good rainy period, grasses such as *Aristida adscensionis*, *Ehrharta delicatula*, *Enneapogon scaber*, *Leucophrys mesocoma* and *Stipagrostis obtusa* are found in abundance. Annual herbs such as *Amellus nanus, Plexipus gariepense, Cleome foliosa, Fagonia capensis, Forskaolea candida, Gorteria diffusa* var. *diffusa*, *Osteospermum scariosum*, *Pegolettia oxyodontaen* and *Trichodesma africana* are also present. Other common plants include *Monechma mollissimum*, *Calicorema capitata*, *Brownanthus schlichtianus*, *Opophytum aquosum* and *Blepharis furcata*. Van Jaarsveld (1981) described the flood plains as being dominated by *Kissenia capensis*, *Rogeria longifolia*, *Codon royenii* and *Rhus burchellii*.

2.7 Fauna

Most of the larger wild mammals are absent from the RNP. The checklist comprises 38 species (Williamson 2000b), of which most are nocturnal. Some of the species include *Petromus typicus* (dassie rat), *Raphicerus campestris* (steenbok), *Pelea capredus* (grey rhebok), *Oreotragus oreotragus* (klipspringer), *Equus zebra hartmannae* (Hartmann's mountain zebra) and many *Canis mesomelas* (black-backed jackal). Interesting species such as porcupine, zorilla, aardwolf, brown hyaena, caracal and leopard are also nocturnal. A variety of smaller mammals occur in the RNP. In common with small mammal communities elsewhere in the region, the RNP hosts small herbivores (rodents and lagomorphs), small insectivores (elephant shrews, fruit and leaf eaters), vervet monkeys, the flying mammals (bats) and a variety of smaller carnivores ranging from termite-eating bat-eared foxes to crab-eating Cape clawless otters in the Orange River. A number of about 200 bird species can be found in the RNP (Williamson 1995).

2.8 Paleohistory

2.8.1 Original inhabitants

The RNP has evidence of arthropod life that could be some 300 million years ago and rippled flagstones reflecting low action of water lapping over sands on the periphery of a glacial lake and fragments of fossil wood which have been recovered during mining operations (Williamson 1995). The earliest archeological evidence for human habitation (settlement) in the RNP was discovered between 4 200 and 3 400 years ago (Webley *et al.* 1993). The ancestors of the

Bushmen (or San) who lived in the area hunted game (such as springbok, zebra and klipspringer) and left behind bones of these animals as well as small stone tools which they attached to the ends of their arrows with a tree glue called resin. A group of pastoralists, known as the Khoikhoi (Khoekhoen) or 'Hottentots', arrived after the hunter-gatherers some 2 000 years ago and, based on faunal remains, introduced sheep into the area (Webley 1992). They brought with them clay pots and other ceramics and later also cattle, that were most likely introduced as a result of their association with black African farmers possibly in the region of the Caprivi or further north (Smith 1993). One of the three riverine tribes of the Khoikhoi, the Namaqua people, acquired goats from the Tswanas (whom the Namaqua called 'goat people') from the Botswana region and herded them in small numbers close to the Cape as early as 1661 (Elphick 1977). By 1797, the Namaqua people had lost most of their herds of cattle, and now owned mostly sheep and goats (Boonzaier *et al.* 1996). While of little importance and virtually unknown amongst the Khoikhoi during the 17th century, goats only replaced sheep as the main subsistence animal in the 20th century (Elphick 1977). The Nama-speaking pastoralists in the Richtersveld today are descended from these first pastoralists (Webley 1992).

2.8.2 Semi-nomadic pastoralism

Of about 30 to 40 million people in arid and semiarid regions of the world who have 'animal-based' economics, over 50% of these people live on the continent of Africa and are commonly referred to as pastoralists (Sandford 1983). Nomadic pastoralism has largely dwindled in southern Africa and the Richtersveld is one of the last areas in South Africa where traditional, semi-nomadic pastoralism still occurs (Hendricks 1998). The Richtersveld communal rangeland is more than a half million hectares in size and is the largest of 23 "Rural Coloured Reserves" (comprising 1.7 million hectares) in South Africa (Boonzaier 1996). It is also the largest of the nine communal areas in the magisterial district of Namaqualand (Hoffman *et al.* 1999). Most of these reserves were created during the 19th century and had their origin as mission stations to protect the indigenous Khoikhoi populations and people of mixed descent from dispossession of their lands by the encroaching "European" settlers. At the turn of the century, pockets of communal tenure were created around these stations (Boonzaier 1987) within a larger framework of private land rights in the Karoo. The Richtersveld communal land comprises about four percent of the total dryland of South Africa. The total human population of the Richtersveld communal area is estimated to be between 5 000 and 6 000 people (Archer *et al.* 1996).

People in the Richtersveld communal area call themselves Namas (Plate 2.4). Unlike in Namibia, where the Nama language is still widely spoken, only the older people of the Richtersveld still make common use of it. The majority of people speak Afrikaans. The land belongs to the Namas under communal tenure. The average household consists of five to six people, but some households of 20 people in the Sanddrif community and 21 people in the Kuboes community have been recorded (Archer *et al.* 1995). Since their introduction to the Richtersveld, the Namas maintained an intimate familiarity and respect for the land. This might sound a little glorified, but numerous evidence in their religious (Carstens 1985; Smith 1992) and farming practices (this thesis) make mention of strategies used by Namas to have lived and sustained themselves in this difficult and fragile environment. Life for the Namas is extremely precarious and traditional stock farming forms an integral part of their economy and culture. Wage-labour in the nearby mines provides the major source of income for the population (Boonzaier 1987; Smith 1991).

2.8.3 Land tenure

The Khoikhoi people practised a traditional lifestyle which can be described as a subsistence economy with stock farming and the collection of plant material for ethnobotanical purposes such as medicinal use. Land was presumed to be of value mainly as pasture. It is reasonable, therefore, to suggest that the occupation of land took place in terms of the use of resources and not as a result of ownership.

Plate 2.4

A. Herder making sure that kids drink enough milk from their foster mother. **B**. Preparation of a goat's head over an open fire before it is cooked in their traditional three-legged pots. **C**. The late Nicodemus de Wet at his stock post. **D**. Hand-made tools for basic repairs of clothing at the post. **E**. A farmer milking a goat.

In the Namaqualand district, including the Richtersveld, grazing land in communal areas is still under the communal system of land tenure (Hoffman *et al.* 1999). Communal land tenure in the Richtersveld is based upon membership and a series of rights and duties with respect to the use of the land. Each pastoralist has the right of access to areas of the commonage which provide grazing. Thus, tenurial grazing arrangements occur by respectful understanding and 'who is grazing where' is currently based on informal consensus amongst the pastoralists. There is also no control on stock movement or formal rules governing the numbers of stock to be kept on the communal rangeland. The establishment of the so-called 'economic units' during 1985 in terms of the Rural Coloured Areas Act (No. 24 of 1963) (Boonzaier 1987) was amongst previous attempts by the South African government against the communal land tenure system because it was perceived that the system, due to the lack of control on stock numbers and movement, encouraged overgrazing of communal rangelands. It is also important to note that not all people in the Richtersveld are accorded full citizenship status. Outsiders (such as schoolteachers, missionaries and traders) and co-residents (such as herders from other regions) are generally regarded as having been incorporated into the community because of their often lifelong relationship with individual citizens and may also be granted rights to grazing as long as they become 'registered occupiers' of the community (Erasmus 2000).

A different tenurial arrangement exists for the RNP. The South African National Parks initiated a 30-year lease in 1991 with the local communities surrounding the RNP. The aim of this Contractual National Park is to conserve the biotic diversity and manage the grazing resources of a portion of their communal area in cooperation with the local communities of the Richtersveld. The original inhabitants remain within the RNP and have agreed to limit the total number of livestock grazing within the confines of the park to 6 600 small stock animals (sheep and goats). The carrying capacity was based on recommended agricultural stocking rates of 25 hectares per small stock unit. Pastoralists are not allowed to graze their animals outside the RNP for more than six months as this will terminate their grazing rights inside the RNP. The Richtersveld community also receives an annual compensation payment. The current (2003) amount ca. R105 000, which rises with inflation, from the South African National Parks. These funds are used mostly in the education field such as for bursaries and transport of children to schools.

2.8.4 Ownership of resources

The Richtersveld communal lands lack formal structures to manage the grazing resources. According to the communal property regime, residents of communal lands obtain rights to the use of natural resources if they are 'registered occupiers' (Hoffman *et al.* 1999). A 'registered occupier' is a resident who has completed confirmation (i.e. a religious event amongst Christians which allows the resident to become an accepted member of the church and therefore a member of the village) at the village church and pays a membership fee. The current amount for residential membership is R120.00 per annum. Though not all exercise the right, basically any 'registered occupier' of the Richtersveld has the right to graze anywhere. The Richtersveld, as a system, is potentially open to abuse because it is a 'free-for-all' system where there is a notion that individuals could maximise short term gains at the expense of the long term interests of the community (Boonzaier *et al.* 1990; Hardin 1968). It seems to be a global concern that the rights and obligations of users of communal systems are very seldom clearly defined (Bourbouze 1991), and this legal haziness is a major source of difficulties. Traditionally, these rights and obligations were maintained in the form of unwritten laws that were carefully observed (Boonzaier *et al.* 1990; Chiche *et al.* 1991). Today, most of the Nama institutions have faded away and the allocation of grazing areas is based on informal consensus amongst the users. There is also no private ownership of water and land to influence who grazes where.

2.8.5 Livestock

(a) *Animals*

The flocks of livestock in the Richtersveld communal area consist primarily of Boergoats (*Capra hircus*) and some sheep (*Ovis aries*), particularly the fat-tailed variety. Other animals include cattle, horses and feral donkeys. These animals roam freely. The few free-ranging donkeys around the two southern local villages of Richtersveld are used for pulling carts.

(b) *Ownership*

According to research conducted in 1996, a total of 1 748 households in Namaqualand owned livestock; 44% of the total households owned less than 45 goats and sheep, 17.7% maintained between 46-90 goats and sheep while 3.5% households owned more than 450 goats and sheep (Anon. 1997). A study performed in the Richtersveld showed that more than 50% of the total households surveyed (n = 158) owned livestock (Archer 1992). Each herd is owned by single family units, generally a husband and wife with their children, but relatives also keep their animals with these herds. Considerable numbers of stock are "owned" by children, but the animals stay under parental control until such time as the children are able to take over the responsibility. In the case where the owner of the livestock dies, children inherit their part of the herd. Livestock owned by a woman stay with her father's herd, but may be transferred to her husband's responsibility.

(c) *Importance*

Unlike other African countries (Devendra 1975; Gall 1975; Okello & Obwolo 1985) and parts of Namaqualand (Hoffman *et al.* 1999), goat's milk seldom plays an important role in the household of stock farmers in the Richtersveld. Milk is essentially only used in tea. Livestock forms an essential part of the family's diet as household meat consumption and provides a source of income through the sale of live animals and meat. See Chapter 6 for the cultural importance of livestock.

(d) *Market*

Marketing of livestock in the Richtersveld is extremely irregular. Pastoralists sell their animals to members of the village, roaming speculators in the region or a nearby abattoir in the form of meat per unit kilogram. The lack of markets, local abattoirs and freezers means that there tends to be a surplus of animals in the Richtersveld.

2.8.6 Cropping

The farming enterprise is based entirely on pastoralism and cropping is not practised at all amongst the local people of the Richtersveld. Cropping is confined to regions with generally better-watered areas south of the Richtersveld, such as the Leliefontein rural reserve (Hoffman *et al.* 1999).

2.8.7 Pastoral management

The livestock is kept at a stock post stock post (the place where pastoralists keep their animals at night and to which they return every evening after the day's herding) and brought back to the base every evening after the day's herding. Most of the farmers kraal their animals at night in animal pens to protect them from predators, but at the same time making it easier for pastoralists to handle the animals. The time at which the animals leave the stock post each morning varies seasonally. During the rainy period and colder mornings, the animals leave the stock post at around ten o'clock in the morning, while they leave the stock post around eight o'clock in the mornings during the drier and warmer months. Stock farmers milk only goats. Milking takes place in the morning after which the animals are taken out for grazing. In most cases, a herder will walk with the animals during the day, either actively herding the animals or just guiding the lead animals. The pastoralists of the Richtersveld adapted to the harsh environmental conditions of the region by virtue of flexible herding strategies between grazing zones (See Chapter 5a). The stock farmers periodically return to the same stock post again during better grazing conditions.

2.9 Richtersveld National Park

2.9.1 Debut of Contractual National Parks

In South Africa, the conservation strategies in the past were characterised by fencing off protected areas (Grove 1987). This had the advantage of reducing conflict between people and animals, but reduced opportunities to share benefits from management of wildlife with local communities (Hanekom & Liebenberg 1994). Benefits from conservation only reached a minority of the population and, as a result, South Africa (like many countries under colonial rule) has had a history of conflict regarding its natural resources (Fourie 1994). Forced removal of local people from areas which they had previously inhabited was a common practice, for example the Riemvasmaak community (Hoffman *et al.* 1995) and Makuleke community (Steenkamp 1998). However, land claims and reinstating land to previously dispossessed communities were announced by the South African government during the middle of the 1990s. This unleashed a growing concern about the future prospects for protected areas in the country (Bond 1999). Since then, the South African National Parks recognised the necessity to integrate human needs with the national park system if effective conservation is to continue (Ledger 1998). This led to the establishment of Contractual National Parks, hence RNP.

2.9.2 Historical context

The RNP has a long history of negotiation. Agitation for protection of the Richtersveld ecosystem grew steadily beginning in the 1970s. In 1972, a group of people described the northern part of the Richtersveld as having "particularly attractive desert scenery and unique endemic vegetation which is threatened by collectors and development" and recommended that it be proclaimed as a conservation area (Botha 1986). However, inter-departmental bureaucratic forces made it difficult for the idea to progress. Most local residents remained blissfully unaware of the plans until the 1980s when the notion of a contractual national park for the Richtersveld was developed and legislation for the designation of the park tabled. At the time, it was argued that the environment had to be protected from the local population and the national park was thus justified on aesthetic, moral and scientific grounds. Despite strong opposition, negotiations with governmental authorities during this period were characterised by the virtual exclusion of the local people.

In stark contrast, 1989 saw a complete reversal of this trend. The local community established a Community Committee which rejected the highhandedness of the Management Board, the local authority which had been negotiating with the South African National Parks, and sought legal assistance. On 19 March, the day before the contract for the park was to be signed, a delegation of the Community Committee obtained an urgent court order from the Cape of Good Hope Supreme Court interdicting the parties to the contract from signing it. After that, negotiations were protracted, taking 18 months to culminate in an agreement. The new contract was substantially changed (Table 2.2). More importantly, it was established in principle that there would be no expropriation or forced removals from any part of the park and that pastoralism could continue with overall numbers of stock being limited. On 20 July 1991 a ceremony was held for the formal signing of the contract and accompanied by a simulated Nama wedding ceremony in a traditional reed dwelling between a woman from the community and the chief director of the South African National Parks. The signatures of all the parties to the contract allowed the RNP to be proclaimed on 14 August 1991.

The RNP has since then been managed jointly by representatives from both the local communities and the South African National Parks through the Management Planning Committee (known by its Afrikaans initials, BPK). The BPK constitutes one representative of each of the local communities (i.e. Kuboes, Lekkersing, Eksteenfontein and Sanddrift), a stock farmer representative, four representatives (including the Park manager and park researcher) of the South African National Parks and the recent additional representative from the local council of the Richtersveld. The work of the BPK is based on: (1) discussions and decision-making regarding the Management Plan of the park, (2) ensuring the implementation of the Management Plan, (3) handling revision and alterations upon the Management Plan, (4) ensuring local community participation, and (5) protecting the interests of the local communities (Anon. 1995). The BPK has a subcommittee, called the Action Committee, whose representation is similar to that of the BPK. Generally, the BPK is responsible for the development of the overall management policy of the RNP while the Action Committee is responsible for implementing the outcome of the BPK. The BPK supposedly meets every three months with subcommittee meetings in between. The lease payment is paid into the Richtersveld Community Trust. The community-elected Trust was officially established in 1993. Trustees are independent and respected outsiders. The funds were to be used for various community projects, but are currently used mainly in the education field in the form of bursaries and transportation of school children.

Table 2.2. A summary which juxtaposes the original aspects of the RNP contract with the changes that were made to the contract after the community became involved in the negotiations. (Source: Adopted from Archer *et al.* 1996)

	Pre 1989	**Post 1990**
Management structure	SANParks - with input from an Advisory Board (no decision-making powers) appointed by the local government	Management Plan Committee with four members from the SANParks and five elected from and by the Richtersveld community - one for each community and one to represent pastoralists
Use of RNP	Three zones with gradual withdrawal of all use within one year	Utilisation of grazing and other natural resources remains. Stock numbers limited to *status quo* of 1989
	'Corridor west' farms as compensation for grazing	'Corridor west' farms were excluded from contractual agreement
Payment of lease	Into coffers of local government	Trust formed. Community members elect Trustees (who are outsiders)
Lease period	99 years	24 years with a 6-year notice period

2.9.3 Contemporary status

From early settlement, the Richtersveld rangelands was communally used and managed. Today, part of the communal rangelands is proclaimed as the RNP. It is unique in that it is the only completely Contractual National Park in southern Africa. Unlike the rest of the communal rangeland being administered by the Richtersveld Municipality, the South African National Parks administrates the RNP rangeland as a Contractual National Park under section 2B(1)(b) of the National Parks Act (Act 23 of 1983); an area either in private or government ownership which is under management of South African National Parks in agreement with the landowner. However, land use in the RNP is managed by the BPK. The BPK meets quarterly for the joint decision-making strategic management of the RNP. These joint management decisions are filtered through to the Parkmanager for implementation. The Parkmanager is also responsible for the day-to-day management activities of the RNP. There is no regular interaction between the park officials and pastoralists. Although the rangeland in the Richtersveld is close to an 'open access' resource in that any land within the RNP can be utilised by any of the pastoralists, the RNP has a defined boundary. This boundary forms a territorial area where only 26 resident pastoralists can graze their 6 600 animals (upper limit on the stock numbers).

The RNP has various problems at this stage, especially herd management (both numbers and movement) and the monitoring of impacts on biodiversity. It is difficult to impose the upper limit of livestock numbers through stock reduction at times of overstocking (in accordance with the agreement) because there is no approved management plan for the RNP. The local people have not yet formally accepted the existing concept management plan due to issues that are still in dispute (mainly reduction in the number of feral donkeys and use of herding dogs). This has resulted in a situation where pastoralism has been practiced in the RNP for the last decade without any rules and regulations. Presently, pastoralists herd their animals wherever and whenever they want and with as many as they want. Localities with rare, threatened, or endemic species of special conservation interest have not been managed in such a manner as to reduce the potential impact of goats and sheep on the biological diversity of the RNP. To date, no research has been published on the grazing impacts on the RNP environment caused by the current situation.

Chapter 3

Management history, overall livestock demography and its role in household economy

3.1 Introduction

Animal husbandry forms the backbone of the Nama lifestyle. It plays an important role in their livelihoods and the household economy in the Richtersveld community. As in many other African countries (Devendra 1979; Mason 1980; Nauheimer & Schwartz 1991; Otchere *et al.* 1987) and Australia (Squires 1979), livestock are important suppliers of meat and provide a source of income. They also supply milk for human consumption, hides and pelts, and occasional draught power for transport. In this chapter, I tried to understand the management of the RNP in the overall context of its management history, livestock population patterns and the importance of livestock in the households of pastoralists. Chapter 4 considers the question of how rainfall, livestock numbers and herd management affect the production system in terms of feedbacks on productivity.

The livestock industry of the Richtersveld is based on small stock, especially Boergoats and some Dorper sheep. In the RNP, these animals are often grazed in mixed herds. The exact mix of goats and sheep is determined largely by individual pastoralist preference. Boer goats form the major component of the small stock. This animal breed is much more hardy than sheep; able to thrive in a wide range of environments (Campbell 1984) and seemingly on a great variety of diets (Chapter 7). Cattle generally form a minor component in the karoo communal lands (Hoffman *et al.* 1999). The few cattle are separated from the small stock and roam freely. Horses and donkeys also roam freely in the RNP. Like the situation in other South African rural areas, the Richtersveld has a permanent population of largely economically inactive inhabitants. Incomes are low and mostly obtained from mining, pastoralism, and remittances or government pensions (Chapter 6). A profitable annual market of animals does not exist.

Most of the Richtersveld constitutes traditional communal grazing land (Chapter 2) with distinctive semi-nomadic nature of livestock management (Chapter 5a). None of the pastoral families live within the RNP boundaries, but have permanent homes in the surrounding villages (mostly continually inhabited by women, children and other men). Stock posts in the RNP are used by resident herds that never leave the RNP (Chapter 5a), despite the absence of boundary fences. The RNP has set an upper limit for livestock numbers for the park to 6 600 small stock units (25 ha/SSU). This limit is based on the assumption that the larger the total livestock population, the heavier the impacts on plant diversity. In addition to this limit, a selected group of 26 pastoralists have been granted the conditional right to use the park resource. Both these limitations have been imposed in the contractual agreement between the local community and the RNP administration.

The objectives of this part of my study were; to determine the history of livestock grazing in the RNP, to describe important events in livestock farming, to record the stock numbers maintained in the RNP since 1995 (including a composition analysis between goats, sheep, cattle, horses and donkeys), and to analyse the annual age composition of animals. To understand the importance of livestock in the household, I recorded animal slaughtering for household meat consumption and assessed the income derived from cash transactions through animal sales. The latter was compared to the financial expenditure of each pastoralist.

3.2 Methods

Stock posts are scattered throughout the Richtersveld, away from village centres. A stock post is the place where pastoralists keep their animals at night and to which they return every evening after the day's herding. Pastoralists and their herds are usually located at a stock post and not confined in their movements (see Chapter 5a for their traditional wet and dry season grazing areas). They can dismantle the living quarters of the stock post within one hour and pack them for transport to another post. In the RNP, they are allowed to have two dogs per herd, primarily for the protection of livestock.

3.2.1 Management history

Participatory Rural Appraisal (PRA) techniques are tools that can be used in an analytical process to produce high quality results about information on various topics when working with rural people (Van Vlaenderen 1996). PRA is also an efficient means of eliciting a broad range of information in a short period of time. The historical profile technique was used to construct a timeline of the prominent events in land management patterns that took place in the area of the

RNP. Two pastoralists with the longest grazing experience in the RNP area described the changes in management patterns, which were recorded on a historical line. This analytical process involved a group effort between the two pastoralists and took two days to complete. This was followed with a secondary data review in the literature on existing information about the field site. Both the information of the two informants and the literature review were incorporated into the timeline.

3.2.2 Seasonal cycle of livestock farming

A seasonal calendar (another diagram PRA technique) was used to construct a time analysis diagram about how important events of livestock farming in the RNP change in a one-year time period. This exercise was performed during a one-day workshop with all the pastoralists under a *Prosopis glandulosa* tree along the Orange River. The advantage of this technique is that it is an analytical process which helps the group to think through issues clearly. On the day of the workshop, the group first identified all the important events associated with livestock farming. Thereafter, the facilitator (myself) made a line drawing comprising of only a Y-axis and X-axis on the ground. The events were written on the Y-axis and the individual months in a year on the X-axis. Pastoralists were asked to indicate when these events take place in the year by placing a piece of blue cloth (for rainfall) and sticks (for socio-economic and reproductive phenomena) in a horizontal line next to the respective events. The length of the cloth and sticks were used to indicate the duration of the event between months.

3.2.3 Livestock demography

Livestock populations in the RNP were counted four times a year (January, April, July and October) between July 1995 and January 2001. During these surveys, I located a herd at a stock post and recorded its position with a Garmin Plus2 hand-held Geographical Positioning System. Thereafter, all the animals (goats and sheep) of the herd were gathered at the stock post. The enumerator (myself) counted the animals whilst they were directed, running individually, through a temporary 'gate' formed by the pastoralist and his herder. This was critical to ensure a high reliability in the herd count. All the information was recorded on a datasheet (Annex 1).

Because the animals were counted on this individual basis, the enumerator was able to classify each animal into breed, sex and age. The age estimation of animals chosen at the stock post was based on age categories used by pastoralists in the RNP (Annex 2). This age classification system used by pastoralists was later translated to the standard agricultural classifications. Only two pastoralists kept cattle and one kept horses in the RNP at low densities. It was difficult to ascertain their actual population sizes because the cattle and horses were feral and roamed predominantly in areas with inaccessible landscape terrain. However, because there were few animals, the pastoralists knew their population sizes. At each survey, I asked the pastoralists about cattle and horses and used their estimated totals. The population size of donkeys in the RNP was estimated at 96 individuals during an aerial survey (Knight & Otto 1997), but has since been difficult to ascertain because they are largely feral within the RNP. Donkeys were excluded from this study.

3.2.4 Importance of livestock in household

Data concerning household food consumption and economy were not based on accurate records, but rather on pastoralists' estimates of number slaughtered, monetary income and financial expenses per annum. During each survey count, pastoralists were interviewed about their offtake (sales and slaughter) which occurred since the previous census. The household meat consumption was estimated from the number of animals slaughtered per annum. Animal sales were considered a monetary income to the household and calculated as the total amount of cash per annum received from selling animals to local speculators and a nearby abattoir. The lease fee for the RNP does not contribute to pastoralist income (Chapter 2). A one-off recall method (ILCA, 1990) was used to conduct a questionnaire survey for estimating financial expenses per month (extrapolated to a one-year period) (Annex 3). Expenditure data included money spent on the maintenance of household basic services (water, electricity and sewage) and social welfare (mainly food and clothes) including current accounts at trading stores. Financial expenses from livestock herding were also included. These surveys were conducted individually with pastoralists.

3.2.5 Data analysis

All livestock were converted to Small Stock Units (SSU, the metabolic equivalent of a 33kg adult goat) according to Meissner *et al.* (1983)(see Table 3.1 for weights used and conversion to SSU).

Cattle and horses were converted to small stock units at a ratio of 1 LSU : 7 SSU according to the RNP contractual agreement (Anon. 1991). Stocking rates were calculated as the number of SSU per hectare (ha) of grazing area. The available grazing area in the RNP was calculated at 110 315ha (Chapter 5a). Rate of increase or decrease in animal populations can be expressed in a number of ways. This study used the simplest measure, the finite rate of increase i.e. the ratio of numbers in two successive years and expressed in percentages. Calculated coefficient of variation (*cv*) was used for detailed analyses of fluctuations of goat, sheep and LSU populations between 1995-2002. An analysis of variance (one-way ANOVA) was used to determine if the 1998 drought (see Chapter 4 for the impact of this drought on the production system) caused a significant decrease in population and herd sizes. Pearson product-moment correlations were used to assess the relationship between total population and herd size for further analysis in Chapter 4. A t-test was calculated for a significant difference in herd number; herds comprising of goats vs mixed herds comprising of goats and sheep. Spearman Rank correlations were used to correlate herd number with year. One-way ANOVA was used to test for significant differences in animal sales and slaughtering between lambs/kids, young adults and adults. The income generated from transaction cash through animal sales was equated to US dollars at an exchange rate of R7.80 : US$1 at the time of the study.

Table 3.1. Mass and conversion to Small Stock Units (SSU) of different sex classes and phase of production for small stock, cattle and horses in the RNP.

Sex and phase of production	Mass (kg)	Number of SSUs equivalent to one animal
Lamb/kid, unweaned	12	0.24
Young adult, weaned (goat or and sheep)	23	0.47
Ewe, 2-tooth and older (goat or sheep)	65	1.00
Ram, 2-tooth and older (goat or sheep)	90	1.35
Castrate, 2-tooth and older (goat or sheep)	70	0.96
Cattle, 3-year old cow (dry)	400	7
Horse, 3-year old mare (dry)	460	7

3.3 Results

3.3.1 Management history

A general chronology of key events in the history of the Richtersveld is presented in Table 3.2. Early Stone Age hunter-gatherer-fisher sites have been located in the RNP. The longest memory of sites in the RNP, however, seems to go back only two generations amongst the pastoralists. Two pastoralists could recognise the few graves as the grandparents of certain people in the Richtersveld. According to a survey conducted in 1890, the Richtersveld region was grazed by ca. 10 800 small stock, ca. 1 010 cattle and ca. 135 horses (Carstens 1985). These had dropped to 6 687, 528 and 47 respectively in 1925 (Carstens 1985). Sheep in those days mostly comprised of Namaqua Afrikaners and blackheaded Persians.

Mr Paul Avenant was the first white pastoralist to have grazed his animals in the area in 1923 (Plate 3.1). Every year the family would move away from De Hoop to De Koei to stay during the winter with their livestock when rain had transformed the veld into a lush green pasture (see Figure 2.2 for locations). When Paul and his wife, Daisy, passed away three years after their arrival, their son, Paul (jnr), inherited the livestock and continued grazing until 1959 when he was forced to leave the area because of government policy regulations (Reck 1996). Another pioneering pastoralist, Charles van Rensburg, and his wife (sister of Daisy Avenant), also grazed animals in this area between 1933 to 1952 before they too had to leave.

The implementation of the Rural Coloured Areas Act (No 24 of 1963) witnessed the trek of the first Nama pastoralist back into the area in 1963 since the Native Land Act in 1913 when they were integrated with the Basters (the origin of the Cape Coloured people). At least four pastoralists soon followed his example until 1967. It was only since 1973 that the livestock activity in the area increased substantially; one herd was noted to be as large as 1 500 animals and five additional pastoralists were reported to have moved into the area. In 1991, the RNP Contractual Agreement was signed which allowed a selected group of 26 pastoralists the grazing rights inside the RNP area with a maximum of 6 600 small stock units. Until recently, only 20 pastoralists have exercised their right to graze inside the RNP.

Table 3.2. Timeline analysis of key historical events relating to land tenure, management and land use practices in Richtersveld. Information was obtained from two pastoralists with the longest grazing history in the RNP and taken from a secondary review of existing literature (sources were cited in Reference list).

DATE	COMMENTS
Pre-history	Hunter-gatherer-fishers living along the Orange River corridor and hinterland. After 2 000 BC joined and largely displaced by herders
1713	Outbreak of smallpox epidemic
1731	Possible excision of one testicle of every male child at or before puberty
1770s	First European travellers visit the region
1797	Khoikhoi people had lost most of their cattle herds, and now owned mostly sheep and goats
1847	Lower Orange River proclaimed as colonial boundary by Cape governor, Sir Harry Smith. The uncertain positioning of boundary lines, disputes over access and crossings initiated conflict
1868-9 & 1878-9	Korana and northern border wars along the Orange River
1870s-1900	Nama and other groups of herders settle in Richtersveld where Khoikhoi pastoralists had lived
1885	British Government blocked off South West Africa German claims to the northern bank of the Orange River
1890-1900	Severe drought
1890-1930	Richtersveld became a migrant labour reserve
1897	Outbreak of rinderpest epidemic
1890	Richtersveld region was grazed by an estimated 10 800 goats and sheep, and 1 010 cattle. About 135 horses were also found in the region
1904-1906	German-Herero war in Namibia
1904-1907	The 'Nama Revolt' against German authority. The great Nama chief (Hendrik Swartbooi) and many Nama were killed. Authority of chiefs replaced to some extent by an increase in the authority of local leaders
1909	Government of the Cape Colony passed the Communal Reserves and Missions Station Act
1913	Native Land Act was implemented Khoikhoi people of Richtersveld became integrated with the Basters (the origin of the Cape Coloured people), but retained Khoikhoi-style political structure
1920	A large area of the Richtersveld was 'sold' as a diamond concession area. Richtersveld became a migrant wage-labour reserve. White pastoralists started to establish themselves in the Richtersveld
1920s	Marriage with any first cousin was permitted, unlike in the past where only cross-cousins were potential spouses. Individual decision-making had been increasing
1923	Mr Paul Avenant and family were the first white pastoralists to graze their livestock (ca. 900 sheep and an unknown number of cattle) in the northern part of the Richtersveld
1925	The livestock population decreased to 6 687 goats, and 528 cattle and 47 horses
1926	Mr Avenant died and his son, Paul (jnr), inherited the livestock and continued their grazing activities
1933	Mr Charles van Rensburg grazed ca. 300 goats and sheep in the area along the Orange River
1936	Government implemented the Natives Trust and Land Act
1947	Government report on land degradation showed agriculture to be in a poor condition
1948	National Party came to power and adopted the policy of Apartheid which promoted 'white' agriculture
1949	A group of people, Basterbosluis, (ca. 400 persons) moved into the area
1952	Mr Charles van Rensburg moved his animals out of the area
1957	Regulations applicable to Native Trust land applied to Richtersveld. Richtersveld

DATE	COMMENTS
	Management Board was established
1959	Mr Paul Avenant (jnr) was made to leave the Richtersveld due to the Natives Trust and Land Act government policy
1960s	Drought occurred
1963	Rural Coloured Areas Act (No 24 of 1963) was legislated Government is keen to introduce 'economic units'. Mr Koos Josob, a Nama pastoralist, moved his ca. 550 goats and sheep into the area which today is designated as RNP
1967	A second Nama pastoralist, Mr Johannes Cloete, also moved his animals into the area, fewer animals than Mr Josob. Another two pastoralists used the area on a seasonal basis with an unknown number of animals
1968	Mr Willem Josob separated his ca. 200 animals from his father's herd and grazed it in a separate herd
1970	Agitation started for the protection of the Richtersveld ecosystem
1972	A group of people from the International Biological Programme recommended the proclamation of the northern part of Richtersveld as a protected area
1973	Livestock activity in the area increased substantially as a result of the additional animals of Jasper Oobies, Laserus Joseph, Piet Domrogh, Paul Moos and Moses Swartbooi
1975	Mr Willem Josob's livestock population was estimated at 1 500 animals. South African National Parks (then the National Parks Board) accepted a report written by Dr PT van der Walt and agreed in principle that a national park should be proclaimed
1978	Rural Coloured Areas Amendment Act (No 31 of 1978) legislated
1980	Legislation for the designation of the RNP was tabled. Population density recorded at less than 0.5

DATE	COMMENTS
	persons per square kilometre
1983	South West African Administration unsuccessfully prosecuted a pastoralist who cultivated vegetables on the flood plain at the confluence of the Orange and Fish rivers. SA National Parks announced the National Park Amendment Act 23 of 1983, in which private land could be contracted by the state in such a way that it would enhance protection of the core area
1984	Introduction of the 'economic units' scheme
mid 1980s	Group decision-making on herd movement and grazing arrangements had deteriorated sharply. Distances travelled by stock from one grazing area to another had diminished significantly
1985	Mr Koos Josob died and his son, Koos (jnr), continued grazing in the area
1986	Inquiry into government plan for land tenure change in the 'Rural Coloured reserves'. Richtersveld Management split into Northern and Southern Richtersveld Management Boards
1988	System of 'economic units' was set aside and communal land tenure was reinstated
1989	Whilst sitting on his donkey cart, Mr Koos Josob (jnr) was told by a conservationist, passing him in a off-road vehicle, that "one of these days you will not be grazing here anymore". He informed the Richterveld community who in turn established a Community Committee which rejected the highhandedness of the local authority board. Community obtained court interdict from Cape of Good Hope Supreme Court that prevented the establishment of the RNP. At least five more Nama pastoralists moved into the area
1990	South West Africa attained independence as the Republic of Namibia

DATE	COMMENTS
1991	RNP was proclaimed. Estimated livestock population was 6 550. The upper limit for the total livestock population was set at 6 600 SSU to be comprised between 26 herds
1992	Mining on their own account by the local inhabitants became legal. Estimate of livestock population was 4 352 animals via aerial survey
1993	Estimate of livestock population was 6 770 animals via aerial survey
1994	Estimate of livestock population was 6 033 animals via aerial survey
1996	Total population for Richtersveld was estimated between 5 000 and 6 000. The donkey population was estimated at ca. 96 during an aerial survey
1998	Richtersveld "Rural Coloured reserve" are subjected to the Transformation of Certain Rural Areas Act (Act 94 of 1998) whereby inhabitants can decide to transfer their communal land to a Community Property Association or to the Local Municipality
1998-1999	Area received very little rainfall. Pastoralists grazed mainly along the Orange River
2003	Signing of the RNP Management Plan

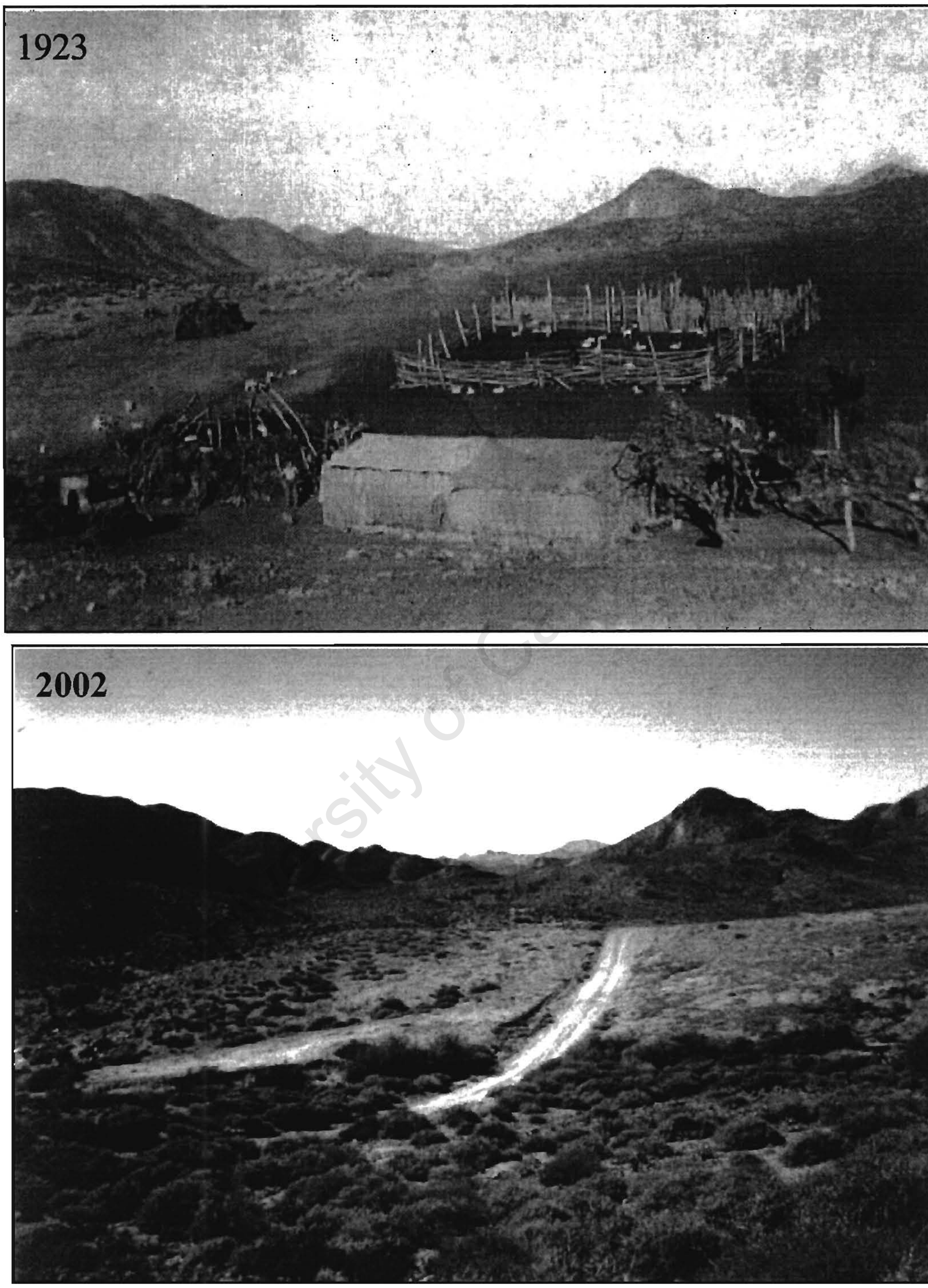


Plate 3.1. Matched photograph of the winter stock post in the RNP of the Avenant family between 1923 (Reck 1996) and 2002 taken from the same camera position. This stock post was abandoned in 1959 and has been colonised with mainly unpalatable *Mesembryanthemum* spp. ('soutslaai') and *Psilocaulon subnodosum* ('asbosvygie') in 2002.

3.3.2 Seasonal cycle of livestock farming

Livestock farming in the RNP until the beginning of April is dominated by the problem of survival of animals in the latter part of the dry season (Figure 3.1). Natural mortality predominantly takes place under the harsh environmental conditions of the dry season. The onset of the dry season is also the time when pastoralists start to encourage mating between animals, which is followed by a gestation period usually until the initial phases of the rainy season. The next six months after the dry season represent a total contrast in environmental conditions. The first winter rain towards the end of April stimulates active plant growth and, more importantly, readily available forage for the animals. This usually coincides with the major lambing/kidding season, which continues until the end of the spectacular flowering show in the beginning of October. Pre-natal mortalities as a result of abortions and diseases are normally prevalent toward the end of the flowering season (September). The last three months of the year are characterised by the onset of weaning the lambs and kids in the herd for the major annual sales period between December and January. These three months also witness the addition of weaned animals into the main population as young animals. By the beginning of the new rainy season the following year, these animals have survived the risks of mortality for almost one year. Mating starts again at the end of the year. Mating usually lasts six weeks, but because adult males and females are kept together, there is the occasional lambing/kidding that takes place outside the major lambing/kidding season.

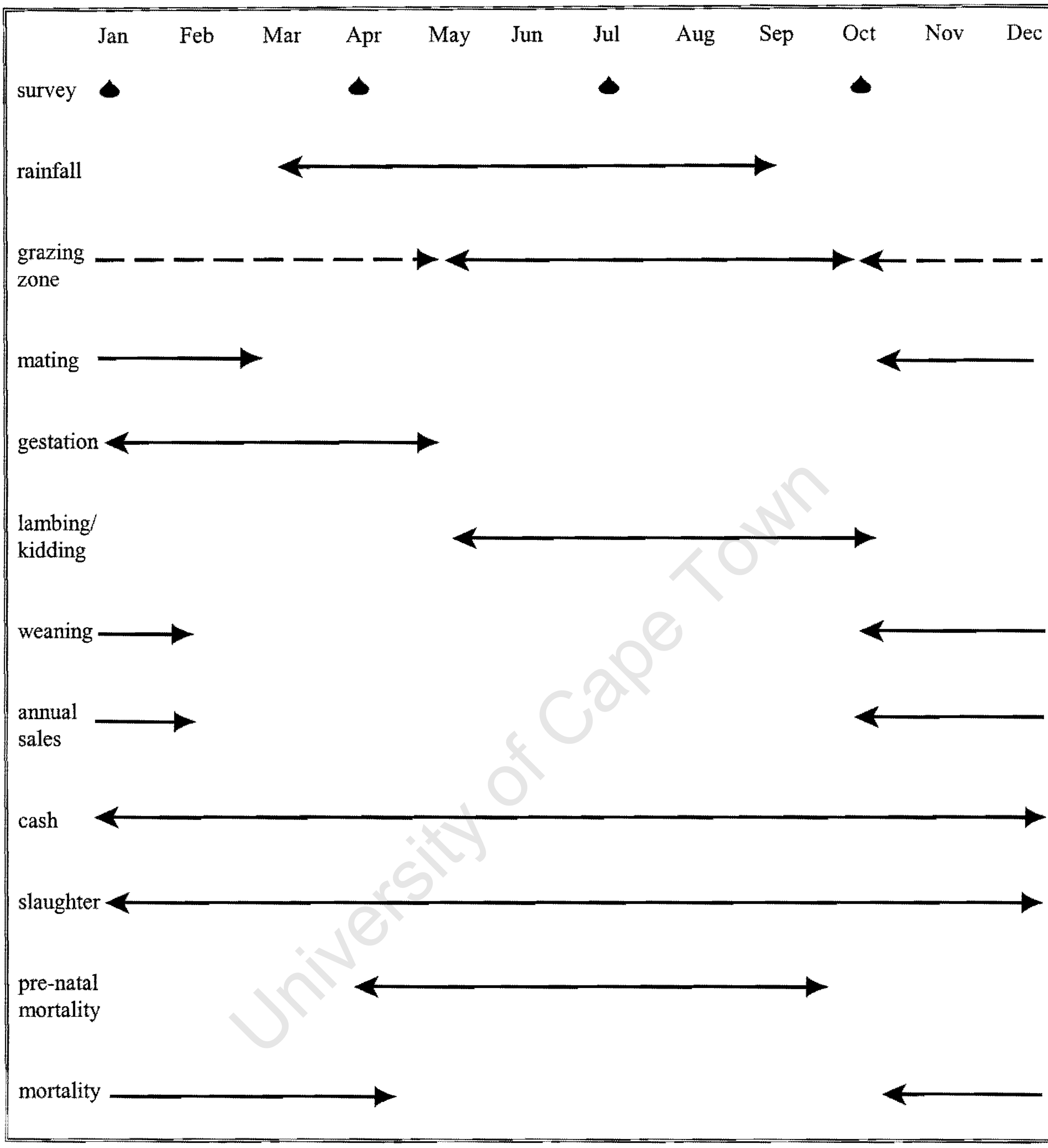


Figure 3.1. Schematic diagram of a time analysis associated with important events in livestock farming in the Richtersveld National Park. Dashed line indicates grazing along the Orange River while the solid line indicates winter grazing.

3.3.3 Livestock demography

(a) Population and herd size

The mean small stock units per annum maintained in the RNP between 1995-2002 was 4 492 SSU (Table 3.3). The most animals were recorded in January 2002 (7 285 head) and the least in July 2000 (4 307 head). The stocking rate was 0.04 SSU per ha (or 37.14 ha for every one SSU) per annum. The average herd size was 391 goats and sheep (a median of 388).

Table 3.3. Stocking rate (SSU/ha), total number of animals and mean herd size recorded in the RNP between 1995-2002 from quarterly surveys. See text for the calculation of small stock unit (SSU) for the different animal species.

Year	**Stocking rate** (SSU/ha)	**Total number of animals** (head)				**Herd size** (head)	
		goats	sheep	cattle	horses	mean	median
1995	0.032	4 315	594	36	7	427	449
1996	0.044	5 606	764	46	8	463	497
1997	0.046	5 318	812	62	8	454	442
1998	0.048	5 524	984	53	8	444	400
1999	0.041	4 100	1 056	45	8	348	315
2000	0.031	3 282	782	40	9	313	327
2001	0.037	4 014	1 074	37	6	301	291
2002	0.047	5 284	1 474	45	1	375	381

(b) Livestock composition

Overall, the mean livestock pool (SSU) per annum for the RNP consisted of 74% goats, 18% sheep, 7% cattle and 1% horses (Table 3.4). Detailed analysis on the variation of total livestock population showed fluctuations in all animal populations over the study period. Larger stock (cattle and horses combined) showed the highest calculated coefficient of variation (51%) compared to sheep (26%) and goats (22%) during the study period. Overall, the livestock population (SSU) consisted of 5% lambs/kids, 13% young adults, 38% ewes, 1% rams and castrated animals each. Pastoralists herding with goats kept on average 134 reproductively mature ewes for every ram. Pastoralists grazing with mixed herds kept on average 83 mature sheep females for every sheep ram.

Table 3.4. Total small stock units (SSU) for goats, sheep, cattle and horses in the Richtersveld National Park. See Table 3.1 for the conversion of goats and sheep to small stock units (SSU) according to Meissner *et al.* (1983), and large stock (cattle and horses) according to the RNP contractual agreement (Anon. 1991). The total numbers represent the mean from the quarterly counts.

		1995	1996	1997	1998	1999	2000	2001	2002
Goats	lamb/kid	300	336	394	392	210	264	330	511
	yng adults	521	594	227	227	184	71	105	69
	ewes	1 822	2 826	3 106	3 320	2 766	1 999	2 364	2 965
	rams	15	32	30	24	31	30	35	41
	castrates	119	87	61	66	43	11	24	12
Sheep	lamb/kid	26	24	21	32	36	36	55	81
	yng adults	41	36	17	9	5	3	3	0
	ewes	382	572	682	794	886	610	826	1 115
	rams	11	11	10	7	6	13	15	27
	castrates	8	9	0	30	4	5	1	0
Cattle		252	319	431	368	315	282	261	315
Horses		49	56	58	56	56	61	42	7
	Total SSU	**3 546**	**4 902**	**5 037**	**5 325**	**4 542**	**3 385**	**4 061**	**5 143**

(c) Herd composition

Mean number of goat herds (54%) was greater than mixed herds (46%) in all years except 1997 and 2000 ($t = 2.095$; $P < 0.05$)(Figure 3.2). Herd number increased significantly over the study period from an average of about 13 herds in 1995 to 18 herds in the beginning of 2002 ($R = 0.75$; $P < 0.001$). The variation in the number of herds grazing the RNP within a year also increased on average from 13 herds during the rainy period (May-September) to 16 herds in the drier months (November-April). The question of whether there was a trend towards increasing or decreasing goat and sheep herds was not possible to answer because of annual increasing numbers of both herds during the study period.

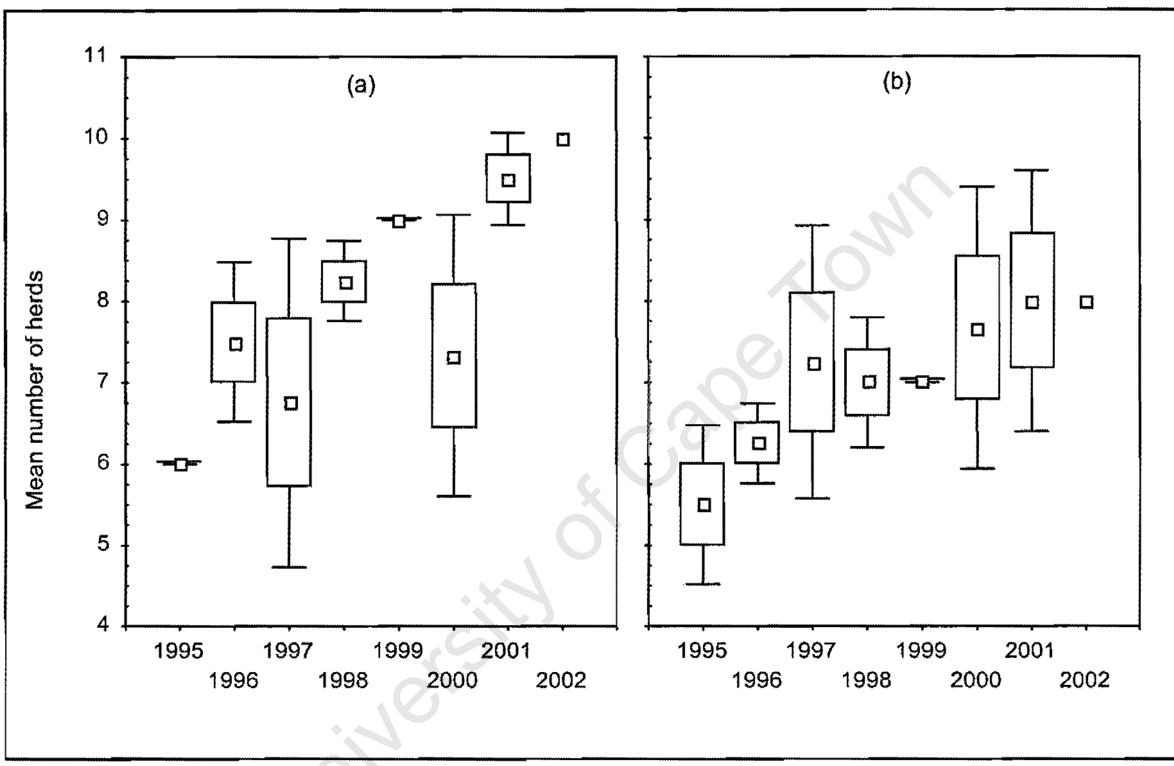


Figure 3.2. Mean (±SE) number of herds comprising of goats only (a) and goats and sheep (b) per annum that grazed the RNP between 1995 and 2002. Numbers for a given year represent the mean between quarterly counts.

3.3.4 Importance of livestock in household

A total of 7 098 goats and sheep were removed from the livestock population between 1995-2002 as a result of animal slaughtering and sales (Table 3.5). The annual rate of offtake was 13% (ca. 966 head per year). Animals sold were mostly adults and young adults ($F = 12.114$; $P < 0.001$) whilst slaughtering mainly occurred amongst adults ($F = 31.034$; $P < 0.001$). On average, adult sales and slaughtering contributed to 60% of the annual offtake rate during the study period compared to 39% for subadults.

Table 3.5. Mean (±SE) annual and total offtake for lambs/kids, young adults and adult goats and sheep in the RNP between 1995-2002.

Offtake (head)					
	Mean (n = 8)	SE	lambs/kids	young adults	adults
Slaughter	245	94.95	20	520	1 424
Sales	642	88.47	57	2 296	2 779

(a) Household meat consumption

A total of 1 961 animals (or 245 head per annum) were slaughtered for household meat consumption by stock pastoralists in the RNP during the study period. Each stock pastoralist slaughtered on average 17 animals each year.

(b) Household income

The stock pastoralists sold most of their goats and sheep either to members of the village or to roaming speculators in the region. The pastoralists received between R180-00 and R240-00 per head depending on the age and the condition of the animals. The pastoralists also sold some of their animals to a nearby small abattoir owned by the Trans Hex mining company. The abattoir paid them R240 per head which included R9 per kilogram meat and a fee for the slaughtering process. The income generated from sales was calculated as the amount of cash received from selling animals at an average price of R210 per head (about US$27 at the time of this study).

Within the period of investigation, the pastoralists sold a total of 5 132 goats and sheep (mean of 642 head per annum, Table 3.5). The average income from selling animals for each herd during the study period was R9 030 per annum. Their income per annum ranged from as high as R14 280 prior to 1998 to as low as R3 570 the following year, but increased again to an average of R8 035 per annum for the last two years of the study period.

Eight pastoralists received allowances (ca. R500 per month from the government and ca. R650 from mines), seven were wage labourers and five did not receive additional income to their annual cash transactions (see Chapter 6 for an elaboration). The seven wage labourers refused to respond to the optional question of how much money they earned per month from their respective employment. If it is assumed that their wages are at least equivalent to an allowance from the mines (ca. R650 per month), then the income per annum for each of these pastoralists was R16 830 compared to the R9 030 for pastoralists who did not receive additional income.

(c) Household expenditure

In the RNP, the average (n = 20) age for all the pastoralists interviewed was 56 years old and each farming household consisted of eight people (see Chapter 6 for an elaboration). On average, each pastoralist supported at least two grandchildren attending schools in villages. Each pastoralist in the RNP spent on average R2 943 per month (ca. R35 300 per year) on their households. Almost half (43.1%) of each pastoralist's income per month is spent on food and clothing while 2.8% is spent on basic household services (water, electricity and sewage). Pastoralists staying in the Kuboes village have to pay an additional amount of R2.50 per month for having streetlights in their village. An additional amount of R362 per month, on average, will allow each pastoralist and his family to have access to a television, telephone and an account with a furniture trading store in nearby towns.

The majority (12) of pastoralists interviewed used their own vehicles for transportation. For these pastoralists, it cost them an additional amount of R189 per month for transportation between stock posts and the village. Fifteen pastoralists (those who made use of herders) spent on average a further R486 per month towards the salary and basic needs of their herders. During the study period, pastoralists spent on average R35 per month on veterinary services towards the well being of their livestock.

3.4 Discussion

3.4.1 Management history

Khoikhoi pastoralists (who became known as Nama at a later stage) arrived in the area around 2 000 years ago (Webley 1992). These people were unable to subsist from their herds and were therefore also hunter-gatherers within historical times (Webley 1992). Livestock was owned by individual pastoralists and individual decision-making had been increasing since as early as the 1920s (Archer *et al.* 1996). Already since then, as remarked by the Magistrate of Springbok about the management of the area, the inhabitants of the Richtersveld maintained a nomadic lifestyle (Moolman 1981). In addition to the Rural Coloured Areas Act (No 24 of 1963), the boundary placed on the RNP was a further inducement for these semi-nomadic pastoralists to settle in a specific area. Today, livestock is as much a natural resource as any other form of animal life and lives in close symbiosis with the original inhabitants of the Richtersveld. It has become an inseparable component of the management of the RNP through a contractual agreement and, therefore, part of its ecology.

The proclamation of the RNP seems to have been followed by an increased utilisation of the area as seen by the increased number of herds since 1995 and increased total number in the area (less clear). Archer *et al.* (1995) reported only three stock pastoralists using the same area between 1914 and 1960. Since Jürgens (Jürgens *et al.* 1995) began his research in the RNP in 1980, he estimated a maximum of five pastoralists grazing the area and was under the impression that severe overgrazing was avoided. Twenty pastoralists have exercised the right to graze their individual herds inside the RNP since its proclamation in 1991. Mainly two, sometimes three, pastoralists moved their animals between the RNP boundary and adjacent communal area within periods of about two months. These movements usually took place toward the end of the year and the beginning of the following year causing a fluctuation in number of herds within the RNP between and within years. The reason for these movements is unknown.

3.4.2 Livestock demography

Livestock were the most frequently sighted animals in the RNP during the study period - in fact domestic dogs were sighted more often than any wildlife species. The goat population exceeded both the sheep, and cattle and horse population with an overall ratio of 1:6 and 1:23 respectively.

Literature on communal farming practices shows that not only does stocking rate change greatly with rainfall per year (Todd & Hoffman 2001), necessitating tracking strategies (Smith 1992), but also that the production objectives of communal pastoralists are different from commercial production systems (Rohde *et al.* 1999; see Chapter 6). In the case of the RNP, the stocking rate between 1995-2002 was within the upper limit as stipulated in the contractual arrangement, occasionally dropping to almost half the agreed rate of 0.04 SSU/ha (or 25ha/SSU) (i.e. year 2000). Thus, the commonly held assumption that most communal rangelands in southern Africa are over-stocked (Cousins 1996), often at two or three times the recommended agricultural rate for some parts of Namaqualand (Hoffman *et al.* 1999), did not apply to the RNP. Overstocking is likely to occur on rangelands where animal survival is more important than production *per se* (see Chapter 6 for the objectives of communal pastoralists in the RNP).

Archer (1992) indicated that the 52% households in the northern region of the Richtersveld who owned livestock was similar to the 57% households reported for communal areas in Namaqualand (Hoffman *et al.* 1999). Goats and sheep were kept in similar proportions to other communal areas in Namaqualand (Anon. 1997). The average herd size for the RNP (391 head) was comparatively higher than that recorded for the rest of Namaqualand (116 animals) (Hoffman *et al.* 1999) and other African countries (137 animals) (Nauheimer & Schwartz 1991). Large herd sizes are possible when a single herd has many owners and if the underlying herd management strategy is to keep as many animals as possible alive and sell a few when the household needs money (see Chapter 6 for herd ownership and the motives for keeping livestock). The number of individual herds grazing in the RNP increased since 1995. Forage and water availability become critical particularly during December and February each year, and as a result stock pastoralists herd their goats and sheep along the Orange River.

The annual number of adult females for the RNP was lower than the recommended number of female animals when calculated at 70% of the total stocking units. By having more adult females in a herd, pastoralists perceived that they would have a good lambing season that would satisfy their farming objectives. As a direct consequence, pastoralists maintained less than the recommended 3% rams that is required to effectively cover all the ewes (recommended ram percentage for ewes in the RNP was 2.6% compared to the actual percentage of 0.7% maintained). Two-tooth and older castrated rams, locally known as 'kapaters' for goats and 'hommels' for sheep, were maintained at ca. 63 SSU per annum. These animals provide a store of potential capital and a growth potential if pastoralists are only concerned with weight of meat for own consumption or the occasional sale into local markets.

3.4.3 Importance of livestock in household economy

Changes in the household economy of the pastoralists in the region are reflected in the present system of land utilisation. Unlike in the past when pastoralists rarely moved far from the settlement (Webley 1992), families are resident in villages whilst pastoralists are found at stock posts located great distances away. Even though it was estimated that the livestock generated a total income from sales of more than one million Rand between 1995-2002, the income from livestock sales for each pastoralist was about R750 per month. The five pastoralists that depended solely on selling animals for their cash needs needed at least R2 000 per month to cover their basic household and farming financial expenditures. The rest of the pastoralists included in this investigation received an additional income from either pension funds or wages, which increased their total income per month to at least R1 400. Migratory labour (especially from nearby mines) has become an important financial supplement in recent years (Chapter 6).

So, how do these pastoralists cope with the shortfall in income against expenditure, especially those not receiving additional income? I would also imagine that fluctuations in income due to severe droughts must cause serious cash shortages during extended periods. My responses to these questions are speculative. Chapter 6 concludes that the families of pastoralists form close households with each member of the household managing their own money (including married couples), but also supporting other family members within the household. Furthermore, no access to televisions and telephones, limited driving around as well as cost-saving in water and electricity usage additionally assists pastoralists to cope with a shortfall in income. Cash from intermittent sales of animals throughout the year were mostly needed for buying grain products, sugar and tea, and tobacco. The income from annual sales was seldom used by pastoralists for veterinary supplies and services. Herd reproductive ability was the primary source of income to the household of those pastoralists who did not receive an additional income other than from annual sales. Beside sales to members of the village for immediate daily cash, a local speculator (Mr A. Hudson) mentioned that animals are mostly sold in larger numbers during the few weeks before the Christmas season and immediately after the New Year as a result of a traditional increase in the consumption of goat meat by black communities primarily from the

KwaZulu-Natal Province of South Africa.

The pastoralists slaughtered animals only to meet the basic daily household meat consumption required by the family, i.e. one and a half animals per month. At this slaughter rate each family member of the household consumed about 3kg of meat per month for their basic household meat consumption.

3.5 Conclusion

Land ownership in the Richtersveld was always communal even as late as 1931. The identification of graves by the two pastoralists in this study suggests a continued habitation in the RNP by descendants of the same families for at least the last three generations. However, the establishment of a National Park on their land was something completely outside the community's experience. On the other hand, the RNP experience reflects the uncertainty within the then National Parks Board of the new understanding that people and parks can indeed coexist.

The history of pastoral activity in the Richtersveld region is well documented. Livestock production has been an important factor in the economy and as a source of household meat consumption for the Nama people for many centuries. Unlike the past when mainly cattle and sheep were herded, goats, and to a lesser extent sheep, formed the backbone of the current livestock industry in the RNP. Goats were herded separately or sometimes in mixed herds with sheep. With the advent of changes in land utilisation patterns, the magnitude of this traditional reliance on livestock farming has decreased by additional income from other sources (Chapter 6). The establishment of the RNP also forced pastoralists to become resident pastoralists (Chapter 2). The RNP communal rangeland never exceeded the total carrying capacity of 6 600 SSU between 1995-2002 set by the RNP, often with herd sizes much larger than those recorded in other communal rangelands of Namaqualand. Mainly adult animals were sold and slaughtered. Pastoralists depending solely on selling animals earned half the income of pastoralists receiving an additional income from either pension funds or wages. Pastoralism under the current condition contributes nearly half of the needs of the household budget. It remains speculative why pastoralists farm under such harsh conditions with such low returns.

Annex 1. Livestock population survey datasheet.

	Species		goats					
	Age		<2months	2-5months	5-9months	9m-1year	adults	kapater
	Total							
Offtake	Sex	male						
		female						
	Sale	male						
		female						
	Slaughter	male						
		female						
Losses	Drought	male						
		female						
	Disease	male						
		female						
	Predators	male						
		female						
	Theft	male						
		female						
	Other							
	Species		sheep					
	Age		<2months	2-5months	5-9months	9m-1year	adults	hommel
	Total							
Offtake	Sex	male						
		female						
	Sale	male						
		female						
	Slaughter	male						
		female						
Losses	Drought	male						
		female						
	Disease	male						
		female						
	Predators	male						
		female						
	Theft	male						
		female						
	Other							

Annex 2. A comparison between standard agricultural age classification of goats used by the Department of Agriculture (Meissner *et al.* 1983) and age classification based on local pastoralists' knowledge and thorough one-year observations prior to the investigation.

Department of Agriculture	Local pastoralists' knowledge		
Standard age class	Category	Age class	Description
Lamb/kid, unweaned	Infant "sypmelkpenslam"	from birth until < 3 months old	* Always kept at stock post * Primarily dependent on mother's milk * Unable to walk long distances
	Juvenile "lam"	from 3 months until < 6 months old	* Herding with older animals * Still drinks mother's milk, but not dependent anymore * Start to browse and graze * Able to walk long distances * Not able to produce milk * Udder of female is not yet visible while scrotum is developing
Young adult, weaned	Subadult "speenous" and "ramlammers"	from 6 months until < 11 months old	* Predominantly do not drink mother's milk * Engage in mating behaviour * Reproductively immature * Udder starts developing while scrotum is developed * Not able to produce milk
Ewe, 2-tooth and older	Ewe "ooibok"	from 11 months and older	* Mature developed body size * Reproductively matured * Have developed udders with distinct black nipples * Able to produce milk
Ram, 2-tooth and older	Ram	from 12 months and older	* Mature developed body size * Reproductively mature * Scrotum is developed and expands in size
Castrate, 2-tooth and older	Castrate "kapaters" or "hommel"	from 12 months and older	* Mature developed body size * Reproductively immature * Scrotum is removed

Annex 3. Financial expenditure datasheet.

Financial expenditure (RNP)

A. Personal details

A1. Name:.......................... A2. Age:.......... A3. Highest qualification:.............

A4. Status: pastoralist ....../ pensioner....../ wage labourer...... (earnings per month ....)

B. Family dependants

B1. wife......../ sons......../ daughters......../ grandchildren......../ other.................................

B2. How many are wage labourers........../ jobless........../ scholars........../ small children.........

C. Household expenses

C1. How much do you pay per month for:

Residential tax = ...; Water = ...; Electricity = ...; Sewage = ...

Other =...

C2. Do you have any monthly current accounts? Yes.../ No.... Total amount:....................

C3. How much money per month do you spend on food? =....................

C4. How much money per month do you spend on clothes? =....................

D. Running expenses from assets

D1. Do you own a house? Yes.../ No.... Which village :.............................

D2. How much money per month do you spend on house maintenance? ....

D3. Do you own a vehicle? Yes.../ No....

D4. Do you a pay monthly instalment on your vehicle? Yes.../ No.... Amount: ....

D5. How much money per month do you spend on vehicle maintenance? ....

D6. Besides to stock post, how many kilometres do you drive in a month? ....

D7. Beside to stock post, how much money per month do you spend on fuel? ....

E. Livestock expenses

E1. How often per month do you visit your stock post? ....

E2. How do you get to your stock post? Own transport ..../ Hire transport ....../ Walk ...../ Lift ....

E3. How much money per month do you spend to get to your stock post?

Fuel .... Oil .... Maintenance .... Other ....

E4. How much money per month do you spend on your herder?

Wage .... Food .... Cloths ....

E5. How much money per month do you spend on livestock inputs?

Veterinary supplies .... Dip/vaccinations .... Feed supplements ....

Chapter 4

The role of rainfall, herd size and pastoralist management on livestock production

4.1 Introduction

Herbivores are generally thought to have great impacts on ecosystems; these effects can be either positive or negative on plant communities (see Chapter 8). Stocking rate has been considered the tool whereby range managers can adjust herd size and production and thus influence the impacts on the vegetation. This is based on the assumption of density-dependence and the equilibrium theory of ecosystem function (Behnke & Scoones 1993; Bell 1985; Jones & Sandland 1974). Subjective studies of rangeland dynamics (Fynn & O'Connor 2000; Milchunas *et al.* 1988; O'Connor & Roux 1995) and condition (Du Toit 1995; Friedel 1991; Vorster 1982; Wilson & Tupper 1982) prompted the suggestion that high stocking rates decrease plant diversity. However, in arid environments with very high climatic variability, stocking rate may have minimal effects on herd size, and production and vegetation dynamics because forage availability varies to such a great degree with rainfall that livestock population dynamics are driven by rainfall (via its effect on forage availability) rather than density-dependent interactions (Ellis & Swift 1988). A key factor in whether rainfall variability could control herbivore populations is drought (Ellis *et al.* 1993). Drought frequency strongly influences the population stability of grazing animals (Coppock 1993). Low food availability during droughts will cause herd sizes to crash. Herd recovery rates are assumed to be too slow for animals to be food limited in the inter-drought periods (Ellis & Swift 1988).

In the case of the RNP, the central motivation of the park is the maintenance of its unique plant diversity of arid karoo shrubland. Heavy grazing pressure is seen as a threat to this conservation objective and, as a result, the upper limit of grazing animals is set at 6 600 SSU. However, at an individual herd level, animal numbers are also thought to influence herd productivity (standard rangeland theory) and, therefore, variation in herd size might influence the well being of pastoralists. The implementation of a policy which may require individual pastoralists to reduce stock would be simpler if clear benefits of smaller herds could be demonstrated. The worst, from the pastoralists point of view, is to be forced to reduce herd size resulting in impacts on their livelihood. To influence herd size management and make it less traumatic for both the pastoralists and RNP, one needs to know both how animal numbers impact biodiversity and how numbers influence the livestock enterprise of individual pastoralists. This chapter deals with the latter problem.

In this chapter, I addressed the questions whether herd size matters for herd production, offtake and resilience to drought (by inference, because of food limitation or density dependent effects). I examine overall herd size in the RNP over time and explore aspects of individual herd performance in relation to rainfall variation during the study period, herd size and pastoralist interventions and skills. These are key aspects for determining the best intervention to help pastoralists improve their cash income (if they wish to do so). If herd size is important for herd performance, it would help the RNP in justifying its limit on total herd size (and/or stocking rates) to reduce herd impacts on the vegetation. The RNP interventions which impact negatively on the ability of pastoralists to maintain their livelihoods must be avoided.

In the RNP, net sales of livestock out of the system are limited (Chapter 3). I set out to examine the following hypotheses that help tell us what the consequences of setting particular herd sizes might be in the RNP from the pastoralists point of view;

(a) rainfall regulates stock numbers and its recovery in different years,
(b) an increase in herd performance is achieved with smaller herd sizes,
(c) all herds are likely to be completely eliminated in severe droughts, but small herds have a higher risk of extirpation than larger herds,
(d) herd performance is a function of various production objectives and varies with pastoralist interventions and skills.

4.2 Methods

Although a full assessment of ecosystem dynamics should ideally include vegetation, the forage as well as herbivores, my focus in this study was confined to the animal component. Stock numbers used in the analysis were the numbers of cattle, goats and sheep in the RNP for all years available within the period covered by rainfall data (Chapter 3 presented these livestock numbers in SSU and SSU/ha). Chapter 2 showed that the livestock population in the RNP consists mainly of goats, and few sheep and cattle; this study therefore only investigated the goat population for detailed herd dynamics. In addition to the demography data and pastoralists offtake (sales and slaughter) estimates (Chapter 3), pastoralists were also interviewed about the mortality of their animals that occurred annually during 1995-2002. The following herd management indicators were also recorded; (a) the number of people staying at the stock post to take care of the livestock, (b) pastoralist age, (c) livestock farming skills as perceived by other pastoralists, (d) employment status, and pastoralist usage of (e) transport and (f) veterinary services.

The RNP rangeland supports unique forage (succulent Karoo) in South Africa and in the world. The characteristics of the vegetation of this pastoral rangeland (mainly dwarf succulent shrubs) are different from the savanna grazing systems and the ecology of the system as a source of livestock food is still poorly known. Therefore, the data analysis (and certainly the chapter) is preliminary in nature. To determine differences in herd dynamics, I make the assumption of equivalent herding range around a stock post for the different herds (Chapter 5a). The assumption is reasonable because the area utilised by a herd is limited by the daily distance a pastoralist can graze his animals from the stock post. I also assumed that each pastoralist grazed similar habitats and that forage supply was equally similar in feeding areas which receive winter rainfall (Chapter 7). This implies that all habitats (i.e. plains, foothills and mountains) foraged had comparable production potentials (see Chapter 8 for the vegetation dynamics around stock posts). This assumption of equivalent intrinsic primary production in the different herding ranges as well as the habitats remains to be tested in further research.

4.2.1 Data analysis

4.2.1(a) Rainfall

In addition to the rainfall collected from six weather stations in the RNP between 1995 and 2002, rainfall was also obtained from two weather stations outside the RNP administered by the South African Weather Services between 1964 and 2002. The mean annual precipitation was calculated as the total amount of rainfall recorded between years for eight weather stations. Although the rainfall record for the RNP is short, values correlate well with those collected over 38 years outside the RNP ($r = 0.99$; $P < 0.001$). The annual rainfall for the Richtersveld region has not been constant since the 1960s (mean annual rainfall is 72mm)(Figure 4.1). Relatively wet conditions followed dry periods, usually for consecutive five-year periods. Annual rainfall calculated for 1998 and 1999 was 44mm and 41mm respectively (hereafter referred to 'drought') compared to the relatively high total recorded in 1996 (99mm). This drought was not as severe as those recorded in 1965 and 1979 when annual rainfall decreased to ca. 25mm. However, 1998 and 1999 were the lowest consecutive rainfall years over the measurement period. The calculated rainfall coefficient of variance (*cv*) in mean annual rainfall for all the weather stations in the Richtersveld region was 50% (*cv* decreased to 45% for the RNP). For the correlations with livestock numbers and their performance, I used the total rainfall in the season (February to January) preceding the first stock census of the year, which is taken in April. The running mean of two seasons preceding the livestock census was also used in case there was a carry-over effect in forage production and availability between years. The annual rainfall deviation (i.e. variability of rainfall around the mean annual rainfall) was first calculated for each month and each weather station, using the formula;

Rainfall deviation (%) in month t = [(actual measured rainfall$_t$ - mean rainfall$_t$)/mean rainfall$_t$]x100

The rainfall deviants for all the weather stations were then averaged for all months within years to obtain the average rainfall deviation per annum for the region.

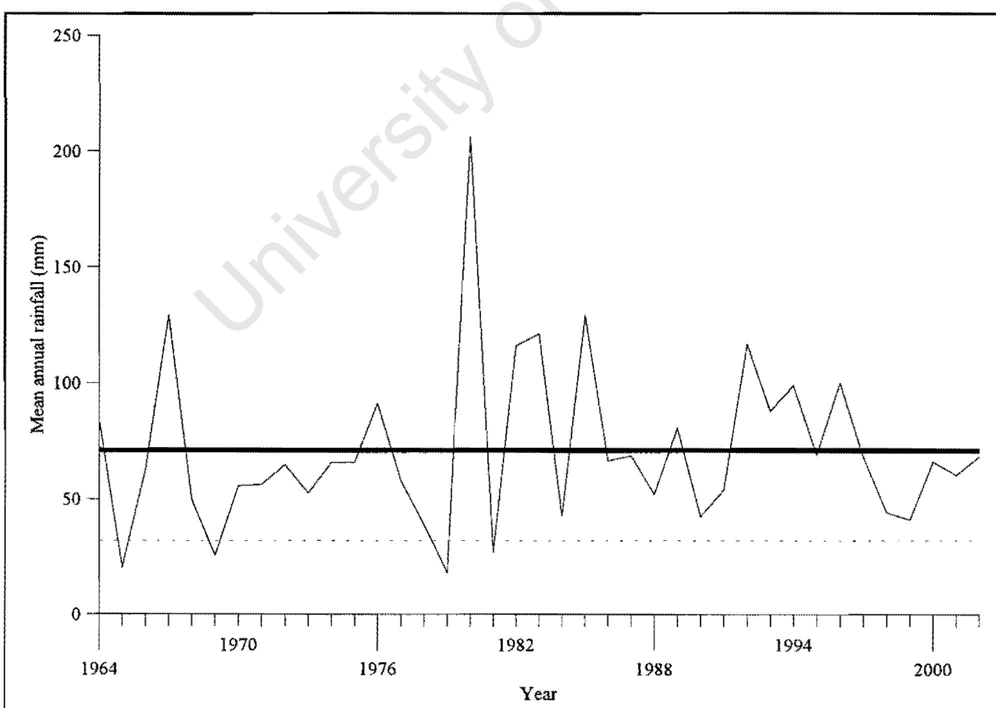


Figure 4.1. Annual rainfall totals (mm)(thin line), mean annual rainfall (thick line) and lower percentile rainfall set at 15% (dotted line) for the Richtersveld region over the last 40 years (Lekkersing weather station).

4.2.1(b) Herd performance

A total of 20 individual herds were investigated in this study. I used detailed census data between 1995 and 2002 (Chapter 3), to calculate the following variables of herd performance;

(i) Kidding

Kidding represented the total number of kids born and counted in the RNP between the herd census in January in year t (N_t) to the herd census in January in year t+1 (N_{t+1}), excluding those counted at N_t, and in relation to the average number of reproductively mature female animals (does at the age of 2-tooth and older) within the same period. Kids were taken as animals with an age of less than three months old at the stock census. Herd kidding was expressed as;

$$\text{Kidding in year t (\%)} = (\text{Kid}_{\text{April t}} + \text{Kid}_{\text{July t}} + \text{Kid}_{\text{October t}} + \text{Kid}_{\text{January t+1}}) / \text{No. of does} \times 100$$

Fecundity represented the total kids born and counted in quarterly censuses between the herd census in January in year t (N_t) to the herd census in January in year t+1(N_{t+1}), excluding those counted at N_t. The ram:doe ratio was defined as the total number of does for each ram.

(ii) Offtake

Offtake was the pastoralist's estimate of total number of animals sold and slaughtered from N_t to N_{t+1}, excluding those estimated for N_t. It was expressed as;

$$\text{Offtake in year t } (O_t) = O_{\text{April t}} + O_{\text{July t}} + O_{\text{October t}} + O_{\text{January t+1}}$$

where O_t is the total number of animals sold and slaughtered since the previous animal census.

(iii) Mortality

Mortality was the pastoralist's estimate of total number of animals lost as a result of predation, diseases, droughts and unknown causes from N_t to N_{t+1}, excluding those estimated for N_t. It was expressed as;

$$\text{Mortality in year t } (M_t) = M_{April\ t} + M_{July\ t} + M_{October\ t} + M_{January\ t+1}$$

where M_t is the total number of animals lost since the previous animal census.

(iv) Production

Production was calculated as the sum of total number of animals taken off (sold and slaughtered) and the difference in animal number between N_t and N_{t+1}. Herd production was expressed as;

$$\text{Production at year t } (P_t) = O_t + N_{t+1} - N_t$$

As herd performance starts at conception, and kids are weaned towards the end of the year (Chapter 3), the following specific variables were also noted for individual herds; weaned kids per doe, the proportion of yearlings transferred to does, the proportion of does sold and died annually.

An alternative measure for studying herd performance is to ascertain herd persistence. Here, I considered how the risk of extirpation of a herd varied among individual pastoralists in the RNP before and after the recent drought. One measure of persistence is variability in herd numbers, especially the decline in herd size through drought and its rate of subsequent recovery. The magnitude of the drought effect on herd size was estimated on the difference between the maximum herd size before the drought and the minimum herd size during the drought. Herd size recovery was measured as the difference between the minimum herd size during the drought and the maximum herd size after the drought. I calculated herd drought decline for 16 herds and recovery rates for 15 herds between 1995 and 2002 (data records for the rest of the pastoralists were incomplete either before or after the drought).

4.2.1(c) Herd management

(i) Stock post people

It is possible that a paid herder may not be as dedicated to the well being of the livestock as the owner would be (Sutter 1987; White 1990). This implies that the animals would be looked after better when the pastoralist is at the stock post or herding the animals himself (see Chapter 6 for differences between pastoralist, owner and herder). Relatives of the owner might also have a similar effect on the well being of the animals. I ranked this management indicator from least care to most care in the following manner; (1) the shepherd alone at the stock post, (2) the presence of the pastoralist/owner's son, (3) the presence of the pastoralist/owner's wife, and (4) the presence of the pastoralist/owner. The ranks were summed where more than one of these people were present at the stock post.

(ii) Age

Age is commonly regarded as a correlate of the degree of knowledge amongst rural people in communal areas (Hendricks & Van der Heyden 1998) and it is accepted that pastoralists have a good working knowledge of the environment they manage (Boonzaier *et al.* 1990, Scoones 1995). There is a common perception that older people are more knowledgeable than younger people in rural areas. I tested the assumption that an older pastoralist with more experience in stock farming, would be more successful (higher herd production). Overall, a younger pastoralist would want to be closely located to the village, driven by the desire to be amongst peers. I categorised the pastoralists into three age groups: (1) young pastoralists below the age of 45 years, (2) middle-aged pastoralists between 46 and 60 years old, and (3) old pastoralists as above 60 years old.

(iii) Knowledge

A matrix ranking exercise was completed whereby each pastoralist ranked themselves and others according to their knowledge of how to farm. These ranking scores were averaged between pastoralists; a higher rating represented a more knowledgeable pastoralist perceived by the others and a lower rating represented a pastoralist who is perceived to be less skilful.

(iv) Employment status

The status of a pastoralist was thought to play a very important role in farming with animals. I assumed that those pastoralists taking part in wage labour will not be as strongly motivated for their livestock enterprise as a pastoralist who does not receive additional income. Thus unemployed pastoralists, i.e. pastoralists with no income other than those from selling livestock, would be more dependent on their livestock and might therefore treat their animals with more care. I rated a pastoralist who is employed as category one which indicated least dependence. A pastoralist who receives an old-age pension was rated as two, while an unemployed pastoralist was rated three, indicating a strong dependence.

(v) Transport

A pastoralist with transport is in a better situation to transport water and supplementary food to the stock post and at the same time transport animals to buyers. I tested whether pastoralists with vehicles had different herd performance than those without a vehicle.

(vi) Veterinary services

It is commonly believed that a high investment in veterinary services would tend to improve the health and performance of animals (Gefu & Adu 1982), and hence better possible herd performance. I compared herd performance between pastoralists who made use of veterinary services and those that did not.

4.2.2 Statistical analyses

Two databases were used for different statistical analyses. To avoid 'pseudo-replication' and interdependence between successive censuses, I used the mean taken from quarterly counts to test for correlations and differences in stock numbers and herd size between 1995 and 2002 (n = 6). I used the data from each quarterly count to study the herd dynamics during the study period (n = 123) and among individual pastoralists for the different years (n = 20). To determine the regulatory effect of rainfall on livestock populations for the different years, I calculated Pearson's Product Moment correlations of total stock numbers and herd size against the previous season's rainfall as well as the mean of the previous two seasons' rainfall. Annual rates for herd kidding, offtake, production and pastoralists estimates on their herd mortality for the different years were correlated with the average absolute annual rainfall, using Pearson's Product Moment correlations. The latter were also used to study dynamics between herd size and performance variables (mean annual kidding, offtake, mortality and production) for the different years. Detection of density dependent relationships is fraught with the problem of analysis and has been debated for more than half a century (e.g. Berryman 2002; Murray 1999). For example, one is likely to obtain density-dependent relationship between random numbers of herd growth over time because λ (i.e. N_{t+1} / N_t) is a function of herd size (N_t). To reduce the problem of interdependence between dependent and independent variables, results are presented in relation to the expected output from the mean for all herds. Points above the expected output line indicate higher than mean output. To test for significant relationship with herd size, I calculated the number of points above or below the line expected from the mean of all herds and tested whether smaller herds (< median) had a different distribution of positive or negative values than larger herd sizes (> median) using Fisher's exact test. For example, from a hypothetical example (Figure 4.2), herd size smaller than the median had nine herds less than expected and none more than expected while larger herd sizes had 6 herds more than expected and three herds equal or less than expected, giving $P < 0.01$ (Fisher's Exact test).

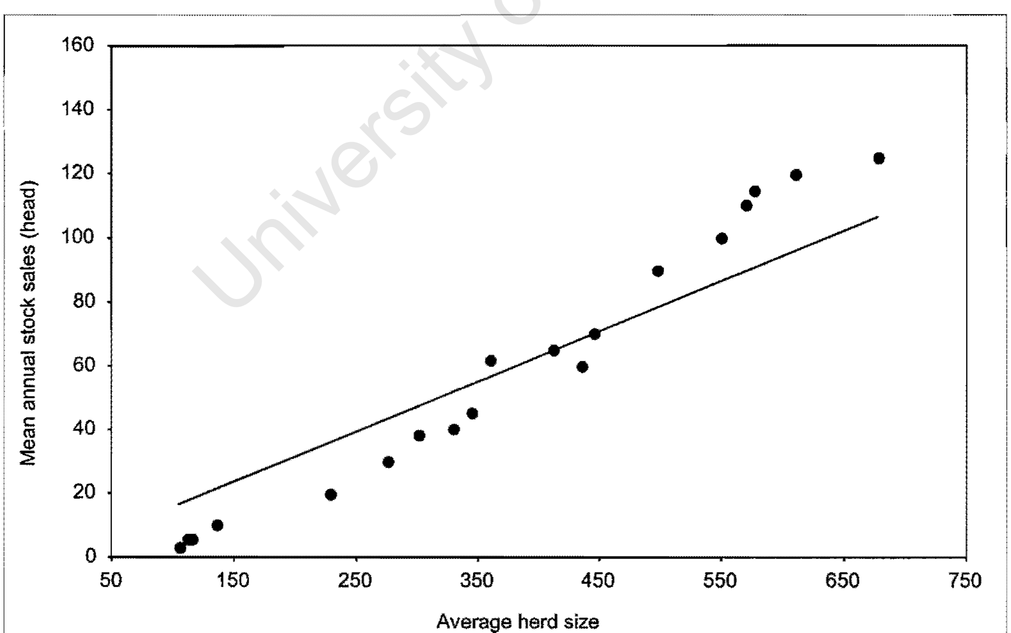


Figure 4.2. Mean annual stock sales in relation to the average herd size maintained between 1990 and 2000. The line indicates the expected number of animals sold calculated from the mean for all the herds; points above the line indicate higher number of animals sold than mean stock sales.

Generalised Linear Modelling (GLM) was used to determine the extent to which herd management influence the production and herd size of individual herds. The model for analysis included effects for continuous (i.e. total people at stock post, pastoralist age and perceived skills) and categorical (i.e. employment status, usage of transport and veterinary services) independent variables using the sigma-restricted parameterisation representation of effects. Herd production and size were used as response variables. Differences in performance variables in relation to total people staying at the stock post to take care of the livestock, pastoralist age and skills were tested with Spearman Rank correlations. T-tests were performed to determine if livestock inputs, such as the usage of own transport and veterinary services, significantly contributed to herd performance. Analysis of variance was used to test for significant effects in herd productivity due to the employment status of pastoralists (LSD test was performed for post hoc comparisons of means).

4.3 Results

4.3.1 Stock numbers and rate of recovery in response to rainfall

Stock numbers (mean taken on quarterly counts) did not track the rainfall closely, but seemed to experience a lag-effect with the mean of the two previous season's rainfall ($r = 0.72$; $P < 0.05$; $n = 6$)(Figure 4.3). Only goats showed a significant correlation with the mean annual rainfall for the two seasons ($r = 0.67$; $P < 0.05$; $n = 6$). Total stock numbers have been relatively constant since 1995 until 2002; ranging from as low as 4 407 animals to a maximum of 7071 animals. Stock numbers increased during wet years and decreased in drier years. For example, the total stock numbers in the RNP decreased by 20% following the stock recorded in 1998. This was followed by another 21% reduction in stock numbers in 2000 before the population started to recover during the following years. Stock numbers seem to lag 1-2 years after the previous season's rainfall. However, a larger data series is needed to evaluate whether the variability in stock numbers, indeed, tracks annual rainfall.

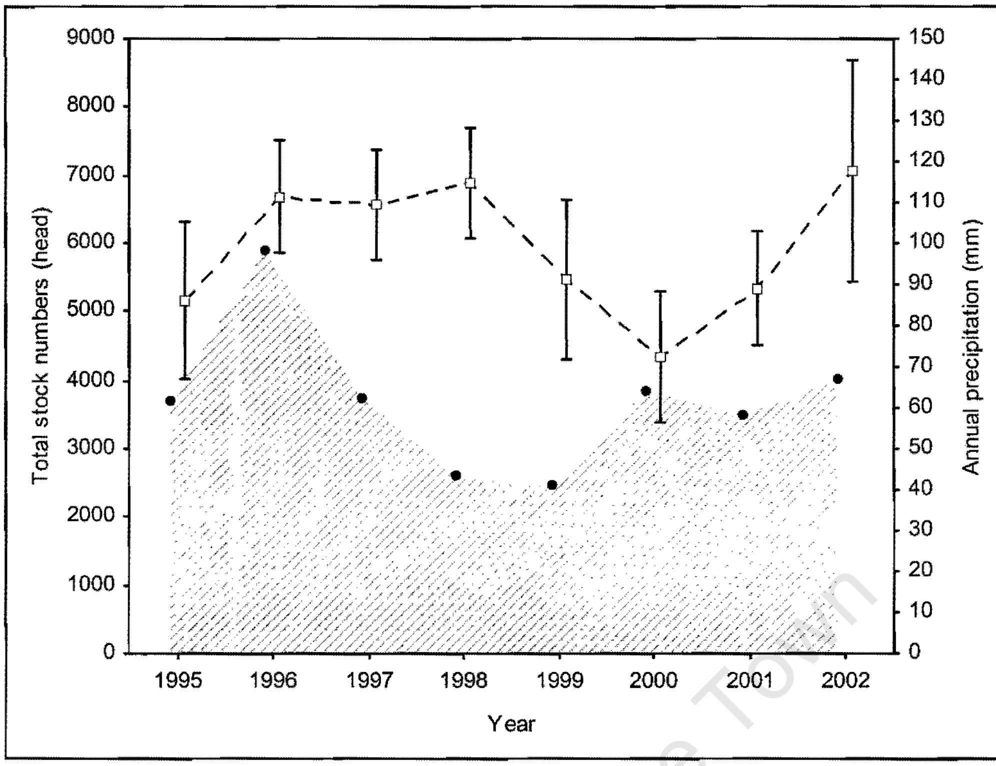


Figure 4.3. Total stock numbers (taken from quarterly counts) and annual precipitation (mm) for the RNP between 1995 and 2002.

The mean annual kidding for herds in the RNP between 1996 and 2001 was 54% and correlated significantly with the annual rainfall deviation for the different years ($r = 0.97$; $P < 0.05$)(Figure 4.4). Both mean annual herd offtake ($r = 0.93$; $P < 0.05$)(Figure 4.5) and production ($r = 0.81$; $P < 0.05$)(Figure 4.6) in the RNP also showed positive correlations with annual rainfall deviations. Pastoralists estimates about their annual stock losses did not correlate with the deviation in annual rainfall during the same study period (Figure 4.7).

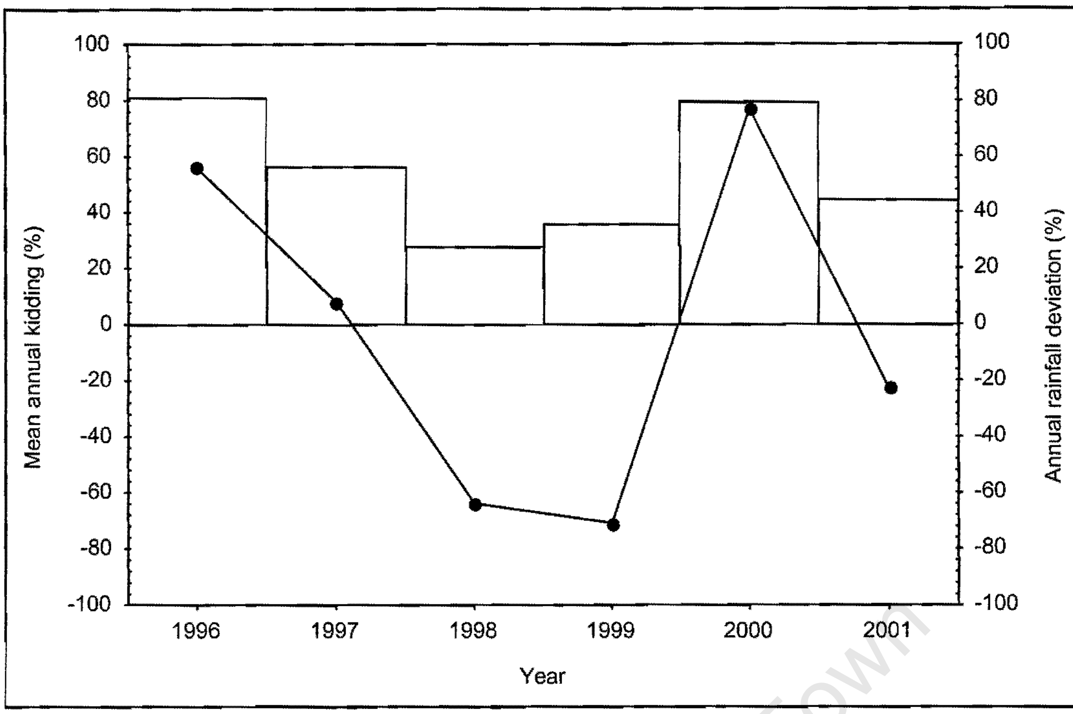


Figure 4.4. Mean annual kidding (%) (bar) for goat herds in relation to annual rainfall deviation (%)(line) in the RNP between 1996 and 2001

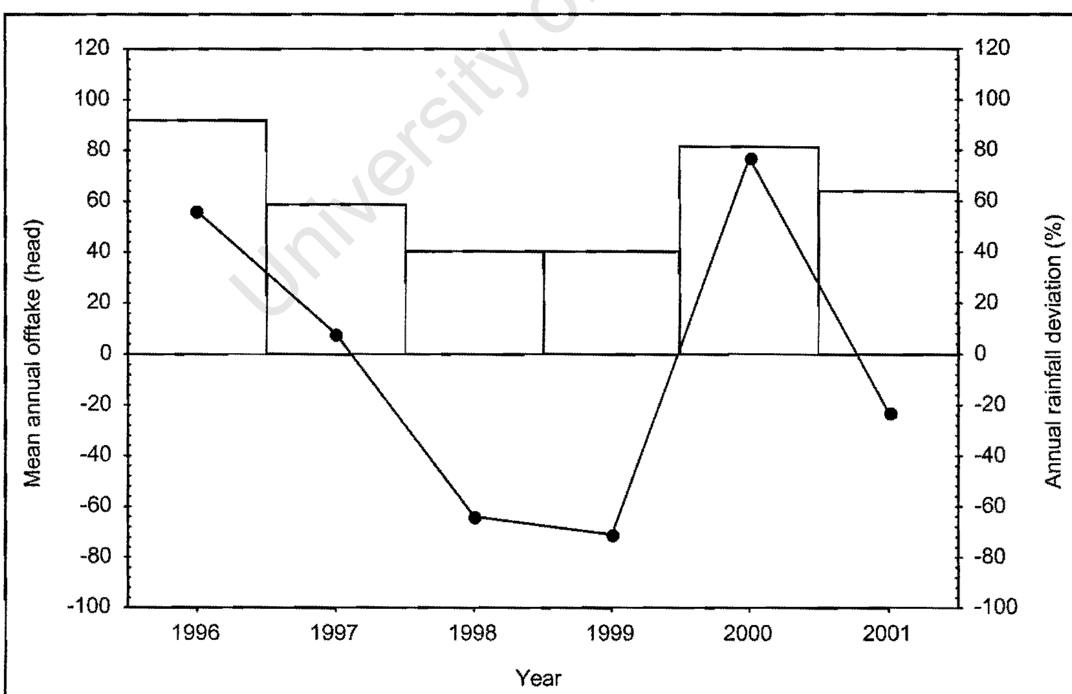


Figure 4.5. Mean annual offtake (head)(bar) for goat herds in relation to annual rainfall deviation (%)(line) in the RNP between 1996 and 2001.

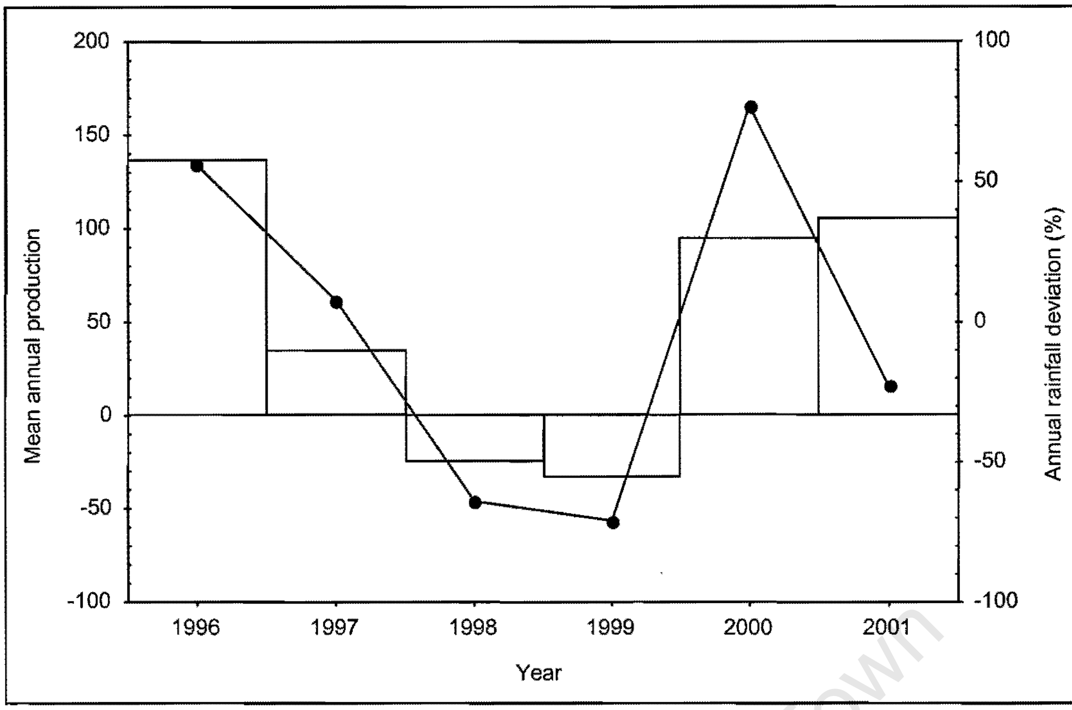


Figure 4.6. Mean annual herd production (head)(bar) for goats in relation to annual rainfall deviation (%)(line) in the RNP between 1996 and 2001.

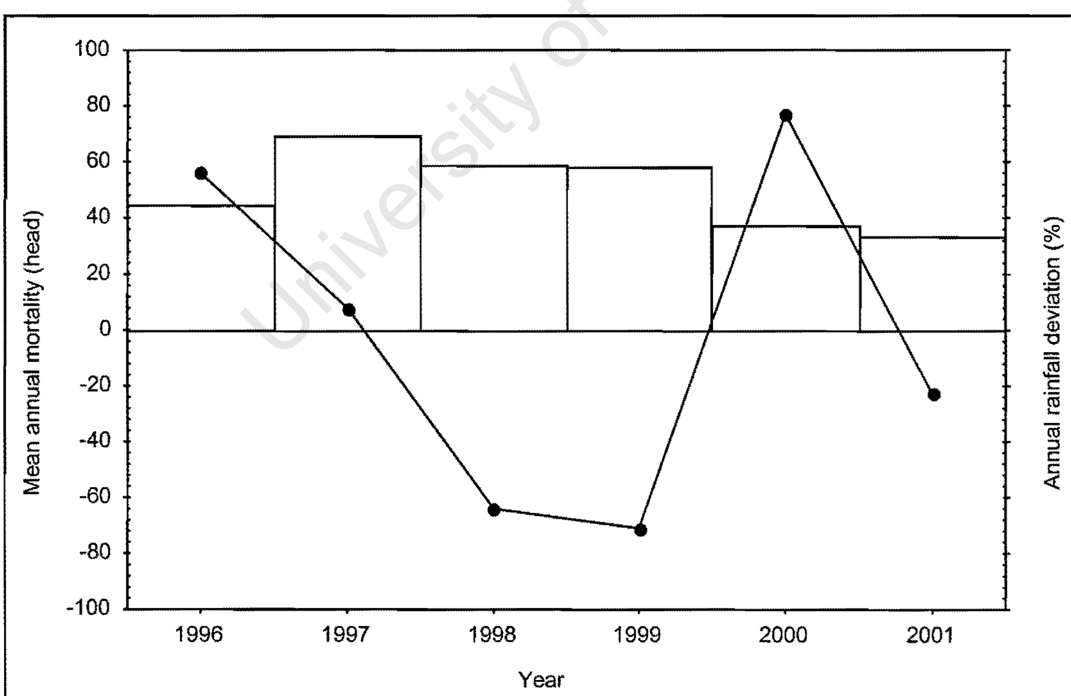


Figure 4.7. Mean annual herd mortality (head)(bar) for goats in relation to annual rainfall deviation (%)(line) in the RNP between 1996 and 2001. Mortality is based on pastoralists estimates of annual stock losses.

Mean herd size (taken from quarterly counts) also decreased by 21% in 1999 and a further 11% in 2000 to reach its lowest size of ca. 300 animals during the study period (Figure 4.8). Mean herd size correlated significantly with the two previous seasons' rainfall for the different years ($r = 0.67$; $P < 0.05$) and total stock numbers between 1995-2002 ($r = 0.76$; $P < 0.05$). An increase in mean herd size for individual pastoralists for the different years was mainly as a result of an increase in the number of does in the herd ($r = 0.78$; $P < 0.01$; $n = 123$). The latter was correlated with the number of yearlings in a herd transferred to does ($r = 0.59$; $P < 0.05$; $n = 123$). When comparing herd sizes before and after the drought, a higher mean annual herd size (ca. 450 animals) was maintained before 1998 than after 1999 (ca. 330 animals) in the RNP.

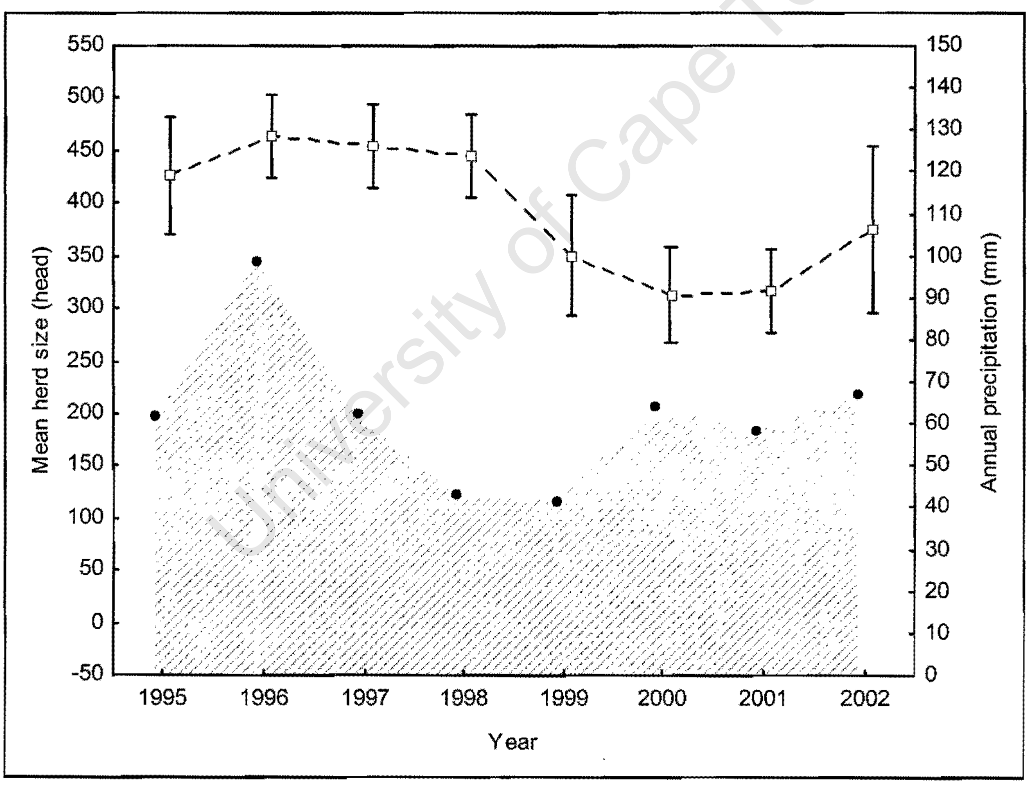


Figure 4.8. Mean annual herd size (taken from quarterly counts) and annual precipitation (mm) for the RNP between 1995 and 2002.

4.3.2 Herd dynamics

(a) Kidding

Mean annual number of kids per herd was strongly correlated with herd size ($r = 0.76$; $P < 0.01$; $n = 20$) for the different years. Based on the expected number of kids produced from mean herd size, the ten smaller herds experienced higher than mean kid production per annum while all ten pastoralists with herd sizes larger than 350 animals produced lower than mean kidding (on average 35% lower than the expected kid production)(Figure 4.9). The mean annual kidding rate for goats of individual herds in the RNP between 1996-2002 was calculated at ca. 20% of the size of the herd. The number of weaned kids per doe was positively correlated with annual rainfall ($r = 0.48$; $P < 0.05$; $n = 123$). All the herds with larger than ca. 500 animals maintained on average 25% fewer does per ram in a herd than those with smaller herds in the RNP.

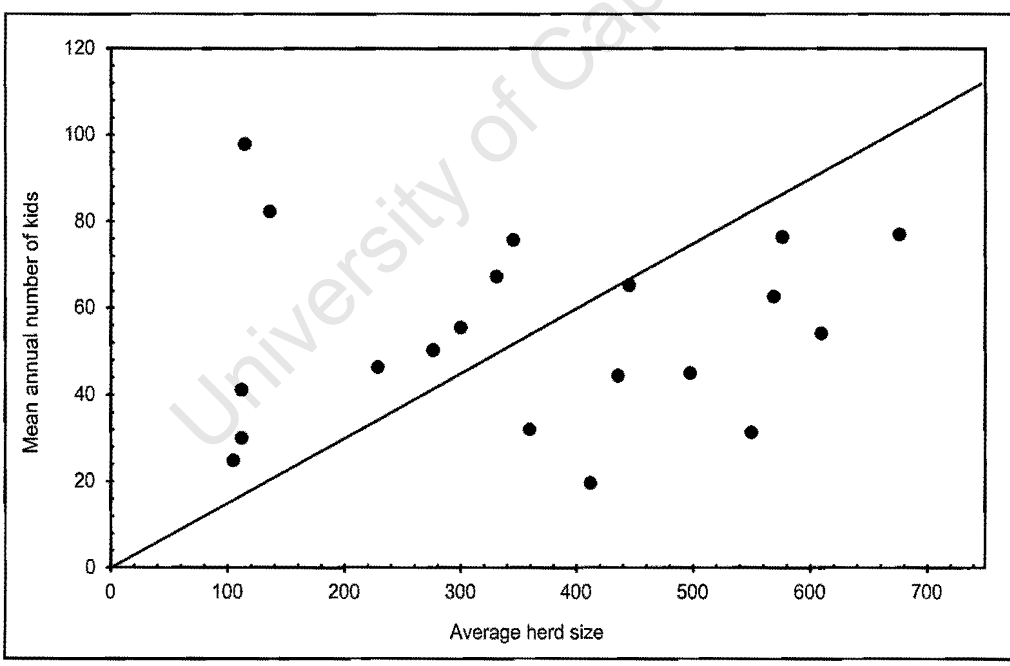


Figure 4.9. Mean annual kidding (see text for definition) for goats in relation to average herd size between 1996-2001 in the RNP. The line indicates the expected kidding from the mean for all herds; points above the line indicate higher than mean kid production. $P < 0.001$ (Fisher's Exact test)

(b) Offtake

Pastoralist estimates of animal sales and slaughter are correlated with their respective herd sizes for the different years ($r = 0.72$; $P < 0.05$; $n = 20$). During the interviews, it seemed that pastoralists with larger herd sizes were not completely aware of their offtake and therefore, the quality of the data is questioned. There was no clear relationship between herd size and the magnitude of animal offtake (Figure 4.10). Based on pastoralists estimates, the mean annual offtake for individual herd sizes was 16%. The total number of animals harvested ranged from zero to 138 animals per annum. The proportion of doe sales by individual pastoralists was not correlated with their herd sizes between 1995 and 2002 ($r = 0.02$; $P = 0.86$; $n = 111$).

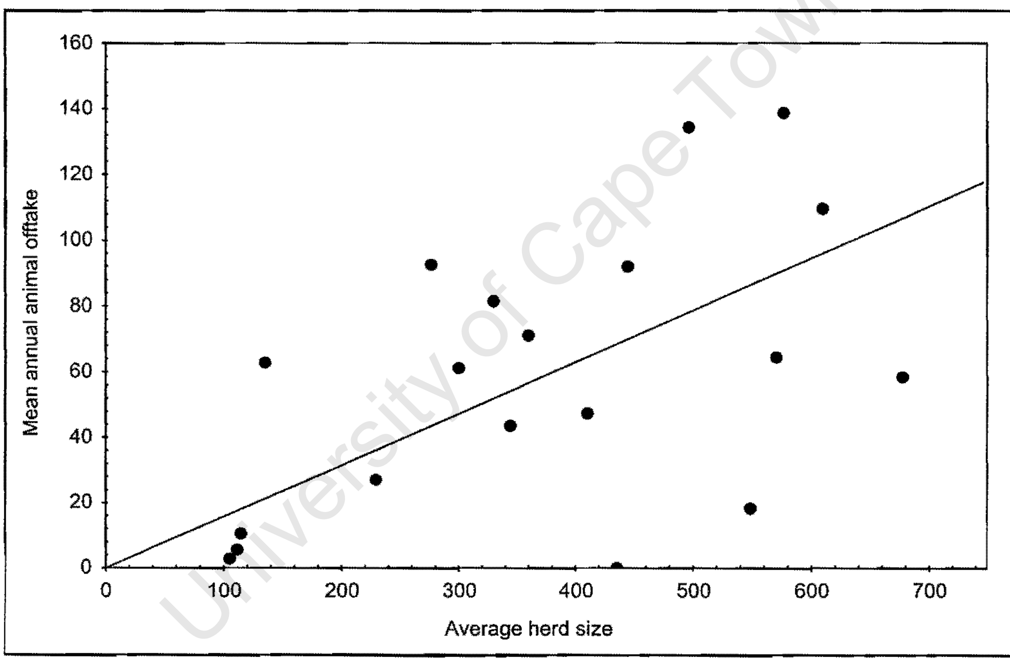


Figure 4.10. Mean annual number of animals slaughtered and sold in relation to the average herd size maintained between 1996 and 2001. The line indicates the expected number of animals harvested calculated from the mean for all herds; points above the line indicate higher offtake than mean harvest. $P > 0.1$ (Fisher's Exact test)

(c) Mortality

Mean annual mortality was correlated with herd size (r = 0.67; P < 0.01; n = 20)(Figure 4.11). There was no clear trend in density dependent mortality, except for the four smallest herds that showed lower rates than the mean mortality over the period. On average, pastoralists estimated the mortality for their individual herds at 13% per annum.

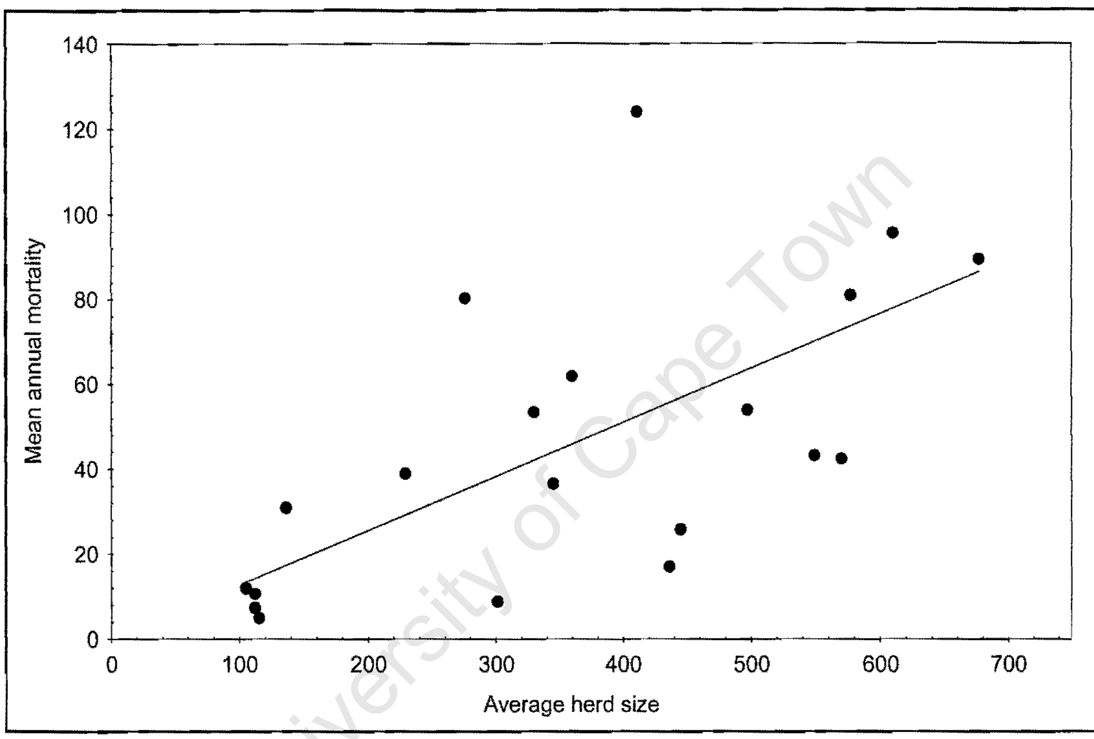


Figure 4.11. Mean annual stock mortality, based on pastoralists estimates, in relation to the average herd size maintained between 1996 and 2001. The line indicates the expected number of animals lost calculated from the mean mortality for all herds; points above the line indicate higher losses than mean mortality. P > 0.1 (Fisher's Exact test)

(d) Production

All, but two, of the pastoralists experienced positive herd production from the beginning to the end of the study period (Figure 4.12). The mean annual herd productivity for all the herds in the RNP during the study period was 15%, but ranged from as low as 4% to as much as 43% over the study period. The herd sizes of only two pastoralists showed negative growth over the study period.

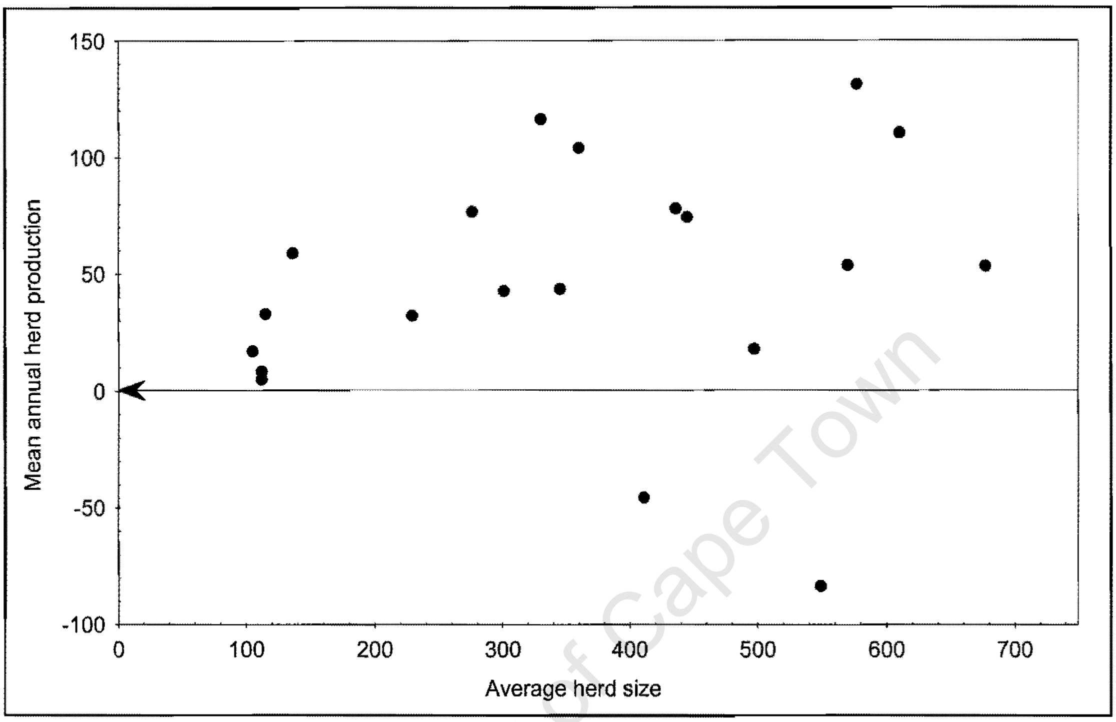


Figure 4.12. The sum of total number of animals taken off (sold and slaughtered) and the difference in animal number between N_t and N_{t+1} for the different herds between 1996 and 2001 in the RNP. The arrow indicates the level of herd productivity where herd size remains constant after kidding and offtake have been incorporated in the production formula; above the line indicates better herd production with no decrease in herd size.

(e) Persistence

The population response to the drought varied among the individual herd sizes; nine herds experienced decreasing sizes during 1999 and at least six herds during 2000 (Figure 4.13).

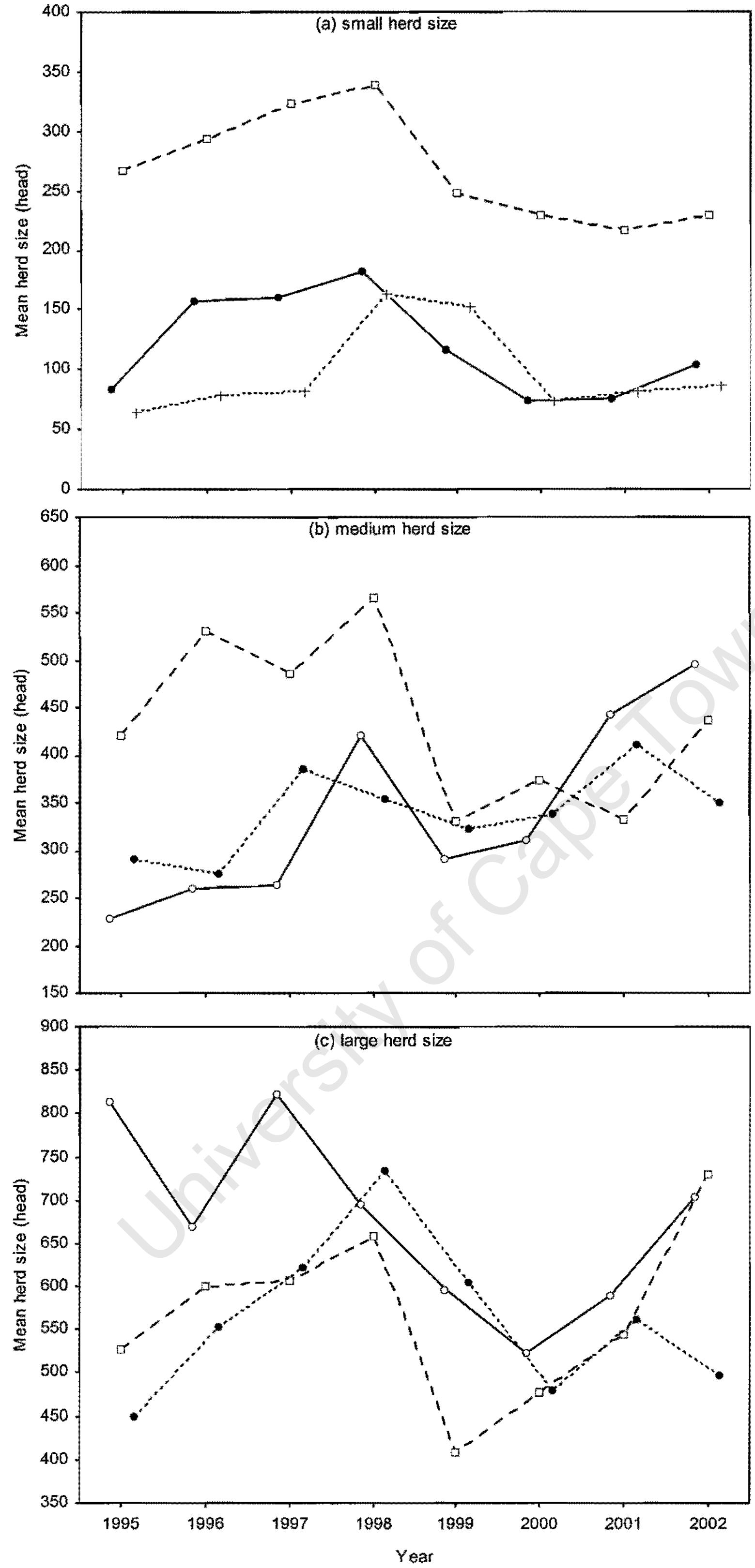


Figure 4.13. Mean herd size for pastoralists with (a) small herds (<300 animals), (b) medium herds (>300, but less than 500 animals) and (c) large herds (>500 animals) in the RNP between 1995 and 2002. Note different scales on each graph.

Figure 4.14 showed the drought-related population crashes for the individual herds in the RNP between 1995 and 2002. The average population crash for individual herds during the drought period was 42%; ranging from as low as 13% to as high as 69%. Larger herd sizes did not experience higher proportional stock losses during the drought than smaller herds (Figure 4.14).

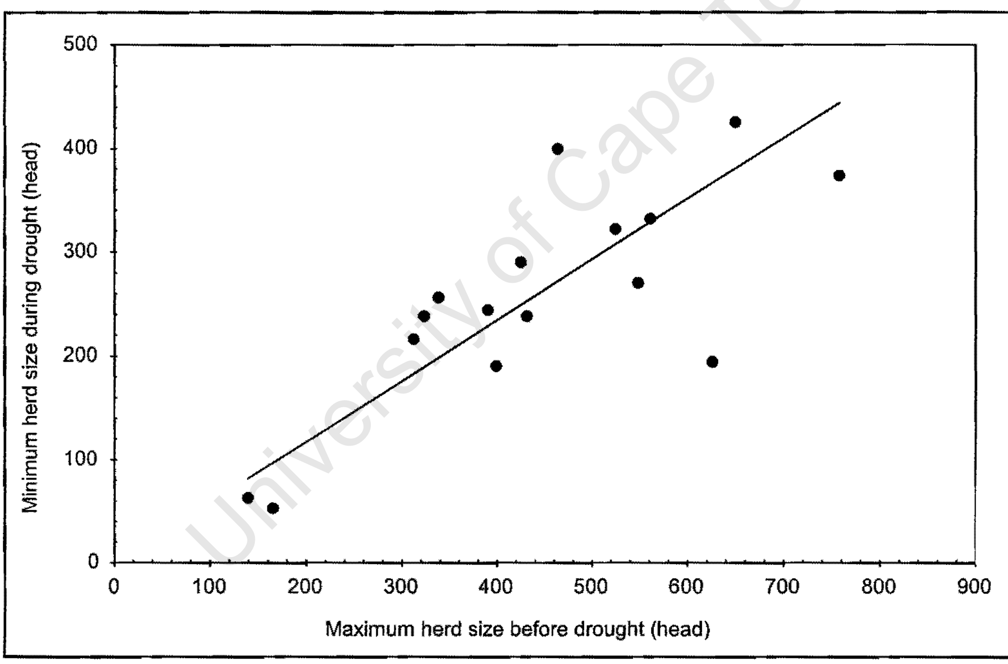


Figure 4.14. The relationship between minimum herd size during the drought and maximum herd size before the drought in the RNP during the 1998-1999 drought period. The line indicates the expected population crash from the mean for all herds; points above the line indicate higher than mean population reduction. $P > 0.1$ (Fisher's Exact test)

The average recovery rate for the individual herds in the RNP after the drought-related population crashes was 36% (Figure 4.15). The herd recovery after the drought ranged from as low as 1% to as high as 92%. The rate of recovery (max. N_t after drought / min. N_t during drought) was not related to herd size (Figure 4.16).

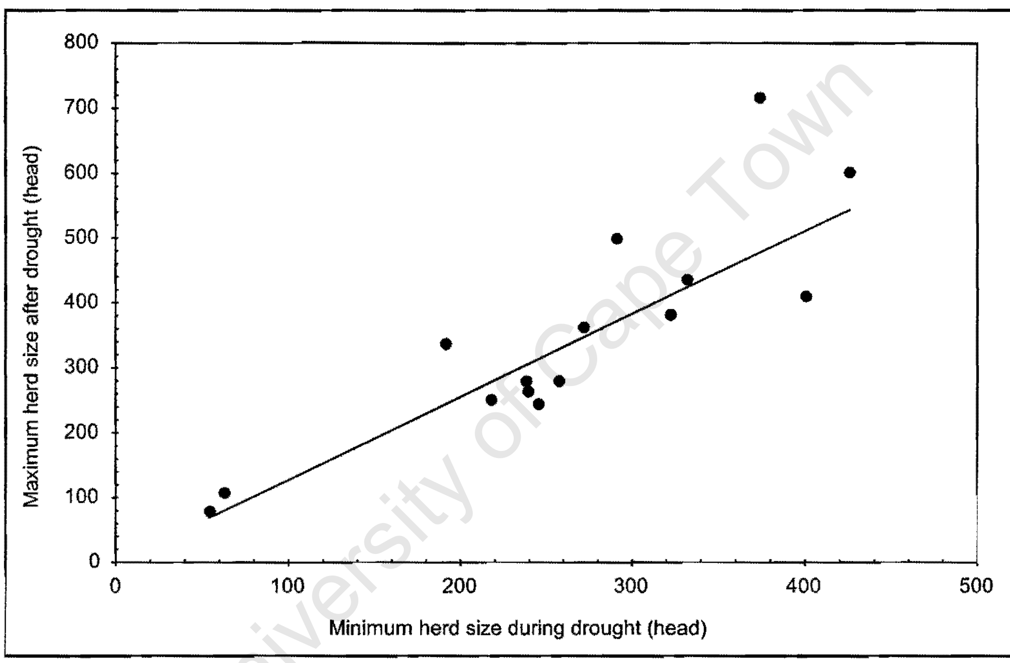


Figure 4.15. The relationship between maximum herd size after the drought and minimum herd size during the drought depict the recovery rate for individual herds in the RNP after the 1998-1999 drought period. The line indicates the expected recovery rate from the mean for all herds; points above the line indicate higher than mean population increase. $P > 0.1$ (Fisher's Exact test)

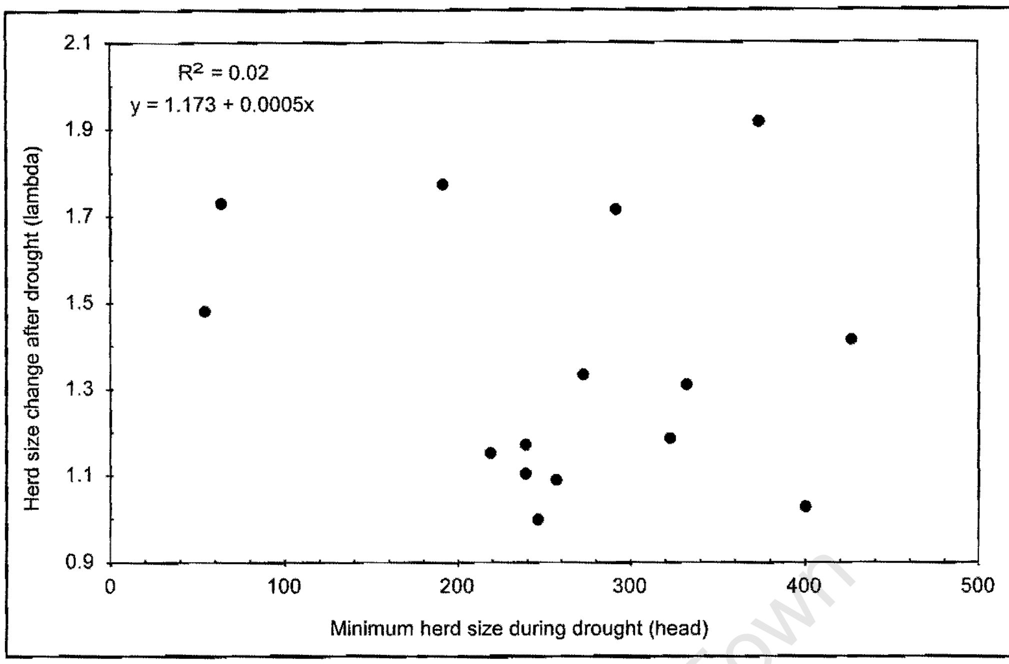


Figure 4.16. The population change (lambda) for individual herds in the RNP after the 1998-1999 drought in relation to the minimum herd size during the drought period showing no density-dependence.

4.3.3 The effect of herd management strategies on herd performance

GLM tests of significance showed that the total number people at the stock post was the only factor predicting variation in herd production in the RNP during the study period ($F = 3.83$; $P < 0.05$)(Table 4.1). Usage of transport ($F = 5.99$; $P < 0.05$), and possibly also pastoralist skills ($F = 3.76$; $P = 0.05$), were significant related to variation in herd sizes. Pastoralists skills in farming was correlated with the composition aspects of a herd (i.e. size, number of does, number of yearlings and total kids produced) for the different years (Table 4.2). The presence of the herder, the pastoralist and his family, as opposed to the herder alone, at the stock post were significantly correlated with higher offtake rates ($R = 0.62$; $P < 0.05$) and herd production ($R = 0.55$; $P < 0.05$) over time. Annual stock mortalities were also positively correlated with the number of people staying at the stock post ($R = 0.56$; $P < 0.05$). Pastoralists that make use of their own transport for their management strategies maintained higher average herd sizes in the RNP over time ($t = 3.44$; $df = 18$; $P < 0.01$), but with higher mortalities ($t = 2.17$; $df = 18$; $P < 0.05$). The percentage of weaned kids per doe was correlated with the usage of veterinary services ($t = 2.48$; $df = 18$;

P < 0.05). The analysis of variance performed for herd productivity between pastoralists with different socio-economic profiles showed that neither offtake (F = 2.04; df = 2,17; P = 0.16) nor mortality (F = 1.87; df = 2,17; P = 0.18) rates differed between employed, pension and unemployed pastoralists.

Table 4.1. GLM test results of significance for the influence of herd management on herd production and size in the RNP. Production and herd size were the response variables. The model included effects for continuous (i.e. total people at stock post, pastoralist age and perceived skills) and categorical (i.e. employment status, usage of transport and veterinary services) independent variables.

	Herd production		Herd size	
	F value	P	F	P
No. people at stock post	3.83	P < 0.05	2.27	P = 0.13
Pastoralist age	1.75	P = 0.19	3.19	P = 0.07
Pastoralists skills	0.28	P = 0.60	3.76	P = 0.05
Employment status	0.01	P = 0.94	0.14	P = 0.71
Usage of own transport	0.05	P = 0.82	5.99	P < 0.05
Usage of veterinary services	0.63	P = 0.43	3.18	P = 0.07

Table 4.2. Spearman Rank correlation matrix showing relationships between herd performance variables and three herd management indicators for 20 pastoralists in the RNP. Significant R values (p<0.05) are highlighted.

	People at stock post	Pastoralist age	Farming skills
Herd size	0.37	0.31	**0.67**
No. does	0.36	0.27	**0.63**
No. yearlings	0.36	0.23	**0.66**
Fecundity	**0.53**	0.36	**0.73**
Kidding	0.13	0.01	0.20
Weaned kids/doe	**0.46**	0.31	**0.46**
Prop. yearlings transferred to doe	0.16	0.23	0.38
Prop. does sold	0.13	0.06	**0.49**
Doe mortality	**0.55**	**0.55**	0.30
Offtake	**0.62**	0.30	0.42
Mortality	**0.56**	0.41	0.32
Production	**0.55**	0.06	**0.48**

4.4 Discussion

4.5.1 Rainfall regulates stock numbers and its recovery

The rainfall in this study not only fluctuated from season to season within a year, but also varied between one year and another (*cv* 50%). The stock numbers did not track the annual rainfall closely (1-2 year lagged), suggesting that the carrying capacity (and therefore the extent of food limitation) of the RNP rangeland in a given year was primarily determined by the amount of rainfall of the two previous seasons. Rainfall generally affects plant growth (Hatch *et al.* 1996; Hoffman & Cowling 1990), which results in seasonal and inter-annual fluctuations in the quantity of forage availability (Danckwerts & Tainton 1993; Illius & Hodgson 1996; Owen-Smith & Danckwerts 1997). Research has shown that stocking rates were correlated with mean annual rainfall at magisterial district level in South Africa (Dean & Macdonald 1994; Hoffman *et al.* 1999), but mean annual rainfall was a very poor predictor of stocking rates at the Communal Reserve level (Todd & Hoffman 2001). The finding of the latter research suggests that mean annual rainfall or total annual forage production does not always determine how many animal units can be maintained every year. The rate of recovery for total stock numbers after population crashes in 1998 and 1999 in the RNP was rapid (< 2yrs). This finding suggests that populations are probably food limited most of the time, with the amount of food varying with rainfall in particularly the winter foraging areas. Therefore, the notion that grazing has a minimal impact on the vegetation of arid environments (Ellis & Swift 1988) may not hold for the RNP because the vegetation has little time to recover after drought-induced reduction in livestock foraging. Mean herd size for the RNP did not recover rapidly after 1999 because new herds (ca. 3) were established in recent years by sons who inherited stock after their father's death. The strong correlation between goat numbers and rainfall suggests that goats are better able to closely track a highly variable carrying capacity. Boergoats are generally perceived to be hardy and survive well in a wide range of environments (Campbell 1984), seemingly on a great variety of diets (Raats 1997, Chapter 7). In the Eastern Cape region, Raats (1982) and Scheltema (1994) demonstrated higher reproductive rates in Boergoats than different breeds of sheep and cattle.

The recent multi-year drought period (1998-1999) in the RNP has not resulted in direct stock mortalities (Figure 4.7), but rather had a direct correlation with herd production (kidding and offtake) resulting in variation in animal numbers with rainfall over time. However, the uncertainty of pastoralists estimates about stock losses raises questions on the quality of the data. Desta & Coppock (2002) demonstrated that long periods of gradual herd growth in the Borana pastoral system of Ethiopia were punctuated by drought-induced cattle losses which occurred when high stocking rates were combined with large rainfall deficits, as opposed to being purely controlled by rainfall variation. The finding that fluctuations in herd size were only correlated with the previous season's rainfall for the different years (Figure 4.8) suggests that herd size in RNP for a given year was kept in check by livestock reproduction and survival. One of the reasons why herd production was correlated with lagged rainfall, is probably related to the existence of riparian 'key resource' areas (Coppock *et al.* 1986; Homewood & Rogers 1987; Scoones 1990). I recorded concentrations of large number of animals grazing along the Orange River during periods of low rainfall (Chapter 5a). Besides water, the Orange River provided a good supply of forage and shade which could have helped to maintain herd productivity over the study period.

4.4.2 Herd dynamics

Herd sizes below 350 animals produced higher than expected kid production while those with larger herd sizes experienced lower than average kid production per year compared to the mean from all herds (Figure 4.9). Larger herd sizes are likely to experience at least one third less kidding from their herds than that achieved in smaller herds. Changes in number of ewes per ram from 35 to 248 had no effects on kidding percentages, suggesting that the mating capability of Boergoat rams is considerably greater than is recognised by recommended agricultural practices (ca. 3%). Most of the kids that died during this study died within their first two months. When this takes place, it affects the available proportions of yearlings transferred to does and the potential to replace the old breeding stock. For both the two pastoralists with unsustainable herd production (411 and 549 animals respectively) (Figure 4.12), high reproductive rates were offset by high rates of kid mortality (the causes of these were not known to pastoralists). As a result, their herd sizes decreased when they sold and slaughtered animals to sustain the needs of their families. They could also not profitably exploit their large standing crop of animals as in the case of other African countries (Devendra 1975; Okello & Obwolo 1985; Boor *et al.* 1987) and parts of Namaqualand (Hoffman *et al.* 1999) where live-animal products, for example milk, are important in the household and do not require slaughtering of the animal. One of these pastoralists abandoned pastoralism within the last few months of this study.

Whereas conception is directly related to veld condition (Unanian & Feliciano-Silva 1984), which in turn is related to rainfall (O'Connor & Roux 1995), this study showed that kidding and weaning rates were related to annual rainfall. Decisions about offtake rates (which also determine herd size) were also related to annual rainfall. Sales of goats accounted for more of the offtake than slaughter and were usually local, to people at village level. The finding that estimates of animal sales and slaughter seemed to be correlated with their respective herd sizes for the different years, suggests that offtake strategies are likely to be driven by demand for, rather than availability of, goats. The results indicate that one could find both high and low offtake rates and mortalities among larger herd sizes (>300 animals), also suggest that other factors (such as different herd management strategies) may influence the performance of the herd.

The response patterns of population change of goats to the recent drought within the study area were diverse among the herds (Figure 4.9), suggesting that some herds experience populations crash earlier than others. In percentage terms, however, the collapse of populations was not higher in larger herds than smaller herds. The population recovery rate after the drought was also not density-dependent. These findings suggest that small herds (ca. 100) are more likely to be eliminated in severe droughts due to the low number of animals (nucleus herd) likely to survive until the next wet season.

4.4.3 The effects of herd management strategies on herd performance

The results of this study suggest that different husbandry practices and socio-economic profiles affected different aspects of herd performance. The number of people at the stock post to take care of the stock, usage of own transport and possibly also pastoralist skills are important predictors of herd productivity. Higher herd production and offtake rates were maintained when many people (usually the whole family of the pastoralist and his herder) attended to the animals at the stock post. Income from wages and pension funds are often invested into livestock farming in the form of buying veterinary supplies and using their own transport between stock posts and the village. These kind of livestock inputs enabled pastoralists to maintain higher herd sizes in the RNP than those that do not make use of veterinary services and use their own transport. Herding and veterinary care at a regional scale also increased production efficiency to the extent that pastoral areas in South America were able to supported ten times the herbivore biomass per unit area than wildlife areas with similar carrying capacity levels (Oesterheld *et al.* 1992). Pastoralists in the RNP did not invest their income into purchases of goats, or any other livestock for that matter. Pastoralists who receive additional income from remittances did not sell and slaughter more animals than those who are solely dependent on their animals to sustain their daily needs, suggesting that offtake is not need-driven. However this result is based on the quality of pastoralist estimates about their annual offtake. Pastoralists seemed to be perceived to be more skilful when they farmed with larger herd sizes.

Pastoralists have various production objectives and not all trying to 'maximise' herd productivity (Chapter 6). One pastoralist maintained the third highest kidding per herd for the different years, but maintained a constant herd production that allowed him to harvest only 10% of his animals each year. This pastoralist was not trying to 'maximise' productvity, but was merely attempting to increase his herd size. Another pastoralist maintained a herd production of almost 40% of his herd sizes (ca. 330 animals), while harvesting at least 25% of his animals each year. This particular pastoralist had the highest sustainable offtake rate at which the animal population was growing most rapidly, suggesting that he was trying to 'maximise' productvity whilst increasing herd size. In the case of two other pastoralists (ca. 577 and 610 animals), high offtake was maintained at lower population growth suggesting that these pastoralists keep stock primarily for monetary income and meat consumption. Because of the perceived importance of their breeding stock, pastoralists sold mainly yearlings which resulted in an average of 10% recruitment of 2-tooth and older animals per annum (recommended agricultural practice is ca. 25%; C. Smith, Pers. Comm. 2001). This created a situation where pastoralists herded with animals beyond their most productive stage of life (Scheltema 1994 demonstrated this age for goats to between three to four years). This issue of keeping old animals rather than recruiting and culling for regular productive age classes was a function of pastoralist objectives in response to drought - and yet another scenario for the potential influence of different husbandry practices on herd performance.

4.5 Conclusion

Herd size and stocking rates have been the main focus of intervention to 'improve' livestock farming for many years. This study found little relationship between herd size and herd performance although higher kidding rates for smaller herds suggest that herd size could matter for herd production (if kids survived). The study also found little relationship between herd size and density dependent losses and recovery rates during a two year drought (density independence). This means that smaller herds have a higher risk of disappearing than larger herds. The number of people at the stock post to take care of the animals and the usage of own transport indicated that pastoralist management skills contribute significantly to herd performance. The results of this study are therefore surprising in the context of the standard rangeland theory and also given the conclusion that herds are usually food limited because of rapid recovery. The lack of strong density dependence recorded is likely due to the presence of the Orange River - a huge 'key resource' area. Developments along the Orange River may have much greater impact on herds than interventions on herd size and management. Patterns of food availability within the landscape are poorly known for this ecosystem. From this study, there is clearly no obvious incentives to an individual pastoralist to reduce herd size. And, therefore, it is unlikely to have a win-win situation for the pastoralists and RNP.

Chapter 5a

Spatial and temporal livestock movement
- response patterns of livestock (by pastoralists) to rainfall variability

5a.1 Introduction

Large areas of Africa are arid and semi-arid, and are generally subjected to periodic low rainfall. Not only is rainfall limited, but it may also be spatially unpredictable. Thus, the uneven seasonal rainfall distribution causes an uneven distribution and fluctuation in resource availability (Breman & de Wit 1983). Intra-annual fluctuations in forage and water availability thus pose a challenge to pastoralists in their choice of grazing strategy (Ellis & Swift 1988). The nature of this challenge becomes clearer when I examine the rangeland of RNP. In the RNP, opportunities for plant growth and livestock grazing are limited for most of the year; a fairly short winter rainfall period (May until July and again in September) followed by an extended dry period. In response to this harsh and seasonally varying environment, pastoralists move with their animals from one stock post to another to exploit available grazing resources. For the implementation of effective conservation strategies that would still allow pastoralists to exploit available pastures, it is important to determine the current extent to which the rangeland of the RNP is utilised by goats and sheep.

Livestock grazing in a seasonally varying environment show different travelling distances in response to changes in the amount and quality of forage on offer (Scoones 1995). The underlying assumption for these responses is that pastoralists adopt a flexible grazing strategy to take advantage of pasture (or grasslands in the case of wild ungulates, Coughenour 1991) responses when and where they occur (Smith 1992). It has been suggested that livestock keepers in nomadic pastoralism systems, as opposed to those making use of rotational grazing (Jarman & Sinclair 1979), appear best able to persist and exploit seasonally varying plant resources (Coughenour 1991). In Saudi Arabia, where forage is communally owned, the Bedouin herders move opportunistically among very large areas of land in response to random, patchy rainfall (Perevalotsky 1987). The Phala nomads of the Tibetan Plateau (Goldstein *et al.* 1990) rotate between a multipasture encampment used in winter, spring and summer and an encampment used in autumn and early winter. This allows them to utilise growing foliage during summer and provides an ample supply of ungrazed forage reserve for use in autumn and early winter, which prepares animals for subsistence through the long winter. Nomadic pastoralists in Turkana, Kenya (McCabe & Ellis 1987) are most densely aggregated on annual grasses during the wet season. As the dry season progresses, the pastoralists disperse throughout the high rainfall areas and in late dry seasons (Coppock *et al.* 1988), or in drought, pastoralists utilise the mountains and plateaus where there is little water and difficult terrain (Coughenour 1991). The Jie of Uganda move in an opposite pattern (Gulliver 1965). Camps are widely dispersed on the wet season ranges and as the dry season progresses, the Jie shift to the west and become progressively concentrated around permanent water sources. Pastoralists of the Niger delta of the Sahel traditionally moved into the northern drylands in the wet season to exploit the transient pulse of plant growth, but return to the more productive Niger delta in the dry season (Coughenour 1991). In the Balkhash basin of Russia, traditional Kazak nomads move from desert regions where livestock over-wintered, into semi-desert and semi-steppe zones for spring, up into high mountain pastures for summer and back to the drier plains for autumn, all in a transect of 250km length (Kervin *et al.* 2003).

In this chapter I explain patterns of herd movement in the RNP. If forage is limited more by rainfall than by animal number (Chapter 4), I hypothesised that more movements are expected during periods of low rainfall. Periods of low rainfall would result in grazing activities closer to water while high rainfall periods would allow pastoralists to migrate further away from perennial water sources. For daily movements within seasons, I postulated that small herds move more often than larger herds because size may affect the ease of moving. The number of days at a stock post vary inversely with the number of herd movements between stock posts because longer time spent at a post would reduce the number of times a herd was moved. How far animals move on a daily basis (i.e. foraging range) and the speed of travelling throughout the day's herding were also determined. For the purpose of this study, it was important to distinguish between herd size and pastoralist, because the movement of the herd is controlled by the pastoralist, who makes the decisions. If the animals were left to their own, herd size might be very important, but might become less important under the control of a pastoralist.

5a.2 Methods

The movement patterns of 20 individual herds of livestock were monitored between 1995 and 2001. Table 5.1 shows the profile of each pastoralist. Pastoralists do not have a permanent base in the RNP; they take all their provisions with them as they move with their livestock. Pastoralists make use of ca. 14 livestock watering points (boreholes, temporary springs, rock reservoirs, seepages and Orange River) throughout the year. All stock post locations and water points in the RNP were verified to metre accuracy using a Trimble Geographical Global Position model.

For the seasonal movement patterns, two periods of livestock movement data collection were followed; quarterly and weekly. The quarterly movement data covers a period of six years and herd location was recorded during January, April, July and October each year. The weekly movement data was recorded every week by RNP field rangers for three years (1999-2001). The local scale for diurnal movement patterns was defined as the area around a stock post that is foraged within one day (foraging orbit) in the 'buiteveld' between 1999-2001. This data was collected by accompanying herds on foot during 50 day-long excursions between May and September. I used a Garmin Plus2 GPS to record the movement of livestock from the time the animals left the stock post until they returned in the evening. The recordings involved a GPS location every 30 minutes from the time the animals left the stock post until noon and every 60 minutes thereafter. The data for 40 herding days (417 telemetry locations) were analysed for the size of foraging area and speed of travelling when grazing away from the stock post. Days in which herding was interrupted by pastoralist management practices such as stock sales, vaccinations, maintenance and movement between stock posts were not analysed.

Table 5.1. The profile of pastoralists whose livestock movements are discussed in this study.

Name	Ave herd size	Age	Remarks
Benjamin Swartbooi	136	44	Second eldest brother between Timotheus and Dawid. Not employed and herds animals himself.
Johannes Cooper	610	54	Not related to any other pastoralist. Makes use of son to herd his animals while staying behind with his wife at stock post.
Koos Josob	445	42	Younger brother of Willem and works as field ranger for RNP. Makes use of his uncle to herd his animals and visits stock post twice a week.
Frikkie Smith	330	65	Brother-in-law of Koos Diergaardt. Makes use of a herder and visits stock post during weekends.
Koos Diergaardt	577	64	Retired RNP field ranger and married to Frikkie's sister. Koos herds his animals while his wife stays behind at stock post.
Jakobus de Wet	276	75	Older brother of Nicodemus. A pensioner and makes use of his grandson to herd his animals while staying behind at stock post.
Joseph Domrogh	345	63	Older brother of Willem Domrogh and cousin of Piet and Paul. Herds animals himself.
JJ Links	112	45	RNP field ranger and employs a herder to look after his animals.
Joel Swartbooi	549	73	Is the uncle of Benjamin, Timotheus and Dawid. Makes use of a herder while staying behind at the stock post.
Paul Moos	360	43	Not related to any other pastoralist. Herds animals himself.
Nicodemus de Wet	301	66	Younger brother of Jakobus and makes use of herder. Visits stock post during weekends.
Paulus de Wet	497	68	Cousin of Jakobus and Nicodemus. Makes use of Paulus (jnr) and two younger brothers to herd animals. Stays in the village and visits the stock post weekends.
Paul Domrogh	411	61	Cousin of Piet and Joseph. Makes use of a herder while staying behind at stock post.
Piet Domrogh	229	76	Cousin of Paul and Joseph. Herds his animals himself while his wife stays behind at stock post.
Timotheus Swartbooi	570	46	Eldest brother of Benjamin and Dawid. Works as mine worker and makes use of two herders. Visits stock post during weekends.
Willem Domrogh	677	55	Younger brother of Joseph Domrogh and cousin of Piet and Paul. Works as mine worker. Uses son as herder and visits stock post during weekends.
Willem Josob	436	63	Older brother of Koos and makes use of herder. He visits the stock post mostly during weekends.
Dawid Swartbooi	115	40	Youngest brother of Benjamin and Timotheus. Works as mine worker and visits his stock post once a month.
Paulus de Wet jnr.	112	41	Son of Paulus de Wet and works as mine worker. Makes use of a herder and visits his animals once a month.
Thomas de Wet	105	35	Grandson of Jakobus de Wet and works as mine worker. Makes use of a herder and visits his animals once a month.

Geographical Information System software packages (ArcView GIS Version 3.2 and Cartlinx) were used to calculate temporal and spatial livestock movement data. These data were imported into the STATISTICA software package for statistical analyses. One-way ANOVA was used to test for a significant difference in the movement frequency between seasons. Because the effect of season on movements might be better modelled using rainfall instead of designated seasons as the independent variable, a regression analysis of the 16 quarters' rainfall on the number of herd movements between 1999-2001 was done. The median distance calculated from a stock post to its closest water source recorded during the weekly data reflects the favoured distance a pastoralist is willing to stay from water without having to move to another stock post closer to water. Pearson Product-Moment correlations were used to correlate the average distance from water per month with the mean monthly rainfall for the RNP between 1999-2001. The same test was performed to examine if larger herd sizes moved more frequently than smaller herd sizes. A t-test was performed to compare mean travelling rate in the morning and afternoon. Because the movement of the herd is largely determined by the decisions of pastoralists, I used an association pattern and pattern recognition software package (ASSOC1, Weber *et al.* 2001) to investigate the spatio-temporal association index of individual herds with each other. In using the association index (Dice 1945), ASSOC1 allowed the approximation of the amount of time each individual herd spent with another herd, and assessed the level of independence at which these herds grazed. Prior to performing association (the incidence of spatial association observed between two herds) and similarity (how similar are patterns of association between two herds) tests, I selected spatial (the maximum distance two individual herds could be found from one another and still be considered associated) and threshold (the minimum amount of time two associated individual herds spent together) values. I defined the spatial threshold as any two herds within 5km of each other (straight-line-distance) between 1999-2001, and set the temporal threshold at 70%. This particular spatial threshold was chosen to account for the average foraging range while the temporal threshold was chosen so that only closely associated herds were used in the association analysis. ASSOC1 software was not developed to provide a rigorous statistical test with critical values and a probability statement, but rather acts as a spatial analysis tool that provides the biologist with a set of measures upon which a decision of association can be more easily determined (Weber *et al.* 2001).

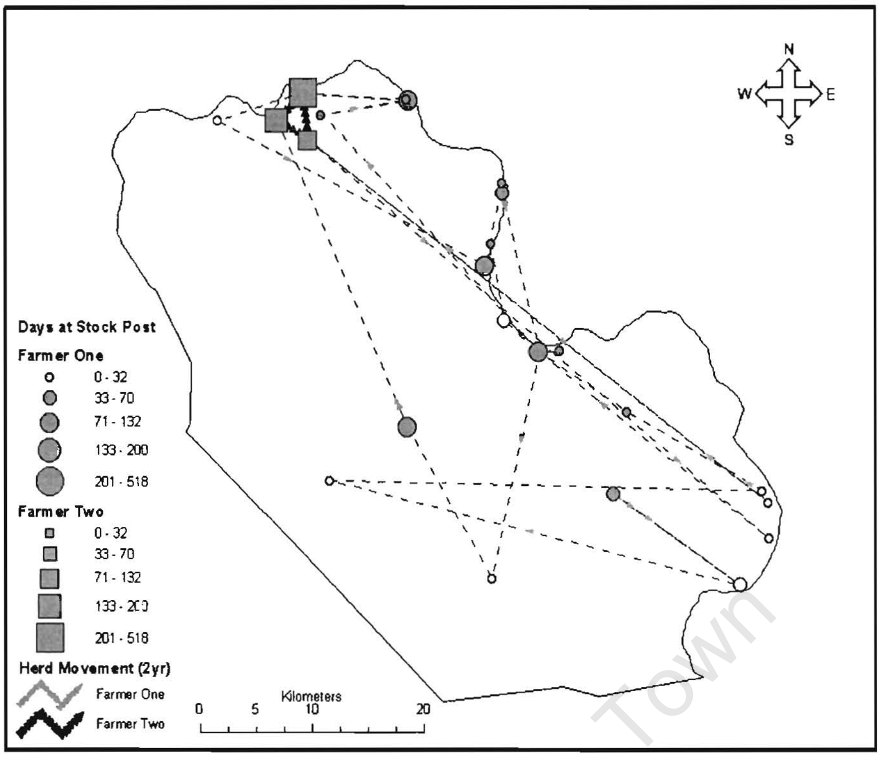
5a.3 Results

5a.3.1 Seasonal movement patterns

The majority (70%) of pastoralists registered to graze their livestock inside the RNP continued herding their animals in the park between 1995-2001. The rest of the herds also grazed areas outside the park over a cumulative period of two months. Generally, treks over approximately 10 km occurred between the two ecological zones; the inland winter grazing area during May-September and the rest of the year in the riparian zone along the Orange River. There was no statistically significant difference in movement frequencies between the arbitrarily designated quarters (seasons) between 1995-2001 ($F = 1.983$; $df = 3,76$; $P = 0.124$). However, the regression analysis for seasonal trend in movement frequencies between 1999-2001 indicated that more moves were associated with periods of higher rainfall ($R^2 = 0.279$; $P < 0.01$; $n = 30$). The average distance between any stock post and its closest water source in the RNP during 1995-2001 was 2.4 km, with more than 50% of the posts located 1.6 km from the closest water source (median). The distance that a herd moved from water per month was correlated with the mean monthly rainfall for the RNP ($r = 0.599$; $P < 0.05$; $n = 29$); closer to water during low rainfall and further away during high rainfall periods. The distance ranged from less than 10 m along the Orange River in the absence of rainfall to 9.6 km in the winter grazing zone.

Figure 5.1 shows the contrasting temporal movement patterns between six pastoralists and the length of stay at each stock post between 1999-2001. The movement patterns of two pastoralists with smaller average herd sizes (136 and 276 animals respectively)(Figure 5.1a) were compared to those patterns of pastoralists with average herd sizes of 411 and 445 animals (Figure 5.1b) and pastoralists with larger average herd sizes (610 and 577 animals)(Figure 5.1c) respectively. Three pastoralists (pastoralists one, four and six) were considered to be opportunistic; regularly moving between the two ecological zones and therefore covering a larger grazing area than the other three pastoralists with localised movement patterns.

(a)



(b)

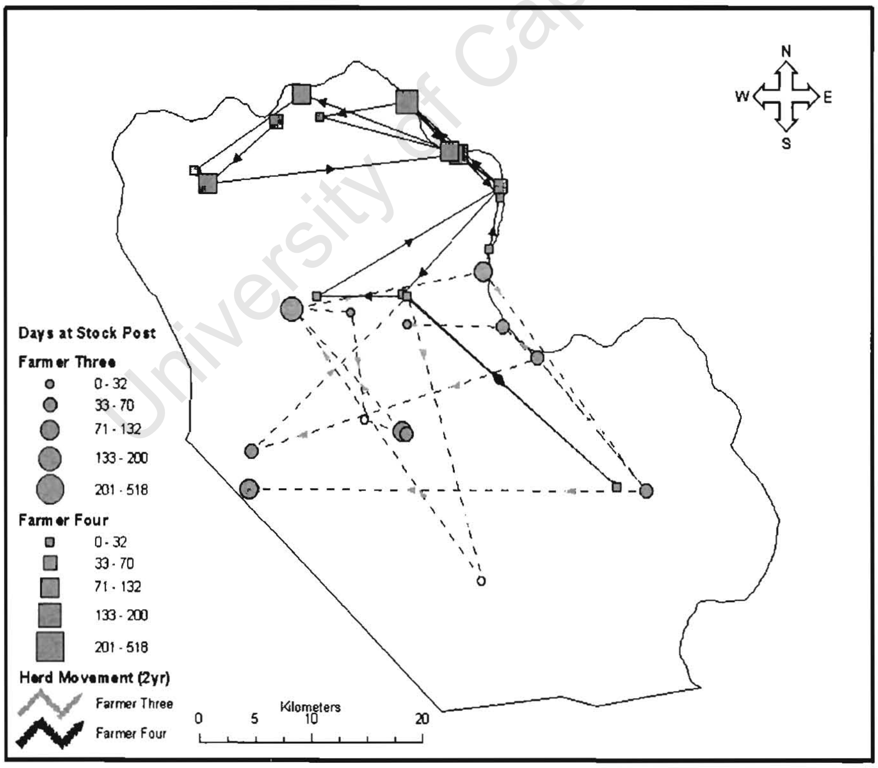


Figure 5.1. Seasonal movement patterns of six pastoralists (a = small herd sizes, b = medium herd sizes and c = large herd sizes) and the length of stay at each stock post between 1999-2001 in the RNP. See text for definition of herd sizes.

(c)

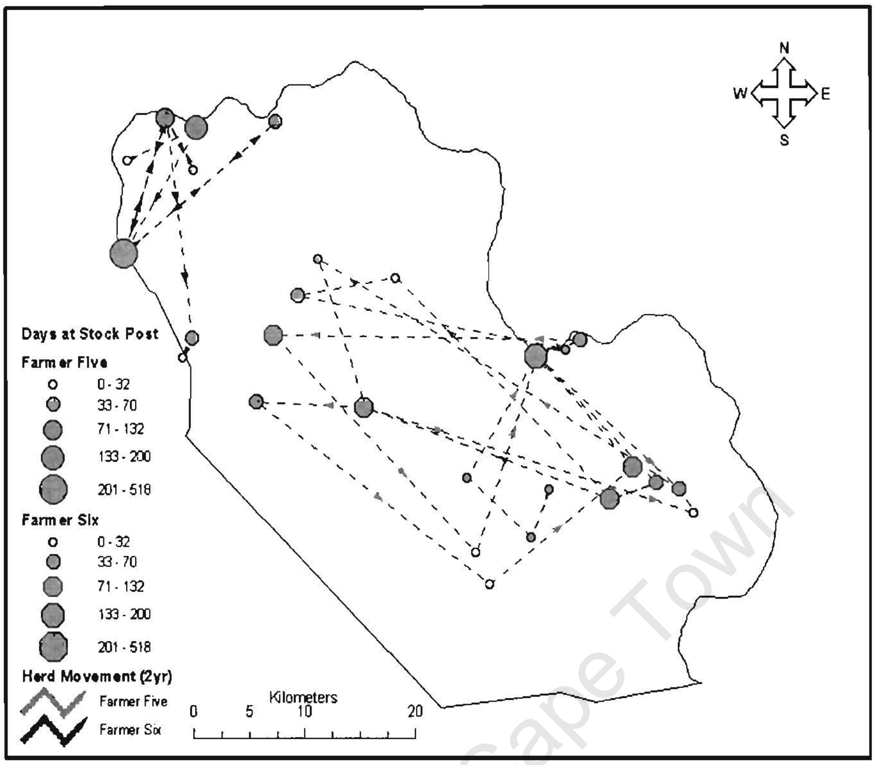


Figure 5.1 (cont.). Seasonal movement patterns of six pastoralists (a = small herd sizes, b = medium herd sizes and c = large herd sizes) and the length of stay at each stock post between 1999-2001 in the RNP. See text for definition of herd sizes.

If an individual herd was found within the spatial threshold of another and spends an adequate amount of time with that herd, those two herds were considered associated. Table 5.2 showed that most of the individual herds in the RNP were not associated with each other as defined within the particular spatio-temporal threshold. Only two pairs of individual herds were associated within a maximum distance of 5km between herds and spent 50% time of the three years together. The overall mean spatial association between any two individual herds set at this spatio-temporal threshold was found to be only 9.5%. The highest associations observed between any two herds during this study was 59.1% (pastoralists 19 and 16) and 55.2% (pastoralists 18 and 1) respectively.

Table 5.2. Matrix of percentage association between two individual herds as defined by the spatial threshold of any two herds within 5km of each other (straight-line-distance) and spending 50% of the time together between 1999-2001.

	Association (%)																			
ID no	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1																				
2	7.8																			
3	15.6	0																		
4	10.4	0	0																	
5	1.7	0	7.8	27.8																
6	19.1	7.8	11.3	0	0															
7	0.8	0	0	19.2	8.7	0														
8	0	0	0	24.6	4.6	0	0													
9	0	0	0	0	0	0	0	0												
10	3.4	0	0	15.6	6.0	0	9.5	2.6	0											
11	0	0	0	0	0	0	0.8	2.6	0											
12	8.7	0	0	9.8	10.9	0	16.4	12.0	0	0	0									
13	4.3	0	0	26.0	4.3	0	4.3	34.7	8.6	0	0	0								
14	0	41	0.9	11.6	0.9	0	0	11.6	0	0.9	0.9	10.6	0							
15	6.7	0	0	9.6	9.6	0	11.5	7.6	0	10.5	0	25.0	0	7.6						
16	4.3	0	0	0	9.5	0	39.1	0	0	8.6	0	15.6	0	0.8	13.9					
17	4.2	0	14.8	2.1	21.2	0	0	17.0	0	0	0	0	0	0	6.3	0				
18	55.2	11	31.5	2.6	6.5	36.8	0	0	0	0	0	0	0	0	0	0	6.5			
19	0	0	0	0	0	0	30.9	0	0	0	0	28.1	0	0	5.6	59.1	0	0		
20	0	0	0	0.8	0	0	0	21.5	0	0	0	10.9	0	11.6	7.6	0	2.1	0	0	

5a.3.2 Daily herd movement patterns

A pastoralist in the RNP moved his animals on average six times a year between stock posts. Some pastoralists moved as frequently as 14 times a year compared to others who moved only once. The total number of moves between stock posts was significantly ® = 0.54; $P < 0.05$; n = 20) correlated with herd size (Figure 5.2). This correlation became highly significant when an outlier was excluded from the data analysis ® = 0.70; $P < 0.001$; n = 19).

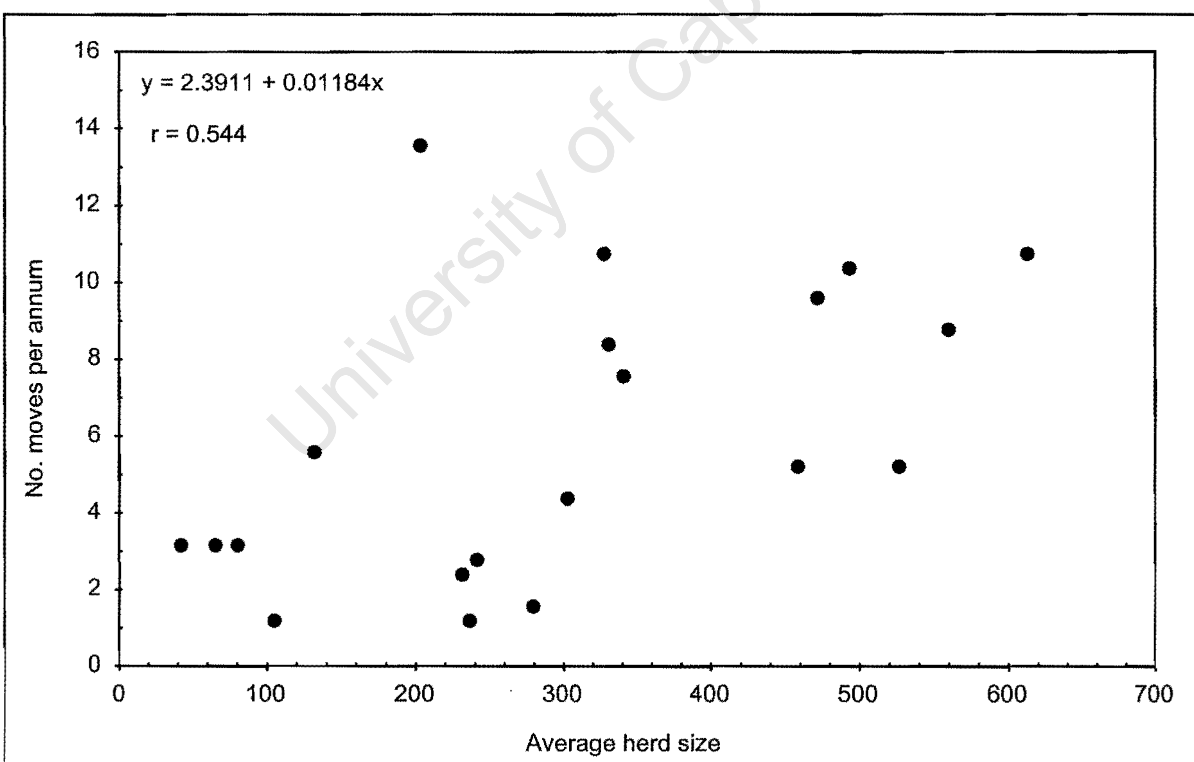


Figure 5.2. Relationship between total number of moves per annum and average herd size in the RNP between 1999 and 2001.

Only 45% of the total stock posts recorded for the RNP were used between 1999-2001. The duration of occupying a single stock post between 1999-2001 ranged from as short as one day to as long as 319 days in a year. On average, each stock post was used for 18 973 stocking days per annum (Figure 5.3). In simple terms, this means that an average herd size of 318 animals stayed in total for almost 60 days per annum at a stock post before it moved to another.

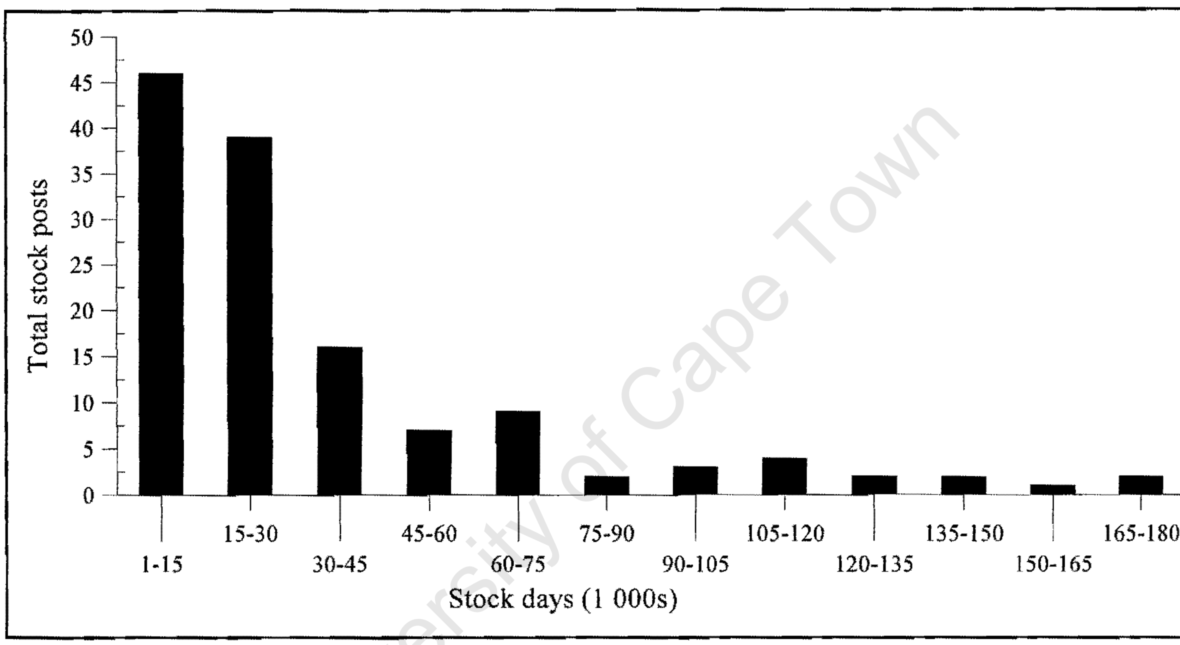


Figure 5.3. The frequency of use of stock posts measured as stocking days (duration of stay x animal number) between 1999-2001.

The average foraging range from a stock post that a herd travelled in one day during grazing was 2.49 km (Figure 5.4). This foraging range around a stock post varied from as small as 1.26 km to as large as 5.06 km. The furthest daily distance that a herd grazed away from the stock post was reached just after mid-day. For a round-trip, the shortest distance travelled in one day was 2.86 km and the longest distance was 11.40 km. The average herding rate travelled by a herd in the morning was 1.25 km/hr compared to the 0.82 km/hr in the afternoon ($t = 6.75$; $df = 376$; $P < 0.001$)(Figure 5.5).

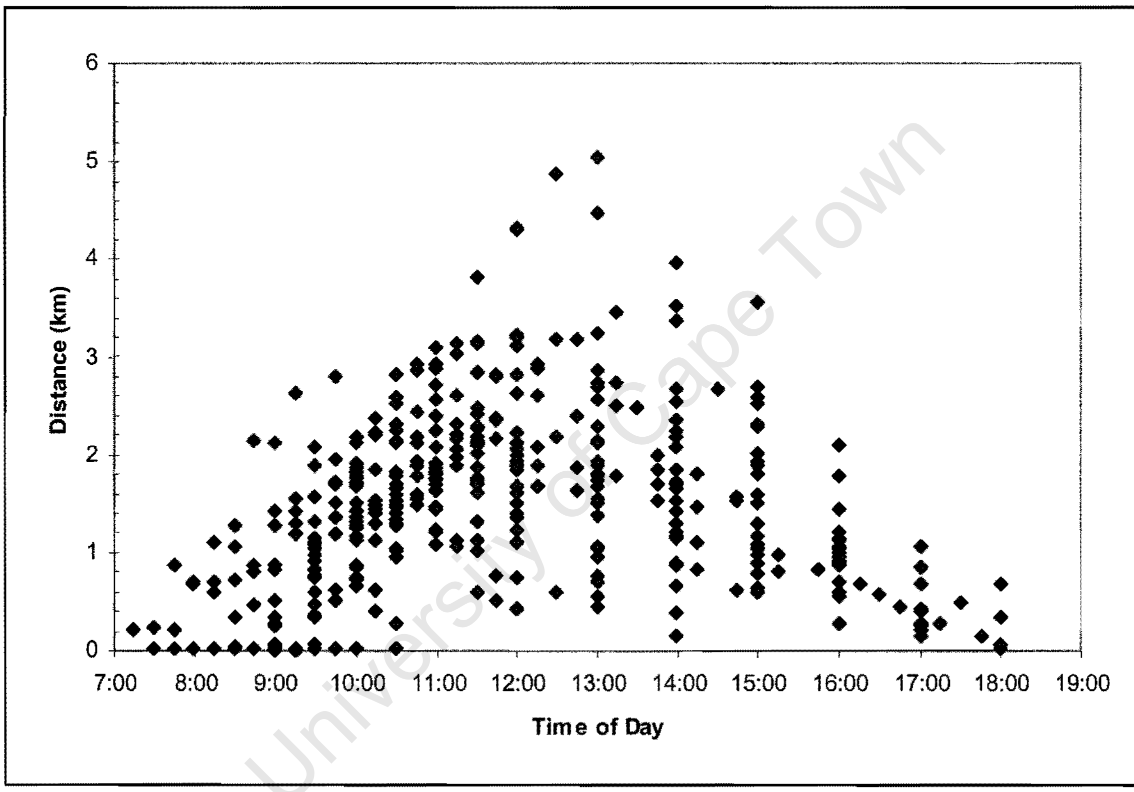


Figure 5.4. The distance (km) of livestock grazing away from a stock post in relation to the time of day.

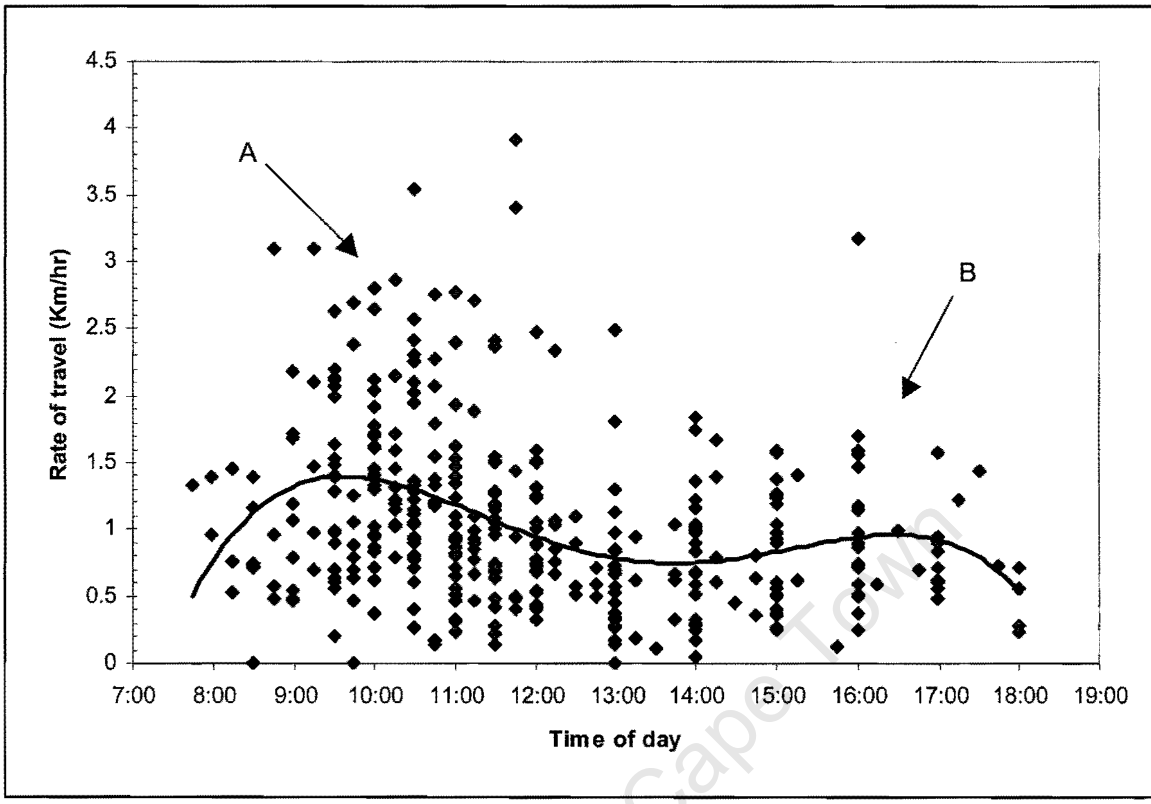


Figure 5.5. The rate (km/hr) of travelling (herding) for grazing animals in the RNP in relation with time of day. The symbols A & B suggest peaks in travelling speed along a superimposed curve for a typical herding day. The animals left the stock post in the morning and travelled great distances within short periods of time (A). This travelling speed gradually reduced to 0.6 km/hr at mid-day before it increased again in the afternoon (B) as herders were forcing the animals to turn around and head towards the stock post.

5a.4 Discussion

5a.4.1 Seasonal movement patterns

The movement of livestock in the RNP was dominated by seasonal shifts over approximately 10km between wet and dry season pastures. Wet season pastures ('buiteveld') provided a higher supply of forage but limited access to water and the dry season pastures (Orange River riparian zone) provided a constant supply of forage and better access to water. This pattern of movement suggests that forage is the motivation for winter movements and water for summer movements. The traditional annual movements back to the 'buiteveld', which normally take place during the onset of the rainy season (May) hardly occurred in 1999. This resulted in a concentration of a large number of animals grazing along the Orange River for an extended period of time characterised by low rain. Other research on 'key resource' areas has shown that drainage lines in Turkana (Coppock *et al.* 1986), the Baringo swamp in Kenya (Homewood & Rogers 1987) and wetlands (vleis) in Zimbabwe (Scoones 1990) were important for resource acquisition for livestock during periods of low rainfall. During the dry summers in better-watered regions of the Namaqualand communal areas, when natural forage becomes increasingly scarce, pastoralists make use of the stubble on harvested croplands to prevent abortion and lamb fatality (Hoffman *et al.* 1999).

The extent to which the rangeland of the RNP was utilised was also influenced by socio-political arrangements between the Richtersveld community and South African National Parks. According to the contractual agreement, pastoralists are not allowed to graze their animals outside the RNP for periods longer than six months or else forfeit their grazing rights (its justification is unknown). This arrangement constrained 'transhumant' migrations across long distances. Temple & Thomas (1973) also noted that seasonal movement patterns practised by transhumant herders in rainfed areas of Sahelian West Africa were constrained by a tightening of national boundaries and a change in resource tenure. One particular herd has been grazing in the vicinity of the RNP for the last 12 years, but the dry season in 1990 caused it to move 120km south - as it had done during the 1960s (Archer *et al.* 1996). Regular treks over 70km were recorded during seasonal transition periods amongst Ngisonyoka families in northwestern Kenya (McCabe 1984).

Seasonal movement patterns varied amongst the pastoralists in the RNP, suggesting diverse approaches to tracking resources. For example, pastoralist five had an average herd size of 610 animals and adopted a localised movement strategy. Pastoralist one, on the other hand, had much fewer animals (136) and grazed more opportunistically by covering a larger grazing area. Swallow (1994) also noted a similar opportunistic management strategy for more effective harvesting of scattered resources. These movements (tracking of rainfed forage) in arid areas usually lack a regular pattern because the amount and geographical distribution of rainfall is irregular (Scoones 1995). The results of association patterns between individual herds in the RNP also indicated that the majority of herds moved independently of one another in the 'buiteveld' and, therefore, not as a discrete unit across the landscape. The causes and effects of diverse movement strategies in the RNP are not understood. Herd cohesion is likely to be maintained between two individual herds where the resident pastoralist (e.g. Benjamin Swartbooi) is an immediate family member of a wage-labour pastoralist (e.g. Dawid Swartbooi) who is not able to visit his herd regularly (Table 5.1). I assumed that able-bodied pastoralists are in a position to graze their livestock more opportunistically. However, the age of pastoralists' was not significantly correlated with the number of moves per annum ® = -0.18; n = 20; P = 0.44). In all likelihood, the age of the herder might be a better predictor of diverse approaches to tracking resources since they herd the animals every day.

5a.4.2 Daily movement patterns

In addition to the scale of movement, the findings of this study also showed that the regularity of livestock movement differed between the pastoralists in the RNP. Larger herds generally moved more frequently than smaller herds. The decision to leave a particular stock post for a more productive area, and therefore the duration of occupying a stock post, depended on how pastoralists perceived the condition of the pasture and the foraging behaviour of animals (Chapter 7). This resulted in some pastoralists occupying a stock post as short as one day or as long as 319 days in a year between 1999-2001. The average number of moves per year recorded in the RNP was similar to the six to eight moves per year recorded amongst the Maasai semi-nomadic pastoralists in the Amboseli district of Kenya (Western & Dunne 1979). A lack of water points (and possibly the inaccessibility of stock posts for road transport) was the major reason why large areas of the RNP were avoided by the pastoralists (< 50% of the total stock posts were used during 1999-2001). For example, temporary springs, rock reservoirs and seepages have dried up while the majority of boreholes in the 'buiteveld' have also begun to fail as a result of the low rainfall prior to and throughout most of 1999. For two months of the year, normally late winter and early spring, livestock obtain enough moisture from the vegetation and stay without drinking water for up to 10 days. In the summer, however, these animals drank water every second day, if not almost every day. The distribution of stock posts in the RNP also suggests a network of grazing routes that is used to link a range of alternative grazing zones and drinking water sites.

A home range contains a finite potential energy resource that is proportional to its area, with habitats of greater productivity resulting in smaller home ranges (Harestad & Bunnell 1979) inter-related with body size (Lindstedt *et al.* 1986; Saunders & Kay 1996). If the area around a stock post in the RNP varies as a function of the square of the radius, livestock grazing within ca. 2.5km radius of the post will have ca. 1 950 ha at their disposal. The relationship between area available for grazing and the distance walked by livestock is such that by walking twice as far the animals have almost four times the area available to them. A number of factors affect the grazing range of livestock in the RNP, presumably related to pasture condition and the physiological status of animals (whether pregnant, lactating or dry). Because walking is one of the activities that consumes a lot of time and energy of goats and sheep, social structure within a herd is another factor influencing the dispersion of animals, hence, the reason why pastoralists in the RNP kept their kids/lambs behind at the stock post was to avoid unnecessary dehydration. The average total distance travelled by a herd around a stock post in one day was similar to that often recorded for free-ranging sheep in the arid zones of inland Australia (Squires 1984).

The study found that goats and sheep walked at a slower rate (1.06 km/hr) than those observed in other arid African rangelands (2.5 km/hr) (Coppock *et al.* 1988; McCabe 1984; Western 1975). Differences existed in the speed of travel during grazing days. Herds walked much more quickly in the morning than in the afternoon and thus covered more ground per unit time. Travelling rates as high as 3.9 km/hr were recorded in the morning in the RNP compared to rates as slow as 0.04 km/hr in the afternoon. This pattern of travelling suggests that most of the physical destruction of plants potentially occurs in the morning due to running, trampling and scuffling while pastures visited in the afternoon experience mainly foraging impact (Chapter 7). Goats and sheep also appeared to walk much more quickly to water than away from it.

5a.5 Conclusion

A few attempts have been made to document direct measurements on the scale of spatial and temporal livestock movements in African pastoral societies (Coppock *et al.* 1988; McCabe 1984; Western 1975; Western & Dunne 1979). This study focussed on the extent to which the rangeland of the RNP is utilised by goats and sheep and the results can now be used to determine potential areas of conflict for competing land use in the RNP.

In the RNP, goats and sheep dispersed away from the Orange River to the 'buiteveld' after the first winter rains where they exploit a variety of habitats until herds begun to congregate again along the riparian zone of the Orange River with the onset of the dry, hot summer. The movement of herds allowed livestock to exploit a variety of environments across spatial and temporal dynamics. However, this approach to tracking resources offers no system of rotational grazing which ensures that certain areas in the RNP could lie fallow for vegetation recovery. Regular 'transhumant' migration over a larger scale (outside park), in response to unpredictable periods of low rainfall, was not a feature of the RNP rangeland. Competition for limited riparian forage results in severe conflict between pastoralists when grazing along the Orange River for extended periods. Small 'key resource' patches along the Orange River became densely stocked during dry, hot summers, leaving little room for herds *en route* somewhere else. The cessation of the annual movement back to the 'buiteveld' (for example in 1999) also led to complaints from tourists camping along the Orange River. Management interventions clearly need to recognise these causes and effects of livestock movement (pastoralists), under changing circumstances encountered daily and seasonally from year to year in the RNP, and should initiate immediate dialogue with pastoralists.

Chapter 5b

Spatial and temporal livestock movement

- impacts of livestock settlement on high risk conservation sites

5b.1 Introduction

Chapter 5a showed the extent (different seasonal time frames and spatial distribution) to which the rangeland of the RNP is utilised by goats and sheep. This short chapter explores what these usages mean for the conservation of key plant species in the RNP, as a first step towards determining potential areas of competing land use between conservation and pastoralism. The three objectives were to (1) obtain a more thorough knowledge of the location of rare, threatened or endemic species of special conservation interest, (2) quantify the potential impacts of herd movement on these high risk conservation sites, and (3) propose management strategies for the conservation of these areas.

5b.2 Methods

Sites of conservation importance were defined as those localities with plant species endemic to the Richtersveld region and southern parts of Namibia as well as those localities with a particularly high combination of succulent plants that could potentially be damaged by grazing activities (Williamson 2000b). All these sites in the RNP were mapped to metre accuracy using a Trimble GPS. I calculated percentage areas for stock posts and conservation sites and expressed usages of these high risk sites in both hectares and percentage surface area. In an attempt to investigate the impact of livestock movements over longer distances on the conservation-worthy sites I superimposed the daily foraging activities of all pastoralists and a summary of seasonal livestock movements of two pastoralists on the locations of conservation-worthy sites.

5b.3 Results

A total of 36 sites in the RNP were identified as areas of special conservation importance (Figure 5b.1). The conservation-worthy sites comprised 50 516ha of the surface area of the RNP; localities with plant species endemic to the Richtersveld region and southern parts of Namibia (5%) and localities with a particularly high combination of succulent plants that could potentially be damaged by grazing activities (26%) (Table 5b.1). The majority of these sites were restricted

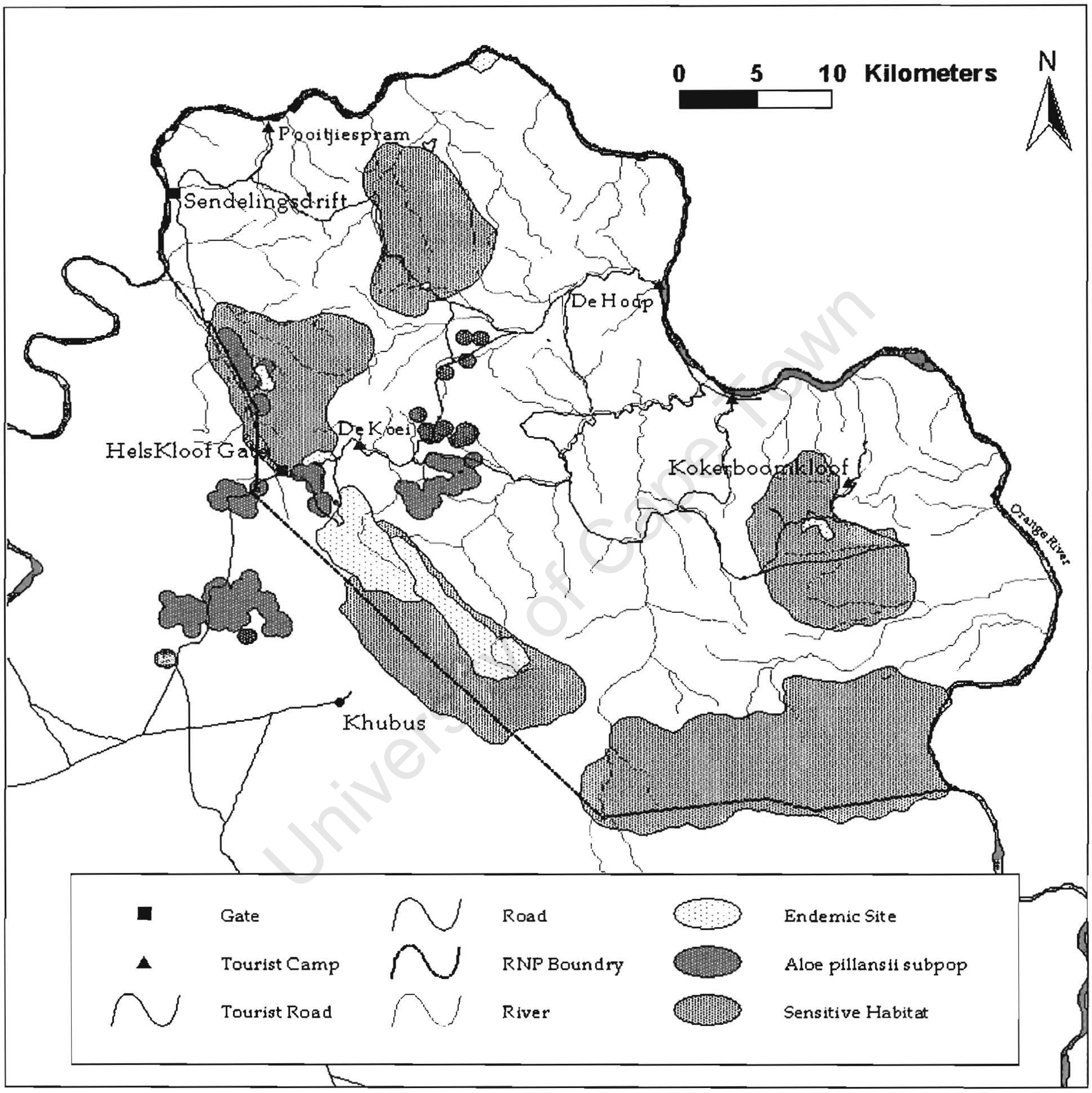


Figure 5b.1. The distribution of localities with plant species endemic to the Richtersveld and southern parts of Namibia as well as plant habitats with a high composition of plant species (particularly succulents) potentially sensitive to foraging activities.

to mountainous terrain. The cumulative number of stock posts comprised 110 315ha of the total surface area of the RNP when each stock post was buffered at 2.5km.

Table 5b.1. Calculated foraging area around stock posts (grazing 'orbit', i.e. stock posts buffered at 2.5km) and conservation-worthy sites in the Richtersveld National Park.

	Surface area	
	Hectares (ha)	Percentage of RNP (%)
Stock posts		
grazed between 1995-2001	110 315	67.9
grazed between 1999-2001	85 540	52.1
Conservation sites		
(a) total surface area	50 516	31.1
rare/endemic/threatened	*7 991*	*4.9*
sensitive habitats	*42 525*	*26.2*
(b) used between 1995-2001	32 431	20.0
(c) used between 1999-2001	18 085	11.1

The potentially foraged areas (i.e. stock posts buffered at 2.5km) were superimposed with the conservation-worthy sites in the RNP to help determine the overlap of livestock impact on biodiversity conservation (Figure 5b.2). A large proportion (64%) of the conservation-worthy sites were regularly foraged by livestock between 1995-2001. The average distance between a stock post and a conservation site was 1.03 km. A total of seven stock posts in the RNP were located in the exact localities of the conservation-worthy sites. For the rest (n = 291) of the stock posts located near conservation-worthy sites, the distance ranged from 0.1 km to 2.5 km.

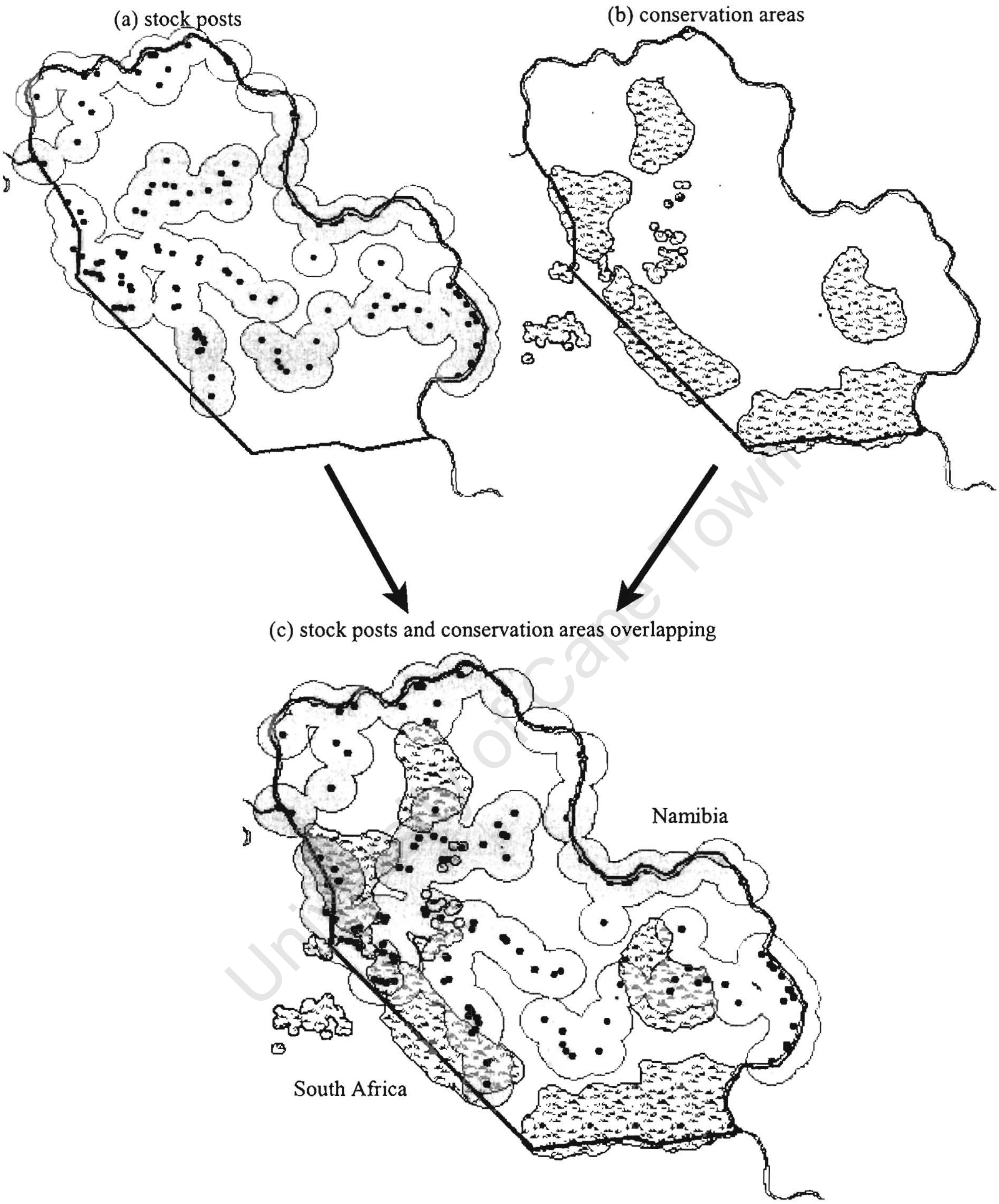


Figure 5b.2. (a) Foraged areas (stock posts buffered at 2.5km) and (b) conservation-worthy sites superimposed (c) to identify the potential areas of competing land use between conservation and pastoralism in the RNP.

Figure 5b.3 showed the predominant migration corridors of two pastoralists between 1999 and 2001.These pastoralists spent between 32 and 132 stock days at a stock post within the conservation-worthy sites. Their annual movements over longer distances were characterised by cross-cutting routes through the conservation-worthy sites.

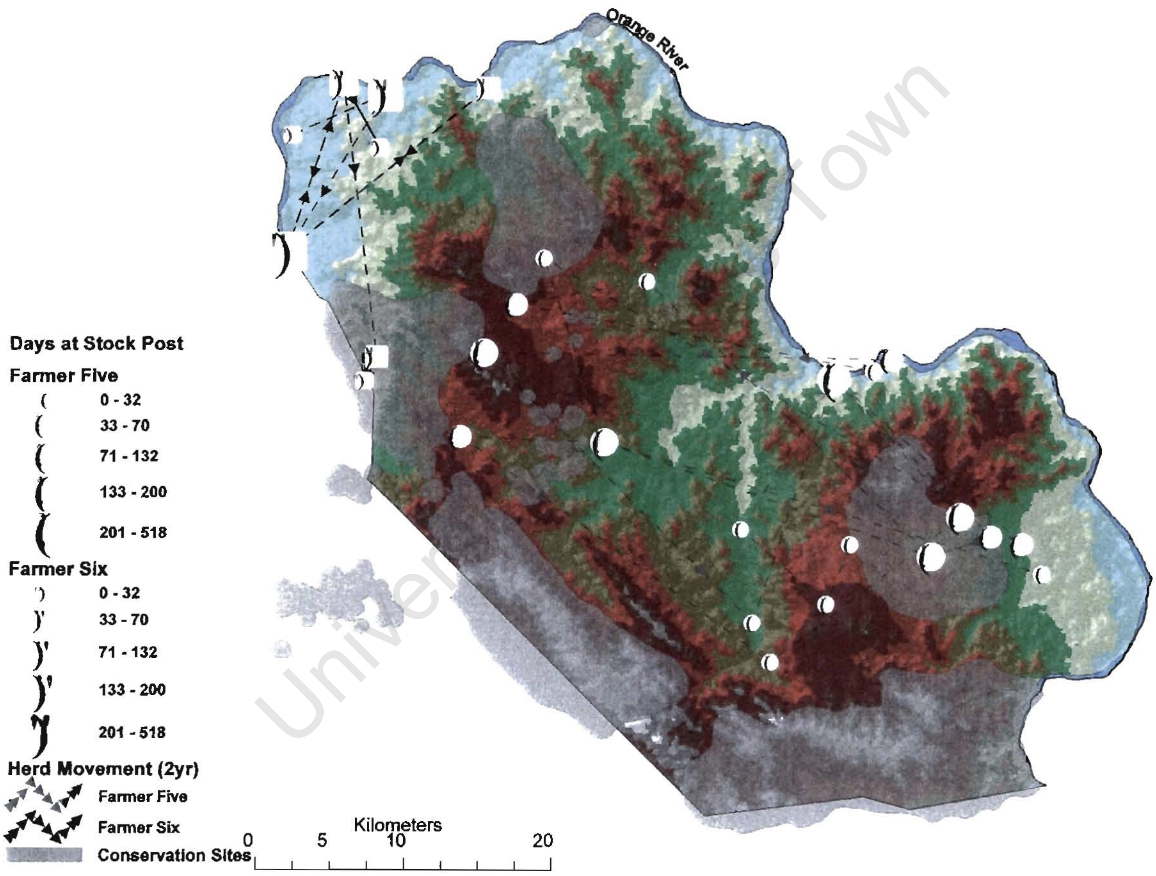


Figure 5b.3. Seasonal livestock movements patterns and the number of days at a stock post for two pastoralists between 1999 and 2001 in relation to conservation-worthy sites (grey areas) in the RNP. See text for definition of conservation-worthy sites.

5b.4 Discussion

Observation of herd movements (over a two-year time period) showed that herds range at 2.5km from a stock post, foraging an area of ca. 1 950 ha (Chapter 5a). This has serious implications for the management of important conservation-worthy sites in the RNP since the average distance between stock posts and these sites is much smaller (1.00 km). In fact, seven of these sites are already at immediate risk of destruction due to grazing impact because they overlap with stock post locations. Furthermore, the maximum distance between a stock post and a conservation-worthy site (2.5 km) was about the same as the radius of grazing activity around a stock post, suggesting that all the 36 sites in the RNP are threatened by livestock foraging. The rates of traveling, particularly in the morning when animals reach a herding rate of 1.06 km/h (the fastest rate recorded was 3.9 km/h), at these sites are also of concern for trampling of sensitive succulent plants within the genera *Conophytum*, *Lithops*, *Haworthia*, *Larrylichia*, *Avonia*, *Anacampseros*, *Amaryllis*, *Cephalophyllum*, *Ontonia*, *Bulbine*, *Tylecodon*, *Aloe*, *Pelargonium*, *Adromiscus* and *Crassula*. The majority of the species in these genera are normally not eaten by goats (Chapter 7), but in most cases the running and scuffling of goats break the branches of these plants. Additionally, smaller succulent plants suffer the trampling impact of these animals.

5b.5 Management implications

The study inferred that both seasonal and diurnal livestock movement in the RNP are likely to impact sensitive areas of the environment creating potential areas of conflict for competing land use. The daily movement patterns of individual herds threatened all the localities with rare/endemic plant species and those sites generally regarded as sensitive habitats because they overlap with stock post locations. The 1998 drought caused a concentration of an unusually large number of animals grazing along the Orange River for an extended period of time and because of its small size relative to the 'buiteveld' the riparian zones along the Orange River 'key resources' area developed a browse line of the dominant trees and tall shrubs (Pers. Obs.). In the last two years, for example, at least 10 new stock posts were established in the vicinity of existing stock posts for reasons unrelated to herd performance. The effect is the spread of denuded areas and, if close enough, coalescence of these into large tracts of denuded areas.

Effective management strategies should be implemented in the RNP to strike a balance between the conservation of its biodiversity that would still allow pastoralists to exploit suitable pasture. Reducing livestock numbers is not popular. Intervention based on protection of conservation important sites by restricting herd movement in some areas is likely to be much easier to influence pastoralists than reducing herd size. Fencing off these sites might not be suitable because of the visibility to tourists in a RNP, but zoning the RNP area into specific land use management purposes could be a suitable intervention. This also includes the closure of ca. 10 stock posts located within the conservation-worthy sites. About 30% of the surface area of the RNP was not used for stock post establishment and avoided by pastoralists mainly due to the inaccessibility of the terrain for road transport and a lack of water points. The establishment of new roads in these areas must be prevented. The fact that the contractual agreement between the Richtersveld community and RNP does not prevent the establishment of a new herd (i.e. when sons and daughters inherit livestock after their father's death and decide to herd on their own) and its implications on livestock farming in the RNP needs to be investigated revisited.

5b.6 Conclusion

Herd movements have put sites with a high conservation value at risk of destruction. Recommendations such as closing certain stock posts and careful consideration before developing new stock posts and new roads could reduce conflicts between conservation and pastoralist objectives in the developing of a partnership between the RNP and pastoralists. The role of 'key resource' areas, especially the Orange River, is a common subject extending from sustaining animal numbers to major tourist attraction to possible degradation that needs investigation before any policy making could take place. In the meanwhile, dialogue can be initiated to formulate a policy for the winter forage in the RNP. This could potentially include fewer stock days at a stock post, adequate water points in working condition and limited access to conservation-worthy sites. However, I must stress the need for wider consultation. Ideally, these and other management options must be tested in relation to the objectives and perceptions of the pastoralists in the RNP.

Chapter 6

Why pastoralists do what they do

6.1 Introduction

Attempts to 'improve' livestock farming practices by agricultural practitioners have often failed in arid and semi-arid communally farmed areas (Ellis & Swift 1988). Ellis (1996) argued that this is because appropriate management interventions are different for equilibrial and non-equilibrial ecosystems and also for communal versus commercial farmers. For example, Hoffman *et al.* (1999) presented three main differences for the latter in the arid and semi-arid rangelands of the karoo; producer goals (subsistence vs profit), the relatively greater emphasis on stocking rate as a management tool in commercial agricultural production systems, and the institutional arrangements under which grazing occurs (common property in communal systems vs private and/or state property in commercial economies). Unlike commercial livestock enterprises (Jones & Sandland 1974), communal farmers neither aim to maximise yield of meat or other products from their herds for cash sales (Behnke 1995) nor attempt to minimise the number of people per livestock unit in order to maximise profits per individual (Swift *et al.* 1996). Their objectives are more complex and varied (Behnke 1985 & 1994; Debeaudoin 2001; Dikeni *et al.* 1996). They rather aim at maximising what they perceive as total benefits from livestock keeping (Tapson 1991) in an effort to manage livestock risks, reduce household vulnerability and enhance livelihood security (Cousins 1998; Damarah 2001; Ward 2000). In the context of the RNP, it is important to understand pastoralists' objectives and the motives underlying herd management. Without such an understanding, it will be very difficult to develop mutually agreed strategies for both improving the livelihoods of pastoralists and the conservation objectives of the RNP (Chapter 1).

The thesis underlying this chapter is that much of the problem with successful interventions in communal rangeland systems has been a case of planning without facts, and that much of the solution lies in a learning process into *why pastoralists do what they do* as opposed to a blueprint approach. Research conducted in the communal areas of the Northern Cape and Eastern Cape of South Africa (Allsopp *et al.* 2003) inferred that most agricultural advisory services lack knowledge concerning three key aspects of communal livestock keeping *viz* livestock keepers' objectives, their practices and regulatory institutions. The approach of agricultural extension in this country still focuses predominantly on technical aspects (Mollel & Mahlakoane 1998) and is premised on the supposition that commercial agricultural production systems should be supported. Preliminary research might lead to a better understanding of *why pastoralists do what they do*, and I thus proposed three key areas where knowledge of communal rangeland systems should be improved; (1) the socio-economic profile of stock farming, (2) the farming objectives of pastoralists, and (3) the motives underlying herd management practices.

6.2 Methods

There are three categories of people involved in farming; pastoralists, owners and herders. Although both the pastoralist and an owner possess livestock, there is an important distinction between them; all pastoralists are owners, but not all owners are pastoralists. The pastoralist governs the herd, owns most of the animals and manages the day-to-day grazing of the animals. Owners seldom stay at the stock post because they mostly work in nearby mines. Herders seldom own livestock and are merely hired to herd animals. Of the 26 registered pastoralists only 20 pastoralists who have exercised their right to graze inside the RNP were interviewed in 2001 during a once-off session in summer (owners were excluded from this study because of their limited interaction with the animals). The survey instrument for this study is in Annexure 1 and consisted of a combined structured quantification approach and semi-structured qualitative approach. These approaches included a range of analytical Participatory Rural Appraisal (PRA) techniques (Van Vlaenderen 1996). The fourth PRA technique, semi-structured interviews, provided the bulk of information.

To determine the socio-economic profile of stock farming, I interviewed pastoralists separately and recorded their age, employment status and family dependents (also see Table 5.1 for how pastoralists are related to each other). A PRA analytical technique was used to assess the structure livestock ownership for each herd. Each pastoralist was asked to place a total of 20 beans (according to six ownership categories; himself, wife, sons, daughters, grandchildren and relatives) to express the proportion of the total number of animals owned by each member of the family or relatives within his herd. The total number of beans per category was expressed as proportional livestock ownership percentage for each herd. For example, a pastoralist who placed 10 beans under his name and five under his two sons respectively expresses that his herd has three owners of which he owns 50% of the total animals and the rest 25% each.

I used an importance ranking exercise to allow pastoralists to rank various aspects of their farming objectives (see Annexure 1). The ranking scores for each aspect were summed to rate pastoralist objectives on a scale of interest; a low value on the scale represented a social interest while a high value more likely represented an economical interest (Neuman 1997). This technique was also used to rank the importance of livestock products. Another PRA analytical technique, preference matrix rating, was used to rank pastoralists' needs. The preference scores for each individual need among the pastoralists were averaged to reflect the overall pastoral needs in the RNP; a lower matrix score indicates less needed and a higher score indicates more needed. I also explored pastoralists' perceptions about their ideal herd size (including animal type) in relation to their household needs and rangeland condition using a semi-structured approach. This approach involved an informal interview where only some of the questions were predetermined and new questions or lines of questioning emanated during the interview (Neuman 1997). The same method was used to interview the pastoralists about their herd management practices in the RNP.

A major ethical issue in this survey was the invasion of privacy. Pastoralists insisted on the right to privacy, especially relating to actions and personal beliefs regarding their grazing practices in the RNP. They regarded research as an attempt to provide scientific evidence for the removal of their animals from the park. I allowed pastoralists the opportunity to answer questions, but also to refuse to participate at any time. Thus, participation was voluntary. I was particularly careful not to mislead pastoralists about the purpose of the survey, especially in avoiding the creation of expectations. Survey data often contains errors, for example from possible question wording or order and interviewer bias (Oppenheim 1992). I took this into account in determining the questionnaire.

To examine the influence that migrant labour had on pastoralist household size, I performed a Pearson product-moment correlation between the age of pastoralist and his number of family dependents (age was normally distributed among pastoralists). I envisaged that pastoralists would look after their grandchildren in the absence of sons and daughters. Kruskal-

Wallis ANOVAs were used to determine differences in needs between old (>60 years) and young (<60 years) pastoralists. I used a t-test to analyse if pastoralists regarded their presence at the stock post as important for herd management compared with just having the herder alone at the post.

6.3 Results

6.3.1 Socio-economic profile

The pastoralists ranged from as young as 37 years old to 76 years old (mean 56 years) and were men who inherited their animals from their fathers. An older pastoralist had more family dependents than a younger pastoralist ($r = 0.838$; $P < 0.001$; $n = 20$)(Figure 6.1). Average household in the RNP comprised of seven to eight individuals. A third of the total family dependent members comprised grandchildren attending schools in villages while another third of the dependents are young people who have left school and are not interested in livestock farming. Only five pastoralists derived their income solely from livestock farming. The majority of pastoralists interviewed received an additional income from either allowances ($n = 8$) or wages ($n = 7$). Allowances included pension grants (applicable to pastoralists over 65 years) received from the government ($n = 7$), estimated to be about R500-00 per month during the study period, and from remittances contributed by the mines ($n = 1$) in the Richtersveld. At the time of this study, herders were paid between R200-00 and R250-00 per month, with their food and clothes additionally provided. Fifteen pastoralists made use of a herder and five pastoralists herded their animals themselves.

A pastoralist owned, on average, 65% of animals in the herd (Figure 6.2). About 25% of the animals within a herd were owned by immediate children (sons and daughters) of the pastoralist, but the animals remain under parental control until such time as the children are able to take over the responsibility. Relatives and friends, mainly characterised as absentee stock owners, kept their animals with these herds to minimise the overall expenses for maintaining the animals. Their contributions (money and food) would otherwise have to be additionally covered by the pastoralist if they decide to separate their animals from the herd.

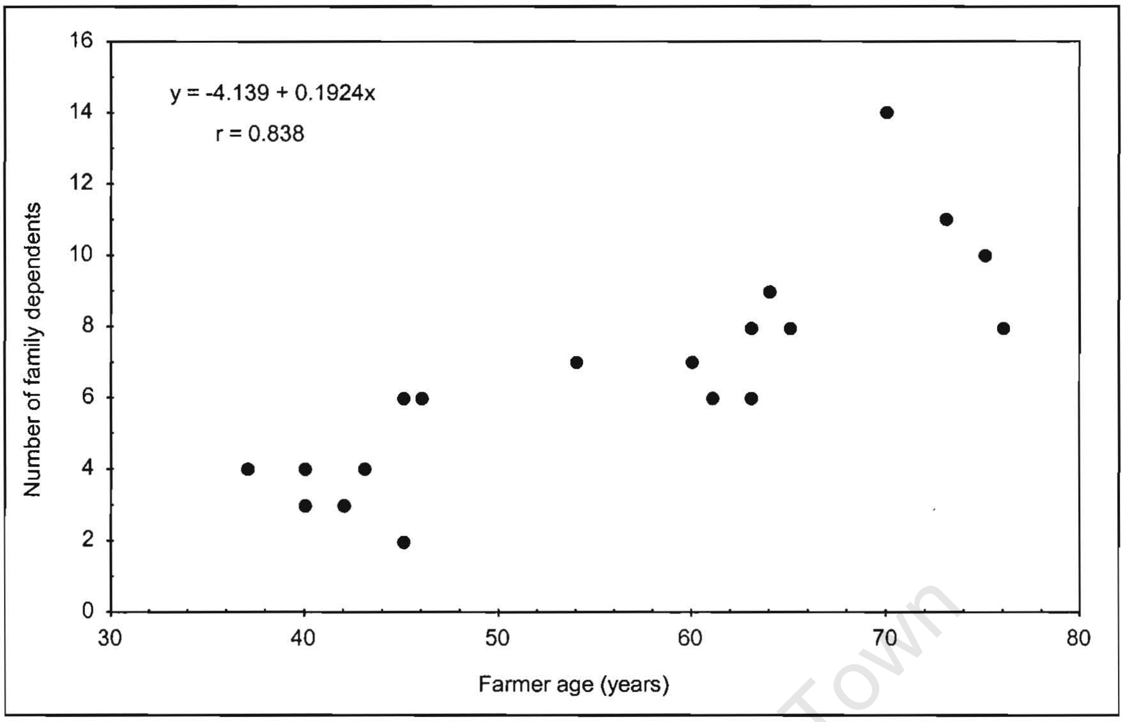


Figure 6.1. The relationship between the age of a pastoralist and his number of dependents. The x-axis is pastoralist ranked by age from young to old.

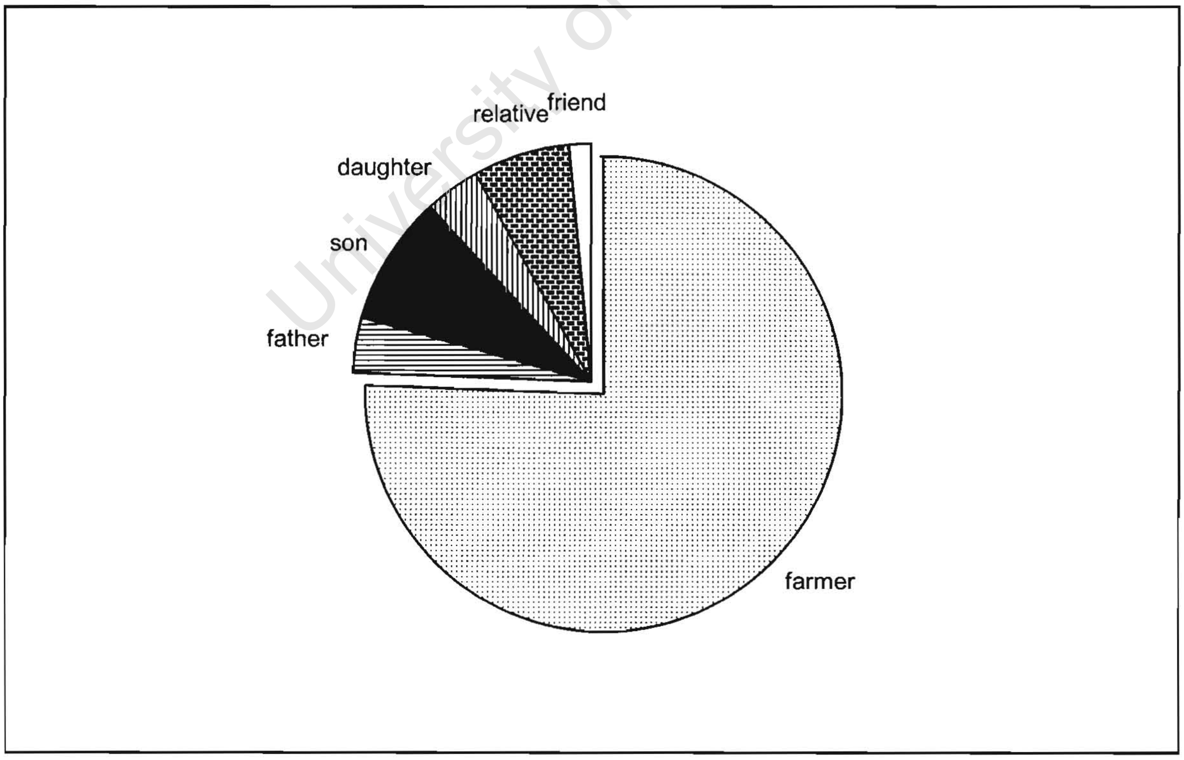


Figure 6.2. Average proportion (%) of animals owned by people in a herd in the RNP.

6.3.2 Farming objectives

More than 60% of the 20 pastoralists reported that they kept livestock for storage of wealth compared to the 25% of pastoralists who regarded additional income from intermittent sales as the main reason for keeping livestock (Figure 6.3). Despite being ranked lower on the list of reasons for keeping livestock, at least 70% of the pastoralists acknowledged that they kept livestock to also sell animals to members of the village. This enables them to obtain immediate cash for buying basic daily consumer goods (mainly tea, sugar, bread flour and tobacco). Only two pastoralists regarded their animals as more important for supplying animal meat as an essential part of their families' diet, instead of for economic reasons. Almost every pastoralist interviewed in this study did not regard herding with higher number of animals as synonymous with becoming a wealthier member of society, but instead considered it as a strategy to lower the risk of destitution.

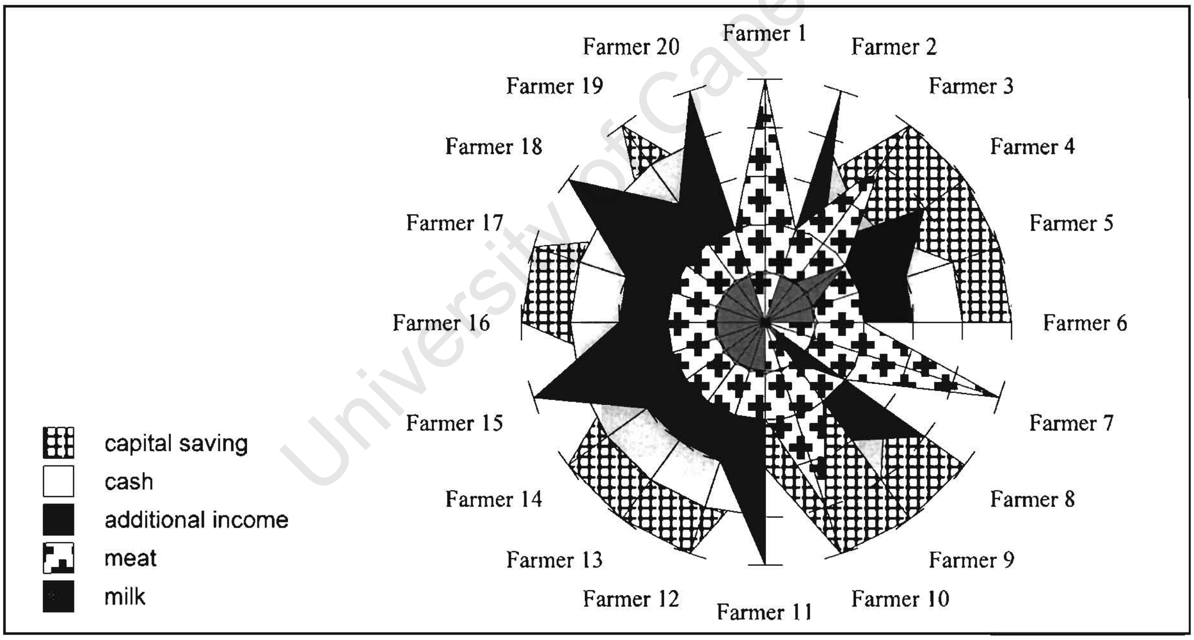


Figure 6.3. The reasons why pastoralists keep livestock in the RNP. Reasons were ranked from least important (score of 1 located in centre of radar) to highly important (score of 5 located at the edge of radar).

Farming subsidies, supplementary fodder, water and veterinary services were what the pastoralists needed the most in the RNP (Table 6.1). The need for a vehicle was regarded as an integral part of farming as it remained the primary mode of transport for the pastoralist between the stock post and the village when either visiting, selling livestock, or transporting water to the stock post. Employment and livestock markets were overall less needed among the pastoralists. However, the older pastoralists (>60 years) interviewed in this study did not regard employment ($H = 13.0$; $P < 0.001$) and livestock markets ($H = 6.2$; $P < 0.05$) as important as much as younger pastoralists did. Instead, they anticipated farming subsidies to be more important for them ($H = 8.4$; $P < 0.01$).

Table 6.1. Mean (SE) matrix rating scores for the different needs of pastoralists in the RNP comparing age responses. A lower matrix score indicates less needed and a higher score indicates more needed. (Significance levels from Kruskal-Wallis ANOVAs; *** = $P < 0.001$, ** = $P < 0.01$, * = $P < 0.05$, ns = not significant)

	Mean matrix rating scores (SE)						
	job	vehicle	farming subsidy	supplement fodder	water	market	veterinary services
all ages	5.5 (0.83)	7.9 (0.49)	10.3 (0.79)	10.3 (0.3)	10.2 (0.38)	2.7 (0.3)	11.6 (0.4)
<60 years >60 years	8.4 2.6	7.6 8.2	5.6 10	9.8 10.8	9.8 10.6	3.4 2	11.4 11.8
H P (n=20)	13.0 ***	0.3 ns	8.4 **	2.6 ns	0.6 ns	6.2 *	0.2 ns

No single pastoralist in the RNP regarded <100 animals as enough to support his household. Fourteen pastoralists considered 300 animals as the minimum number of animals required to sustain their household needs, hence their speculation about the size of individual herds in the future (Figure 6.4). The three youngest pastoralists in the RNP were mine workers and built up their total number of animals by seldom making use of offtake (sales and slaughter). Four pastoralists (aged 42, 45, 75 and 76 years old respectively) regularly sold their 5-year old animals and often managed to secure the survival of the majority of lambs/kids during the first three months after birth. By contrast though, thirteen pastoralists could not recall any specific herd strategy in building up their individual herd sizes. About 70% of the pastoralists in the RNP regarded goats and sheep as the ideal grazing flock mainly as a response to droughts and diseases (Figure 6.5). Pastoralists were of the opinion that all their reproductively mature female animals gave birth to at least one kid/lamb per year and were satisfied with their current herd production levels.

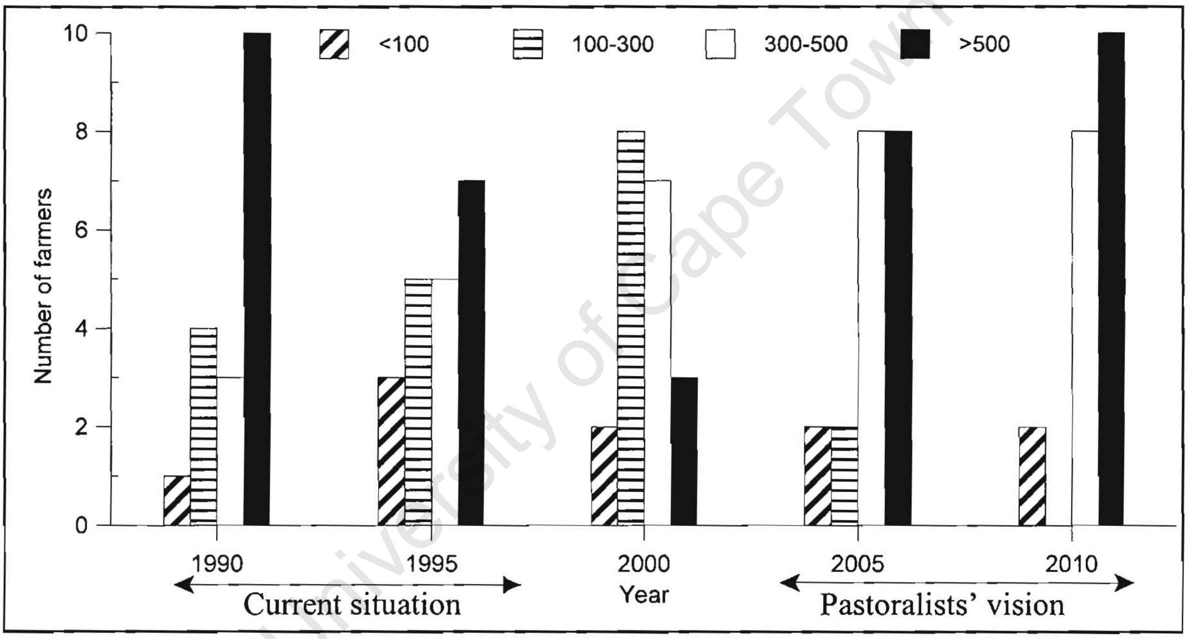


Figure 6.4. An overview of herd size over the last decade (current herd sizes between 1990-2000) and how pastoralists envisaged herd sizes to change over the next 10 years in the RNP.

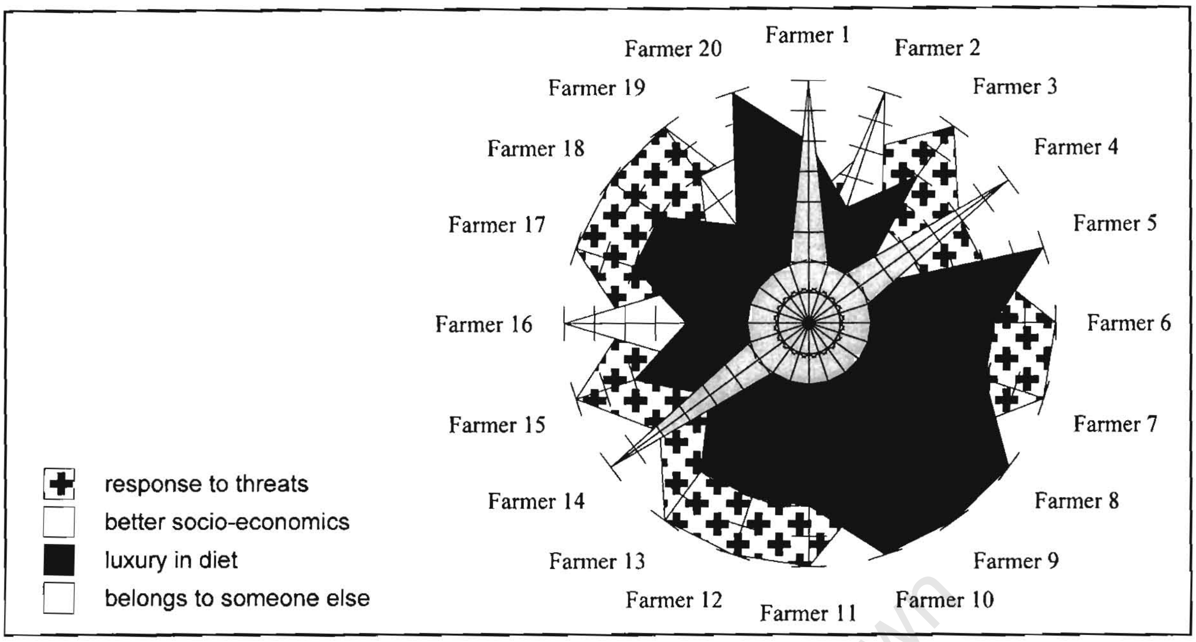


Figure 6.5. The reasons (ranked from least important in the centre of radar to highly important at the edge) for farming with mixed animal species (goats and sheep).

6.3.3 Herd management practices

(a) At the stock post

All the pastoralists agreed that more people (herder, pastoralist and his family) at the stock post are better for livestock farming than just having the herder alone at the stock post (t = 15.079, P < 001). More helping hands at the post enabled the pastoralist to attend to all the animals. Herds always spent the night at the stock post. Milking normally took place in the morning after which the animals were taken out for foraging. The time at which the animals left the stock post varied seasonally; in winter they left at about 10am and around 8am in summer when milking was completed more quickly. After suckling in the morning the lambs/kids were placed in a special animal pen during the day and released in the afternoon when the mothers returned to the stock post. They were often kraaled separately at night from their mothers in summer. At the age of six months, lambs/kids usually stopped suckling, but pastoralists already weaned them at the age of five months to ensure a less traumatic separation experience between mother and offspring prior to annual sales. Unlike in summer when most pastoralists kraal their animals at night, animals often sought shelter between rocks from the cold conditions in winter.

(b) Decision-making

Pastoralists, and not owners or herders, made the decisions about herd movement at different temporal and spatial scales. In response to the significance of the person who makes the decision to forage in which direction, pastoralists preferred the herders to report their daily herding observations to them to allow them to make this decision. Only three pastoralists were really confident in the decisions taken by their herders who, interestingly, were all older than 60 years. The study recorded varying opinions regarding how pastoralists decide in which direction to send their animals for grazing. At least 60% of the pastoralists sent their animals out for foraging at an alternating direction every second day, followed by a three-day resting period for the foraged area. For the rest of the pastoralists, the direction of grazing was not important as long as the animals were allowed to forage as long as possible during herding days with very limited interference.

The timing of movement was entirely the concern of the pastoralist and so was the new location to which he moved. The criteria that pastoralists followed to stay in a particular foraging area were generally three-fold; (1) the veld measured by the condition of grazing bushes and presence of forage plants and 'opslag' (ephemerals), (2) the animal condition and if they stand still and feed for long periods of time, and (3) whether water is nearby. Ten pastoralists based the difference between good and bad foraging areas on the presence and absence of *Rhus populifolia* and *Ceraria fruticulosa* foraging species and toxic plants, especially *Tylecodon wallichii* (locally known as 'krimpsiekbos'). Five pastoralists maintained that there was no such thing as a bad grazing area in the RNP, but that pastoralists slip up on the signals presented to them by both the animals and the plants and do not respond quickly enough to prevent a bad grazing experience. The decision to leave a particular stock post in the RNP was also prompted by the condition of the animals. Apparently, goats have a 'kospens' (i.e. a food stomach) and a 'waterpens' (i.e. a water stomach). The 'kospens' and 'waterpens' are located between the thigh and the stomach on the left- and right-hand-side of the animal respectively. A depression between the thigh and the stomach indicates a shortage of food or water depending on the left- or right-hand-side of the animal.

(c) Seasonal migration

In this study, seven pastoralists preferred to move their animals as little as possible while most pastoralists moved regularly between stock posts. The pastoralists indicated that they use, on average, two stock posts in the winter and four during summer. This highlights the question of stock post ownership; winter stock posts were 'earmarked' for use by specific pastoralists who returned to it periodically while summer stock posts were used by different pastoralists. Pastoralists inferred that water supply was one of the most acute problems facing the pastoralist and his livestock in the RNP. Almost all (n = 18) the pastoralists preferred to forage along the Orange River during summer. Besides a good supply of water, the Orange River provided forage and shade for their animals while the riverbank supported valuable patches of 'kweek', *Cynodon dactylon*. Islands in the Orange River were occasionally used, but generally not preferred due to the risk of animals drowning. Whereas foraging featured a radial pattern around stock posts in the 'buiteveld', foraging along the Orange River was mostly linear (up and down along the riverbank). The latter pattern often resulted in conflict between the pastoralists especially where stock posts were too closely located to each other and foraging animals were herded towards each other.

6.4 Discussion

6.4.1 Socio-economic profile

The findings about the socio-economic profile of stock farming in the RNP showed livestock were not the only source of income toward the households of pastoralists, and income from livestock was supplemented from other sources. Household income in the form of welfare payments from the South African government and from remittances played an important social role in providing "safety-nets" to alleviate the constantly fluctuating crises of poverty in these pastoral families. In sub-Saharan Africa, reliance on agriculture tends to diminish continuously as income level rises (Ellis 1999), i.e. the more diverse the income portfolio, the better off is the rural household. Whereas the farming activity in Lesotho is particularly important during old age (given the inadequate provision of pensions) (Spiegel 1979), its significance in this study was accentuated during unemployment. Married sons and daughters of pastoralists formed closely-associated households and thus used their monies to meet the welfare of family members within the household. So-called subsistence farming in the RNP thus appears to be a misnomer since the importance of stock farming to family budgets is attenuated by remittances, pensions and wages. When compared to other communal areas in Namaqualand (Hoffman *et al.* 1999), herds in the RNP appeared to be large (>300 animals) and worth a large sum of money (>R60 000).

Younger pastoralists sought permanent employment rather than sole dependency on livestock for generating income, suggesting that livestock farming was a past-retirement activity and a way of supplementing pension grants. There are indications that this is also the case in the commercial sector of the contemporary American West whereby lifestyle factors may play an equally or more important role in the decision to go into ranching (Liffmann *et al.* 2000; Rowe *et al.* 2001). Farming on its own was unable to provide a sufficient means of survival for younger pastoralists in the RNP. The fact that the average pastoralist in the RNP was older than 50 years, and that the younger generation practised 'hobby' farming (i.e. with other sources of main income) further suggest that semi-nomadic pastoralism in the RNP could be a dying tradition (the threat to sustainability comes when nobody from the family is willing to take over). Wives expected their husbands to manage the herds (Webley 1997).

6.4.2 Farming objectives

The findings of this study suggested that pastoralists strived to maximise animal numbers even if the productivity and condition of individual animals were compromised. Pastoralists concentrated on keeping as many animals as possible by selling animals only when it was necessary to buy food. They claimed that larger herds provided greater security during dry seasons; the bigger the herd the greater number of animals is likely to survive until the next wet season. I presumed that commercial farmers would assess the forage available towards the end of the rainy season and then adjust their stock numbers accordingly. Nonetheless, a large standing stock is the typical reason for livestock keeping in most African communal rangelands (Behnke & Abel 1996; Sandford 1983). Research in Namaqualand (Modiselle 2001; Rohde *et al.* 2001), the Eastern Cape (Ntshona & Turner 2002) and elsewhere noted that livestock acted as storage of wealth and contributed to household food consumption. The findings of this study also indicated that young wage labour pastoralists associated small herd sizes of animals only with household meat supply, emphasising the variable nature in their motives.

Livestock keepers in most communal areas in South Africa sell very few of their animals in comparison to commercial farmers (Allsopp *et al.* 2003). Lack of markets is a contributing factor (Ainslie 2002). However, literature dealing with pastoral economies (Swallow & Brokken 1987), suggested that if the rate of inflation is high and returns on savings are not well above inflation, the return to saving in livestock can well exceed the returns from savings in the bank. In the case of the RNP, banking services were few and far between and difficult to get at (the closest banking services were ca. 100km away in Alexander Bay), and pastoralists experienced some source of ready cash rather convenient.

Pastoralists did not have to give of their livestock when they got married. This made pastoralists different from those in pastoral systems where wives and animals are synonymous with wealth so that a wealthier owner must give many stock at marriage (Gulliver 1955; Carstens 1985). Animals were also not kept in the RNP for ceremonial (sacrificial) purposes.

6.4.3 Herd management practices

The findings showed that the pastoralists employed a range of strategies in the RNP to maximise the efficient harvesting of available forage and water resources. These included manipulating herd composition, spatial distribution and timing of grazing. Besides maintaining highest possible number of animals, these strategies apparently also enabled them to reduce the risk of destitution. Often referred to as mixed farming systems found in dry areas of southern Africa (Abel 1993; Scoones 1992), diversity emerges as a strategy both in terms of the kinds and classes of livestock kept, and the range and heterogeneity of habitats exploited by pastoralists (Fernández-Giménez & Swift 2003). Goats and sheep were kept in mixed herds in the RNP as a risk-mitigating strategy. Individual herds also comprised of several owners. Kids/lambs (<2 months old) stayed behind at the stock post during daily foraging periods. The decision to change the direction of daily grazing from the stock post was based on the grazing behaviour of animals while the decision to move to another stock post was determined by the condition of forage and prompted by the condition of the animals. Pastoralists claimed that the death of sheep especially is another important indicator for them to move to another stock post because sheep appear to be more prone to livestock diseases than goats. Previously animals were forced to run through the smoke of a fire to give them a scent repellent to predators (Schapera 1930), but nowadays at least one animal in a herd is harnessed with a bell and pastoralists monitor predation by the rhythmic noise of the bell.

Pastoralists appeared to have a specific knowledge of the vegetation and water supply in their foraging areas. They used this knowledge to employ their individual decision-making strategies about herd management practices. There were no formal institutions in the RNP that regulated individual resource use. Pastoral alliances between the pastoralists were mainly a matter of mutual convenience and maintaining social ties with kin or friends from another stock post. A diversity of herd management practices existed among pastoralists. Pastoralists, primarily, made the decisions about their daily herding strategies, but herders played a more important role in this decision-making in the absence of pastoralists.

6.5 Conclusion

For an area which seems to be fairly well researched for its plant diversity and high endemism (Chapter 2), it is only recently that the communal rangelands of Namaqualand have received empirical attention regarding the close interface between local people and their environment (Debeaudoin 2001; Solomon 2000). This study provided detail about three key aspects into why pastoralists do what they do. It is now necessary to initiate the dialogue between the RNP administration and the resident pastoralists to marry the RNP's conservation objectives to these guiding principles of pastoralism.

Rangeland in Richtersveld has always been used in common and it took a High Court decision in 1991 against the government to return the then proposed RNP to commonage (Chapter 2). Therefore, these traditional uses of the rangeland have to be respected when developing mutually agreed strategies for both improving the livelihoods of pastoralists and the conservation of biodiversity. A step toward developing mutually agreed strategies would be to obtain a commonly agreed carrying capacity for the RNP. Notably, a commonly agreed carrying capacity would not force pastoralists to use lower stocking rates for greater productively (Abel 1993). However, since the upper limit has already been set somewhat arbitrarily at 6 600 animals (Chapter 3), the suggestion for a commonly agreed carrying capacity calls for a dialogue between the RNP administration and the pastoralists. What incentives could pastoralists have to better protect succulents? Dialogue on this and other questions would help remove the mistrust among resident pastoralists brought about by the RNP administration's unsuccessful attempt to replace communal land with private land ownership for conservation in the late 1980s (Chapter 2).

Two fundamental problems underlying livestock marketing in arid and semi-arid rangelands zones are price and supply variability (Kervin 1992). In the RNP, the prices often asked for stock are too high for members of the village to afford. This and the lack of local abattoirs and freezers mean that a surplus of animals is often found in the RNP. The Richtersveld is a special case involving few people and, for 20 households, it is hardly feasible to start a marketing scheme under these circumstances. Until an alternative investment that is comparable with goat production in terms of risks and returns is found, it might be more helpful for now to find ways of encouraging a saleable surplus when pastoralists need money to fulfil the needs of the household. Notably, raising small livestock in the RNP seems to be a fairly low-cost activity (no substantial inputs).

ANNEXURE 1. **Why pastoralists do what they do**

A. SOCIO-ECONOMIC PROFILE

Name of farmer : .... Age : ....years

Status : farmer ..../ pensioner ..../ wage labourer ....

No. dependants : wife / son(s) / daughter(s) / grandchildren / other (specify)

No. of animals : wife ...... / son(s) ...... / daughter(s) ...... / grandchildren ...... / other (specify) ......

B. FARMING OBJECTIVES

B1. Local people in communal areas often farm with livestock. Why do you farm with livestock?

Social — Socio-economical — Economical

1	2	3	4	5	6	7	8
ceremonial ↔	draught ↔ power	transport ↔	meat ↔	milk ↔	additional ↔ income	capital ↔ saving	cash

B2. And what is your aim with livestock?

0	1	2
To have insurance (sideline)	To only maintain farming (survive)	To improve farming (wealthy)

B3. Why do pastoralists keep large numbers of animals?

Social — Socio-economical — Economical

1	2	3	4
higher respect amongst members of village	lower risk of destitution	because of greater household demand	wealthier&richer

B4. Complete the matrix exercise to rank your immediate dependence on the following from most important to least important.

Social — Socio-economical — Economical

1	2	3	4
meat	milk	immediate cash	annual sales

C. PASTORALISTS' NEEDS

C1. Complete the preference matrix exercise to rank your needs from most important to least important.

	job	vehicle	agric. subsidy	suppl. fodder	water supply	market	veteriary services
job	**						
vehicle		**					
agric. subsidy			**				
suppl. fodder				**			
water supply					**		
market						**	
veterinary services							**

C2. Indicate (✔) the number of animals you had previously and how many you expect to have in years to come.

No. animals	1990	1995	Currently	2005	2010
> 500	....	....	....	....	......
300 - 500	....	....	....	....	......
100 - 300	....	....	....	....	......
< 100	....	....	....	....	......

C3. What do you think is the ideal herd size to support your household?

< 100	100 - 300	300 - 500	> 500

C4. How did you build up your herd?

C5. Are you satisfied with your herd production?

YES ....

NO .... , If No what do you intend to do about it?

D. HERDING PRACTICE

Mixed animal species

D1. If you had to compose a flock of animals, what will its composition be?

...................../...................../......................../

WHY?

.................=...

.................=...

.................=...

D2. Rank the following reasons as to why people farm with mixed animal species from least important to most important.

One species belongs to someone else	luxury in diet	better soci-economic benefits	response to threats of diseases

Farmer management

D3. Rank the following according to your perception from least importance to very important in farming.

Farmer age

young (<35yrs)	middle aged (35 - 60yrs)	old (> 60yrs)

Why? ....

Farmer status

Employed	Pensioner	Unemployed

Why? ....

No. of people at the stock post

shepherd alone	shepherd & farmer	shepherd & farmer & family

Why? ....

Livestock movement

D4. How many winter and summer stock camps are specifically yours? winter = ...summer = ...
D5. What are the differences between winter and summer for farming?
D6. How many camps do you potentially use within one year?
D7. Could you make a quick sketch of your land with;
- best areas for grazing (why are they the best?)
- best areas for resting
- worse areas for grazing (why are they bad?)

D8. Also show how does your herd move in your land throughout a year?
D9. What are your criteria to say that an area is good or bad?
D10. How do you manage the different areas that you have shown before?
D11. How long do you usually stay at one stock camp?
D12. Why do you move your livestock from one camp to another?
D13. How do you know when to move your livestock to another camp?
D14. How do you decide which direction to send your animals from the stock post?
D15. Do the movements change often? E.g. every day / every week
D16. Why do the movement change and who decides to change them?
D17. At the end of the day, have the animals eaten enough - how do you know?
D18. How do you see if your herding is successful or not and how do you evaluate this? e.g. number of surviving infants, quality of the animals, etc)
D19. Why do you move your livestock to the Orange River?
D20. When do you move livestock to the Orange River?
D21. How do you use the Orange River riparian system?

Relations with other farmers / shepherds

D22. How do you manage to share the land with your neighbours? Do you have an agreement?
D23. Do you have any contact with other farmers / shepherd? If YES, how many times in the last month and six months?
D24. Do you exchange your knowledge about livestock keeping with your shepherd and other farmers? And about plants?
D25. Do you help another farmer or shepherd if needed? If YES, then how?
D26. Do you encourage your shepherd to speak or visit another shepherd? Why / Why not?

Other activities inside park

D27. What do you use access to the National Park for?
Grazing.......... Fuel wood.......... Wood for fencing..........
Plants and wildlife for food.......... Plants for medicinal purposes..........
Other..........
D28. Are you doing this outside the RNP as well?
D29. Why are you grazing inside the RNP?

Comments

D30. Comment on the importance of the following in farming;
- the upper limit of 6 600 animals for the RNP
- the current status of the RNP rangeland

Chapter 7

Diet selection of goats

7.1 Introduction

Central to the study of animal performance is the use an animal makes of its environment (Johnson 1980), specifically the relationship between food resources on offer in the vegetation and the ability of the animal to harvest and utilise the nutrients they contain (Owen-Smith 1991). In the case of livestock farming on communal rangelands in Namaqualand, and other rural areas of South Africa, goats and sheep are free to choose their diets from the variety of forage plants available to them. Principal food plants are those which animals eat in greatest quantities and form the largest percentages of food items in the animals' diet (Mason 1997). A preferred food plant is one that is proportionately more frequent in the diet of an animal than it is available in the environment (Owen-Smith & Cooper 1987; Winkler 1992). In Namaqualand, there is little information about the feeding behaviour and diet selection of small stock to support the claim that livestock grazing poses a threat to the biodiversity of the region (Cowling & Pierce 1999; Hilton-Taylor 1994). The diet selection of goats in this study helps provide empirical evidence for whether goats feed on plants of high conservation status. However, a problem with a goat-centered study is the detection of rare plant species in diet profiles because they are often uncommon (if not eliminated already).

The manner in which goats select their diet is, however, poorly understood (Illius *et al.* 1999). Optimal foraging theory (Stephens & Krebs 1986) has been used by ecologists studying wild herbivores as a basis for predicting animal responses to changes in food resources and other environmental factors (Owen-Smith & Novellie 1982). The underlying principal is that foraging animals want to obtain the most energy from food intake relative to the energy expended in securing and eating their food, within the limits set by various constraints acting on them (Owen-Smith 2002). The latter could be a result of limited protein supply (Owen-Smith & Novellie 1982), energy and mineral requirements (Willig & Lacher 1991), avoidance of secondary compounds (Palo & Robbins 1991) or by plant structural characteristics (Cooper & Owen-Smith 1986). Much research on food plants has found that goats tend to choose a mixed diet of forage plants, even when it is possible for animals to spend all their time eating the preferred plant species (Abate 1996; Illius *et al.* 1992). Man exerts only limited managerial control through such decisions as season and location of grazing, stocking rates and herd composition. The diet ultimately selected in a particular situation is a function of many interacting and poorly understood plant- and animal-related factors (Crawley 1983).

The main objectives of this study were to (a) provide an account of the dietary plant composition of goats, and (b) compare the consumption of these species with their relative availabilities in order to elucidate dietary preferences and conservation status. Emphasis was placed on (1) plant species and their growth forms in the diet, (2) preferred and principal food plants, and (3) a comparison between these food plants and their conservation status. The latter was determined for individual plant species based on distribution patterns in southern Africa as well as Red Data status (Hilton-Taylor 1996).

7.2 Methods

The study was conducted in 1997 and 1998. The total annual rainfall for the Richtersveld for these years was 78mm and 47mm respectively; the rainfall for both these years was below the long term annual rainfall of 80mm for the region. Feeding observations were restricted to the winter rainfall period (May–September), in the western region of the park. This is the active growing season of most plant species in the Succulent Karoo biome (von Willert *et al.* 1992). Succulent Karoo vegetation is found in the western region of the RNP (Acocks 1988) and contains the plant species of conservation significance (Cowling & Hilton-Taylor 1994; Hilton-Taylor 1996). During the drier months of the year (October until April) the stock farmers herd their animals along the Orange River. The composition of the vegetation along the Orange River comprises mainly widespread riparian trees. Different techniques for assessing diet selection of goats would be required for feeding observations in this vegetation due to the tree density. As a result, and because the succulent shrubland are the central conservation interest, the riverine habitat along the Orange River was excluded from this study.

7.2.1 Feeding observations

The foraging recordings involved continuous observations of eight herds from dawn to dusk for one day once a month between May and September for 1997 and 1998 (i.e. eight herd days per month). A total of 207 five-minute interval feeding observations were recorded during the study period. All feeding observations were undertaken only on goats because they are the most common livestock in the RNP (Chapter 3). Feeding observations were not made when goats were herded towards watering points because goats seemed to walk faster and eat less than when they were herded away from watering points. Generally, these goats and sheep were accustomed to the presence of people and the presence of the observer was therefore unlikely to have influenced forage choice. Most goats could be approached within five metres without disturbing the behaviour of the animals.

The animals were located at the stock post each morning and followed from the time they left the stock post until they returned in the evening. After the animals had moved exactly one hour away from the stock post in the morning, a five-minute interval feeding observation was conducted. The feeding observation involved the random selection of as many foraging animals as possible within a duration of five minutes and marking the forage plants with dowel sticks.

After all the forage plants within the feeding observation were clearly marked, the data recordings were made at each foraged plant including all the plant species present within a distance of 2m from each forage plant. Thereafter, the observer caught up with the flock again, which usually took between 40 to 65 minutes, before another feeding observation was started. The 2m radius chosen represents the range over which individual plants were readily visible to either side of the foraging animal. Each five-minute interval represented a unit of feeding observation. Independence between feeding observations was ensured by recording only one feeding observation on average every 40 to 65 minutes, i.e. the time it took the observer to catch up with the animals. This meets the requirement for independence between successive feeding quadrats as replicates of observation sites (Winkler 1992).

7.2.2 Data sampling

Diet composition was quantified in terms of (1) physiognomic classes, (2) species composition, (3) life-span categories and (4) plant conservation priority. The following physiognomic classes were recognised; (i) grasses, (ii) forbs, (iii) small shrubs (<50cm), (iv) tall shrubs (>50cm), (v) trees, (vi) leaf succulents, (vii) stem succulents, (viii) tree succulents and (ix) geophytes according to Todd & Hoffman (1999), Whittaker (1980) and von Willert *et al.* (1992) (See Appendix 7A for detailed plant list). Plants were also grouped into two life-span categories: annuals and perennials. Plant nomenclature for plant species was made at the Compton and Kimberley Scientific Services Herbaria and additionally followed Arnold & de Wet (1993), Le Roux & Schelpe (1988), Van Breda & Barnard (1991) and Van Wyk & Smith (1996). Herbarium specimens were collected for plants not identified and assigned with a sampling number for identification.

The forage plants were categorised into species conservation status and habitat status. Hilton-Taylor (1996) was used for the Red Data status of plants (i.e. a list of natural flora known to be rare or declining which sets out to indicate existing or potential losses of species or populations and, where appropriate, to propose remedial conservation action), ranking forage plants into seven classes (1 = endangered, 2 = vulnerable, 3 = rare, 4 = indeterminate, 5 = insufficiently known, 6 = not threatened and 7 = not applicable).

Plants were also ranked into being either endemic (ranked 1) or not endemic (ranked 2) to the Succulent Karoo biome according to the updated database from PRECIS (National Herbarium, Pretoria (PRE) Computerised Information System) of the National Botanical Institute. In addition to their conservation status, plants were ranked according to regional and local occurrences. I used Arnold & de Wet (1993) for the regional occurrence; a plant was ranked 1 if it was found to occur only in the Cape Flora region, ranked 2 if it was found in the Cape Flora region and Namibia, and ranked 3 if it was found in other regions of southern Africa as well. For local occurrences, plants were subjectively ranked into three categories of occurrence inside the park based on the author's extensive knowledge of the vegetation; 1 = occasional, 2 = frequent and 3 = abundant. Habitat status was based on habitat specificity and plant distribution. A plant was ranked 1 if it occupied a specific habitat and ranked 2 if it occupied any type of habitat (i.e. generalist). If a plant has a localised distribution (in other words if it is only found in the RNP) the plant was ranked 1 and ranked between 2 to 4 according to the additional protected area, including Augrabies Falls National Park (Zietsman & Bezuidenhout 1999), Goegap Nature Reserve (Rösch 2001) and Namaqua National Park (Bezuidenhout 2000), in which it was also found. The conservation status and habitat status scores were summed for each forage plant and assigned a total conservation score (ranging between 1 and 21) from which conservation priorities were delineated. A forage plant with a total conservation score of 10 and less was considered to be of high conservation priority (i.e. endangered to indeterminate and endemic to the Succulent Karoo biome with limited conservation protection), a total score between 11 and 16 was considered to be of intermediate conservation priority (i.e. not threatened but endemic to the Cape Flora and those adjacent in Namibia and with limited conservation protection in cases of habitat specific locations) and those plants with a higher score as plants of least conservation importance (i.e. no Red Data status with a wide distribution in southern Africa and formally conserved in at least two protected areas in South Africa).

7.2.3 Data analysis

The proportions of the various plant growth-forms in the dietary plant composition were assessed using the "grazed-plant" technique (Barnes 1976). In using this technique, each forage plant was categorised into a physiognomic class. The annual proportion of each plant growth-form in the diet of goats was expressed as the mean percentage of the combined feeding records for all the plant growth-forms for each year of the study period. The diet for each month was cumulative. In order to assess whether the various plant growth-forms were eaten to the extent of their availability, the utilisation frequency for the different plant species was calculated as the total number of feeding records per plant, expressed as a percentage of all observations. The utilisation frequency of the forage plant was then compared to its availability frequency.

In order to assess the principal and preferred food plants in the diet of goats, the usage of each forage plant was compared to its availability. The selected food plants were assessed using adjustments from the "Feeding Quadrat Acceptability Index" of Winkler (1992). In the calculation of the Feeding Acceptability Index (FAcI) for this study, the acceptability of each forage plant was defined as the number of feeding observations in which the plant species was eaten divided by the number of feeding observations in which the plant species was present within 2m of a plant that was eaten. The acceptance values can vary from 0 to 1, where larger scores represent increasing preference. The "Feeding Quadrat Acceptability Index" is similar in principal to the "Site Acceptability Index" of Owen-Smith & Cooper (1987), in that both indices are obtained by comparing food consumption and availability within a defined feeding site. These acceptability indices reflect the likelihood of an animal commencing feeding on a plant species when that species is available nearby. According to Owen-Smith & Cooper (1987), acceptability indices have the advantage that food availability is accessed simultaneously with dietary intake, eliminating sampling errors in estimation of availability. They concluded that it was unnecessary to conduct additional sampling for the calculation of relative plant abundance along the foraging pathway, since meaningful patterns were obtained by simply listing the plant species available nearby while conducting feeding observations. The Feeding Availability Index (FAvI) of forage plants was defined as the number of feeding observations in which the plant species was present divided by the total number of feeding observations investigated. For the purpose of this study, a plant was regarded as available and included in the calculation of the FAvI if it occurred in at least three feeding observations. The mean annual availability was thus estimated for a total of 100 out of 128 plant species that were encountered by the goats.

Only plants which were utilised with a frequency of at least 10% and which occurred in at least three feeding observations are reported in this study. Principal food plants were considered to include all those eaten in more than 20% of the total feeding observations. Acceptability indices were calculated for forage plants that occurred in 10 or more feeding observations within the study period. Only 56 plant species were eaten sufficiently often and included in annual acceptability calculations. Food items with a FacI value between 0 - 0.29 were considered to be less likely preferred, between 0.30 - 0.69 were considered to be intermediate preference, and those with an acceptability index value of 0.70 and greater were considered as highly preferred. For the range of food plants in the diet, this study also used an Electivity Index to display preferences (Chesson 1983). The Electivity Index (EI) ranges from +1 to -1 with zero representing no preference. Plants with a positive EI value were considered to be preferred while those with negative values were considered as less likely to be eaten.

7.2.4 Statistical analyses

Statistical analyses were carried out using the software package STATISTICA (StatSoft, Inc. 1995). A t-test was used to calculate if goats ate significantly more perennial plants than annuals during the study period. A regression analysis was performed to test if the response variable, utilisation frequency, was significantly related to the availability of forage plants. One-way ANOVA was applied to test for significant proportional differences amongst the individual growth forms represented by the forage plants.

7.3 Results

7.3.1 Dietary plant growth-form composition

The mean proportion of perennial plants in the diet of goats between 1997 and 1998 was 78.7% (SD 0.677) compared to the 21.3% (SD 0.677) recorded for annuals ($t = 60.005$; $df = 2$; $P < 0.001$). Notably, the perennials were more abundant than annuals in the ecosystem during the study period. The utilisation frequency of forage plants was significantly correlated with frequency of availability ($r = 0.74$; $P < 0.001$; $n = 83$) (Figure 7.1).

Seventy-seven different plant species occurred in at least three feeding observations during the study period. Herbaceous plants, including annual and perennial forbs and graminoids, comprised 43% of the total winter forage selected by goats, of which forbs were eaten in greater proportion ($F = 730.59$; $df = 8, 9$; $P < 0.001$) (Figure 7.2). Shrubs and trees constituted 27.1% and 3.7% respectively. Succulent (stem, leaf and tree) plants comprised 25.5% of the total winter diet. Only two geophytes were recorded in the diet of goats.

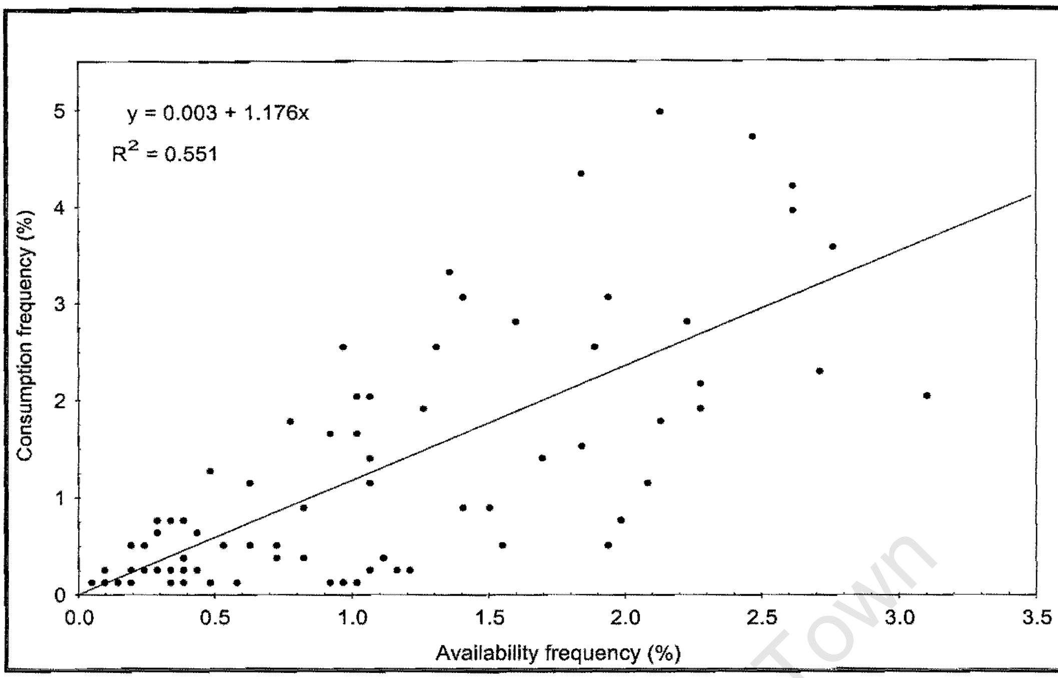


Figure 7.1. The correlation between the utilisation and availability frequencies of forage plants in the diet of goats in the RNP between 1997 and 1998.

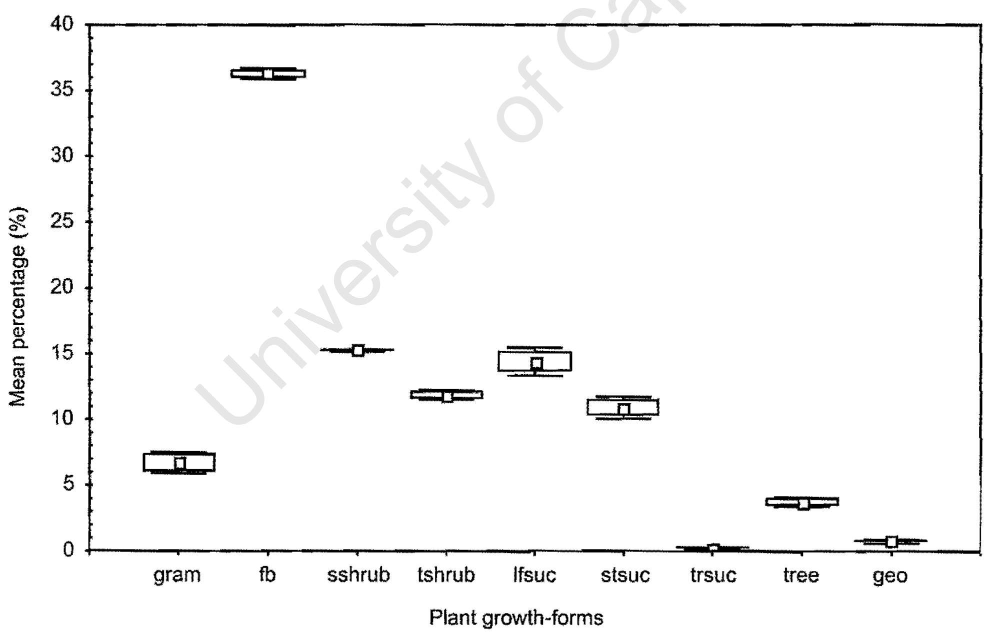


Figure 7.2. The mean proportion (%) of plant growth-form in the diet of goats in the RNP between 1997 and 1998 (gram = grass, fb = forb, sshrub = small-shrub, tshrub = tall-shrub, lfsuc = leaf-succulent, stsuc = stem-succulent, trsuc = tree succulent; tree = tree and geo = geophyte).

7.3.2 Dietary species composition

The botanical composition of plants in the diet of goats and principal food plants, as well as the FacI and EI for each plant species is shown in Table 7.1. A total of 1 865 individual plants, representing 87 species, were eaten by goats while 39 plant species were completely ignored during the study period. During the course of a 12-hour day comprising five to seven feeding observations, up to 16 different plant species were eaten by goats. Of the 56 species for which FacI were calculated, a total of 32 plant species were considered as preferred and 24 as being avoided (inferred by the EI). Of the preferred species, 19 were considered as intermediate preference food plants and 13 as highly preferred (i.e. eaten in greater proportion to its relative abundance).

7.3.3 Conservation status of food plants

More than half (59%) of the plant species encountered by goats in the park (Table 7.2) had no Red Data List status, and are widely distributed in the southern Africa region (including Namibia, Lesotho, Botswana and South Africa). Only four of the species encountered by goats had Red Data status. Of these four only two species were regularly eaten, one species was less eaten and the fourth completely ignored. All the Red Data List foraged plants (including those less eaten) were intermediately preferred by goats. None of the highly preferred and principal food plants of goats in this study had Red Data List status. About 39% of the total plant species encountered by goats were endemic to the Cape Flora and Namibia. Only 2% of the total plants were rare or endemic to the Succulent Karoo biome with limited conservation protection.

7.4 Discussion

7.4.1 Dietary plant growth-form composition

Goats ate more perennial plant species than annual species during the study period. These results could be ascribed to the prevailing dry climatic conditions over most of the Richtersveld region that may have limited annuals during the study period. Jürgen *et al.* (1999) showed that the number of evergreen, leaf succulent shrubs doubled between 1980-1996, fluctuating in response to dry years. Although more perennial plants were eaten in this study, ephemerals play a valuable role in year-round feed availability (Carrick 2003). The time of annual spring flowering (August-September) in Richtersveld coincides with the major goat lambing season (Chapter 3). A study

(Hendricks 1994) conducted in the southern region of the Namaqualand district suggested that ephemerals supplement the diet of lactating ewes and their kids during the annual spring flowering season. Malechek & Provenza (1983) also reported that goats are highly flexible in their feeding habits and seemed particularly responsive to exploiting ephemeral types of feed.

Generally, forage nutritional quality varies between seasons (Illius *et al.* 1999). Nutrient content of herbage on dry areas is concentrated according to season; levels of cell solubles, crude protein and mineral elements are high in the early growing season and substantially declines as plants become dormant during the dry season (Abate 1996; Holechek *et al.* 1995). The botanical composition of the diet can also be influenced to a large extent by individual preferences (Du Toit 1972) and seasonal variation in the availability of food plants (Owen-Smith & Cooper 1985). In this study, the preference for herbaceous forage was apparent from the proportional representation of forbs in the diet. It appeared that woody browse and leaf-succulent plants were important in the diet in those parts of the study area where forb availability was limited.

7.4.2 Diet composition, principal and preferred food plants

The diet of goats included a wide variety of plant species. On the other hand, goats were never seen to consume the deadly poisonous *Tylecodon wallichii*, locally known as "krimpsiekbos".

Only 16% of the total plant species in the diet of goats were considered principal food plants. *Ceraria fruticulosa* was regularly eaten and formed the largest percentage of food items in the goats' diet. It is a leaf-succulent plant with monopodial branching and stores reserves in its corm which allows the plant to resprout after being foraged extensively. This plant maintains up to 80% water-content in leaves and stems (von Willert *et al.* 1992). Amongst other leaf-succulents, *Zygophyllum prismatocarpum* and *Trianthema triquetra* were also considered to be principal food plants.

The Euphorbiaceae make up a very important constituent of the flora in the RNP (Williamson 1995). Euphorbiaceae contributed 8.8% to the total annual forage of goats. The enormous variety of these stem succulents in the park made identification to the level of species difficult. One *Euphorbia* species (HB859), which could not be adequately identified to species level, was the second most frequently eaten food plant amongst the largest percentages of food items in the diet of goats. This *Euphorbia* species was similar in appearance to *E. chersina* and *E. spinea*, being a densely branched plant with terminal branchlets which are either short and blunt or long and distinctly tapered to a spiny point. Only the new growth was observed to be eaten. Other principal food plants of Euphorbiaceae included *E. guerichiana* and *E. dregeana*.

The evergreen *Rhus populifolia*, *Boscia albitrunca* and *Nymania capensis* were considered to be the principal woody food plants and constituted about 10% of the total forage eaten during winter. Though the availability of an alien invasive *Prosopis* sp. was limited, the goats showed a tendency to favour the pods. Occasionally the animals avoided fresh leaves and picked out dry leaves of *Prosopis* sp. The grass species (*Stipagrostis obtusa*, *Leucophrys mesocoma* and *Enneapogon desvauxii*) constituted 6% of the total forage selected by goats.

Continued goat browsing in RNP may threaten populations of plant species that are highly preferred by goats. However, plant species may vary greatly in their tolerance of browsing (Owen-Smith 2002) so that there may be little relationship between preference ranking in goat diets and future population trends. For example, *C. fruticulosa* is able to resprout after browsing. However, it will be naïve to ignore the potential link between browsing pressure and population decline in this study. Instead, these species should be monitored to determine the impact that goat browsing may have on them over the long term, including ecosystem integrity and functionality in the Richtersveld. *Nymania capensis* was the most preferred food plant; goats had a particular liking for its leaves. *Boscia albitrunca* was the second most preferred food plant. Because of morphological characteristics of goats such as small mouths, prehensile lips and the ability to choose from a wide spectrum of food by standing on hind legs (Haschick & Kerley 1998), *B. albitrunca* appeared to have been eaten to a distinctive browsing height up to 1.7m high. Goats also showed a strong preference for *Leucophrys mesocoma*, *Sisyndita spartea*, *Rhus populifolia*, *Hermannia stricta*, *Ceraria fruticulosa*, *Sarcocaulon crassicaule*, *Dyerophytum africanum* and *Trichodesma* sp. The loosely-branched treelet with very minute and inconspicuous leaves, *Ephorbia guerichiana*, was also highly preferred by goats.

7.4.3 Conservation of food plants

Van Wyk & Smith (1996) predicted that *Aloe ramossissima* (listed as vulnerable, Hilton-Taylor 1996) will go extinct as a result of livestock grazing in the Richtersveld. This shrubby plant is endemic to the Succulent Karoo biome with restricted distributions towards mountain slopes of the Richtersveld and southern Namibia. It is currently conserved only in the RNP. Leaf litter was observed to be an important dietary component of goats. This was noted particularly in the case of *A. ramossissima*. *Rhynchosia emarginata*, a rare species endemic to the Succulent Karoo biome with occasional individuals distributed along moisture traps on the lower slopes of mountains, was of intermediate preference to the goats. Goat grazing could potentially threaten this plant, and it is recommended that its population should be monitored in addition to the other 12 highly preferred food plant species. At the time of the study, *B. albitrunca*, *L. mesocoma*, *S. spartea*, *R. populifolia*, *H. stricta*, *C. fruticulosa* and *S. obtusa* did not show any perceived total plant destruction after being browsed (Pers. Obs.). However, continued browsing pressure on these plants may prevent new plants from recruiting following substantial heavy browsing. For example, the removal of reproductive structures leads to a dramatic reduction in seed availability (Hoffman 2003; O'Connor & Pickett 1992; Sternberg *et al.* 2003), which in turn causes a decline or, under heavy browsing intensities, an absence of recruitment (Carrick 2003). The fact that goats often access the key resource conservation sites in the RNP (Chapter 5b), exacerbates the seriousness of this problem.

7.5 Conclusion

Although livestock grazing in Namaqualand is often thought to pose a threat to the biodiversity of the region, there have been few attempts to test its importance. This study provided information on the diet preference of the dominant browser in the RNP. Goats utilised a wide spectrum of forage plants (from herbaceous plants to the foliage of woody browse and leaf-succulent plants) during winter. They also utilised leaf litter as well as the lower leaves of tall woody plants. However, the study did not provide any information on plant response to browsing. The latter is needed before the actual threats to the different plant species from goat browsing can be assumed. Diet breadth is also likely to vary depending on food availability and may be broader in drought periods or where herd sizes are larger. Also, rare listed plant species are, by their very nature, uncommon and as a consequence difficult to infer threats to these species in a survey of this nature. However, this study has provided a foundation for understanding goat foraging in a highly diverse succulent shrubland and a basis for studying plant response to browsing.

Table 7.1. All the plants encountered by goats in at least three five-minute feeding observations in the RNP in 1997 and 1998. The mean acceptability (FAcI), availability (FAvI) and electivity (EI) were calculated for those forage plant species found in 10 and more feeding observations(*). For the purpose of this table, plant species were grouped according to their FAcI value (group one is from FAcI value 0.50 to 1; group two with FAcI value 0.01 to 0.49 and group three with FAcI values equivalent to zero) and ranked from best to worst preference. Principal food plants (#) were eaten in at least 20% of the total feeding observations.

Plant species	**FAcI**	**FAvI**	**EI**
Ozoroa dispar	1	0.0290	0.9437
Commiphora capensis	1	0.0870	0.8401
**Nymania capensis*	0.9688	0.1740	0.6964
**Boscia albitrunca*#	0.9435	0.2513	0.5795
**Rhus populifolia*#	0.8902	0.3527	0.4327
**Hermannia stricta*#	0.8571	0.2705	0.5183
**Trichodesma africanum*#	0.8525	0.2657	0.5204
**Sisyndita spartea*	0.8452	0.0628	0.8619
**Ceraria fruticulosa*#	0.8432	0.4299	0.3238
Rhus incisa	0.8333	0.0580	0.8653
**Leucophrys mesocoma*	0.8304	0.1450	0.7030
Crocyllis anthospermoides	0.8286	0.0580	0.8698
**Sarcocaulon crassicaule*#	0.7984	0.2658	0.5009
**Euphorbia guerichiana*	0.7955	0.2126	0.5762
Cucumis spp	0.7750	0.0435	0.8940
*Unknown sp (HB851)	0.7632	0.1836	0.6094
**Dyerophytum africanum*	0.7381	0.2029	0.5685
**Euphorbia* spp (HB859)#	0.7244	0.4735	0.2098
**Zygophyllum prismatocarpum*#	0.6615	0.3140	0.3562
**Eriocephallus* spp	0.6462	0.1112	0.7077
**Pteronia glabrata*	0.6429	0.2173	0.4951
Aristida adscensionis	0.6250	0.0677	0.8027
**Indigofera pungens*#	0.6171	0.3913	0.2237
**Osteospermum scariosum*#	0.5997	0.5073	0.0836
**Tetragonia spicata*#	0.5853	0.5362	0.0438
**Euphorbia dregeana*	0.5593	0.2416	0.3969
Lophiocarpus polystachyus	0.5500	0.0435	0.8537
Justicia cuneata	0.5278	0.0822	0.7308
Leysera gnaphalodes	0.5000	0.0290	0.8782
Galenia fruticosa	0.5000	0.0386	0.8565

/continue.

Plant species	FAcl	FAvl	EI
*Ceraria namaquensis	0.4762	0.0628	0.7282
*Hypertelis salsoloides[#]	0.4729	0.5411	-0.0675
*Trianthema triquetra	0.4674	0.2174	0.3635
*Stipagrostis obtusa[#]	0.4565	0.4445	0.0128
*Pentzia spp	0.4321	0.3672	0.0721
*Helichrysum spp	0.3950	0.2078	0.3106
*Trachyandra falcata	0.3846	0.1256	0.4960
*Microloma calycinum	0.3845	0.1498	0.4401
Aloe ramosissima	0.3750	0.0386	0.7946
*Salsola zeyheri	0.3571	0.3382	0.0236
*Rhynchosia emarginata	0.3485	0.0967	0.5669
*Galenia spp1	0.3371	0.4589	-0.1541
Zygophyllum microcarpum	0.3333	0.0580	0.7037
Pentzia suffruticosa	0.3304	0.0725	0.6378
*Ruschia robusta	0.3194	0.1014	0.5009
*Forsskaolea candida	0.3139	0.4155	-0.1392
*Aptosimum spinescens	0.3000	0.1449	0.3136
*Berkheya fruticosa	0.3000	0.1594	0.3050
Indigofera argyroides	0.2917	0.0338	0.7859
*Didelta carnosa	0.2768	0.5411	-0.3272
*Enneapogon desvauxii	0.2660	0.4541	-0.2683
*Brownanthus schlichtianus	0.2551	0.3575	-0.1791
*Mesembryanthemum squamulosum	0.2410	0.4203	-0.2741
*Dimorphotheca polyptera	0.2218	0.6088	-0.4680
Berkheya spinossima	0.2143	0.0676	0.4870
*Ruschia spp	0.2069	0.2802	-0.1563
Galenia spp2 (muisbos)	0.2000	0.0387	-0.1082
*Gorteria diffusa	0.1613	0.2995	-0.3263
*Lycium cinereum	0.1507	0.3188	-0.3625
*Eberlanzia spinescens	0.1471	0.1643	-0.0648
Ruschia leucosperma	0.1250	0.0386	-0.1345
Tribulus spp	0.1250	0.0773	-0.2370
Cleome foliosa	0.1250	0.0338	-0.1345
*Acanthopsis disperma	0.1250	0.2319	-0.3172
*opslag (dry material)	0.1232	0.3913	-0.5248
*Codon royenii	0.1232	0.3913	-0.5245
*Drosanthemum spp	0.1186	0.1208	-0.0313
*Stoeberia spp	0.1087	0.2222	-0.3490
*Solanum burchellii	0.1050	0.2173	-0.3956
*Leipoldtia frutescens	0.0955	0.1014	-0.0304
*Ursinia cakilefolia	0.0889	0.2174	-0.4192
Gethyllis namaquensis	0.0714	0.0676	-0.3224
Eberlanzia cyathiformis	0.0625	0.0821	-0.3832
*Galenia africana	0.0476	0.2029	-0.6198
*Opophytum aquosum	0.0417	0.1159	-0.5830
*Psilocaulon subnodosum	0.0400	0.2416	-0.7521
*Monechma mollissimum	0.0263	0.1740	-0.7780

Plant species	FAcI	FAvI	EI
Euphorbia chersina	0	0.1111	-1
Trachyandra muricata	0	0.1014	-1
Prenia sladeniana	0	0.4782	-1
Ehrharta calycina	0	0.0580	-1
Fingerhutia africana	0	0.0290	-1
Heliophila trifurca	0	0.0387	-1
Mesembryanthemum pellitum	0	0.1063	-1
Kleinia longifolia	0	0.0290	-1
Crotalaria meyeriana	0	0.1884	-1
Gazania lichtensteinii	0	0.1159	-1
Felicia spp	0	0.2416	-1
Nemesia anisocarpa	0	0.0290	-1
Euphorbia hamata	0	0.2174	-1
Tylecodon wallichii	0	0.0724	-1
Galenia crystallina	0	0.1352	-1
Felicia merxmulleri	0	0.1932	-1
Tylecodon paniculatus	0	0.0531	-1
Tylecodon reticulatus	0	0.0290	-1
Didelta spinosa	0	0.0483	-1
Sarcostemma viminale	0	0.0483	-1
Asparagus spp	0	0.1111	-1
Cephalophyllum spp	0	0.0483	-1
Blepharis furcata	0	0.2560	-1
Cheiridopsis robusta	0	0.0386	-1

Table 7.2. Foraged plants and those readily encountered by goats categorised into species conservation status and habitat status. The conservation status and habitat status scores were added for each forage plant and assigned with a conservation priority (*** = endangered to indeterminate and endemic to the Succulent Karoo biome with limited conservation protection; ** = not threatened but endemic to the Cape Flora and those adjacent in Namibia and with limited protection if the plant is habitat specific; * = no Red Data status with a wide distribution in southern Africa and formally conserved in at least 2 protected areas). (See text for a complete description of conservation and habitat status categories).

Plant species	Conservation status				Habitat status		Conserv.
	Red Data List	Endemic (S.K. biome)	Occurrence (regional)	Occurrence (local)	Specificity	Distribution	priority
Acanthopsis disperma	7	2	3	3	2	2	*
Aloe ramosissima	2	1	2	2	1	1	***
Aptosimum spinescens	7	2	3	3	2	4	*
Aristida adscensionis	7	2	3	2	2	2	*
Berkheya fruticosa	7	2	1	2	2	3	*
Berkheya spinossima	7	2	3	2	2	4	*
Blepharis furcata	7	2	3	3	2	3	*
Boscia albitrunca	7	2	3	2	2	4	*
Brownanthus schlichtianus	7	2	1	3	1	1	**
Cephalophyllum numeesense	7	2	1	2	2	1	**
Ceraria fruticulosa	7	2	3	3	2	1	*
Ceraria namaquensis	7	2	3	1	1	2	**
Cheiridopsis robusta	7	2	1	3	2	1	**
Cleome foliosa	7	2	3	1	1	2	**
Codon royenii	7	2	3	3	2	4	*
Commiphora capenses	7	2	3	2	1	1	**
Cotyledon orbiculata	6	2	2	2	1	4	*
Crasssula muscosa	7	2	3	1	2	3	*
Crocyllis anthospermoides	7	2	3	2	2	2	*
Crotalaria meyeriana	3	2	3	2	2	2	**
Didelta carnosa	7	2	3	3	2	3	*
Didelta spinosa	7	2	3	1	1	3	*
Dimorphotheca polyptera	7	2	3	3	2	2	*
Dyerophytum africanum	7	2	3	2	2	3	*
Eberlanzia cyathiformis	7	2	1	2	2	1	**

Plant species	Conservation status				Habitat status		Conserv.
	Red Data List	Endemic (S.K. biome)	Occurrence (regional)	Occurrence (local)	Specificity	Distribution	priority
Eberlanzia spinescens	7	2	1	2	2	1	**
Enneapogon desvauxii	7	2	3	3	2	3	*
Ehrharta calycina	7	2	3	2	2	3	*
Euclea pseudobenus	7	2	3	3	1	2	*
Euphorbia chersina	7	2	3	2	2	1	*
Euphorbia dregeana	7	2	3	3	2	2	*
Euphorbia gregaria	7	2	1	2	1	2	**
Euphorbia guerichiana	7	2	3	1	1	1	**
Euphorbia gummifera	7	2	3	2	1	1	**
Euphorbia hamata	7	2	3	1	1	2	**
Euporbia mauritanica	7	2	3	2	2	4	*
Felicia merxmuelleri	7	2	1	2	2	3	*
Fingerhutia africana	7	2	3	1	1	4	*
Forsskaolea candida	7	2	3	3	2	4	*
Galenia africana	7	2	3	2	2	4	*
Galenia crystallina	7	2	3	2	2	2	*
Galenia fruticosa	7	2	2	2	2	2	*
Gazania lichtensteinii	7	2	3	3	2	4	*
Geigeria vigintisquamea	7	2	3	1	1	2	**
Gethyllis namaquensis	6	2	2	1	2	1	**
Gorteria diffusa	7	2	1	3	2	3	*
Heliophila trifurca	7	2	3	1	1	1	**
Hermannia stricta	7	2	3	2	2	2	*
Hypertelis salsoloides	7	2	3	3	2	4	*
Indigofera argyroides	7	2	3	2	2	2	*
Indigofera pungens	7	2	3	2	2	2	*
Justicia cuneata	7	2	1	2	2	1	**
Kleinia longiflora	7	2	3	2	2	2	*
Leipoldtia frutescens	7	1	1	2	2	1	**
Leucophrys mesocoma	7	2	2	3	1	2	*
Leysera gnaphalodes	7	2	3	2	2	2	*

Plant species	Conservation status				Habitat status		Conserv.
	Red Data List	Endemic (S.K. biome)	Occurrence (regional)	Occurrence (local)	Specificity	Distribution	priority
Lophiocarpus polystachyus	7	2	3	1	1	1	**
Lycium cinereum	7	2	3	2	2	3	*
Mesembryanthemum pellitum	7	2	1	2	1	1	**
Mesembryanthemum squamulosum	7	1	1	3	2	1	**
Microloma calycinum	7	2	1	1	1	2	**
Microloma incanum	7	2	3	1	1	3	*
Monechma mollissimum	7	2	3	3	2	1	*
Nemesia anisocarpa	7	2	3	1	1	3	*
Nymania capensis	7	2	3	2	1	2	*
Opophytum aquosum	7	2	1	3	1	1	**
Osteospermum scariosum	7	2	3	2	2	1	*
Ozoroa dispar	7	2	3	1	2	3	*
Pentzia suffruticosa	7	2	3	3	2	2	*
Prenia sladeniana	7	2	1	3	2	1	**
Psilocaulon subnodosum	7	1	1	2	2	1	**
Pteronia glabrata	7	2	3	2	2	3	*
Rhus incisa	7	2	1	1	1	2	**
Rhus populifolia	7	2	3	2	2	2	*
Rhynchosia emarginata	3	1	1	1	1	1	***
Rhynchosia schlechteri	7	2	1	1	1	2	**
Rogeria longiflora	7	2	3	1	1	2	**
Ruschia leucosperma	7	2	1	3	2	1	**
Ruschia robusta	7	2	1	3	2	2	*
Salsola zeyheri	7	2	3	3	2	3	*
Sarcocaulon crassicaule	7	2	3	3	2	3	*
Sarcostemma viminale	7	2	3	2	2	3	*
Senecio cardaminifolius	7	2	1	2	2	2	**
Sisyndita spartea	7	2	2	2	1	2	**
Solanum burchellii	7	2	2	2	2	3	**
Sphalmanthus tetragonus	7	2	1	2	2	1	**
Stipagrostis obtusa	7	2	3	3	2	4	*

Plant species	Conservation status				Habitat status		Conserv.
	Red Data List	Endemic (S.K. biome)	Occurrence (regional)	Occurrence (local)	Specificity	Distribution	priority
Tephrosia dregeana	7	2	3	2	2	2	*
Tetragonia spicata	7	2	3	2	2	3	*
Trachyandra falcata	7	2	2	2	2	1	**
Trachyandra muricata	7	2	2	2	1	2	**
Trianthema triquetra	7	2	3	2	2	2	*
Tribulus terrestris	7	2	3	2	2	3	*
Trichodesma africanum	7	2	2	1	1	3	**
Tylecodon hallii	7	2	2	2	1	1	**
Tylecodon paniculatus	7	2	2	2	2	3	*
Tylecodon reticulatus	7	2	2	1	1	3	**
Tylecodon wallichii	7	2	1	1	1	3	**
Ursinia cakilefolia	7	2	1	2	2	3	*
Ursinia speciosa	7	2	2	2	2	2	*
Zygophyllum microcarpum	7	2	3	2	1	2	*
Zygophyllum prismatocarpum	7	2	2	3	2	1	*

APPENDIX 7A

List of plant species, with abbreviated reference name in brackets, encountered in the RNP. Sample number (HB) refers to species not identified. (p = perennial; a = annual; gr = grass; fb = forb; geo = geophyte; s-shr = small shrub; t-shr = tall shrub; l-suc = leaf succulent; s-suc = stem succulent; and tr = tree)

FAMILY	SPECIES	Life-form	Growth-form
ACANTHACEAE			
	Acanthopsis disperma	a	fb
	Blepharis furcata	p	s-shr
	Justicia cuneata	p	s-shr
AITONIACEAE			
	Nymania capensis	p	t-shr
AIZOACEAE			
	Galenia africana	p	t-shr
	Galenia crystallina	p	fb
	Galenia fruticosa	p	s-shr
	Galenia spp	p	s-shr
	Hypertelis salsoloides	p	fb
	Tetragonia spicata	p	l-suc
	Trianthema triquetra	p	l-suc
AMARYLLIDACEAE			
	Gethyllis namaquensis	p	geo
ANACARDIACEAE			
	Ozoroa dispar	p	tr
	Rhus incana	p	t-shr
	Rhus populifolia	p	t-shr
ANATHACEAE			
	Monechma mollissimum	p	t-shr
ASCLEPIADACEAE			
	Microloma calycinum	p	t-shr
	Sarcostemma viminale	p	s-suc
ASPARAGACEAE			
	Asparagus spp	p	t-shr
ASPHODELACEAE			
	Trachyandra falcata	p	geo
	Trachyandra muricata	p	geo

/continue..

FAMILY	SPECIES	Life-form	Growth-form
ASTERACEAE			
	Berkheya spinossima	p	t-shr
	Berkheya fruticosa	p	t-shr
	Didelta carnosa	p	fb
	Didelta spinosa	p	t-shr
	Dimorphotheca polyptera	a	fb
	Eriocephallus sp	p	t-shr
	Felicia merxmulleri	a	fb
	Felicia spp	a	fb
	Gazania lichtensteinii	a	fb
	Gorteria diffusa	a	fb
	Helichrysum spp	p	fb
	Kleinia longifolia	p	t-shr
	Leysera gnaphalodes	p	s-shr
	Osteospermum seariosum	p	t-shr
	Pentzia suffruticosa	a	fb
	Pentzia spp	a	fb
	Pteronia glabrata	p	t-shr
	Ursinia cakilefolia	a	fb
BORAGINACEAE			
	Trichodesma africanum	p	fb
BRASSICACEAE			
	Heliophila trifurca	a	fb
BURSERACEAE			
	Commiphora capensis	p	s-suc
CAPPARACEAE			
	Boscia albitrunca	p	tr
	Cleome foliosa	a	fb
CHENOPODIACEAE			
	Salsola zeyheri	p	t-shr
	Lophiocarpus polystachyus	a	fb
CRASSULACEAE			
	Tylecodon paniculatus	p	s-suc
	Tylecodon reticulata	p	l-suc
	Tylecodon wallichii	p	s-suc
CUCURBITACEAE			
	Cucumis spp	p	s-shr

/continue...

FAMILY	SPECIES	Life-form	Growth-form
EUPHORBIACEAE			
	Euphorbia chersina	p	s-suc
	Euphorbia dregeana	p	s-suc
	Euphorbia guerichiana	p	s-suc
	Euphorbia spp (HB859)	p	s-suc
	Euphorbia hamata	p	s-suc
FABACEAE			
	Crotalaria meyerana	p	s-shr
	Indigofera argyroides	p	s-shr
	Indigofera pugens	p	s-shr
	Rhynchosia emarginata	p	s-shr
GERANIACEAE			
	Sarcocaulon crassicaule	p	s-suc
HYDROPHYLLACEAE			
	Codon royenii	p	fb
LILLIACEAE			
	Aloa ramosissima	p	s-suc
MESEMBRYANTHEMACEAE			
	Brownanthus schlichtianus	p	s-suc
	Cephalophyllum spp	p	l-suc
	Cheiridopsis robusta	p	l-suc
	Drosanthum spp	p	l-suc
	Eberlanzia cyathiformis	p	l-suc
	Eberlanzia spinescens	p	l-suc
	Leipoldtia frutescens	p	l-suc
	Mesembryanthemum pellitum	p	l-suc
	Mesembryanthemum quamulosum	p	l-suc
	Opophytum aquosum	p	l-suc
	Prenia sladeniana	p	l-suc
	Psilocaulon subnodosum	p	l-suc
	Ruschia spp	p	l-suc
	Ruschia leucosperma	p	l-suc
	Ruschia robusta	p	l-suc
	Stoeberia spp	p	l-suc
PLUMBAGINACEAE			
	Dyerophytum africanum	p	t-shr

/continue..

FAMILY	SPECIES	Life-form	Growth-form
POACEAE			
	Aristida adscensionis	a	gr
	Enneapogon desvauxii	a	gr
	Erharta calycina	p	gr
	Fingerhutia africana	p	gr
	Leucophrys mesocoma	p	gr
	Stiopagrostis obtusa	p	gr
PORTULACACEAE			
	Ceraria fruticulosa	p	l-suc
	Ceraria namaquensis	p	l-suc
RUBIACEAE			
	Crocyllis anthospermoides	p	t-shr
SCROPHULARIACEAE			
	Aptosimum spinescens	p	s-shr
	Nemesia anisocarpa	a	fb
SOLANACEAE			
	Lycium cinereum	p	t-shr
	Solanum burchellii	p	t-shr
STERCULIACEAE			
	Hermannia stricta	p	s-shr
URTICACEAE			
	Forsskaolea candida	a	fb
ZYGOPHYLLACEAE			
	Sisyndita spartea	p	t-shr
	Tribulus spp	a	fb
	Zygophyllum microcarpum	p	s-shr
	Zygophyllum prismatocarpum	p	t-shr
Unknown spp [HB851]		p	t-shr

Chapter 8

Plant species richness and composition along a livestock foraging intensity gradient

8.1 Introduction

Livestock production is extensively practiced in Namaqualand. The foraging activities of livestock in the communal areas of Namaqualand cause dramatic changes in the vegetation of the Succulent Karoo biome (Todd & Hoffman 1999). This is a concern because the biome is extremely rich in endemic succulent plant species (Cowling & Hilton-Taylor 1994; Hilton-Taylor 1996; Huntley 1989; Milton *et al.* 1997). Overall endemism is unknown, but is generally higher than 50% for large genera of succulent shrubs and geophytes (Cowling *et al.* 1999; Esler *et al.* 1999; Rossa & von Willert 1999). The biodiversity of the region is thus perceived to be potentially threatened by heavy livestock grazing (Cowling & Pierce 1999). This chapter describes changes in floristic and vegetation features of the Succulent Karoo biome in relation to indices of livestock foraging intensity under a communal land tenure system.

Ecosystems shift across dynamic thresholds between different ecological states in response to a fluctuating environment resulting from interactions among natural and human-induced factors (Milton & Hoffman 1994). Upon crossing a threshold, novel constraints prevent the re-establishment of historic ecosystem states and hence, shape the living environment (Fahrig 2002). For example, the destruction of habitat in a landscape results in different species either disappearing or establishing at different points on the habitat loss gradient. Herbivores appear to affect plant diversity through their impact on species composition of communities (Belsky 1992; Milton 1992; Kauffman *et al.* 1983; Naveh & Whittaker 1979; Noy-Meir *et al.* 1989; West 1993), plant regeneration opportunities and propagule transport (Olf & Ritchie 1998). Although high browsing intensities, such as those experienced under communal land use, are widely considered to bring about a decline in species richness, this has not been reported in all South African studies. These include studies that show little change in species richness at high browsing intensities when compared with those at lower densities (Venter *et al.* 1989) or potential changes in land use (Shackleton 2000) in savanna ecosystems. However, significant compositional changes occur even when species richness is not altered (Fynn & O'Connor 2000; Venter *et al.* 1989). In fence line contrast studies (Todd & Hoffman 1999), which compared the effect of heavy foraging on several lowland sites in Namaqualand, the total cover of leaf-succulent shrubs declined under communal land use due to a compensatory increase in the species richness of annuals. The quantification of the long term impact on shrub species richness after clearing and ploughing as well as short term impact of increasing livestock browsing intensities for a period of 15 years indicated a less dramatic decline in species richness and a marked increase in degradation in terms of cover and abundance (Carrick 2003).

The most obvious effects of livestock foraging on the environment are seen at localised areas such as water points, along herding pathways and around stock posts. High animal impacts on vegetation and soils close to drinking water points produce a spatial pattern known as a grazing gradient or 'piosphere' that is well documented (Bastin *et al.* 1993a; Bastin *et al.* 1993b; James *et al.* 1999; Landsberg *et al.* 1997; Pickup 1989; Tynan *et al.* 1999; van Rooyen *et al.* 1990). However, little is known about the possible gradients in vegetation composition around stock posts in rangelands, especially in the arid shrublands characteristic of the RNP.

In the case of the RNP, a total of 298 stock posts exist inside the park (ca. one post for every 500 hectares). This total reflects an accumulated number of stock posts (both past and present) and does not indicate the number of active stock posts at the time of the study. I estimated that each stock post, on average, was occupied for about 60 days per annum over the last six years (Chapter 5a). The defecation, trampling and herbivory of animals at the stock post has created an environmental effect with a gradient of decreasing impact away from the stock post that is analogous to the piosphere effect found at water points. A stock post is generally heavily covered with faecal pellets and the centre of the stock post is denuded of vegetation. Abandoned stock posts are often naturally re-vegetated with pioneer plants that are able to resist the chronic foraging effects and nitrogen enhancement. Vegetation change is associated with changes in soil resources (Allsopp 1999). The urine of animals cause an elevation in salinity of the soil at the stock post, and hence alter soil chemistry (Milton *et al.* 1999). The soil structure may also be altered around piospheres (Owen-Smith 1999; Tainton 1981). In the case of the RNP, animals alter the structure of the soil surface by loosening it to a fine texture that is prone to gully erosion (Pers. Observation). In Namaqualand, however, loss of soil as a result of grazing is a minor feature in contrast to the major changes in vegetation composition in response to heavy grazing (Hoffman & Ashwell 2001).

The objective of this study was to determine the effects of livestock herbivory on plant species richness and composition of the vegetation in the RNP along a foraging intensity gradient. For plant richness, I hypothesised that (1) plant species richness should increase with increasing distance from the stock post as foraging intensity declines, (2) species richness would be higher in mountains than plains and footslopes, and (3) the highest plant species richness should be associated with low stocking densities from smaller herd sizes. For the vegetation structure, I hypothesised that (4) plant canopy cover should increase with increasing distances from the stock post, (5) annual plants should occur predominantly closer to the stock post, while (6) palatable perennial plants should increase with increasing distances from the stock post.

8.2 Methods

The investigation was conducted in the western area of the RNP, which receives predominantly winter rainfall (Figure 8.1). The study area supports vegetation of the Succulent Karoo biome (Rutherford & Westfall 1986). It consists of extremely mountainous terrain with large altitudinal changes in the landscape over short distances (the highest being 1 363 metres above sea level and the lowest 89 metres above sea level). Field work took place during the plant growing season of September 1998.

8.2.1 Evidence for comparable transects

Different factors, of which herbivory is but one element, could be responsible for the variation in RNP rangeland vegetation. In particular, the effects of herbivory along a gradient may easily be masked by the changes in environmental conditions such as altitude, moisture, soil type, etc. Another problem in investigating the diversity of plant species is the extreme scale dependence of measures of diversity (Schwilk *et al.* 1997). For example, two communities may have the same average number of species in small plot samples, but very different species counts in larger areas because of variation in intra-community patchiness. The study was designed to minimise the variability in the data by selecting replicate stock posts and transect alignments that were comparable in site variables and foraging history. The variables considered in this study are discussed in more detail below.

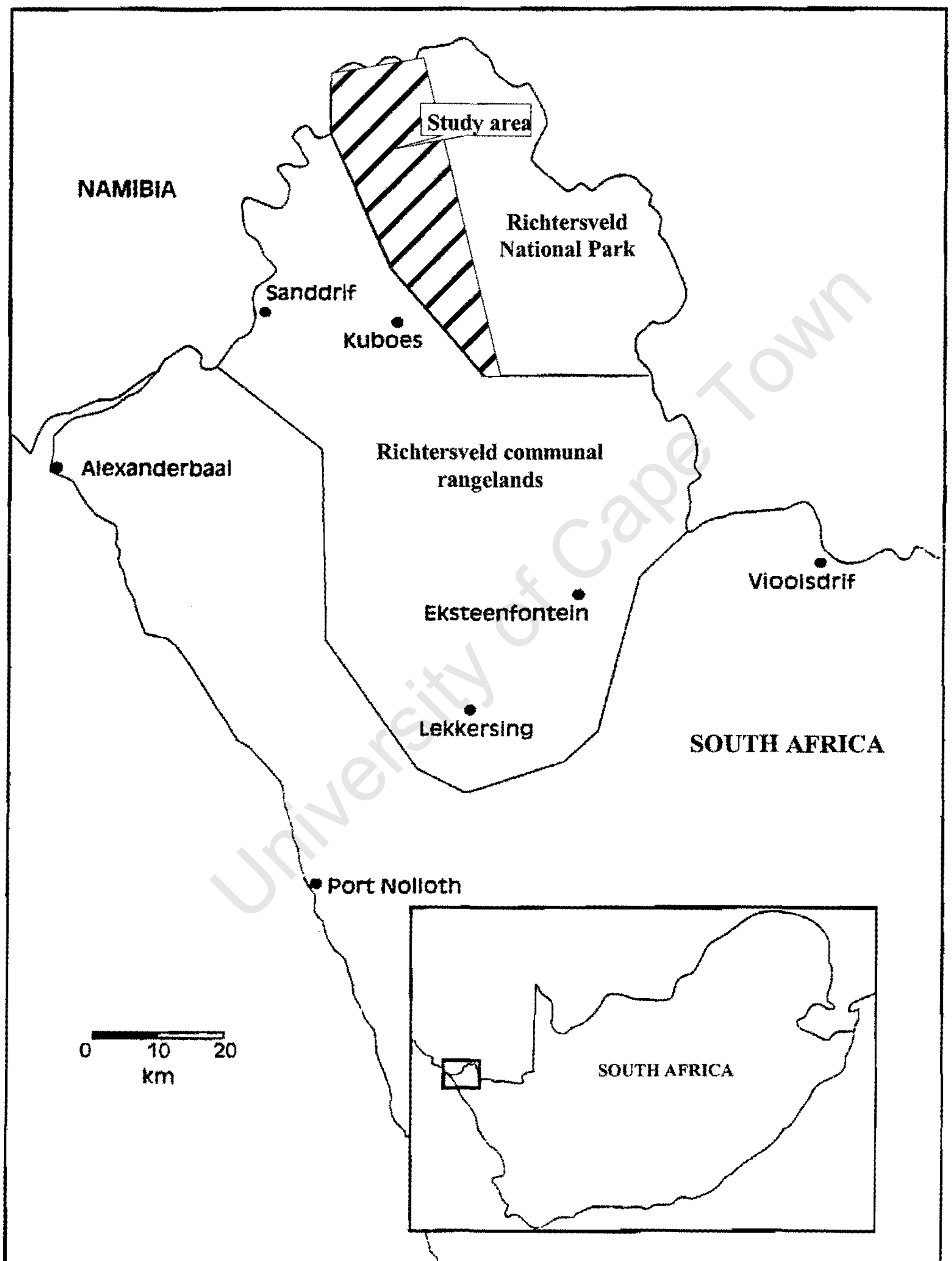


Figure 8.1. The location of the study site in the RNP.

(a) Habitat type

The three habitats included plains, footslopes and mountains (Land Type Survey Staff 1987). The central area of the RNP is mainly characterised by gently undulating plains, comprising of two land types (Ag and Ah). The soils of this landscape were red and yellow, apedal (structureless), well drained, with a low clay content (<15%) and low rock cover. The dominant soil forms included Hutton and Clovelly. The depth of the soil varied from 0.3 metres to 1.0 metres. Footslope habitats were those areas located at the interface between plains and mountains. These habitats had some rock cover and slopes that ranged between 5% and 20%. The soils were stony sand and derived from grey, gneissic granite. Mountain habitat included the mountainous hills with variable aspects and steep slopes. This habitat area comprised the Ic 143 and Ib land types and was typified by rolling hills with exposed rock covering more than 80% of the area. Shallow soil (<0.2 metres) with a low clay content (<10%) occur on the crest and midslopes. The dominant soil forms were Mispah and Glenrosa. In the drainage lines the soil was deeper (0.3-0.8 metres) with a low clay content (<10%) . The dominant soil in drainage lines was Dundee.

(b) Flock type

Forage species selection varies among different animal species on the same range (Ritchie & Olff 1999) and precaution has to be taken to compare foraging effects of similar animals. The stock posts selected for the study varied in the number of goat and sheep flock types. However, an attempt was made to select stock posts which have been historically foraged for at least the last 10 years by a similar type of flock (goats alone or goats and sheep) for all the habitats as far as possible (Table 8.1).

Table 8.1. Flock composition in the different habitats used for the study (g = goats; g+s = goats and sheep).

Habitat type	**Small herd size (replicates)**			**Medium herd size (replicates)**			**Large herd size (replicates)**		
Plains	g	g	g	g+s	g+s	g+s	g+s	g	g+s
Foothills	g+s	g	g	g	g	g	g+s	g+s	g+s
Mountains	g+s	g+s	g+s	g	g	g	g	g	g+s

(c) Stocking density

Different stocking densities result in variations in forage quantity and quality, plant species composition and structure (Coupland 1992). Chapter 5a discussed the spatial and temporal movement patterns of livestock in relation to the location of stock posts and watering points. This study also included the stocking density (i.e. average number of animals herded/kept at a particular stock post, assuming that each farmer grazes his herd at individual zones around the stock post) for each stock post over at least the last six years. Discussions with stock farmers verified that similar stocking densities had been maintained at least since the RNP was established in 1991. I identified stock posts of three different herd size groupings (small, medium and large). The mean value for small herd size was 223 animals, medium herd size was 404 animals and large herd size was 736 animals (Table 8.2).

Table 8.2. The average (±SD) number of animals in the flock for the different herd sizes and habitats used in the study.

Habitat type	Small herd size (replicates)			Medium herd size (replicates)			Large herd size (replicates)		
Plains	314 (±64.8)	230 (±59.5)	276 (±49.4)	404 (±55.1)	400 (±29.9)	404 (±55.1)	863 (±83.9)	615 (±69.5)	863 (±83.9)
Foothills	169 (±46.5)	314 (±64.8)	230 (±59.5)	443 (±74.1)	400 (±29.9)	443 (±74.1)	732 (±96.6)	764 (±42.5)	827 (±105.8)
Mountains	118 (±44.2)	158 (±47.5)	200 (±39.9)	443 (±74.1)	360 (±54.6)	344 (±79.5)	596 (±98.2)	632 (±49.1)	735 (±161.1)

(d) Stock post dynamics

The influence of herbivory on vegetation is likely to vary with the history of grazing. I estimated the age of each stock post as the date since its establishment (some were new posts created and recorded during quarterly livestock surveys) and a verification from interviews with stock farmers. A stock post less than five years old was classified as a young stock post, while old stock posts included those more than five years old.

8.2.2 Sampling and data collection

Nine herds (three each of small, medium and large herds) were investigated on plains, footslopes and in mountain habitats respectively and represented a total of 27 stock posts. A 1 000m transect (going through similar terrain and the habitat in general) was demarcated from the centre of each stock post to facilitate matched transects with similar environmental conditions to that of the stock post. The furthest sampling point away from the stock post was set at one kilometre to (1) avoid potential differences in the topography and environmental conditions along the gradient (such as micro-habitats) and (2) minimise overlap with adjacent herds. Chapter 5a estimated the radius of the 'foraging orbit' from the centre of the kraal as 2.5km during daily feeding forays. The one kilometre transects, therefore, do not extend to the end of the foraging impact zone. A 10 m x 10 m plot was laid out at 200 metre intervals along each transect from the centre of all the selected stock posts in each habitat.

(a) Site variables

The following site variables were recorded for each plot (1) altitude from Garmin GPSII readings, (2) slope (in degrees) from subjective estimations, (3) radiation index (the amount of solar radiation falling on the slope relative to a horizontal surface) (Swift 1976), (4) percentage rock cover, and (5) average rock size estimated for three different size classes as 1 being < 5cm; 2 between 5-30cm; and 3 being >30cm.

(b) Disturbance variables

To evaluate differing foraging intensities, I estimated faecal pellet density, trampling impact and the percentage of bare ground (i.e. habitat related bare patches) within each plot at increasing distances from the stock post on plains and footslopes, and in mountains.

(i) Foraging intensity: The faecal pellet density was recorded within each plot along the transects in three 1m randomly placed plots. The pellet density for the plot, therefore, was the average faecal pellets recorded in three 1m^2 plots and expressed as faecal pellets per square metre following Ellis *et al.* (1998).

(ii) Trampling impact: The trampling impact was subjectively ranked into four classes for each plot on a scale of one to three. The score for trampling impact was based on signs of animal footpaths and the presence of physically damaged plants. A score of one indicated some limited evidence of trampling, a score of two indicated moderate trampling, while a score of three

indicated the heaviest trampling impact. Zero was given where no evidence of trampling was observed.

(iii) Bare ground: Bare ground percentages for plots were visually estimated.

(c) Biotic variables: scale of biodiversity

(i) Species richness: **S** is a biologically appropriate measure of species richness (Peet 1974). This study defined and measured species richness (**S**) as the number of species per plot. The total number of individual plants for each plot was also recorded.

(*ii*) *Community heterogeneity*: Turnover of species between plots can be estimated as the ratio of total species count per transect to mean species richness per plot within a transect (Bond & Ladd 2001). It is a measure of patchiness or community "heterogeneity"(Collins 1992; Schwilk *et al.* 1997). The study examined community heterogeneity (i.e. species turnover within a transect) as the total count of species for all plots along the transect divided by the mean value for all plots. This was done for plains, footslopes and mountains.

(*iii*) *Growth form*: Visual estimates were made of the total canopy cover per plot for each plant species present. All plants were thereafter grouped into two life-span categories (annuals and perennials) as well as into adult and seedling status accordingly. With the exception of annuals, a seedling (an imprecise term, but generally refers to a plant before it reaches the 6-8 leaf stage according to Bromilow 1995), was any plant less than 10cm in height, less than the 8 leaf stage and reproductively immature. Plant species were categorised into the following plant growth forms; grass, forbs, small shrubs (<50cm), tall shrub (>50cm), leaf succulents, stem succulents, trees and geophytes. Annuals were categorised as having a forb growth form. These physiognomic classes were adopted from Todd & Hoffman (1999), von Willert *et al.* (1992) and Whittaker (1980). The proportion of each plant growth-form was calculated and expressed as the mean percentage cover of the combined physiognomic records for all the plant growth-forms for each plot (Barnes 1976).

Chapter 7 showed that goats in the RNP utilised a wide spectrum of forage plants. For the purpose of this chapter, the palatability of plant species was based on a preference rating. A plant species was regarded as palatable if it was available and eaten at least 10 times out of 207 five-minute interval feeding observations. Species eaten less than 10 times or completely ignored were regarded as unpalatable plants.

8.2.3 Statistical analyses

One-way ANOVA was used to test for significant differences in the mean faecal pellet density per plot for different herd sizes. Regression analyses were used to test if the effects of habitat (as a factor) and distance away from the stock post (as the continuous variable) were significantly related to the response variables such as faecal pellet density. Given the perceived importance of the factors that might impede the detection of foraging gradients, a multivariate analysis was performed, using MVSP version 3.1 (Kovach 1985), to extract coenoclines inherent within the data. For this analysis, distance from the stock post was assumed to be a simple linear covariate. Spearman rank correlation was then used to relate the Detrended Correspondence Analysis (DCA) sample scores with the site (altitude, slope, solar radiation, rockcover and rock size) and disturbance variables (pellet density, trampling impact and habitat-related bare patches). One-way ANOVA was used to test for significant differences in the species richness for different habitats. The same test was also used to examine significant differences in mean species richness for each plot at increasing distance intervals (i.e. 200m, 400m, 600m, 800m and 1 000m) from the stock post. Levene's test for homogeneity of variances was employed before applying ANOVAs and appropriate transformation used where variances were heterogenous.

8.3 Results

8.3.1 Transect similarities

In most cases, the habitats differed for almost all site variables (Table 8.3). The radiation index did not differ between the three habitats. The mean altitude for plains and footslopes as well as the mean percentage rock cover for footslopes and mountains also did not differ significantly. Based on the overall foraging history for habitat comparability (Table 8.4), each habitat had five old (those already in existence in 1995) and four young stock posts (those established after 1995). The study investigated the foraging effects of four goat flocks and five goat-sheep flocks on plains, and five goat flocks and four goat-sheep flocks in mountains and footslopes each.

Table 8.3. Mean (±SD; n = 45) plot values of abiotic variables for the different habitat types studied (ANOVA statistical tests: * = $P < 0.05$; ** = $P < 0.01$; LSD test was performed for post hoc comparisons of means).(# represents the amount of solar radiation falling on the slope relative to a horizontal surface and calculated according to Swift 1976)

Habitat type	Altitude (m)	Slope (%)	Radiation[#] index	Rock cover (%)	Rock size class
Plain (Pln)	518[a] ±50.1	0.5[a] ±1.13	0.999 ±0.004	0[a] ±0	1.00[a] ±0
Foothill(Fhill)	506[a] ±85.3	16[b] ±5.4	0.994 ±0.038	12[b] ±6.1	1.93[b] ±0.39
Mountain(Mnt)	566[b] ±40.4	19[c] ±5.8	0.993 ±0.036	11[b] ±7.4	1.67[c] ±0.71
F	2.99	208.91	0.41	61.50	47.69
P	NS	**	NS	**	**

Table 8.4. A summary of the grazing history of the stock posts used in the study. A stock post less than five years old was classified as a young stock post, while old stock posts included those more than five years old (g = goats; s = sheep).

Habitat type	**Herd size**	**Mean stocking rate (SSU/ha) (±SD)**	**Stock post age**	**Type of flock grazed**
Plains	small	0.14 (±0.02)	2old + 1young	3 goat flocks
	medium	0.21 (±0.01)	2old + 1young	3 goat-sheep flocks
	large	0.40 (±0.06)	1old + 2young	1 goat & 2 goat-sheep flocks
Footslopes	small	0.12 (±0.03)	1old + 2young	2 goat & 1 goat-sheep flock
	medium	0.22 (±0.01)	3old	3 goat flocks
	large	0.40 (±0.02)	1old + 2young	3 goat-sheep flocks
Mountains	small	0.08 (±0.02)	1old + 2young	3 goat-sheep flocks
	medium	0.20 (±0.02)	3old	3 goat flocks
	large	0.34 (±0.03)	1old + 2young	2 goat & 1 goat-sheep flock

8.3.2 Foraging intensity gradients

The DCA scatter plot revealed that axis 1 (eigen value = 0.068) explained 61.5% of the variation within the data along the transect while axis 2 (eigen value = 0.022) explained an additional 20% of the variation in transects (Figure 8.2). Spearman rank correlation of the axis scores with the site and disturbance variables, revealed that axis 1 was strongly correlated with pellet density ($r = 0.89$; $P < 0.001$; $n = 135$) while axis 2 was correlated with slope differences ($r = 0.79$; $P < 0.001$; $n = 135$) and percentage rock cover ($r = 0.74$; $P < 0.001$; $n = 135$). The mean faecal pellet density per plot was significantly different amongst the different herd sizes ($F = 3.35$; $df = 2, 132$; $P < 0.05$); a mean density of 45 pellets.m^{-2} was recorded for small herd sizes compared to the 74 pellets.m^{-2} observed within larger herd sizes (>595 animals). Pellet density decreased rapidly to low numbers with increasing distances from the stock post ($r = -0.644$; $P < 0.001$; $n = 135$) (Figure 8.3). The pellet density decreased markedly at about 600m away from the stock post for small herd sizes and by 800m for large herd sizes. Faecal pellet density was significantly correlated with the trampling impact (Spearman $R = 0.302$; $P < 0.001$; $n = 135$) as well as with bare ground percentages ($R = 0.246$; $P < 0.01$; $n = 135$). Plains (39%) had on average significantly higher bare ground percentages per plot than footslopes (27%) and mountains (22%) ($F = 16.33$; $df = 1, 132$; $P = 0.001$).

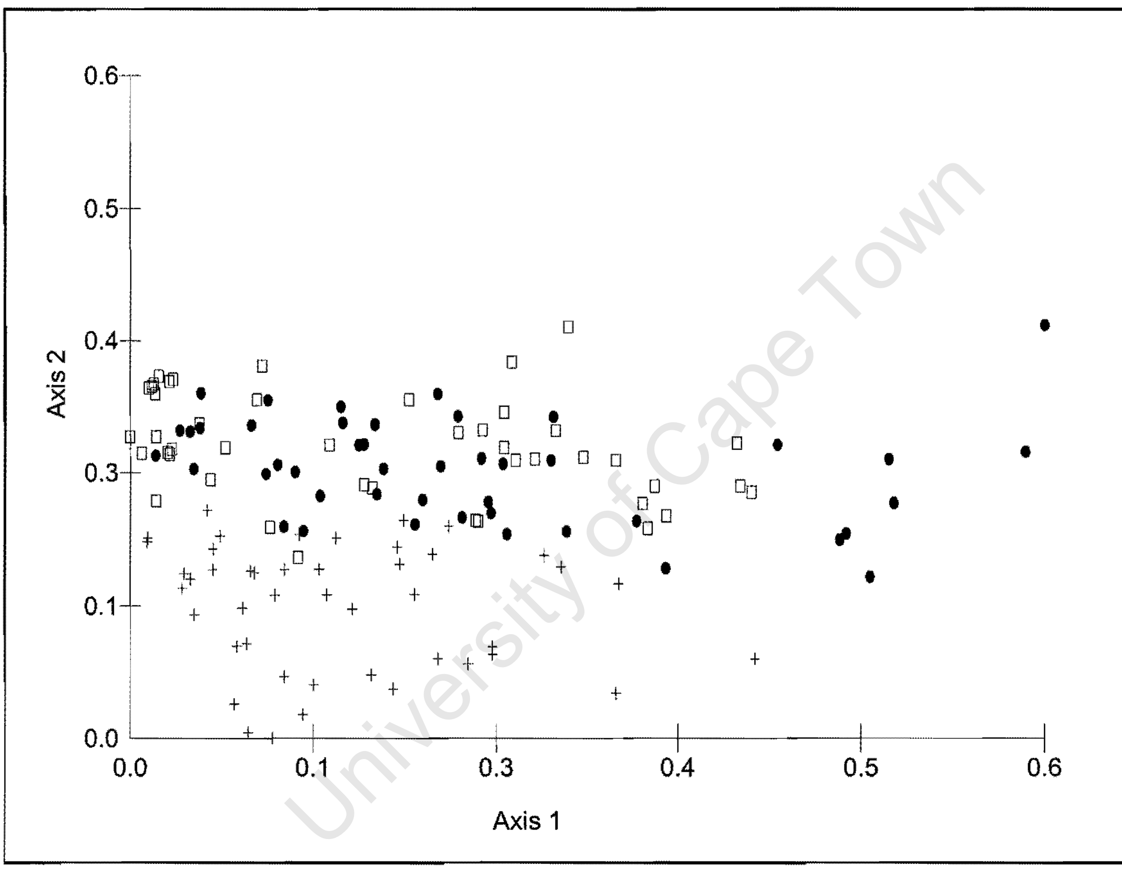


Figure 8.2. DCA scatter plot of site and disturbance variables in 10 m x 10 m plots along a distance gradient transect of one kilometre from the stock post. See text for eigen values of respective axes. (cross = plains, circle = foothills and box = mountains)

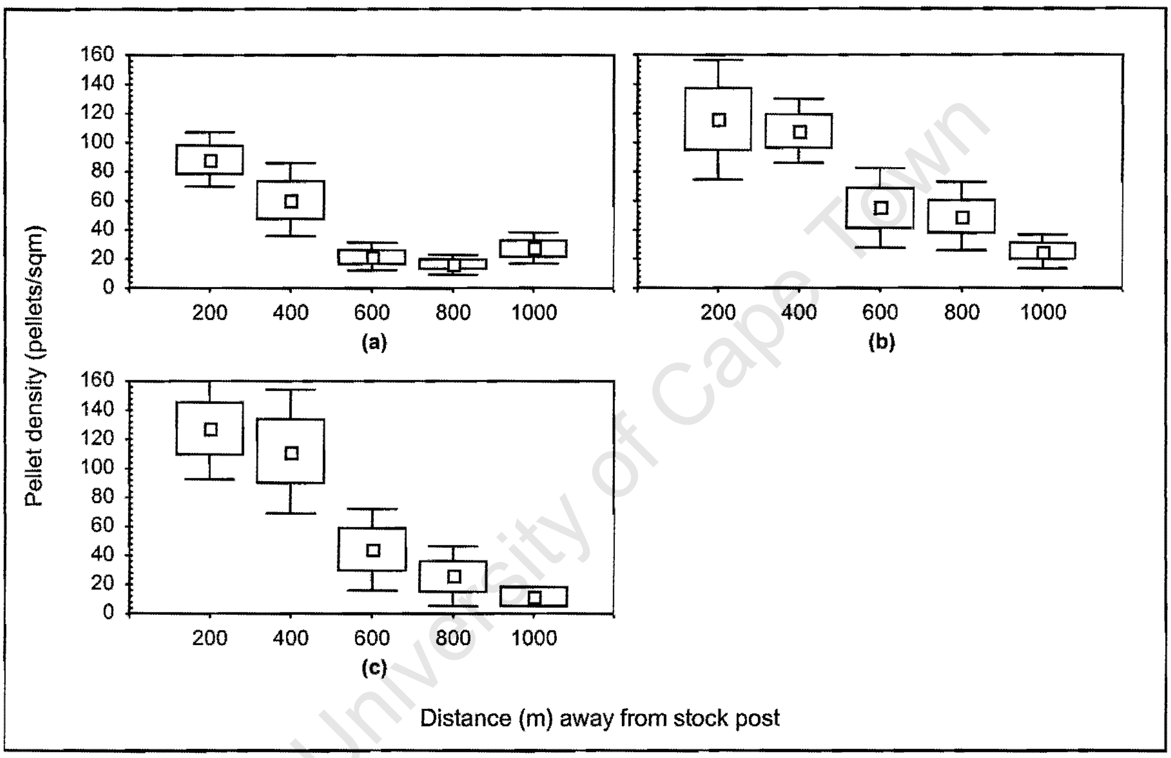


Figure 8.3. The mean (±SE) faecal pellet density (pellets/m^2) with increasing distance from the stock post for (a) small, (b) medium and (c) large herd sizes in the RNP. The mean value for small herd size was 223 animals, medium herd size was 404 animals and large herd size was 736 animals.

8.3.3 Species richness

Footslopes and mountains had on average 8.7 (SD = 2.15) and 9.7 (SD = 2.69) species per plot respectively compared to the 4.2 (SD = 2.07) species recorded for plains. Mean species richness per plot was significantly different between mountainous terrain (mountains and footslopes) and plains ($F = 71.94$; $df = 1, 132$; $P < 0.001$). A total of 10 species were restricted to plains, while five species were restricted to mountains. Plant species richness was correlated with the total plant individuals recorded for each plot, but the amount of variance explained was low ($R^2 = 0.077$; $P < 0.001$; $n = 135$) (Figure 8.4). When transects ($n = 45$) in the individual habitats were considered, plant species richness per 10 m x 10 m plot increased with increasing distances from the stock post in mountains ($r = 0.610$; $P < 0.05$), but not on plains ($r = 0.238$; $P = 0.12$) and in footslopes ($r = 0.281$; $P = 0.062$) (Figure 8.5). Plant species richness for the different habitats did not correlate with the stocking density maintained at each stock post since 1991 ($r = -0.122$; $P = 0.161$; $n = 135$).

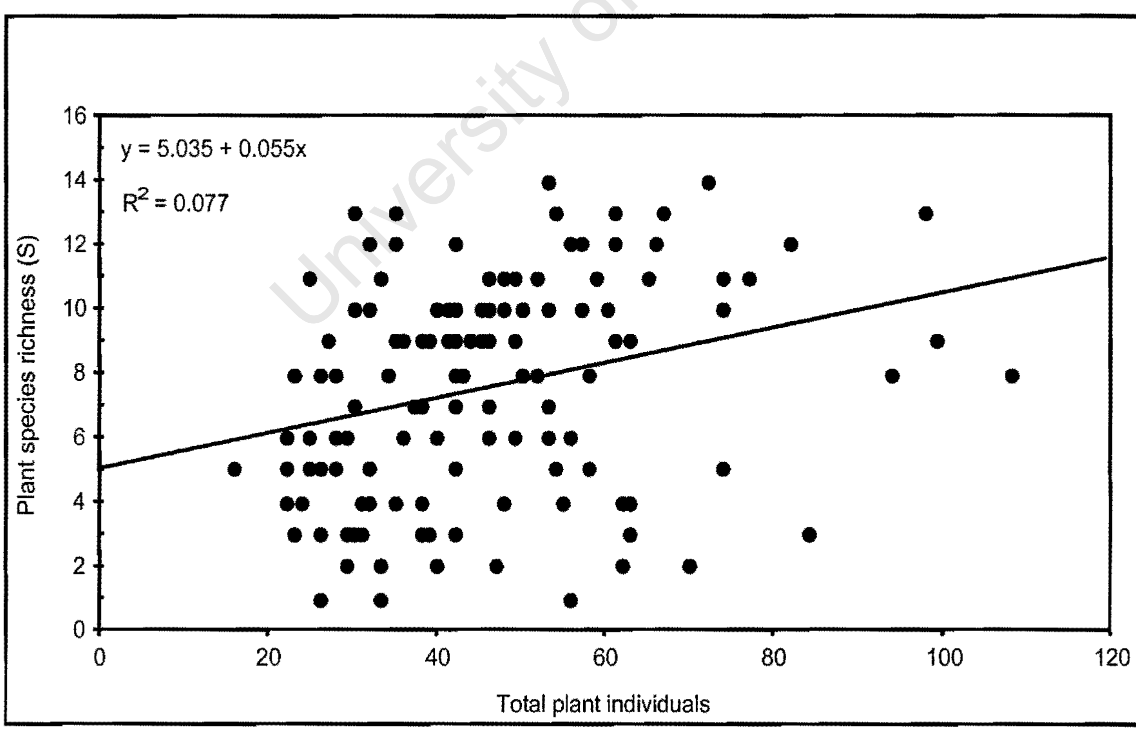


Figure 8.4. Relationship between plant species richness and total plant individuals per plot in the RNP.

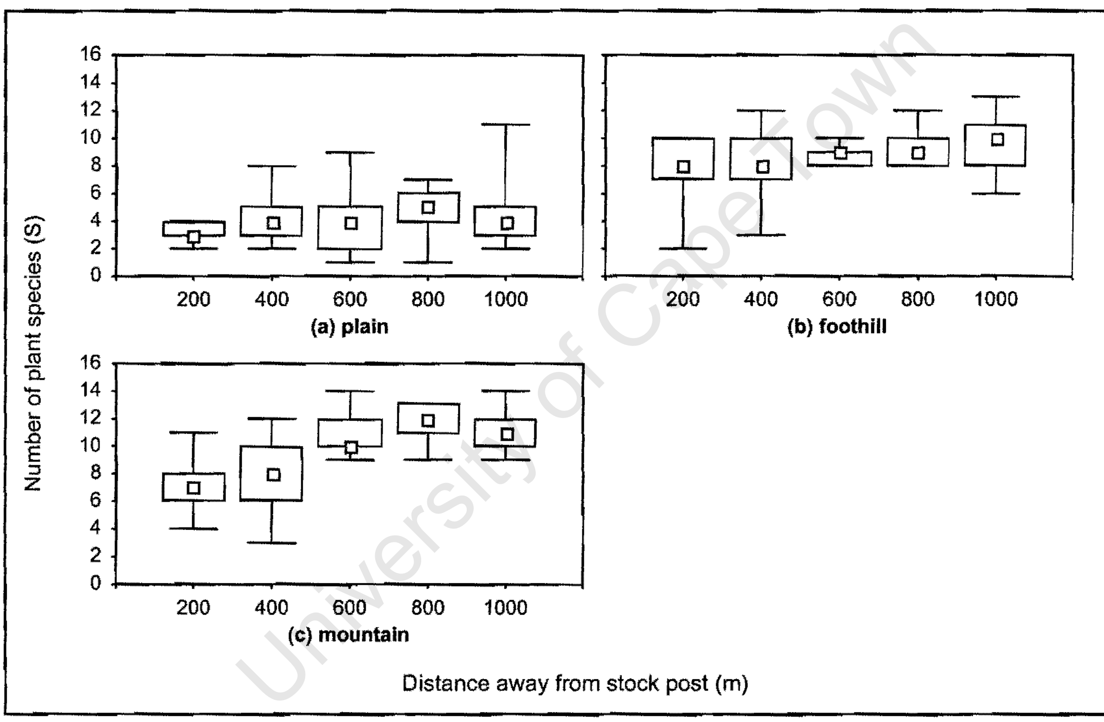


Figure 8.5. Number (median; 25%-75% quartile; min-max range) of plant species (S) per plot along a grazing intensity gradient from the stock post for (a) plains, (b) footslopes and (c) mountains.

8.3.4 Community heterogeneity

The species turnover within a transect was least on the plains (1.67 species), greater on footslopes (2.61 species) and greatest in mountains (2.98 species) (Figure 8.6). Community heterogeneity is determined by the steepness of the slope between mean plot **S** and total **S** at increased transect distance indicating that mountains were the most heterogenous ($F = 165.14$; $df = 2,24$; $P < 0.001$).

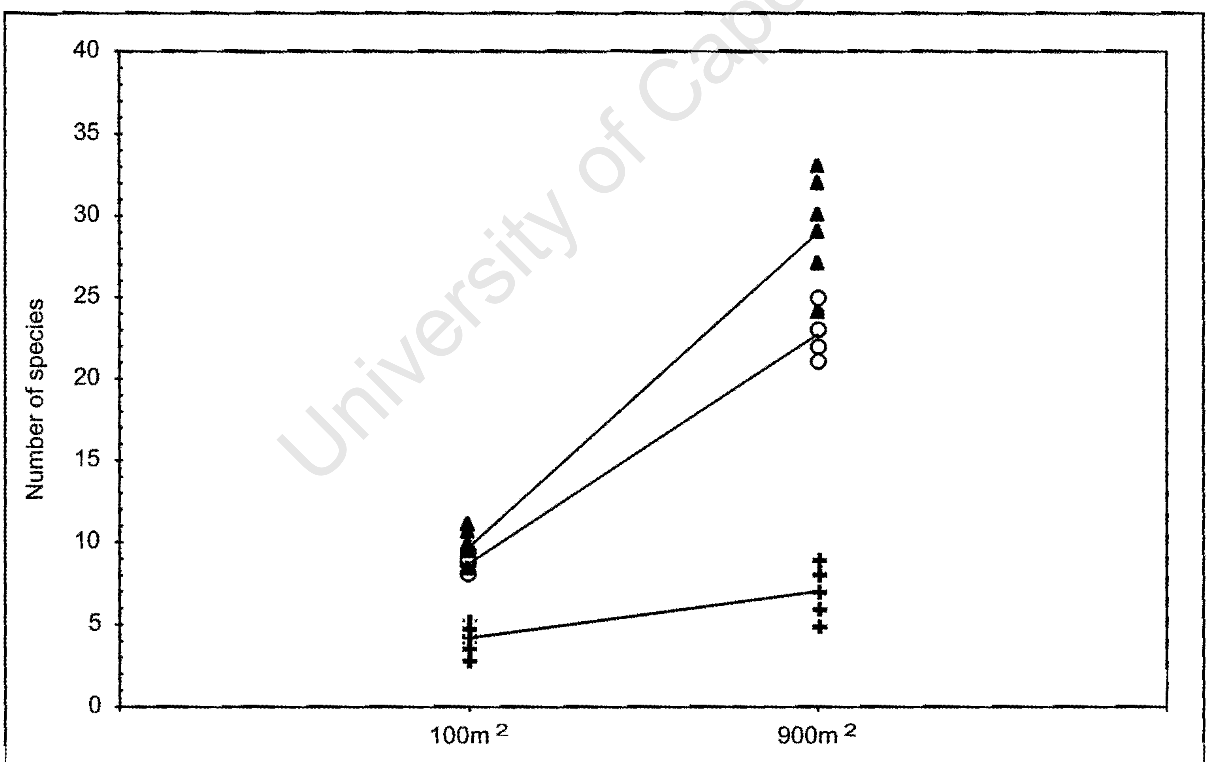


Figure 8.6. Mean species richness per $100m^2$ plot and total species for all plots ($900m^2$) at increasing distances from the stock post for plains (cross), footslopes (circle) and mountains (triangle) in the RNP. The slope of the curve between mean species richness and total species indicates the slope of species turnover (heterogeneity) within the community; steeper slopes indicate greater heterogeneity within the community.

8.3.5 Plant growth form composition

The mean (n = 45) canopy cover for mountains was 70.3% (SD = 13.2) compared to the 64.8% (SD = 12.6) recorded for footslopes and 58.4% (SD = 14.4) for plains. Besides a significant difference in mean percentage plant canopy cover between habitats (F = 8.813; df = 2, 132; $P < 0.001$), total plant cover per 10m x 10m plot also increased with increasing distances from the stock post ($R^2 = 0.077$; $P < 0.001$; n = 135).

Annual plant species frequency was not related to distance from stock posts regardless of the habitat type (F = 0.212; df = 4, 130; P = 0.931). Only nine annual plant species were recorded during the investigation; three (*Aridaria* spp, *Dimorphotheca polyptera* and *Opophytum aquosum*) were recorded only on plains and another three (*Gorteria diffusa*, *Senecio cardaminifolius* and *Trianthema triquetra*) only in footslopes and mountains while the rest (*Didelta carnosa*, *Forsskaolea candida* and *Mesembryanthemum squamulosum*) were recorded in all habitats. Regarding the perennial plants, less than half the perennial species per plot on plains than that on footslopes and in mountains was recorded (F = 77.609; df = 2, 132; $P < 0.001$).

While no differences were recorded for adult plants, the number of seedlings were significantly different in the different habitats (F = 5.738; df = 2, 132; $P < 0.01$). The mean number of seedlings per plot on plains was 2.5 seedlings, 6.3 seedlings in footslopes and 5.7 seedlings in mountains. The number of seedlings was poorly correlated with the number of adult plants recorded for each plot (r = 0.166; P = 0.054; n = 135). Both seedlings (r = 0.009; P = 0.918; n = 135) and adult plants (r = 0.100; P = 0.249; n = 135) per plot did not correlate with increasing distances from the stock post.

The mean percentage cover of the various plant growth forms in plant composition per plot is shown in Figure 8.7. The mean percentages of grass cover (F = 4.706; df = 2, 132; $P < 0.05$) was consistently greater on plains (5.2%) than on footslopes (3.4%) and in mountains (0.2%). Stem succulent cover was significantly higher on plains (36%) than in footslopes (22.5%) and mountains (22.5%)(F = 8.025; df = 2, 132; $P < 0.001$). The mean percentage cover per plot for leaf succulent plants did not differ; 34.9% for plains, 24.8% for footslopes and 44.8% for mountains. Woody plants were restricted to mountains (0.7%) and footslopes (0.5%)($F = 26.578$; $df = 2, 132$; $P < 0.001$).

Figure 8.8 illustrates the mean number of species per plot falling into each growth form category. The various vegetation growth forms in the footslopes were almost equally distributed within plots. The mean percentages of herbaceous plants (grass and forbs) and woody shrubs (excluding woody leaf succulents) between habitats showed similar patterns to the mean number of species for their respective growth form categories. The mean number of stem succulent plant species per plot differed between the three habitats ($F = 7.628$; $df = 2,132$; $P < 0.001$). The number of stem succulent plant species per plot increased from plains (1.2%) to footslopes (1.8%) and mountains (2.4%) in contrast to the downward trend observed in the percentage growth form cover depicted in Figure 8.7. There was no difference in the number of leaf-succulent plant species per plot for the different habitats.

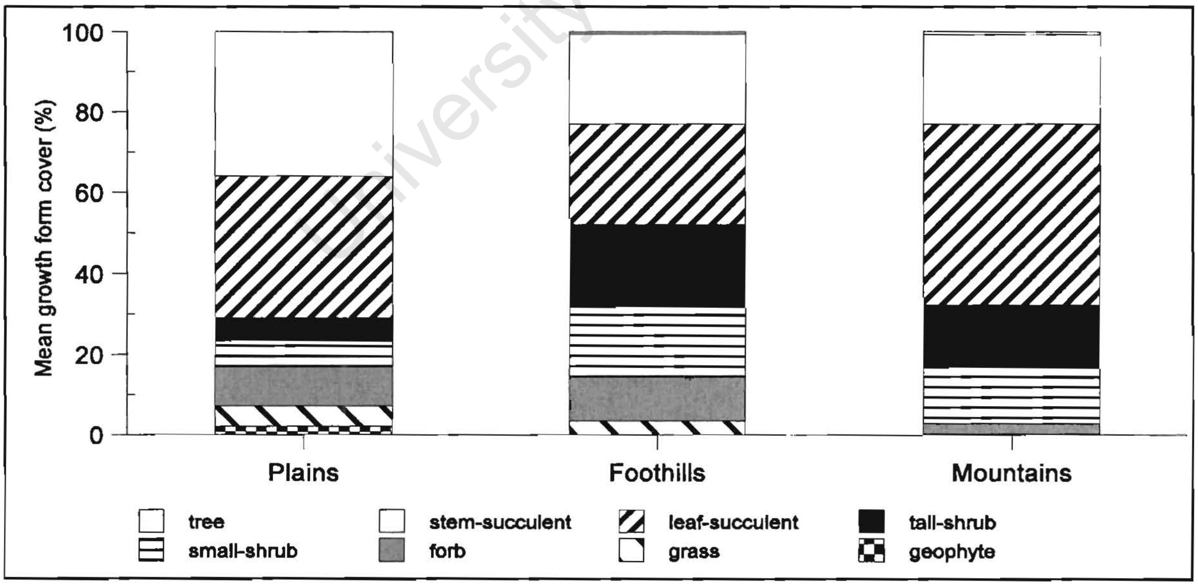


Figure 8.7. The mean percentage cover for the various growth forms per plot in plant composition analysis between plains, footslopes and mountains along a grazing intensity gradient from the stock post.

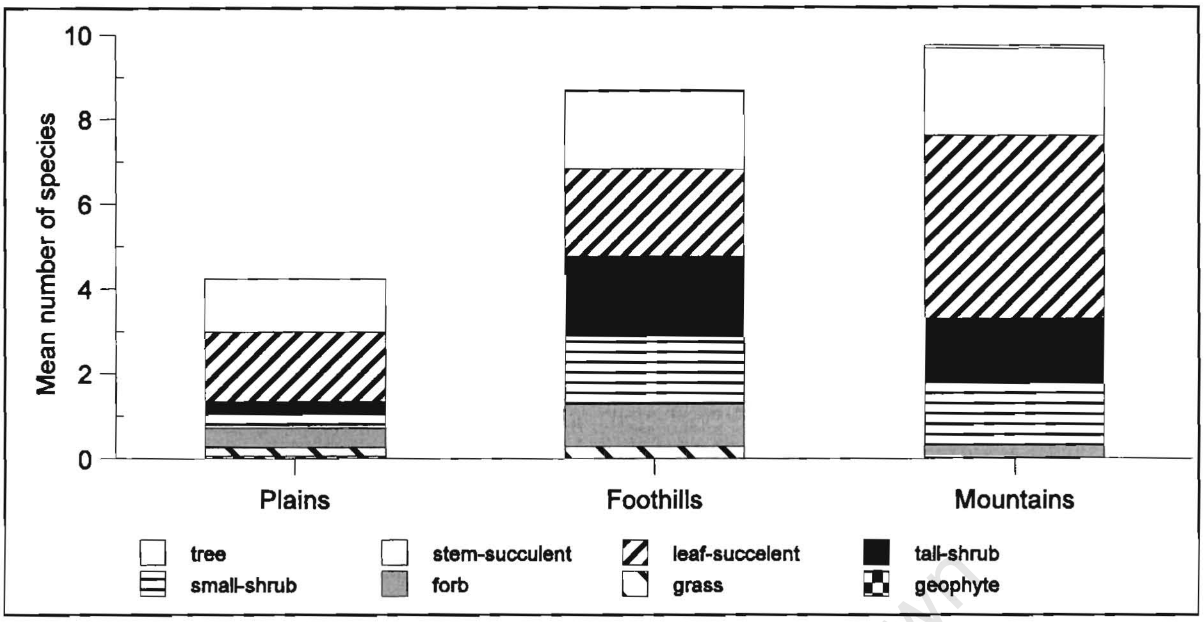


Figure 8.8. Mean number of species per plot falling into each growth form category in plant composition analysis between plains, footslopes and mountains along a grazing intensity gradient from the stock post.

Although plains and footslopes showed poor correlations, mountain habitats confirmed the overall distribution of palatable plant species along the foraging intensity gradient ($r = 0.243$; $n = 135$; $P < 0.01$). Amongst all the different growth forms only succulent plants responded to the gradient in foraging pressure. Leaf succulent plants decreased in species richness closer to the stock post more evidently on footslopes and in mountains than on plains ($r = 0.234$; $P < 0.01$; $n = 135$). Being always higher in mountainous habitats, the mean number of species per 10m x 10m plot with a stem succulent growth form also increased with increasing distances from the stock post ($r = 0.190$; $P < 0.05$; $n = 135$).

8.4 Discussion

8.4.1 Foraging intensity gradients

Landscape variability such as gradients of latitude, elevation, precipitation, nutrients, salinity, etc. can impede the detection of grazing gradients (Bastin *et al.* 1993a; Bastin *et al.* 1993b; Foran *et al.* 1986; Wilson 1986). In South Africa, where rangelands show considerable variability at both local and landscape levels in composition, structure and productivity (Danckwerts *et al.* 1993), it is also important to avoid confusing factors that cause variability at one scale with those factors responding to variability at another scale. For example, coexistence of plants in species-rich communities is suggested to be maintained by fine-scaled habitat differentiation (Jürgens *et al.* 1999) and rapid population turnover among leaf succulent shrubs (Eccles *et al.* 1999). The findings of this study suggest that slope and rock cover were important in the spatial variability of vegetation. Faecal pellet density was a meaningful surrogate for foraging pressure in the RNP; high pellet densities were associated with high stocking densities and trampling impact closest to the stock post.

8.4.2 Responses along foraging intensity gradients

(a) Species richness

The extent of change in species richness with increasing distance from the stock post for different landscapes in the RNP could not be related to herd size differences despite a significant difference in foraging pressure. One possible explanation is that species richness away from the post has already been impacted by centuries of prior foraging activities. Another explanation may be that the impact caused by the different herd sizes may not yet have become evident since the area has only been intensely foraged for the last 10 years since the proclamation of the RNP. The change in vegetation and increase in patchiness due to over-utilisation may take many years (>50) to become evident for some Karoo shrubs (Wiegand & Milton 1996). Jürgens *et al.* (1999) and Milton *et al.* (1998) suggested that the time taken for soils to lose accumulated salts probably exceeds 19 years and the time taken for perennial shrubby vegetation to establish probably exceeds 40 years. The finding of both high and low species richness with the same total number of individuals close to the post suggests that there are other important mechanisms that may also control species richness (Oksanen 1996; Stevens & Carson 1999) such as interaction between the biotic and abiotic components of the Succulent Karoo rangeland system (Todd & Hoffman 1999).

(b) Community heteregeneity

In contrast to the greater heterogeneity in heavily grazed areas of the Succulent Karoo (Todd & Hoffman 1999), heterogeneity in the RNP decreased in heavily foraged areas around stock posts. The species-area curves in Figure 8.6 demonstrated that little variation occurred in the number of species per $100m^2$, but large differences were evident in species turnover along the transects.

In this study, community heterogeneity was highest in mountainous habitats. Plains were dominated mostly by four plant species (*Brownanthus schlichtianus*, *Hypertelis salsoloides*, *Stipagrostis obtusa* and *Drosanthemum* sp.) compared to the more diverse vegetation of footslopes and mountains. Lowlands (plains) have probably been impacted for the last millennium while uplands (mountains) were impacted only within the last century or less as more people were farming in the RNP. So, different histories of exploitation probably account for some of the difference in landscape units. Another possible explanation is provided by von Willert *et al.* (1992), suggesting that plants on well-drained sandy soils are better able to cope with water retention in semi-arid environments and therefore determine the structure of the community.

Community heterogeneity decreased after the 800m distance interval for all the habitats (less apparent on footslopes) (Figure 8.5). This suggests that, as a result of the foraging intensity gradient, plant species distributions became patchier away from the stock post, but that the change in species richness flattened off beyond 800m. This distance from the stock post suggests sites where the least foraging disturbance prevails (inferred by the faecal pellet density) and where species richness is also influenced by competitive displacement between individual plants.

(c) Growth form composition

The Karoo is particularly rich in leaf and stem succulent shrubs (Werger & Ellis 1981) and these contribute the bulk of plant species of the Succulent Karoo biome (Cowling *et al.* 1999). Leaf and stem succulent shrubs contributed on average 62% of the total growth form percentage per plot in this study. There was a difference in the species composition that made up these growth forms for the different habitats. Plains were dominated by the stem succulent, *Brownanthus schlichtianus*, leaf succulents (primarily *Opophytum aquosum* and *Cheiridopsis robusta*) and various species from *Ruschia*, *Drosanthemum* and *Stoeberia*. The single stemmed succulent *B. schlichtianus* dominated all other plant species on the plains and contributed to the high percentage stem succulent cover per plot. Mountain and foothill habitats were dominated by various stem succulent *Euphorbia* species, *Sarcostemma viminale* and *Sarcocaulon crassicaule*, while leaf succulents included *Ceraria fruticulosa*, *Prenia sladeniana*, *Psilocaulon subnodosum* and *Zygophyllum prismatocarpum*.

Leaf and stem succulents were the only growth forms which decreased in species richness closer to the stock post, suggesting that the relationship between species richness and distance is largely ascribed to foraging effects on leaf and stem succulents. The study was undertaken in a low rainfall year (ca 60mm/yr^{1}) compared to the long term mean annual rainfall of ca. 80mm/yr^{1}. This may account for the scarcity of geophytes, grasses and shorter-lived vegetation, and the unusually low abundance of seedlings. The exceptionally high number of flowers and seedlings in 10m x 10m plots recorded by Todd & Hoffman (1999) were likely to be a result of the exceptionally high rainfall recorded over their study period. Generally, recruitment of shrub species in the Karoo is highly episodic and reliant on unusual rainfall events (Hoffman 1989; Esler & Rundel 1999; Milton & Hoffman 1994; Roux & Vorster 1983). An additional complexity of vegetation response is expected in communities with a range of growth forms which react differently to variations in the seasonal distribution of rainfall (Westoby 1980), so that the relative advantage of one growth form compared with another may change between years (O'Connor & Roux 1995). Milton (1991) and Van der Heyden & Stock (1999) suggested that edaphic factors may also play a role in determining the distribution of plant growth forms in the Karoo.

8.4.3 Herbivory effects of conservation concern

Namaqualand's succulent plant richness comprises nearly 10% of the world's succulent flora (Cowling & Pierce 1999). Predicting species loss is essential for pinpointing vulnerable areas and assessing how such loss impacts on community structure and functioning (Cowling *et al.* 1989). This study demonstrated that mountains and foothills are regarded as habitats with the highest species richness. Foothills, and especially mountains, are the main habitats in the RNP to worry about new stock posts. If a new stock post is created in these habitats it will potentially result in as much as 30% reduction in community heterogeneity in the vicinity of the stock post.

The distribution pattern of plant species along the foraging intensity gradient suggests that while some succulent plants are unable to persist under heavy foraging, others seem to tolerate foraging. For example, leaf succulent plants such as *Tetragonia spicata* and *Ceraria namaquensis* are amongst the most important forage plants (Chapter 7) and only occurred further than 600m from the stock post. Other preferred food plants such as *Ceraria fruticulosa*, *Z.*

prismatocarpum and *Trianthema triquetra* showed no specific pattern of distribution around the stock post and seemed to cope under heavy foraging. Two tree species (*Boscia albitrunca* and *Ozoroa dispar*) and three stem succulents (*Tylecodon paniculatus*, *Commiphora capensis* and *Aloe ramossissima*) were restricted to footslopes and mountains.

8.5 Conclusion

Despite complications of landscape variability, distance from the stock post does reflect foraging intensity use (densities in faecal pellets rapidly declined with increasing distances away from the stock post for all habitats studied). For most communal rangelands in Richtersveld, and indeed in Namaqualand and the Succulent Karoo generally, stock post dynamics have a potentially important influence on the overall foraging impacts. As grazing intensity decreases, vegetation cover and species richness increased. Only plants able to persist under heavy grazing occurred near the stock post and those plants unable to persist under heavy grazing occurred further away. The severity of this change in vegetation, however, was not associated with herd size. More grazing gradient data are needed, with special reference to the effects caused by the 'foraging orbit' of 2.5 km recorded in Chapter 5a. Since the survey took place in one of the lowest rainfall years, the influence of livestock herbivory on changes in the annuals and geophytes was less apparent and thus affected heterogeneity in heavily foraged areas.

What do these patterns of change in vegetation and foraging intensity mean for the management of the RNP? Firstly, livestock foraging has a profound negative effect on vegetation of the Succulent Karoo biome and it will be devastating to have new stock posts in areas with a high biodiversity conservation status due to species loss. Despite that the majority of plant species in the diet of goats are considered to be of low conservation priority (Chapter 7), Cowling & Pierce (1999) were correct when they listed livestock grazing by communal farmers as a key threat to the flora of the region. The continued foraging of goats and sheep in the RNP will constitute an ongoing threat to the conservation of plant diversity of the region. The study suggests that current herd size is not an important factor influencing grazing impacts on the diversity of plants. However, the effects may well be too early or too late to detect - hence, the rate of species change and ecosystem transformation remains poorly known. Given the many uncertainties about the diversity of plants in the future, Bond (1999) has suggested that formal protected areas remain the key element for maintaining self-sustained populations of native species in their natural ecosystems in southern Africa. By this, I do not suggest that conservation of biodiversity outside protected areas is not important. The question of how to promote biodiversity in the RNP might also be framed within herd management strategies that limit stock post occupation and rotation.

Chapter 9

A synthesis between semi-nomadic pastoralism and biodiversity conservation

Traditionally, livestock production has been the main use of the Namaqualand communal rangelands, but other considerations such as earnings from conservation and ecotourism have also become increasingly important over the last few decades. The RNP is a tricky mix of an area that conserves the remarkable succulent diversity in a spectacular desert landscape, and at the same time also accommodates and attempts to improve the lives of local communities in the region, especially the pastoralists who are also the present owner. This study set out to investigate aspects of the livestock enterprise which influence pastoral livelihoods and impacts of livestock foraging on biodiversity conservation. The design of the study allowed us to provide information that will help improve and harmonise the livelihoods of pastoralists with the conservation of the unique diversity of plants and animals of the area.

The current argument about resource management in communal rangelands is whether to limit animal numbers, particularly the size of individual herds. This is difficult to implement because it is unpopular and there is no clear agreement on which individual pastoralist(s) should be reducing their herd size. Pastoralist objectives and the motives underlying herd management are also poorly understood. The assumption is that the larger the total livestock population, the heavier the impact is on plant diversity and resource availability. A second assumption is that herd productivity is limited by herd size and that a more productive herd is associated with smaller herd sizes. So, in theory, reduced herd sizes would be beneficial to herd productivity, pastoralist livelihoods and potentially biodiversity conservation. In the RNP, however, all of this is complicated by the fact that the total stock number is made up of 26 pastoralists each with their own individual and variable herds.

So how does herd size of a pastoralist influence herd performance, pastoralist livelihood and biodiversity conservation in the RNP? Based on the animal numbers and how they varied between 1995 and 2002, this study attempted to understand the relative contribution of (i) rainfall, (ii) herd size and (iii) pastoralist skills and management interventions on changes in herd performance. This was coupled to an understanding of the production objectives of pastoralists, their livestock movement patterns and the motives underlying their decision-making. To address the latter part of the question, this study determined the effects of livestock herbivory on the vegetation of the RNP based on the impacts of livestock settlement on conservation-worthy sites, dietary plant composition of goats and changes in plant species richness and composition along a foraging intensity gradient. This chapter revisits all these results to make suggestions in refining RNP management strategies and policy interventions that seek to democratise the relation between 'people and parks' in terms of 'better farming' for both pastoralists and biotic diversity.

9.1 Taking 'stock' - a summary of the main findings

The history of Khoikhoi pastoral activities in the region of Namaqualand is well documented. In summary, continued habitation of Nama pastoralists in the RNP by descendants of the same families took place over the last three generations before and after their integration with the Cape Coloured people in accordance with the Native Land Act in 1913. But it was with the implementation of the Rural Coloured Areas Act in 1963 when the RNP area witnessed the return of Nama pastoralists. The establishment of the RNP in 1991 seems to be followed by an increased utilisation of the area, but was also a further inducement for the pastoralists to settle in a specific area. The boundary placed on the RNP prevented livestock movements over longer distances, hence resident pastoralists. Today, livestock has become an inseparable component of the management of the RNP through a contractual agreement and, therefore, part of the ecology.

In addition to the general aridity of the Richtersveld region, the most important characteristic of the climate is its highly variable rainfall patterns (*cv* > 40%), particularly in the amount and distribution of precipitation. Inter-annual variability in rainfall and hence forage supply, is a major challenge to the sustainable rangeland management in this arid environment. Water availability is the major determinant of the growth and distribution of plants in the Richtersveld.

Total stock numbers in the RNP rangeland (ca. 4 500 SSU) never exceeded the set carrying capacity of 6 600 SSU between 1995 and 2002. Stock numbers seem to lag 1-2 years after the previous season's rainfall, suggesting that the carrying capacity (and therefore the extent of food limitation) of the RNP rangeland in a given year was primarily determined by the amount of rainfall of the two previous seasons. The rate of recovery for total stock numbers after population crashes during the 1998-1999 drought was rapid (< 2yrs), suggesting that populations are probably food limited most of the time. The goat population exceeded both the sheep and cattle populations with an overall ratio of 1:6 and 1:23 respectively. In the RNP, herd number increased from 13 in 1995 to 18 in 2002; goats were herded separately (54%) or sometimes in mixed herds (46%). Mean annual kidding, offtake and production for herds in the RNP between 1996 and 2001 correlated significantly with the annual rainfall deviation for the different years, but the pastoralists estimates about their annual stock losses did not. Pastoralism under the current condition is a net loss for household economy; average income from stock sales was ca. R750 per month in comparison to their monthly expenditure of ca. R2 000.

Pastoralists maintained a mean herd size of 391 animals (ranging from ca. 100 to ca. 700 animals) in the RNP during the study period that are much larger than those recorded in other communal rangelands of Namaqualand. Evidence suggests that herd size is primarily a function of farmer decision-making given the variation of kidding, offtake, mortality and production between different pastoralists. Herd sizes below 350 animals produced higher than expected kid production while those with larger herd sizes experienced lower than average kid production per year compared to the mean from all herds. The study also found little relationship between herd size and density dependent mortality (average population crash was ca. 40%) and herd recovery rates (ca. 35%) during and after a two year drought (density independence).The lack of strong density dependence is likely due to the presence of 'key resource' areas, namely Orange River. Smaller herds, therefore, have a higher risk of disappearing than larger herds. Herd sizes of ca. 400 animals had the highest herd production yield over the study period. The number of people at the stock post to take care of the stock, usage of own transport and possibly also pastoralist skills are important predictors of herd productivity. One or two analyses indicated that pastoralist management skills contribute significantly to herd performance. However, pastoralists have various production objectives and not all are trying to 'maximise' herd-level performance.

The semi-nomadic pastoral system of the Richtersveld is witnessing some changes as people begun to rely more heavily on remittances sent by relatives or allowances from government. Subsistence farming appears to be partly a misnomer since the importance of farming to family budgets is attenuated by remittances, pension funds and wages. Unlike in Namibia, where the Nama language is still widely spoken, only the older people of the Richtersveld still make common use of it. The Khoikhoi were unable to subsist from their herds and had to be hunter-gatherers as well to supplement their diet. On average, two animals each month are slaughtered for basic household use, suggesting that the current estimated meat consumption (i.e. 3kg meat per month) by each member of the family is remarkably high. Animals are also hardly kept for ceremonial (sacrificial) purposes anymore. The fact that the average pastoralist in this study was older than 50 years and the majority of pastoralists made use of 'hobby farming', suggests that semi-nomadic pastoralism in the Richtersveld may be a dying tradition.

The movement patterns of livestock in the RNP were characterised by seasonal shifts (treks over approximately 10 km) between the Upland Succulent Karoo veld (i.e 'buiteveld' with higher supply of forage but limited access to water) and the Orange River pastures. These patterns suggest that forage is the motivation for winter movements and water for summer movements. This approach to tracking resources offers no system of rotational grazing for vegetation recover. Small 'key resource' patches along the Orange River become densely stocked during dry, hot summers, leaving little room for herds to move along the river. Seasonal movement patterns varied amongst the pastoralist, suggesting diverse approaches to tracking resources. The causes and effects of diverse movement strategies are not understood. Larger herds (herds of ca. 500 animals move 8 times a year) generally moved more frequently than smaller herds (herds of ca. 200 animals move 3 times a year). The average foraging range from a stock post that a herd travelled per day during grazing was ca. 2.5 km, hence ca. 1 900ha available grazing area. Goats and sheep walked much more quickly in the morning (1.25 km/hr) than in the afternoon (0.82 km/hr), suggesting that most of the physical destruction of plants potentially occurs in the morning due to running, trampling and scuffling while pastures visited in the afternoon experience mainly foraging impact.

Livestock grazing have varied consequences on the vegetation in the RNP. Areas with special conservation importance (i.e. conservation-worthy sites) were put at risk of destruction.

A large proportion (64%) of these sites (a total of 36, comprising ca. 50 000ha) were regularly foraged between 1995 and 2001. The average distance between a stock post and conservation-worthy site was ca. 1 km; a few stock posts (ca. 10) were located within the conservation-worthy sites. Goats also exploit a wide array of food plants both in terms of species composition (ca. 90 species) and growth form (ca. 10 different types) and we now have some idea of the kinds of species in their diet and how these might change if shifts to new grazing areas take place. However, only four plant species eaten by goats in the RNP had Red Data List status, suggesting that the majority of plant species in the diet of goats are considered to be of low conservation priority. The running and scuffling of goats are destructive, especially the trampling impacts on smaller succulent plants. Distance from the stock post reflected a foraging intensity use gradient. This foraging intensity gradient was characterised by the lowest plant species richness and diversity near the stock posts. Unpalatable plants or plants able to endure the effects of heavy grazing occurred near stock posts where declines in palatable plant species, assumingly sensitive to heavy grazing and trampling, were recorded. Grazing increased vegetation patchiness up to 800m from the stock post. The degree to which this change in species composition occurred did not depend on stocking densities, suggesting that herd size was not a major determinant of the amount of biodiversity loss. Rather, just the sustained use of an area leads to biodiversity loss and hence, the effect of actual herd size on vegetation remains unclear.

9.2 Resource management in communal rangelands

Ellis (1996) draw attention to the lack of success by agricultural practitioners in their attempts to 'improve' livestock farming practices in arid and semi-arid communally farmed areas and which highlights the need for appropriate resource management interventions in communal rangelands.

A common aim of the poor has been described as a secure and decent livelihood (Chambers 1983). People in communal areas strive to achieve this through livestock farming, often with excessive number of animals based on agricultural recommendations. The mainstream economic analyses of such farming systems explicitly or implicitly value it in terms of some measure of output. This has largely been performed on the basis of the commercial farming sector (Jones & Sandland 1974). However, we now know that these suggested 'improvements' to management practices to minimise vegetation impact and increase animal productivity do not necessarily reflect the importance of the system to the producers of communal rangelands. Unlike commercial livestock enterprises, communal pastoralists neither aim to maximise yield of meat or other products from their herds for cash sales (Behnke 1995) nor attempt to minimise the number of people per livestock unit in order to maximise profits per individual (Swift *et al.* 1996). Their objectives are more complex and varied. Since it became clear in this study that livestock numbers are of greater importance to pastoralists than production output *per se*, ways of assessing resource management in communal rangelands should ideally explore the ecological and economic dynamics of livestock grazing based on livestock variables such as herd production objectives, size, performance, mobility and associated pastoralist interventions and skills.

Ellis (1996) argued that appropriate management interventions are also likely to be different for equilibrial and non-equilibrial ecosystems. This study found that communal rangelands with arid shrublands in South Africa are likely to encompass elements of both equilibrium and non-equilibrium states which make these grazing systems complex. I found that herds in the RNP were food limited most of the time during the study period, with the amount of food available varying with yearly variation in rainfall. The non-equilibrium prediction that long term grazing impacts on the environment are negligible is also refuted by the data presented in this thesis, which show that forage plants have little time to recover after drought-induced reduction in livestock foraging. Plant species richness were minimum near the stock posts with increased vegetation patchiness further away. Other strands of evidence suggest that communal grazing systems in arid environments of South Africa may also be described by the non-equilibrium paradigm. These include, for example, rainfall variability and exploitation of resources over a variety of environments across spatial and temporal dynamics (spatial heterogeneity). Ellis & Swift (1988) proposed that environments with a rainfall *cv* of >30% experience mostly non-equilibrium dynamics; plants and animals are uncoupled in most years due to the intervention of drought-induced mortality. The *cv* of the RNP (>40%) was high enough to induce non-equilibrium dynamics (Behnke & Scoones 1993). Herds dispersed away from the Orange River to the 'buiteveld' after the first winter rains where they exploit a variety of habitats until they start to congregate again along the riparian zone of the Orange River with the onset of the dry, hot summer.

In addition to suggestions that appropriate management interventions are also likely to be different for equilibrial and non-equilibrial ecosystems and also for commercial and communal grazing systems, the complex nature of communal rangeland dynamics is also observed at individual herd level. Pastoralists have various production objectives and not all are trying to 'maximise' herd productivity. Seasonal movement patterns varied amongst the pastoralists in the RNP, suggesting also diverse approaches to tracking resources in communal rangelands.

Communal rangelands are thought to be synonymous with overgrazing (Lamprey 1983) mainly due to excessively high livestock numbers maintained under the communal land tenure system, where individual benefit is maximised at the expense of the communal resource (Hardin 1968). Whereas reducing stock numbers would probably result in better veld condition, this study found that there is clearly no obvious incentives to an individual pastoralist to reduce herd size and therefore not a recommended intervention to improve the management of resources in communal rangelands in arid environments of South Africa. Unless pastoralists decide themselves to reduce herd size, another complexity with destocking in these communal rangelands involves the total stock numbers that is usually made up by a group of pastoralists. Who reduce their herd sizes when and with how many animals? The regulation of livestock numbers through marketing, especially surplus animals as in the case of the RNP, is one obvious means to achieve destocking and might be an acceptable strategy to pastoralists in these communal rangelands. However, the establishment of marketing systems that will maintain constant levels of stock sales in order to prevent herd growth remains uncertain in communal rangelands.

Of all countries in the world, South Africa faces formidable challenges in reconciling the imbalance of land ownership that is the legacy of the apartheid era. The government has put in place legislation to address the problem in an orderly and legal way, through the Restitution of Land Rights Act (No. 22 of 1994). Many of the land claims made in terms of the Act are in state-owned protected areas. What to do when the state is committed to conserving biodiversity, as well as restoring land for people to make a livelihood? This study found that it is unlikely to have a win-win situation for the pastoralists and RNP. In this context, very limited opportunities can be created for livestock production in communal rangelands to ensure that protected areas are managed for prosperity.

9.3 Management implications for RNP

The results of this study do not support manipulation of herd size as an effective intervention for pastoralist livelihood and biodiversity conservation in the RNP. This study found little relationship between herd size and herd performance, or herd size and density dependent stock losses and recovery rates during a two year drought. The route to improved livelihoods may owe more to assistance to pastoralists than attempts to reduce herd size. To help determine the decision-making process of pastoralists, an analysis was made of why pastoralists do what they do. However, the evidence presented in the thesis does not adequately address the motivations behind individual pastoralists' decision-making and herd management. Profit from selling animals is not, currently, a major consideration by the pastoralists. Instead, animals are kept primarily as a form of capital with offtake for food and intermittent sales. Though pastoralists rated availability of markets as low in their priorities, the current sale of particularly surplus animals is sporadic and speculative. A move to an annual market might lead to higher incentives from the livestock enterprise than is currently in use. Marketing livestock is likely to remain a challenge.

To the extent that herd size does matter, the optimum herd size in the RNP may be ca. 400 animals for maximum sustained yield. Offtake of larger herd sizes (>500) is compromised by falling kidding and increasingly high mortality rates while smaller herd sizes (>300) carry a risk of complete extinction in severe droughts. The relationship between aspects of herd performance and herd management skills suggests that interventions to improve resource management may be at least as effective as limits on herd size for improving herd performance and herd persistence. If, for the sake of argument, herds were maintained at ca. 400 animals, a pastoralist could potentially harvest ca. 100 animals without destabilising the herd size, earning between R20 000 and R30 000 per annum from animal sales. Though this income is low relative to urban wages, the Richtersveld has few alternatives to pastoral production. If the maximum sustainable yield for individual herds is set at 400 animals, only 16 herds should be allowed to graze inside the RNP based on the upper limit of the park.

Livestock grazing activities create so-called 'piospheric' denuded vegetation areas (Plate 9.1). The grazing intensity gradients away from the stock post create several zones; (a) sacrifice, (b) low nutritious, (c) low impact and (d) competitive displacement. The gradient from high grazing intensity areas to low grazing intensity areas was characterised by areas with a loss of plant cover and dominance of unpalatable plants to areas with negligible soil changes and higher shrub canopy cover, where species richness is determined by competitive displacement instead of grazing. Both species richness and diversity increase with increasing 200m distance increments from the stock post, creating a defined grazing impact sphere of about 314ha around all stock posts. The establishment of a stock post in mountainous terrain will result in at least 30% reduction in community heterogeneity per 900m^2 area.

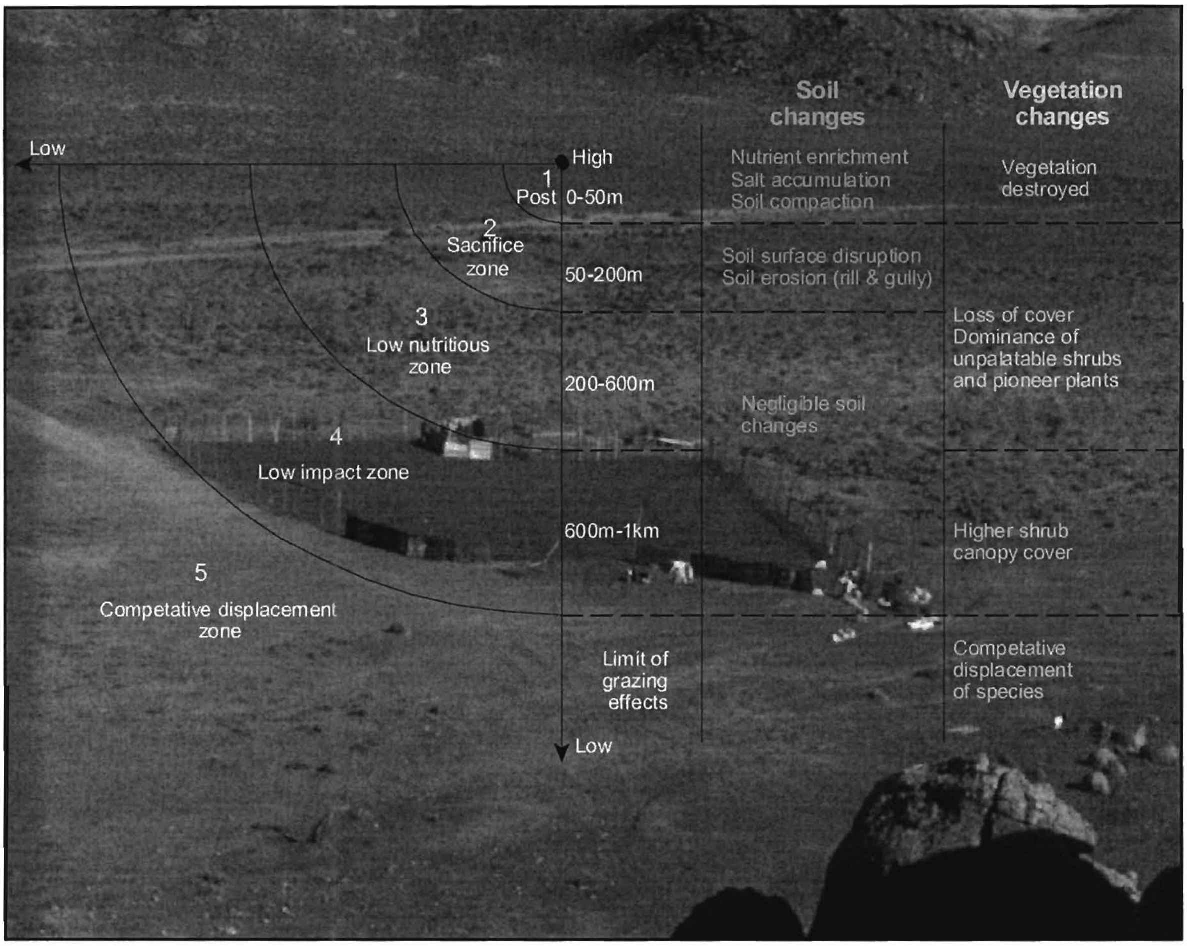


Plate 9.1

Vegetation and soil dynamics along a grazing intensity gradient away from a stock post in the RNP.

Instead of using herd size manipulation as an effective conservation tool, the best option for conservation is zonal land use (conservation, tourism and farming). I must stress, however, that this is not the only alternative to existing management practices. Alternatives could include a policy that precludes the establishment of new stock posts. It could also include no new watering points to be established in the RNP. Road access is also a major factor influencing areas used by pastoralists and construction of new roads could potentially be avoided as far as possible. Besides the rental fee, there is little park revenue sharing with the local people, incentives for pastoralists to agree to zonal land use patterns, possible alternative investment schemes to complement livestock production for capital storage, etc. This may also include an economic incentive (such as a tourism levy) to pastoralists for losing potential grazing habitat along the Orange River for conservation and development.

9.4 Future research

Research into the political and decision-making problems associated with the management of the RNP are urgently needed. How do pastoralists respond to the complex issues raised by the thesis? What are the bottlenecks in communication and information? Where do problems lie in relation to making effective rangeland management decisions. Answers to these and similar questions will contribute to my synthesis for management strategies which will enhance livelihoods and biodiversity.

I also believe that research and outreach recommendations should focus on zonal land use as this is seemingly the most important of local issues to address. This calls for continuous dialogue among RNP administrators, pastoralists and tourist concerns.

Chapter 3 gave speculative reasons toward aspects of livestock demography and households (i.e. shortfall in income against expenditure) that needs further investigation. The rate of change for livestock was conducted at a rather crude level of resolution; it could be useful to see if rates of change were similar among the 20 herds (and examine variability) rather than to lump all 20 herds together for an overall analysis. An analysis of annual change in goat and sheep numbers must also include annual change in rainfall and stocking density.

The development of a clearer understanding of the factors affecting foraging behaviour by goats and sheep is of fundamental importance to the successful prediction of the interactions between these animals and the vegetation in the RNP. The study of feed intake should be extended to include summer type of diets, by a more accurate appraisal of variations in live weight, particularly during early lactation, and by introducing into the model, digestibility and perhaps also ingestion parameters during gestation that might influence the level of intake after parturition. Influences of livestock social organisation and plant species rarity on forage consumption patterns in particular have received little empirical attention.

The dry climatic conditions that prevailed recently over the Richtersveld provided a timely reminder of the fragility of current pastoral practices in communal areas of South Africa. It appeared that the winter grazing areas cannot support a sustainable livestock production and it is the small area of 'key resource' patches mostly along the banks of the Orange River that determined the ability of livestock to sustain themselves through the dry season. The study did not attempt to evaluate the role of the Orange River 'key resource' area as an overall bottleneck on total herd ecology and the above comments lean heavily on speculation.

The Orange River is one of the biggest attractions for ecotourism to the Richtersveld, especially its camping at scenic sites. Currently, the use of the 'key resource' area by goats and sheep threatens the economic development of the RNP because goats and sheep compete with tourists for green patches of grass, while the pastoralists' dogs roam around posting sites for food. A comparative analysis between the importance of the Orange River as a 'key resource' area for livestock grazing and as the biggest tourism attraction for ecotourism is required to provide effective management strategies for conservation that would still allow pastoralists access to suitable resource utilisation. The Orange River is a key aspect of the management of the RNP where the conflict between pastoralists and RNP administrators will be profound.

The assumption of equivalent intrinsic primary production in the different herding ranges as well as the different habitats (bottomlands and mountainous terrain) remain to be tested in further research. This could also include the hypothesis that in arid and semi-arid areas annual yield of natural forage is linearly related to annual rainfall.

9.5 Conclusion

Where resources are used by different groups, conflicts are inevitable. This study focussed on livestock farming and the conservation of biodiversity in the RNP and made suggestions in terms of 'better farming' for both people and plants. The challenge to conservation is therefore to consolidate these various aspects into an integral survival strategy which takes cognisance of the needs and aspirations of the pastoralists as well as requirements which ensure the persistence of a viable biodiversity resource base. The essential partnership between pastoralists and their life-support system must be acknowledged.

The future of the natural resources of the RNP is probably less secure than other National Parks of South Africa. It is dependent on a delicate balance between the needs of the local people and the conservation of those very same resources that the pastoralists use. It remains to be seen whether this Contractual National Park in South Africa will maintain its institutional strength to resolve emerging disputes about integrating human needs with conservation. The lack of community capacity in decision-making for the effective management of biodiversity and the fact that the contract provides little guidance about levels of resource utilisation might become stumbling blocks toward the success of the RNP. At least for now, both the management and local people acknowledge the value of the RNP and the economic development that this unique National Park system brings to the region.

The conservation of biodiversity in the region depends directly on our capacity to provide insights and new ways for the households to survive, and unless we are able to integrate the local community in a process of rural development with nature and ecotourism we will not succeed in our attempts to conserve biodiversity. It requires novel approaches of conservation with due consideration being given to the socio-economic development of rural people (Cowling *et al.* 2002). And, perhaps more importantly, conservation efforts may need to identify and promote those social processes which enable local communities to conserve biological diversity as part of their livelihood system (Pimbert & Pretty 1997). At the same time, it needs to be stated that the Richtersveld environment is a product of an interactive complexity of nature with domestic animals for at least 2 000 years and removing this interaction will change the ecosystem to an unknown and not necessarily more 'desirable' situation. Different types of rangeland management may drive vegetation into different states, all of which may be inherently stable (Rohde *et al.* 1999).

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