# A comparison of standard scientific methods and pastoralists' perceptions of vegetation responses to livestock exclusion in Namaqualand, South Africa

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Thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Conservation Ecology at Stellenbosch University

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March 2010

**DECLARATION**

I, the undersigned, hereby declare that the work contained in this thesis consists of my own original work, and that I have not previously in its entirety or in part submitted it at any university for a degree.

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Signature                                        Date

# ABSTRACT

Protected areas do not always achieve the desired level of biodiversity conservation, while often reducing the welfare of indigenous communities by reducing availability of land for subsistence. Traditional agricultural landscapes are significant biodiversity refugia and can contribute meaningfully to conservation.

Rangelands comprise one-third to one-half of the world's terrestrial surface, providing livelihoods for around 220 million people, usually in a communal subsistence system. Colonial practices impinged on traditional land-use practices with far-reaching social and environmental impacts. This has resulted in management based on assumptions regarding vegetation dynamics and traditional lifestyles that are increasingly shown to be inaccurate. A comparison of a vegetation survey based on conventional scientific methods and a survey of the perceptions of pastoralists was undertaken to highlight differences and similarities between the two knowledge systems with the hope of providing guidelines for more sustainable land-use practices in the communal rangelands of Namaqualand, South Africa.

Vegetation responses to removal of grazing pressure revealed complex interactions that do not correspond with the prevailing management paradigm. Rather than a predictive relationship between livestock and vegetation, environmental factors play a large role in determining plant composition, abundance and cover. Pastoralists' perceptions reflected this complexity in rangeland resource dynamics. The impact of livestock on rangeland resource dynamics was perceived by herders to be secondary to a range of environmental and climatic factors. Both sets of results were at odds with the theories that currently govern management in this system.

Studies in rangeland systems must take the complexity of the subject into account. Research into such socio-ecological systems must take a multiplicity of factors – social, environmental, economic, political and other – into account. Implications for management are that it is inappropriate to adhere strictly to the conventional, conservative strategies that are prescribed by conservation and agricultural authorities. Rather, a more flexible, opportunistic grazing strategy would allow the persistence of traditional subsistence livelihoods without serious negative consequences for biodiversity conservation.

# OPSOMMING

Die instelling van beskermde gebiede lewer nie altyd die gewenste vlak van biodiversiteitsbewaring, terwyl die welvaart van plaaslike gemeenskappe dikwels daaronder ly deur die afname in grond beskikbaar vir bestaanspraktyke. Tradisionele landboulandskappe is beduidende biodiversiteitshawens wat ‘n belangrike bydrae tot bewaring kan maak.

Weivelde bevat ‘n derde tot ‘n helfte van die wêreld se landsoppervlakte en ondersteun rondom 220 miljoen mense, gewoonlik binne ‘n gemeenskaplike bestaansstelsel. Kolonialisasie het inbraak gemaak op tradisionele bestuurspraktyke, met verrykende sosiale- en omgewingsimpakte. Dit het gelei tot bestuurspraktyke gebaseer op standpunte oor plantegroeidinamika en traditionele lewenswyses wat toenemend verkeerd bywys word. ‘n Vergelyking van ‘n plantegroei opname gebaseer op konvensionele wetenskaplike metodes en ‘n opname van die standpunte van veewagters is onderneem om die verskille en ooreenkomstes tussen die twee kennisstelsels uiteen te lê met die hoop om riglyne vir meer volhoubare bestuurspraktyke in die meentgronde van Namakwaland, Suid-Afrika te verskaf.

Plantegroei reaksies tot die verwydering van weidingsdruk wys op komplekse interaksies wat nie ooreenstem met die heersende bestuursparadigma. Eerder as ‘n voorspelbare verwantskap tussen vee en plantegroei, omgewingsfaktore speel ‘n groot rol in die bepaling van plantgemeenskapsamestelling, -getalle en grondbedekking. Die veewagters se standpunte het hierdie kompleksiteit in plantegroeidinamika weerspiëel. Die impak van vee op die weiveldhulpbron is deur veewagters as sekondêr beskou teenoor ‘n reeks omgewings- en klimaatsfaktore. Beide stel resultate is in teenstelling met die teorieë wat tans bestuur in hierdie stelsel bepaal.

Studies in weiveldstelsels moet die kompleksiteit daarvan in ag neem. Navorsing oor hierdie sosio-ekologiese stelsels moet ‘n verskeidenheid faktore – sosiale-, omgewings-, ekonomiese-, politiese- en ander – in ag neem. Implikasies vir bestuur is dat dit onvanpas is om te volhard met konvensionele, konservatiewe strategieë voorgeskryf deur bewarings- en landboukundige gesagte. ‘n Meer aanpasbare, voordeelnemende weidingsstrategie sal die voortbestaan van traditionele bestaanslewenspraktyke toelaat sonder ernstige negatiewe nagevolge vir biodiversiteitsbewaring.

# ACKNOWLEDGEMENTS

My supervisors for their many hours of assistance, advice and support in the preparation of this thesis.

Dr W.S. Watts for support during the initial months of my research.

The following institutions for their financial support:

- Agricultural Research Council
- Global Environmental Facility
- United Nations Environment Programme
- Desert Margins Programme
- Cape Tercentenary Foundation

The people of Paulshoek for their participation and hospitality.

My family and loved ones for all of their love and support.

# TABLE OF CONTENTS

# LIST OF TABLES

to grazing. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given ($n = 32$).

*Table 3.14*. Mean (± SE) of the average abundance of individuals, total volume and average volume of individuals of *Hirpicium alienatum* observed per 100 $m^2$ plot protected from or exposed to grazing. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given ($n = 32$).

# LIST OF FIGURES

# Chapter 1

## Introduction

### Conservation and co-operative governance in rangelands

The effectiveness of protected areas at conserving biodiversity is a controversial issue. Expansion of protected areas does not always achieve the desired level of biodiversity conservation; at the same time it often reduces the welfare of indigenous communities by reducing the land available for subsistence (Johannesen, 2007). Thus, rather than striving for full protection of all remaining pristine areas, strategies should aim for a minimum level of protection over the entire area available (Perrings & Walker, 2004). As significant biodiversity refugia, traditional agricultural landscapes can contribute meaningfully to conservation in this way (Brandon *et al*., 2005; Child *et al*., 2009; Harrop, 2007; Santos *et al.*, 2008).

Rangelands are extensive areas of semi-natural ecosystems used for livestock grazing (Harrington *et al*., 1984; Grice & Hodgkinson, 2002). They comprise between one-third and one-half of the world's land surface and provide livelihoods for around 220 million people (Griffin, 2002; Hobbs *et al*., 2008; Homewood, 2004). These traditional subsistence lifestyles are characterised by low density populations that are highly mobile. Land tenure is usually based on a communal system rather than on individual property rights. Practices introduced subsequent to colonisation impacted on the ownership of and access to rangeland resources, as traditional land-use made way for more modern practices. (Griffin, 2002; Grice & Hodgkinson, 2002). This has had far-reaching social and environmental impacts.

In attempting to redress negative impacts within social and ecological systems, an integrated understanding of environmental governance is called for. Good environmental governance is not a matter of economic efficiency, but rather one of social justice, as it involves the development of institutions that reduce conflict over environmental resources (Paavola, 2007). As local management institutions are fragile, requiring constant external support, policies should facilitate their development in a manner that is effective and sustainable (Balint & Mashinya, 2006; Bennett *et al*., 2010). Cognisance must be taken of the fact that traditional land managers usually seek a mix of economic and social or cultural benefits (Abel, 1997; Allsopp *et al*., 2007; Powell, 1998; Rohde *et al*., 2006). Participatory approaches to natural resource governance will then be able to control exploitation and promote sustainability through greater co-operation from agriculturalists, reduced negative effects of paternalistic conservation measures in agricultural systems and increased economic gains (Frangoudes *et al.*, 2008; Marshall, 2009).

This study seeks to explore both ecological and social issues within utilisation of rangelands. The objective was an improved understanding of the resource dynamics within rangelands, and the interactions between the rangelands and the pastoralists dependent on them. These insights may then be able to advise governance that is both socially and environmentally equitable.

## Namaqualand as an ideal study system

Two of the most pertinent issues within the field of rangeland science regard a proper understanding of rangeland resource dynamics and the validity of traditional knowledge and practices. Communal rangelands are generally managed within a paradigm that plant dynamics are successional in nature and that the main determinant of the vegetation composition is herbivory (*sensu* Clements, 1916). Furthermore, communally-owned resources are almost universally perceived as being open access resources that are degraded – or at least vulnerable to degradation – in accordance with the predictions of Hardin (1968). However, current developments within rangeland science are beginning to challenge these views.

There is increasing evidence in the literature that exclusion of livestock may not necessarily improve rangeland condition (Meissner & Facelli, 1999; Yayneshet *et al.*, 2009; Zaman, 1997). Furthermore, the use of local knowledge systems in the monitoring and refinement of local land practices has proved successful, especially in capturing qualitative features (Girard & Hubert, 1999). Co-operative research involving scientists and local land-users is key to solving management problems in rangelands by integrating local knowledge into decision-making (Bosch *et al.*, 1997). The erection of a livestock exclusion plot – an intervention aimed at improved sustainable grazing practices – at Moedverloor near the village of Paulshoek in Namaqualand provided the opportunity to study both rangeland resource dynamics and traditional ecological knowledge.

The rangelands of Namaqualand, South Africa form an ideal system in which to study these pertinent issues within rangeland science. It is a well-studied area, with research into many of the system's biological, social and bio-physical aspects (Hoffman *et al.*, 2007). It forms part of a biodiversity hotspot of international importance (Mittermeier *et al.*, 2004; Myers *et al.*, 2000), but is under pressure from land-uses such as livestock grazing and mining (Hoffman *et al.*, 2007). In order to explore these two aspects of rangeland management, *viz.*

vegetation dynamics and traditional knowledge and management, a botanical survey based on standard scientific methods and a participatory appraisal of the pastoralists' perceptions regarding the effects of rest from grazing were conducted. A comparison between the results of the two methodologies provided insights into the ecological and social dynamics in the rangeland system. It is hoped that the insights gained from this will be used to advise on improved management strategies for the commons of Paulshoek.

**Thesis outline**

Chapter 2 presents a focused literature review of various issues regarding rangelands and their management. This includes the importance of a proper understanding of rangeland resource dynamics, as well as the appropriateness of participatory research methodologies for encouraging proper governance of rangelands. A background and history of the communal rangeland of Namaqualand, South Africa show its suitability for conducting research on these subjects.

Chapter 3 contains a comparison of the vegetation of the grazed and rested areas. Species richness and abundance of mature plants and seedlings, cover and biomass were determined in order to establish whether rest had resulted in discernable differences in the vegetation condition on the rangeland.

Chapter 4 explores the perceptions of the local land-users of rangelands and their management. Themes such as the determinants of rangeland condition and the assessment thereof, the effects of rest from grazing and appropriate management of communally-owned land were discussed with livestock herders.

Chapter 5 compares the perceptions of the communal pastoralists with the results from the vegetation assessment. Similarities and differences between the perceptions of the two paradigms are related to current trends within theory and research into communal rangeland systems. This proves invaluable in advising future research direction as well as informing management for improve grazing practices.

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# Chapter 2

## Shifting the rangeland management paradigm: participative assessment and management of range resources

### Introduction

The term "rangeland" is generally associated with extensive areas of usually unenclosed and relatively natural pastures used for livestock grazing (Grice & Hodgkinson, 2002). Harrington *et al*. (1984) describes rangelands as semi-natural ecosystems to which domestic stock has been added in order to improve productivity in the area. They usually occur in regions that experience low rainfall, or that have cold and long winters, and are often areas of low and extremely variable productivity (Griffin, 2002).

Rangeland ecosystems cover one-third to one-half of the world's terrestrial surface, and two-thirds of sub-Saharan Africa (Hobbs *et al*., 2008; Homewood, 2004). Africa has an estimated 26 million-strong human population in its rangelands; the global population of rangelands numbers around 220 million (Griffin, 2002). Most of these practice traditional lifestyles that are characterised by low population densities and high mobility. Patterns of land-use are generally flexible and not based on a concept of individual property rights.

The phenomenon of colonialisation impinged on indigenous peoples' land ownership and access to resources, restricting their livelihoods and changing traditional land-use patterns (Griffin, 2002). History has shown the tendency of subsistence pastoralism to replace a hunter-gatherer way of life in rangelands; with the advent of colonialism, commercial pastoralism has replaced both of these (Grice & Hodgkinson, 2002). Subsequent to de-colonisation, development programmes have further marginalised rural populations as traditional lifestyles are considered to be incompatible with the Western economic model imposed on them (Grice & Hodgkinson, 2002; Rohde *et al*., 2006).

Displacement of subsistence livelihoods has had far-reaching social and environmental impacts, further impoverishing indigenous land-users (Griffin, 2002) and contributing to resource degradation (Bayer & Sloane, 2002). With the intensification ensuing from the institution of modern farming practices and technology (e.g. fencing, artificial water-points), natural resources on rangelands gradually experienced degradation (Grice & Hodgkinson, 2002).

The science of rangeland management was originally developed for cattle ranching in the western United States of America, but it gradually evolved into a dogma deemed the only viable management strategy in all rangelands, regardless of local environmental conditions or indigenous management practices (Sayre & Fernandez-Gimenez, 2003). It sought to integrate the study of bio-physical and land-use factors in order to maximise and stabilise livestock production, all the while conserving grazing resources.

**Developments within rangeland science and management**

To date, the primary goal of rangeland management has been stabilised production for external markets through the sustainable exploitation of grazing resources (Hoffman & Rohde, 2007; Quirk, 2002). In order to achieve this, two questions need to be asked. Firstly, it must be established what the current state of the resource is, i.e. “What is the rangeland’s present structure and functioning?”. Secondly, it is necessary to know what the desired state of the resource is, i.e. “What should the rangeland’s structure and functioning be?”.

Descriptive scientific methods allow a clear answer to the first question, albeit according to pre-determined criteria or parameters. However, an answer to the second question – and the means of achieving this – remains elusive. Until fairly recently, it was widely accepted that grazing had a negative impact on rangelands and thus required close management (Quirk, 2002). The management recommendations traditionally involved fixed periods of grazing at a pre-determined stocking rate, interspersed with rest periods.

Recently is has been recognised that grazing is not the primary driver of range condition (e.g. Illius & O'Connor, 1999). Furthermore, removal of grazing pressure did not bring about a reversal of rangeland condition. Indeed, there is no clear advantage of “scientific” grazing management systems over moderate continuous stocking strategies (Quirk, 2002). It has been shown that the response of rangelands to disturbance varies both globally and locally, making the application of general models for sustainable management ineffective in systems in which they have not been tested (Bowman, 2002).

The currently prevailing rangeland management paradigm is based on the assumption that rangeland systems conform to Clements’ (1916) successional theory and the economic behaviour described in Hardin’s (1968) “tragedy of the commons” concept (Rohde *et al.*, 2006; Warren, 1995). Increasingly, the applicability of these assumptions within arid communal rangelands has been challenged.

*Rangeland resource dynamics*

The Clementsian view of vegetation dynamics as a succession through various stages towards a climax vegetation community formed the basis of the dominant rangeland management paradigms during much of the 20th century (Sayre & Fernandez-Gimenez, 2003). Equilibrium theories based on this idea accept that vegetation composition and productivity are functions of herbivory. As a result, management involves determining the optimum carrying capacity of the rangeland, and sees sustainability as dependent on the maintenance of conservative stocking rates based on prescribed livestock densities (e.g. Hoffman *et al*., 1999; Milton & Dean, 1996; Tainton *et al*., 1999). In this paradigm, stocking above the carrying capacity leads to over-grazing, deterioration of the grazing resource and subsequent degradation.

More recently, it has become clear that the variability and uncertainty that are key components of arid rangelands are not adequately explained in equilibrium theories (Briske *et al*., 2008; Buttolph & Coppock, 2004; Ellis, 1995; Vetter, 2005). Grazing systems in arid regions did not react as expected to changes in grazing regimes, such as reduced stocking rates or increased rest periods (Savory, 1988). Non-equilibrium theories of rangeland dynamics arose as an alternative, placing less emphasis on stable and conservative stocking rates (Rohde, 2005). More important than stock density is the effect of factors such as rainfall and landscape heterogeneity, as droughts and forage availability will dictate livestock numbers (Illius & O'Connor, 1999; Scoones, 1995; Vetter, 2005).

As a result of a highly variable environment, management strategies in non-equilibrium systems are inherently flexible (Campbell *et al*., 2006; Cullis & Watson, 2004; Rohde *et al*., 2006). The stochasticity of arid rangelands implies that stock densities will rise and fall as the resource base upon which they depend fluctuates (Vetter, 2005). Instead of a fixed stocking rate, livestock density is permitted to fluctuate based on forage and water availability. Consequently, years with high rangeland production due to increased rainfall could see livestock density above that advocated for equilibrium systems (Campbell *et al*., 2006; Richardson *et al*., 2003; Vetter, 2005). Opportunism is also central in such systems, as mobility allows pastoralists to take advantage of spatial and temporal variability in resource availability. Warren (1995) identifies the need for a new paradigm that acknowledges that arid rangelands are at non-equilibrium and thus extremely variable, but persist at broad spatial and temporal scales.

The prevailing assumption that communal rangelands are degraded has been another key factor dictating management recommendations such as the de-stocking of rangelands (Vetter, 2005). A multitude of sometimes contrasting definitions of rangeland degradation have developed, as perceptions of degradation depend on lines of thoughts regarding management objectives, time frames and other factors (Behnke & Scoones, 1991; de Queiroz, 1993). Shifts in species composition, bush encroachment, decreases in vegetation and litter cover and increased rates of soil loss are often seen as symptomatic of degradation (Abel, 1997). It remains common practice to use commercial pastoral systems as the standard with which communal ranges are compared (e.g. Todd & Hoffman, 1999). When communal lands with higher stocking rates display a different species composition to commercial farms, they are summarily judged as being "degraded" (Abel, 1997).

Such comparisons are inappropriate as communal and commercial livestock systems have different production aims. Grazing-induced changes in rangeland ecosystems are recognised by pastoralists and management strategies are adapted accordingly to promote sustainability (Allsopp *et al.*, 2007; Thomas & Twyman, 2004). It is more appropriate and relevant to describe landscape effects of pastoral grazing within the context in which they happen (Oba & Kaitira, 2006), rather than the universal application of the term "degradation" in such systems. Where degradation does occur, it may be a result of overstocking, but is often a result of political or other factors (Rohde *et al.*, 2006).

Berkes (2004) calls for a move away from a reductionist approach to applied ecology, advocating a more holistic systems view that sees such systems as being complex, dynamic and adaptive. Non-equilibrium rangelands are by nature variable and changing; the complexity of these changes and the benefits inherent in the variability need to be recognised, rather than being summarily adjudged as signs of degradation (Campbell *et al.*, 2006; Thomas & Twyman, 2004; Vetter, 2005).

*Rangelands as common property resources*

Hardin's (1968) prediction of the inevitable degradation of common property resources is another crucial concept within rangeland science that is not universally applicable. His perspective was based on the notion of open and unrestricted access to common property resources, and continually increasing pressure on the resource due to unlimited exploitation and the maximisation of profit.

More and more, this appears not to be the case in traditional pastoral systems (e.g. Allsopp *et al.*, 2007). Indigenous pastoralist strategies take cognisance of ecosystem characteristics and are adapted accordingly. Hardin's argument fails to take into account that profit maximisation is not always the primary aim of the pastoralist. Furthermore, Hardin sees communal property as being an open-access resource. Neither of these is necessarily the case (Ormazabal, 2003).

The logical conclusion drawn from Hardin's position is that common property resources should be commercialised. As a result, communal resources are assumed to be open-access by definition, and thus should be privatised (e.g. Birdyshaw & Ellis, 2007). While the formalisation of property rights can have a positive effect on productivity (e.g. Markussen, 2008), it can by no means be construed that privatisation of communal resources will guarantee sustainability.

Such arguments for commercialisation of common property fail to take various factors into account. Communal rangelands have been shown to be governed by norms that dictate resource sharing and seek long-term sustainability (Allsopp *et al*., 2007; Rohde *et al*., 2006; Samuels *et al*., 2007). Land-users are not ignorant of the characteristics their environments (Calvo-Iglesias *et al*., 2006; Thomas & Twyman, 2004). As a result, traditional management systems have evolved from years of experience gained by land-users from their socio-economic, cultural and natural environment; the management strategies derived from them are thus suited to their context (Bosch *et al*., 1997).

Within a communal tenure setting, proper management can ensure resource sustainability. In commenting on his original work, Hardin (1998) stated that the ruin of the commons that he had predicted was only inevitable within an unmanaged system. Land-users have successfully managed common property resources through the organisation of institutions governing their use for centuries (Ostrom *et al*., 1999). Rohde *et al*. (2006) show three systems that have different social, cultural, ecological and historical contexts – all three had achieved a form of common resource management.

Hardin's (1968) second assumption, *viz*. that profit maximisation is the individual's over-riding goal, has also been refuted. Traditional pastoral systems have multiple goals that are not always based on maximising profit or agricultural productivity (Abel, 1997; Allsopp *et al*., 2007; Rohde *et al*., 2006). However, a narrow view of rangeland productivity has led to underestimation of rangeland benefits, supporting motivations for a shift from communal to commercial pastoralism.

When outside factors cause traditional management institutions to fail, rangeland degradation – as predicted by Hardin (1968) – may ensue. The intrusion of resource competitors from outside of the system, pressure due to limited resources (e.g. due to population growth) and political or other divisions can cause the demise of traditional institutions (Bennet *et al*., 2010; Rohde *et al*., 2006). In such cases, improved management of commons would require the strengthening of local institutions (Moyo *et al*., 2008).

### Participative rangeland monitoring and governance

Regardless of the availability of scientific information and theories, rangeland management is applied by land-users who base strategies on knowledge derived from memory, experiences and relationships (Mills *et al*., 2002). Rangelands are thus the product of local knowledge systems and the resultant practices. Nonetheless, in official policies local knowledge is often ignored in favour of conventional scientific theories and paradigms.

This rigid distinction between scientific and local knowledge is faulty (Mills *et al*., 2002). Both are contextual and heterogeneous with underlying values, and cannot be transported to and applied in a system outside of that within which they developed. Instead, they should link up to one other. A holistic approach to rangeland management requires integrating the needs of both social and natural systems. Key to this is the development of forums for facilitating heuristics that will allow the two to inform each other in seeking solutions to specific problems.

Ellis and Biggs (2001) describe the evolution of rural development through the second half of the 20$^{th}$ century. From an emphasis on modernisation in the mid-1900s, the focus of development shifted towards a framework that encourages participation and empowerment in pursuit of environmental and economic sustainability. Colonial agricultural systems represented a co-evolution of eco- and social systems that was invalid in the contexts in which they were now being applied (Mills *et al*., 2002).

The search for a more comprehensive understanding of rangelands that includes understanding of economic and social aspects has led to expansion of the scope of rangeland science (Campbell *et al*., 2006). Classical theories with a reductionist approach focusing only on ecological and animal production factors provide a limited understanding of these systems (Howden *et al*., 2002). Instead, a more inclusive framework incorporating ecological, social and economic aspects will allow for improved decision-making in rangelands (Campbell *et al*., 2006; Milham, 2002).

Development initiatives and management policies instituted in pastoral systems in Africa during and since colonisation seek to avoid the land degradation seen as inevitable within common property resource systems (Rohde *et al*., 2006). However, they have generally failed to recognise the validity of traditional management institutions that evolved within specific social, economic and environmental contexts. Furthermore, they ignore the importance of involving local communities and institutions in the development and implementation of research, management and other initiatives. Instead, they often exacerbate the very problems they seek to solve by disrupting traditional management institutions and practices (Rohde *et al*., 2006).

Contrary to such perceptions, land-use within rangelands is not restricted to pastoralism; neither is it managed with purely the aim to maximise economic welfare (Abel, 1997; Allsopp *et al*., 2007; Ormazabal, 2003). Any attempt to better understand rangeland systems and improve their management must take into account that non-pastoral land-uses (e.g. mining, tourism) are often also present, that social and bio-physical constraints – both of which are poorly understood in rangeland systems – are at least as important as purely economic aspects, and that rangelands are increasingly affected by social and political decisions made outside of the systems (Grice & Hodgkinson, 2002).

The use of traditional ecological knowledge may provide a useful tool to inform and improve rangeland research and management (Campbell *et al*., 2006). Indigenous knowledge has a key role to play in sustainability within traditional agricultural systems (Warren & Cashman, 1988; Vetter, 2003). Such indigenous knowledge has evolved within a given socio-economic, cultural and natural environment, and contributes towards productive activities in the community. Through years of experience, land-users have gained extensive knowledge on management approaches that are suited to local conditions (Bosch *et al*., 1997).

Land-users are aware of landscape characteristics such as broad-scale changes and inherent variability (Calvo-Iglesias *et al*., 2006; Thomas & Twyman, 2004). Resource variability inherent in rangelands is well understood by pastoralists and has become integrated into traditional management strategies. Such practices are important in contributing towards sustainable management, while also contributing towards scientific understanding of these and similar systems.

Knowledge-sharing between scientists and land-users allows an improved understanding of opportunities and threats facing these land-users (Bosch *et al*., 1997). This is likely to contribute towards a structured knowledge-base that remains relevant within its context. Indigenous values and knowledge systems have proven to be valuable when used to complement scientific assessments and contribute towards biodiversity conservation (Agrawal & Chhatre, 2006; Agrawal & Gibson, 1999; Barrios *et al*., 2006; Bosch *et al*., 1997; Calheiros *et al*., 2000; Fernandez-Gimenez, 2000; Gadgil *et al*., 2000; Mapinduzi *et al*., 2003; Pretty & Smith, 2004). Oba and Kaitira (2006) recommend the integration of herder knowledge with scientific understanding by land-use planners. This is preferable to a continued misunderstanding of various components of rangeland grazing systems that lead to shifts away from communal pastoralism that may be ill-informed and inappropriate (Abel, 1997).

In turn, scientific knowledge can contribute towards understanding the ecological and socio-economic implications of actions advised by land-users (Bosch *et al*., 1997). The original recommendations by the land-user can then be supplemented by the insights gained from scientific research. Knowledge maximisation is clearly dependent on co-operation between researchers and land-users –land-users are in fact encouraged to become researchers themselves.

The involvement of local land-users provides valuable information for informing management decisions by improving identification of goals, problems and solutions, as these land-users are both a primary source of knowledge and the ultimate end-user group (Bosch *et al*., 1997; Fraser *et al*., 2006). The engagement of communities empowers them to participate in the management process, increasing the likelihood of acceptance, development and maintenance of interventions; sustainability is more likely to establish in communities involved in managing the resources themselves (Bray *et al*., 2003; Calvo-Iglesias *et al*., 2006; Warren & Cashman, 1988).

The process of participative management begins with information-gathering and the promotion of participation in the monitoring process (e.g. Oba & Kaitira, 2006). It is crucial that the base of consultation in this initial stage is kept as broad and representative as possible, as including groups that are usually marginalised in part of a wider project makes the success of participatory process more likely (Hickey & Mohan, 2005; Thakadu, 2005). Formally feeding responses from multiple stakeholders into decision-making forums will enhance the perception of such processes as being legitimate and relevant (Fraser *et al*., 2006).

Once local knowledge has been collected, it can be supplemented by scientific information. Contrasting and conflicting views may emerge, but are the result of a diversity of knowledge and objectives; this should in fact be encouraged in order to retain as broad an approach as possible. From this basis of shared understanding, a structured and relevant knowledge base is established with the aim of advising management interventions. At the same time, the integrated intellectual capital should direct on-going co-operative monitoring systems to continually evaluate the effectiveness of the management strategies (Fraser *et al*., 2006).

As rangelands are examples of social-ecological systems, with people forming an integral part of the ecosystems in which they live, their management must move away from an expert-based approach towards a participatory management paradigm (Berkes, 2004). Community management initiatives show benefits for resource management, biodiversity conservation and social and economic justice (Bray *et al.*, 2003). Participatory processes seek to achieve management and economic goals, while at the same time empowering communities by encouraging ownership and autonomy (Moran, 2004). For this, it is essential to integrate local and scientific knowledge into a single, dynamic system, with decision-making based on best current knowledge (Bosch *et al*., 1997; Campbell *et al*., 2006).

**Rangelands and biodiversity conservation**

Governments that currently maintain conservation areas despite the opportunity costs incurred may change their stance as the pressure for land increases with increasing populations (Norton-Griffiths & Southey, 1995). Growth of human populations result in higher stocking rates; in many cases the increased grazing pressure leads to a loss of biodiversity at a local or regional scale (Landsberg *et al*., 2002; Todd & Hoffman, 1999). Exacerbating this problem is the fact that rangeland management decisions are being made by people disconnected from the rangelands themselves (Bowman, 2002; Grice & Hodgkinson, 2002). There is thus a need for conservation to be integrated with land-use outside of protected areas.

A key characteristic of rangelands is that, despite their use as pasture for domestic livestock, they remain areas of natural or semi-natural vegetation (Grice & Hodgkinson, 2002; Harrington *et al*., 1984). Moreover, rangeland productivity depends upon interactions between species and their environment, with higher diversity linked to improved resilience to negative impacts (Swift *et al.*, 2004). Rangelands thus offer the potential to contribute to conservation outside of protected areas while providing economic benefits (Menke & Bradford, 1992). Besides food and fibre production, rangelands provide a number of ecological goods and services – such as carbon sequestration and conservation – which are becoming increasingly important (Havstad *et al*., 2007).

Despite this, biodiversity conservation is a by-product of rangeland grazing that is generally unappreciated and undervalued (Bowman, 2002). Conservation on rangelands will therefore involve the balancing of immediate self-interest against broader public and ecological values, requiring co-operation amongst all stakeholders, involvement of local communities and integration of multiple land-uses with conservation (Bowman, 2002).

Stewardship programmes aim at achieving socio-economic and environmental sustainability within such a participatory framework (Chapin *et al*., in press). By recognising the interdependencies between social and ecological systems, stewardship programmes can contribute towards sustainable management, especially in the face of uncertainty (Chapin *et al*., in press). These programmes have successfully improved environmental awareness amongst land-users (Wilson, 2004). Furthermore, they have the potential to integrate various goals by providing economic and other incentives for achieving biodiversity objectives (Hamblin, 2009).

Provision of financial incentives may result in improvements in biodiversity conservation on rangelands, but such incentives may be difficult to generate, creating tension between the conflicting land-uses of patoralism and conservation (Hendricks *et al*., 2007; Windle & Rolfe, 2008). The optimal use of rangelands involves the maintenance of rangelands in both a more natural state and a more managed state at different points in time – this will depend on factors such as the initial condition of the rangeland, objectives of decision-makers and market prices (Perrings & Walker, 2004).

Unfortunately, understanding the functioning of rangeland ecosystems remains a major challenge to proper management thereof. Inadequate knowledge of social and environmental dimensions of rangeland dynamics has constrained good management practices and sustainable utilisation (Campbell *et al*., 2006; Dong *et al*., 2009; Havstad *et al*., 2007). Studies that integrate various aspects of rangelands and seek to improve understanding of rangeland ecosystem functioning will be able to advise management strategies and objectives that will be more ecologically, economically and socially viable.

Livestock production and biodiversity conservation are both viable outcomes of rangeland management (Perrings & Walker, 2004). However, the socio-ecological nature of rangeland systems makes a participatory management paradigm key to success (Berkes, 2004). Sharing of knowledge between land-users and scientists allows for improved understanding and contribution towards biodiversity conservation (Agrawal & Chhatre, 2006; Agrawal & Gibson, 1999; Bosch *et al*., 1997; Fernandez-Gimenez, 2000; Gadgil *et al*., 2000).

Improved integration of ecological, social and economic objectives will require involvement of the local community in management and decision-making (Bray *et al*., 2003; Campbell *et al*., 2006; Milham, 2002). This can contribute to the sustainability of traditional pastoral systems (Warren & Cashman, 1988; Vetter, 2003). As management institutions improve, communities can be empowered with more decision-making responsibility, resulting in an increased likelihood of sustainability (Bray *et al*., 2003; Calvo-Iglesias *et al*., 2006).

## Future directions within rangeland management

Walker (2002) identifies the dominant trend in rangeland management as "sustainable habitation", *viz*. the maintenance of human societies within rangelands. A critical revision of rangeland dynamics has revealed various factors that need consideration in developing more appropriate and effective rangeland management strategies. The future of rangeland sustainability depends on:

- the recognition of the failure of conventional management plans and the validity of traditional pastoral systems;
- the valuation of rangelands as more than exclusively grazing resources, but rather for multiple uses and values; and
- co-operative governance, built on consultation and participation, stewardship, and effective institutional arrangements (Bayer & Sloane, 2002).

Rangelands and their inhabitants are likely to become more marginalised on a global and local scale (Howden *et al*., 2002). Decisions regarding rangelands are often made by authorities that are disconnected from the rangelands (Bowman, 2002; Grice & Hodgkinson, 2002). It has become necessary to empower local institutions, integrate the various scientific, social and economic considerations and improve creativity in finding solutions to manage rangeland resources. Crucial to this is the involvement of local communities in management and improved exchange of information. This will foster the building of skills and capacity, as well as develop the theories and institutions that will advise resource management.

## Case in point: the rangelands of Namaqualand, South Africa

The rangelands of Namaqualand are situated in the Succulent Karoo Biome, one of the world's biodiversity hotspots and the first arid ecosystem to be classified as such (Brooks *et al*., 2002; Mittermeier *et al*., 2004; Mucina & Rutherford, 2006; Myers *et al*., 2000). The region's rainfall ranges from 50 – 250 mm per annum, mostly falling in the winter months, and it has an estimated 3 500 species, one quarter of which are endemic (Desmet, 2007). Namaqualand's unique climatic conditions are a large contributing factor to the Succulent Karoo's status as world's most speciose arid ecological system (Cowling *et al*., 1998; Cowling *et al*., 1999). The Northern Cape Province – in which Namaqualand is situated – has a high veld degradation index based on perceptions of agricultural extension officers (Hoffman & Todd, 2000). Almost 90% of Namaqualand is used for livestock grazing (May &

Lahiff, 2007), but of this area 29% is in a fairly pristine state and could contribute to biodiversity conservation (Mittermeier *et al*., 2004).

For the last 2 000 years, the grazing of domestic livestock has been a major land-use in the region (Webley, 2007). As spatial and temporal (especially seasonal) variability in forage availability is determined by the rainfall patterns – such as periodic droughts – pre-colonial herders followed a transhumance strategy in order to deal with these variable environmental conditions. However, following the expansion of commercial farming subsequent to South Africa's colonisation, Namaqualand's inhabitants have increasingly been restricted to small communal areas, preventing traditional nomadic pastoralism (Hoffman & Rohde, 2007).

Livestock production in Namaqualand peaked in the mid-1900s following extended periods of high rainfall and elevated markets prices (Hoffman & Rohde, 2007). Subsequently, governmental destocking incentives aimed at benefitting white commercial farming enterprises and preventing perceived degradation of the rangelands resulted in a reduction in livestock densities in Namaqualand (Benjaminsen *et al*., 2006; Rohde *et al*., 2006). This process included measures such as fencing to separate commercial and communal areas, the implementation of stock reduction schemes and fixed stocking rates on commercial farms, and state subsidies to white farmers.

Besides colonialism, *apartheid* and globalisation have also had profound influences on the land-use practices of communal subsistence farmers, who find themselves increasingly marginalised (Cousins *et al*., 2007). As their landscapes have become more confined, their mobility and ability to exploit the variability that is characteristic of the rangeland has become more and more restricted. This is especially detrimental in times of drought (Samuels *et al*., 2007).

Long-term grazing at high stock densities has resulted in changes to the vegetation community composition on communally-owned land, when compared to neighbouring commercial farms (Anderson & Hoffman, 2007; Todd & Hoffman, 1999). However, this is not necessarily an indication that communal areas are degraded. The vegetation in Namaqualand appears to be adapted to grazing disturbances, with a number of species benefitting from the impact of livestock on the plant community (Desmet, 2007).

Practices in the communal rangelands of Namaqualand challenge long-standing assumptions on the sustainability of common property resources, based on Hardin's (1968) famous work (Allsopp *et al*., 2007). Resource use is based on structured norms that are concerned with equitable and sustainable access. Furthermore, grazing practices are based on the herders' understanding of rangeland resource dynamics, such as inherent variability in the resource quality and the occurrence of toxic and unpalatable species.

In the last decades of the 20th century the importance of commercial agriculture to Namaqualand's economy has declined due to new economic opportunities and the globalisation of agricultural markets (Hoffman & Rohde, 2007). At the same time, conservation of biodiversity in the region has become more prominent through a number of initiatives. These factors have led to a decline in stock numbers and the exploration of other livelihood options as a means of adapting to change (Cousins *et al.*, 2007).

In the 21st century, the region faces far-reaching changes presented by a multitude of threats and opportunities (Cousins *et al.*, 2007). These include changes to climate, restructuring of land tenure and a shift in agrarian regimes. A major challenge for Namaqualand's researchers and inhabitants alike is the development of an improved understanding of the rangeland system that will enable them to better deal with such changes (Desmet, 2007). Key to this is the support of institutions governing land-use, improved management of the commons through a reversion to traditional grazing strategies and the diversification of livelihoods (Cousins *et al*., 2007).

In communal rangeland systems such as Namaqualand, it is critical that local and scientific perspectives are integrated into a coherent knowledge system that can be used to support and advise decision-making. Such hybrid knowledge holds significant potential for allowing meaningful appraisals of rangeland resources. Globalisation poses a threat to cultural diversity within rangelands by forcing pastoralists to modify their lifestyles. In order to retain elements of traditional culture and livelihoods, security of pastoralists' land tenure and resource access is crucial. In achieving this, the involvement of local communities is of cardinal importance in ensuring economic and environmental sustainability in the management of communal rangelands.

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# Chapter 3

# Vegetation responses to grazing exclusion in an arid South African rangeland

## Introduction

Since the 1980s, the assumption that rangelands are necessarily degraded and overgrazed with low productivity has been re-examined (e.g. Abel, 1997; Illius & O'Connor, 1999; Savory, 1988). Management strategies based on long-standing theories of rangeland succession, with concepts such as stocking rate, carrying capacity and rest periods, are being re-investigated with a view to providing more appropriate measures (Briske *et al*., 2003; Quirk, 2002; Scoones, 1995). New ecological theories of rangeland vegetation dynamics argue that traditional equilibrial succession models do not accurately represent the complexity, variability and uncertainty inherent in arid rangelands (Buttolph & Coppock, 2004; Ellis, 1995).

Equilibrium models place emphasis on the effect of herbivores on the rangeland. According to this theory, vegetation characteristics such as composition, cover and productivity are primarily influenced by the biotic feedback of grazers and browsers on rangeland vegetation. In such systems, it is fairly easy to make accurate predictions based on simple, deterministic models (Rohde, 2005). Management strategies are thus based upon an optimal carrying capacity, with sustainable rangeland utilisation dependent on maintaining stocking rates at or below this prescribed livestock density. Exceeding this stocking rate will result in over-grazing, which will induce a deterioration of rangeland condition and, ultimately, lead to degradation. Management recommendations for rangelands within South Africa, as elsewhere, almost exclusively involve adherence to a fixed carrying capacity within a rotational system as the only viable method of ensuring sustainable levels of forage availability and thus optimal livestock production (e.g. Hoffman *et al*., 1999; Milton & Dean, 1996; Quirk, 2002; Tainton *et al*., 1999).

In contrast, non-equilibrium theories place much less emphasis on stable numbers of livestock (Rohde, 2005). Instead, stock densities are expected to fluctuate between high and low extremes. Much more important than the biotic feedback of livestock on the vegetation is the influence of stochastic, abiotic factors, the most prominent of these being rainfall (Illius & O'Connor, 1999; Scoones, 1995). Livestock numbers are restricted by frequent droughts and consequently never reach an equilibrial situation. Instead, their density fluctuates according to the amount of forage and water available. Vegetation characteristics are thus primarily influenced by rainfall, with livestock densities having a negligible feedback effect.

Management strategies within a non-equilibrium paradigm have a much more flexible and opportunistic approach to stocking rates. Rather than maintaining a constant density, livestock numbers are allowed to fluctuate according to availability of resources. Thus, in wetter years with higher rangeland production, numbers might be allowed to increase above levels advocated by equilibrium theory. Mobility and nomadism also play a prominent role in non-equilibrial rangelands, as herders allow their livestock to move from areas of low resource availability to areas with higher levels of forage as variable grazing and/or rainfall patterns result in relative scarcity or abundance of forage.

Studies on the effects of grazing and exclusion in arid rangeland ecosystems reveal mixed results. Long-term, intense grazing appears to cause general decreases in vegetation cover (Landsberg *et al*., 2003; Mellado *et al*., 2003), and also results in shifts in the vegetation composition in terms of the growth forms and functional guilds present (Bisigato & Bertiller, 1997; Sternberg *et al*., 2000; Todd & Hoffman, 1999). While local species richness may be improved by grazing, on a regional scale there is a decrease in richness due to loss of species sensitive to grazing (Landsberg *et al*., 2002).

Vesk and Westoby (2001) showed that individual species do not necessarily show consistent responses to grazing; instead responses seem to be somewhat stochastic, with rainfall being a contributing factor in determining exactly what response a species will show under a given grazing regime. Generally, however, it appears that palatable shrubs will show reduced biomass and fecundity (flower production and seedling survival), while unpalatable plants show the opposite trend (Todd & Hoffman, 1999).

Exclusion experiments show that, although in years of normal rainfall there are significant differences in biomass and cover between grazed and ungrazed plots, in periods of low annual precipitation these differences diminish (Zaman, 1997). Extended periods of livestock exclusion may even result in decreases in herbaceous biomass (Yayneshet *et al*., 2009). Any such experiments must take environmental factors such as climate, landscape and human activities into account, since removing grazing pressure alone fails to accurately represent the complex ecosystem dynamics at play (Curtin, 2002).

The Succulent Karoo Biome (*sensu* Mucina & Rutherford, 2006) is one of the world's original 25 biodiversity hotspots (Mittermeier *et al*., 2004; Myers *et al*., 2000) due to its exceptionally high species richness (around 4 500 species) and around 40% endemism (about 1900 endemic species) in only 112 000 $km^2$ (Eccles *et al*., 1999). It is the planet’s most species-rich arid area (Cowling *et al*., 1998), and the first such to qualify as a biodiversity hotspot (Brooks *et al*., 2002), yet less than 4% of it enjoys formal conservation status (May & Lahiff, 2007). The Northern Cape Province, in which a large portion of the Succulent Karoo is located has a high veld degradation index (Hoffman & Todd, 2000). Over 90% of the Namaqualand district is grazed by livestock, mostly sheep and goats (May & Lahiff, 2007). Around 29% of this area is suitable for contributing towards biodiversity conservation due to its relatively pristine state (Mittermeier *et al*., 2004).

Domestic livestock has been an important land-use in Namaqualand for around 2 000 years (Webley, 2007). Pre-colonial herders followed seasonal transhumance patterns in order to cope with the seasonal variability in rainfall and concomitant availability of forage. It appears that the vegetation here, as in other rangelands, is adapted to the disturbances caused by grazing, with many species taking advantage of these very disturbances (Desmet, 2007; Hart, 1999; Manoharan *et al*., 1999). Grazing encourages the establishment of a vegetation community that is as diverse as the one it replaces, and composed of species indigenous to Namaqualand. Since the mid-1700s, however, the original inhabitants of Namaqualand have been increasingly constrained to small communal land areas (Hoffman & Rohde, 2007), which has prevented this nomadic pastoral lifestyle from being followed.

The erection of a livestock exclosure in the Leliefontein commons in 1999 afforded an opportunity to explore the effects that removal of intense grazing pressure by domestic animals would have on the vegetation of an arid rangeland. A fence-line contrast was used in order to establish whether grazing exclusion would have impacts on:

- the abundances and species richness of mature plants and seedlings;
- the vegetation cover; and
- abundances, biomass and size class distributions of three selected plant species.

## Methods

### *Study area*

The study site was located near the village of Paulshoek, in the Leliefontein communal area of central Namaqualand, South Africa. The Paulshoek commons (20 000 ha) are in the Kamiesberg escarpment, at an altitude of 900 – 1500 m above sea-level. It falls within the Namaqualand Hardeveld Bioregion of South Africa (Mucina & Rutherford, 2006).

The vegetation surveys were conducted on either side of the fence-line of the Moedverloor exclosure (33º 20' S; 18º 17' E), which is 251 ha in size. This exclosure, erected in 1999, is found within the Namaqualand Blomveld vegetation type (Mucina & Rutherford, 2006), and is dominated by dwarf shrubs with succulent or deciduous leaves (Desmet, 2007). Ephemerals and geophytes flower after rain and form an important component of this vegetation type. During the period 1999–2004, the annual rainfall in Moedverloor ranged from a minimum of 84 mm to a maximum of 201 mm, with an average of 118 mm and a co-efficient of variance of more than 30%. It is this very selective climatic regime that has resulted in Namaqualand’s characteristic vegetation (Cowling *et al*., 1999).

The Paulshoek area of the Leliefontein commons has been stocked at a rate of around 5.6 ha per small stock unit for a period of at least three decades (Hoffman *et al*., 1999). This stocking density far exceeds the Department of Agriculture's recommended stocking rate of 10.8 ha per small stock unit (S. van der Poll, pers. comm.). However, this stocking rate represents a long-term average, since the actual livestock density shows extreme fluctuations, which appear to be linked to annual precipitation.

*Sampling procedure*

Due to the heterogeneity of the landscape and its effect on the vegetation composition, sampling was done in a pair-wise fashion. Plots were situated adjacent to one another on opposite sides of the Moedverloor fence-line; thus each pair consisted of one plot in a grazed area and one plot within the exclosure. In selecting locations for plots, site factors such topography, rockiness, slope and aspect were kept as similar as possible within each pair. In order to reduce any effects that the fence itself may have had (e.g. livestock trampling along the fence-line), plots were placed at least 10 m from the fence. Sixteen pairs of plots, each measuring 10 m by 10 m (i.e. 100 $m^2$), were placed along the fence, for a total of 32 plots (*cf*. Todd & Hoffman, 1999). Adjacent to each plot, a 50 m-long line intercept transect was placed in order to determine the percentage cover contributed by each species. Sites for pairs were selected to be as representative of the topography as possible.

All sampling occurred in October and November of 2006 after the annual winter rainfall period. This allowed the inclusion of recently germinated annuals and seedlings in the survey.

*Environmental variables*

For each plot, the following environmental variables were recorded: slope (in degrees), aspect, topography and rock cover. Topography was classified into categories as follows:

river bed/river bank; sandy pediment; lower slope; mid-slope; upper slope. Rock cover was estimated as a percentage of each plot's surface area.

*Growth form and seedling abundances and species richness*

Within each plot, the presence of all mature plants was recorded. Plot records thus consisted of a species list and the total abundance of each species within the plot. Included in this recording of mature specimens were all annual plants bigger than 10 cm in size. Plants were classified into one of the following functional growth forms: annuals; geophytes; grasses; leaf succulents; stem succulents; and woody shrubs with non-succulent leaves.

Within each 100 $m^2$ plot, five sub-plots measuring one metre by one metre (1 $m^2$) were randomly placed. In these sub-plots, species abundance lists were recorded for all seedlings and annual plants smaller than 10 cm in size. The data from each plot were pooled for analysis. Seedlings were classified into the same functional growth form categories used for mature plants.

*Vegetation cover*

To determine vegetation cover, the line intercept method was used (Canfield, 1941). A vegetation line transect of 50 m was located alongside each plot and vegetation cover, as contributed by each species intercepting the line, was recorded. From this, the percentage cover for each species was estimated. The same growth form classification used in the preceding sections was applied to categorise the vegetation cover.

*Individual species*

In order to obtain an understanding of the effects of grazing exclusion on plant biomass production, three species were selected as indicators. *Galenia africana* is an unpalatable shrub that is usually used as an indicator of such disturbances as historical ploughing and heavy grazing. *Ruschia robusta* is a moderately palatable leaf succulent. It dominates the landscape of the lightly grazed commercial farms adjacent to the Leliefontein commons, where it is regarded as an important forage species (Todd & Hoffman, 1999). *Hirpicium alienatum* is a highly palatable leaf succulent that is preferentially grazed by livestock.

For each of these three indicator species, all plants taller than 10 cm occurring in each 100 $m^2$ plot were recorded. For each individual, the height, widest width and width perpendicular to this were measured. The volume of each shrub was calculated using the formula for an oblate spheroid (Phillips & MacMahon, 1981). A size class distribution in 10cm intervals for the two treatments (grazed vs. rested) was obtained for each of these indicator species.

*Statistical tests*

Wilcoxon signed-rank tests were used to test for significant differences in the environmental variables measured, as well as the abundances and species richness of both mature plants and seedlings, and percentage cover (all according to the specified functional growth form categories) between the grazed and the rested plots in a pair-wise fashion (*cf*. Todd & Hoffman, 1999). Multiple regressions using best subset model building were used in order to determine which variables were most influential in determining the abundances, richness and cover observed. Those variables selected as best subsets by the model were tested for significant relationships with the vegetation characteristics using ANCOVAs and factorial ANOVAs. Grazing was included in all ANCOVAs and ANOVAs, whether it was selected as a best subset or not.

## Results

*Environmental variables*

While aspect and rockiness remained similar on both sides of the fence-line, the slope was significantly steeper on the grazed plots than those from which grazing was excluded (Table 3.1).

*Mature plants*

There was a significant increase in the abundance of grasses ($Z = 2.028$; $p < 0.05$) and leaf succulent shrubs ($Z = 3.154$; $p < 0.005$) in the plots from which livestock was excluded (Table 3.2). For the other growth forms, no significant differences in mature plant abundances between the treatments were found. Rockiness had a negative effect on the abundances of annuals and woody shrubs, but a positive one on stem succulents. North-facing slopes had higher abundances of annuals, leaf succulents and woody shrubs. Perennial forb and leaf succulent abundances were positively affected by low-lying landforms and steeper slopes respectively, while the latter showed a negative reaction to grazing (Table 3.3).

*Table 3.1*. Mean values (± SE) of the environmental variables associated with vegetation plots. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given ($n$ = 32).

| | Grazed | Exclusion | *p* |
|---|---|---|---|
| Slope (degrees) | 5.06 ± 0.87 | 4.13 ± 0.72 | 0.016 |
| Rockiness (%) | 3.49 ± 1.08 | 3.95 ± 1.26 | N.S. |

*Table 3.2*. Mean abundances (± SE) of mature plants observed within 100 $m^2$ plots protected from or exposed to grazing. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given ($n$ = 32).

| Growth forms | Grazed | Exclusion | *P* |
|---|---|---|---|
| Annuals | 14.6 ± 6.3 | 16.5 ± 7.5 | N.S. |
| Geophytes | 178.8 ± 66.0 | 211.9 ± 82.7 | N.S. |
| Grasses | 0.2 ± 0.1 | 8.4 ± 5.8 | 0.043 |
| Leaf succulents | 64.6 ± 13.2 | 142.1 ± 20.8 | 0.002 |
| Perennial forbs | 287.4 ± 94.0 | 223.5 ± 80.5 | N.S. |
| Stem succulents | 7.2 ± 1.8 | 10.0 ± 3.3 | N.S. |
| Woody shrubs | 109.1 ± 15.9 | 76.6 ± 11.1 | N.S. |
| Overall | 661.8 ± 116.6 | 688.9 ± 102.6 | N.S. |

The species richness of leaf succulent shrubs showed a significant increase ($Z = 2.641$; $p < 0.01$) in the excluded plots as compared with those exposed to grazing (Table 3.4). None of the other growth forms showed significant differences between the two treatments. Rockiness had a positive effect on species richness of mature stem succulents, but a negative effect on that of annuals, while low-lying areas of the landscape had significantly higher species richness of geophytes and grasses (Table 3.5).

*Seedlings*

Perennial forb seedlings showed a significant increase ($Z = 2.947$; $p < 0.005$) in abundance within the grazed plots (Table 3.6). No other growth forms showed in significant differences between the treatments. Grasses displayed significantly lower abundances as rockiness increased, while low-lying areas had higher abundances of perennial forb seedlings (Table 3.7).

*Table 3.3*. Results of ANCOVAs/factorial ANOVAs for the effects of environmental variables on the abundances of mature plants within the plots. Only results for those variables selected as best subsets by the multiple regression are given.

| Growth form | Slope | Rockiness | Aspect | Topography | Grazing |
|---|---|---|---|---|---|
| Annuals | | $p < 0.05$ | $p < 0.05$ | | |
| Geophytes | | N.S. | | N.S. | |
| Grasses | | N.S. | | | N.S. |
| Leaf succulents | $p < 0.005$ | | $p < 0.05$ | | $p < 0.001$ |
| Perennial forbs | | | | $p < 0.05$ | |
| Stem succulents | | $p < 0.05$ | N.S. | | |
| Woody shrubs | | $p < 0.05$ | $p < 0.01$ | | N.S. |

*Table 3.4*. Mean number of species (± SE) of mature plants observed within 100 $m^2$ plots protected from or exposed to grazing. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given ($n = 32$).

| Growth forms | Grazed | Exclusion | *P* |
|---|---|---|---|
| Annuals | 1.1 ± 0.2 | 1.3 ± 0.3 | N.S. |
| Geophytes | 3.5 ± 0.5 | 3.4 ± 0.3 | N.S. |
| Grasses | 0.1 ± 0.1 | 0.5 ± 0.2 | N.S. |
| Leaf succulents | 4.4 ± 0.7 | 5.9 ± 0.6 | 0.008 |
| Perennial forbs | 4.6 ± 0.3 | 5.0 ± 0.6 | N.S. |
| Stem succulents | 1.3 ± 0.2 | 1.6 ± 0.3 | N.S. |
| Woody shrubs | 4.6 ± 0.7 | 5.0 ± 0.6 | N.S. |
| Overall | 19.6 ± 1.5 | 22.7 ± 1.8 | N.S. |

*Table 3.5*. Results of ANCOVAs/factorial ANOVAs for the effects of environmental variables on the species richness of mature plants within the plots. Only results for those variables selected as best subsets by the multiple regression are given.

| Growth form | Slope | Rockiness | Aspect | Topography | Grazing |
|---|---|---|---|---|---|
| Annuals | N.S. | $p < 0.005$ | N.S. | | |
| Geophytes | | N.S. | N.S. | $p < 0.05$ | |
| Grasses | | | | $p < 0.05$ | N.S. |
| Leaf succulents | N.S. | N.S. | N.S. | | N.S. |
| Perennial forbs | | N.S. | | | |
| Stem succulents | N.S. | $p < 0.05$ | | | |
| Woody shrubs | N.S. | N.S. | N.S. | N.S. | |

*Table 3.6*. Mean abundances (± SE) of seedlings observed within 100 $m^2$ plots protected from or exposed to grazing. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given ($n = 32$).

| Growth forms | Grazed | Exclusion | *p* |
|---|---|---|---|
| Annuals | 256.4 ± 44.8 | 318.1 ± 113.3 | N.S. |
| Geophytes | 0.6 ± 0.4 | 0.3 ± 0.3 | N.S. |
| Grasses | 37.4 ± 9.3 | 20.5 ± 6.1 | N.S. |
| Leaf succulents | 4.3 ± 2.5 | 10.4 ± 5.1 | N.S. |
| Perennial forbs | 52.4 ± 15.7 | 21.9 ± 8.7 | 0.003 |
| Stem succulents | 0.0 ± 0.0 | 0.0 ± 0.0 | --- |
| Woody shrubs | 9.2 ± 2.0 | 7.5 ± 1.6 | N.S. |
| Overall | 360.3 ± 45.5 | 378.7 ± 118.1 | N.S. |

*Table 3.7*. Results of ANCOVAs/factorial ANOVAs for the effects of environmental variables on the abundances of seedlings within the plots. Only results for those variables selected as best subsets by the multiple regression are given.

| Growth form | Slope | Rockiness | Aspect | Topography | Grazing |
|---|---|---|---|---|---|
| Annuals | | | N.S. | N.S. | |
| Geophytes | | | N.S. | | |
| Grasses | N.S. | $p < 0.05$ | N.S. | | N.S. |
| Leaf succulents | N.S. | N.S. | | N.S. | |
| Perennial forbs | | N.S. | | $p < 0.05$ | N.S. |
| Woody shrubs | | | N.S. | | |

There was an increase in total species richness of seedlings ($Z = 1.988$; $p < 0.05$) in the plots exposed to grazing, but none of the growth forms showed significant changes when considered individually (Table 3.8). A southern aspect reduced species richness of annual and woody shrub seedlings. Rockiness had a positive effect on richness of woody shrub seedlings, while grazing showed positive effects on richness of grass and perennial forb seedlings. Low-lying areas had significantly higher species richness of annual seedlings (Table 3.9).

*Table 3.8*. Mean number of species (± SE) of seedlings observed within 100 $m^2$ plots protected from or exposed to grazing. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given (*n* = 32).

| Growth forms | Grazed | Exclusion | *p* |
|---|---|---|---|
| Annuals | 7.3 ± 0.4 | 6.1 ± 0.7 | N.S. |
| Geophytes | 0.3 ± 0.1 | 0.1 ± 0.1 | N.S. |
| Grasses | 1.6 ± 0.2 | 1.1 ± 0.2 | N.S. |
| Leaf succulents | 1.3 ± 0.2 | 1.3 ± 0.3 | N.S. |
| Perennial forbs | 2.3 ± 0.3 | 1.8 ± 0.3 | N.S. |
| Stem succulents | 0.0 ± 0.0 | 0.0 ± 0.0 | --- |
| Woody shrubs | 1.7 ± 0.2 | 1.9 ± 0.4 | N.S. |
| Overall | 14.4 ± 0.6 | 10.5 ± 1.0 | 0.047 |

*Table 3.9*. Results of ANCOVAs/factorial ANOVAs for the effects of environmental variables on the species richness of seedlings within the plots. Only results for those variables selected as best subsets by the multiple regression are given.

| Growth form | Slope | Rockiness | Aspect | Topography | Grazing |
|---|---|---|---|---|---|
| Annuals | | | $p < 0.01$ | $p < 0.05$ | N.S. |
| Geophytes | | | N.S. | | N.S. |
| Grasses | | | | N.S. | $p < 0.05$ |
| Leaf succulents | | N.S. | N.S. | N.S. | |
| Perennial forbs | N.S. | N.S. | N.S. | | $p < 0.001$ |
| Woody shrubs | | $p < 0.005$ | $p < 0.05$ | | |

*Cover*

The cover of leaf succulents showed significant increases (Z = 2.534; $p < 0.05$) along those transects experiencing livestock exclusion (Table 3.10). Grazing had a negative effect on the cover of leaf succulents, while rockiness affected it positively. Slope affected stem succulent cover positively (Table 3.11).

*Table 3.10*. Mean estimated plant cover (%) (± SE) observed along line transects protected from or exposed to grazing. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given ($n = 32$).

| Growth forms | Grazed | Exclusion | *p* |
|---|---|---|---|
| Annuals | 1.1 ± 0.4 | 1.6 ± 0.5 | N.S. |
| Geophytes | 0.2 ± 0.1 | 0.2 ± 0.1 | N.S. |
| Grasses | 0.3 ± 0.1 | 0.4 ± 0.4 | N.S. |
| Leaf succulents | 3.3 ± 1.3 | 5.7 ± 1.3 | 0.011 |
| Perennial forbs | 3.4 ± 0.9 | 5.1 ± 1.7 | N.S. |
| Stem succulents | 0.7 ± 0.3 | 0.6 ± 0.3 | N.S. |
| Woody shrubs | 12.4 ± 1.1 | 11.4 ± 1.5 | N.S. |
| Overall | 21.3 ± 1.6 | 25.1 ± 1.8 | N.S. |

*Table 3.11*. Results of ANCOVAs/factorial ANOVAs for the effects of environmental variables on the plant cover along the line transects. Only results for those variables selected as best subsets by the multiple regression are given.

| Growth form | Slope | Rockiness | Aspect | Topography | Grazing |
|---|---|---|---|---|---|
| Annuals | N.S. | N.S. | | | |
| Geophytes | | | N.S. | | |
| Grasses | N.S. | N.S. | N.S. | | |
| Leaf succulents | | $p < 0.05$ | N.S. | N.S. | $p < 0.05$ |
| Perennial forbs | N.S. | N.S. | N.S. | | |
| Stem succulents | $p < 0.05$ | N.S. | N.S. | | |
| Woody shrubs | | N.S. | | | |

*Individual species responses to grazing exclusion*

The unpalatable species, *Galenia africana*, showed no significant differences in average abundance per plot (Z = 1.306; p = 0.191), total volume per plot (Z = 0.155; p = 0.877) or average volume per individual plant per plot (Z = 0.879; p = 0.379) between the treatments (Table 3.12). Likewise, there was no significant difference between treatments in any of the size classes of the plants (Figure 3.1).

*Table 3.12*. Mean (± SE) of the average abundance of individuals, total volume and average volume of individuals of *Galenia africana* observed per 100 $m^2$ plot protected from or exposed to grazing. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given (*n* = 32).

| | Grazed | Exclusion | *P* |
|---|---|---|---|
| Average abundance (per 100 $m^2$ plot) | 79.7 ± 17.8 | 51.2 ± 11.5 | N.S. |
| Average volume ($dm^3$ per 100 $m^2$ plot) | 2003.9 ± 341.8 | 1908.2 ± 448.8 | N.S. |
| Average individual volume ($dm^3$ per individual per 100 $m^2$ plot) | 40.3 ± 12.9 | 51.0 ± 12.0 | N.S. |

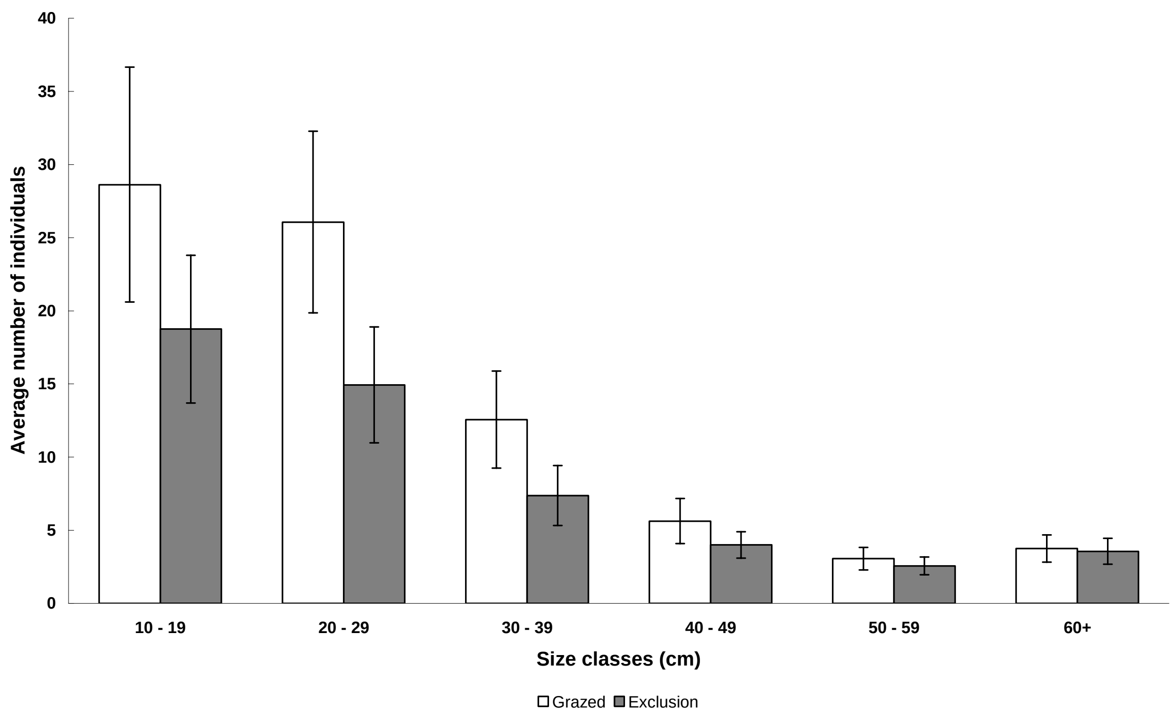


*Figure 3.1*. Average number of *Galenia africana* individuals in each size class per 100 $m^2$ plot protected from or exposed to grazing. Bars indicate standard error.

The forage plant, *Ruschia robusta*, showed no significant differences between the treatments for average abundance (Z = 0.175; p = 0.861), total volume per plot (Z = 0.534; p = 0.594) or average volume per individual per plot (Z = 0.659; p = 0.510) (Table 3.13). Again, no significant differences between the treatments occurred in any of the size classes (Figure 3.2).

*Table 3.13*. Mean (± SE) of the average abundance of individuals, total volume and average volume of individuals of *Ruschia robusta* observed per 100 $m^2$ plot protected from or exposed to grazing. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given ($n = 32$).

| | Grazed | Exclusion | *p* |
|---|---|---|---|
| Average abundance (per 100 $m^2$ plot) | 25.5 ± 10.0 | 28.4 ± 9.9 | N.S. |
| Average volume ($dm^3$ per 100 $m^2$ plot) | 679.4 ± 290.7 | 803.3 ± 283.8 | N.S. |
| Average individual volume ($dm^3$ per individual per 100 $m^2$ plot) | 13.9 ± 4.9 | 17.6 ± 5.2 | N.S. |

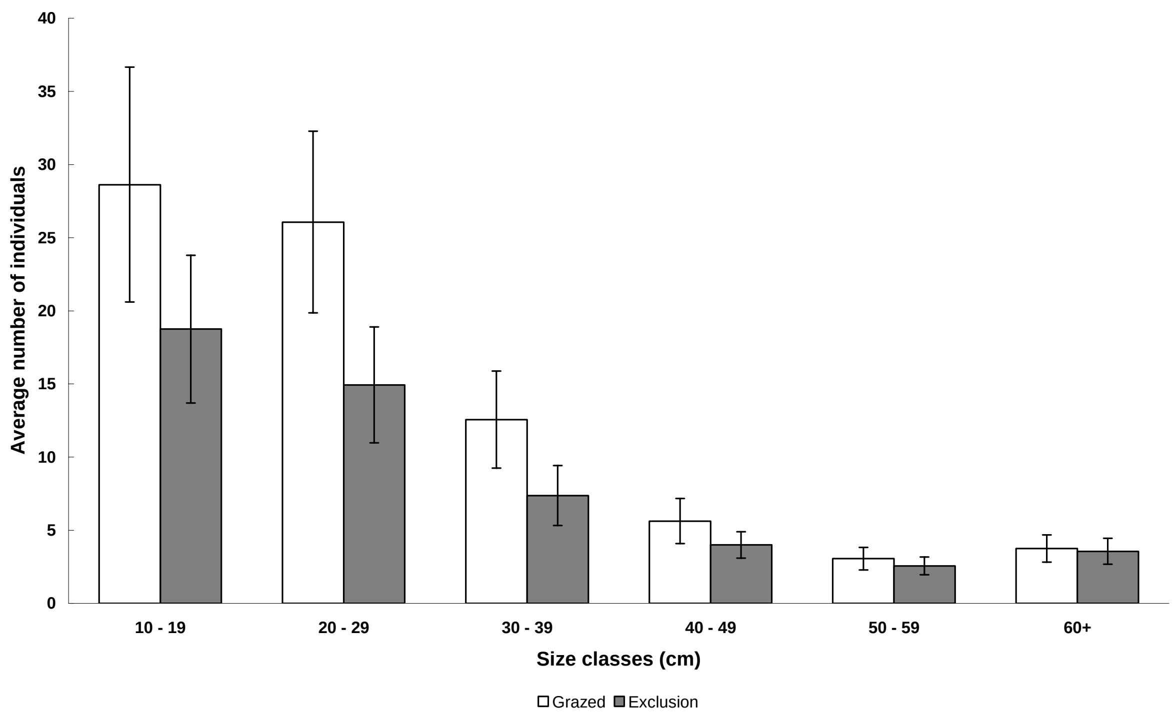


*Figure 3.2*. Average number of *Ruschia robusta* individuals in each size class per 100 $m^2$ plot protected from or exposed to grazing. Bars indicate standard error.

The highly palatable *Hirpicium alienatum* showed significant increases in the average abundance ($Z = 2.934$; $p < 0.005$), total volume per plot ($Z = 3.059$; $p < 0.005$) and average volume per individual per plot ($Z = 2.746$; $p < 0.01$) in the plots from which livestock were excluded (Table 3.14). The grazing exclusion plots had significantly higher numbers of individuals in all size classes except the smallest. Few plants exceeding 20 cm in height were encountered in the plots that were grazed (Figure 3.3).

*Table 3.14*. Mean (± SE) of the average abundance of individuals, total volume and average volume of individuals of *Hirpicium alienatum* observed per 100 $m^2$ plot protected from or exposed to grazing. Treatments were tested using Wilcoxon signed-rank tests; *p*-values for the tests are given ($n = 32$).

| | Grazed | Exclusion | *p* |
|---|---|---|---|
| Average abundance (per 100 $m^2$ plot) | 12.0 ± 6.2 | 34.1 ± 11.0 | 0.003 |
| Average volume ($dm^3$ per 100 $m^2$ plot) | 34.4 ± 17.2 | 419.8 ± 128.0 | 0.002 |
| Average individual volume ($dm^3$ per individual per 100 $m^2$ plot) | 4.2 ± 2.2 | 17.4 ± 6.4 | 0.006 |

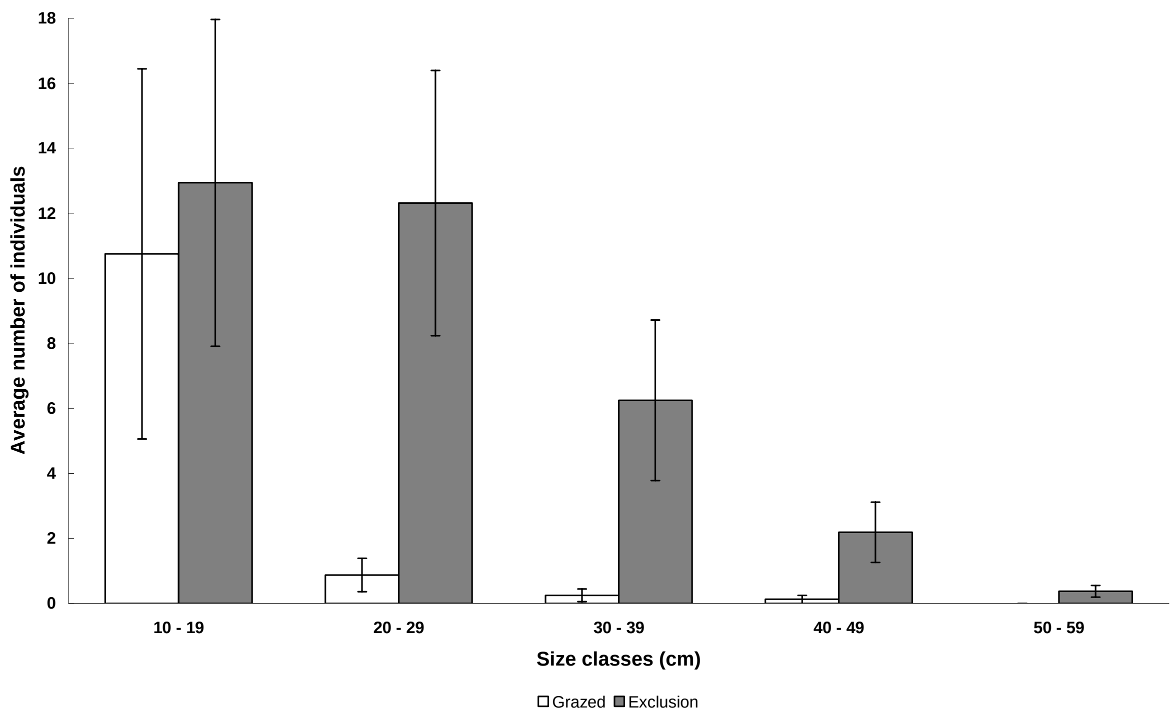


*Figure 3.3*. Average number of *Hirpicium alienatum* individuals in each size class per 100 $m^2$ plot protected from or exposed to grazing. Bars indicate standard error.

## Discussion

Despite seven years of livestock exclusion from Moedverloor, there was a general absence of changes in the abundance, species richness, cover, biomass and size class distributions when comparing the exclosure to the surrounding grazed rangeland. Removal of grazing pressure alone has been insufficient to result in the rangelands changing to some other state, as seen in many long-term rangeland studies (Curtin, 2002). Instead, the response of vegetation to a release from grazing pressure is often overshadowed by the influence of site factors such as topography, slope and substrate (Floyd *et al*., 2003)

*Growth form responses to grazing exclusion*

The significant increases in abundance, species richness and cover of leaf succulent shrubs in the exclusion plots and transects are ascribed to their sensitivity to grazing (Cowling *et al*., 1994; Todd & Hoffman, 1999), with the difference being attributed to the removal of grazing pressure within the exclosure. However, investigation of the population of the leaf succulent *Ruschia robusta* revealed that these differences are not uniform, even within growth form guilds.

The increase in abundance of perennial forb seedlings in response to grazing appears to be the norm for forbs, especially those experiencing cool rainfall seasons (Fernadez-Gimenez & Allen-Diaz, 1999; Todd, 2006; Vesk & Westoby, 2001), and may be related to decreased abundances of other growth forms (Drewa & Havstad, 2001). Species within this growth form are more resilient to grazing pressure, perhaps due to an inherent ability to respond better to winter rather than summer rainfall (Harrington *et al*., 1984), a preference for other growth forms by livestock (Wilson & Harrington, 1984), the benefit of nutrients from dung (Todd, 2006) and their ability to colonise bare and eroded soil (Cunningham *et al*., 1992).

Rather than impact negatively on seedling richness, grazing has not had adverse effects. On the contrary, it is exclusion of livestock that has brought about a decrease in the species richness of seedlings. Seedling recruitment is evidently not harmed and may in fact be stimulated by grazing pressure. The removal of grazing and trampling actions of livestock may result in a decrease in habitat heterogeneity, and thus a decrease in the diversity of micro-habitats that could have lead to higher species diversity amongst seedlings.

The fact that this loss of diversity of seedlings is not reflected in a loss in the diversity of adult plants could result from any of a number of reasons. It may be that a seven year period of livestock exclusion is too short and the adult mortality too slow for the decreased seedling diversity in exclusion plots to be translated to decreased diversity of mature plants. Alternately, factors unrelated to grazing (e.g. variability in incidence and volume of rainfall events) may determine the final vegetation composition, regardless of the abundance and diversity of seedlings after germination. The implication is that there may be an extinction debt (*sensu* Tilman *et al*., 1994) that will begin to reveal itself once the older plants begin senescing and there are none to replace them.

*Individual species responses to grazing exclusion*

*Galenia africana* and *Ruschia robusta*, unpalatable and palatable shrubs respectively, appear to be neither benefiting from nor adversely affected by the exclusion of livestock. In contrast, the increases in abundance and total and average biomass of the palatable *Hirpicium alienatum* in the exclusion plots suggest that this species is highly impacted by grazing in the grazed plots. Palatable species in other rangelands typically are described as showing decreases in the production, biomass and cover of palatable species in heavily grazed areas, as well as negatively affecting population processes such as seedling recruitment (Milton, 1994; Todd & Hoffman, 1999; Zaman, 1997).

All three species appear to be well represented in the smallest size class category, *viz*. 10 – 19 cm in height. This, along with the lack of differences between treatments for the abundances of leaf succulent and shrub seedlings (to which these species belong), indicates that recruitment of seedlings is not impacted by grazing exclusion. However, it appears that *Hirpicium alienatum* individuals are generally unable to grow beyond a height of 20 cm when grazed by livestock (Figure 3.3), which may have implications for reproduction due to reduced flower and seed set.

Clearly, it is also more than merely a species' growth form that determines its response to rest; other factors such as palatability, resilience and recruitment must also play crucial roles. Both *Ruschia robusta*, a leaf succulent, and *Hirpicium alienatum*, a shrub, react in a manner contrary to that seen for their growth forms as a whole. Whereas the results of the growth form analysis (Table 3.2) suggest that abundance of leaf succulents should increase and shrubs remain unchanged when protected from grazing, these two species behave in precisely the opposite fashion to the guilds to which they belong. Furthermore, despite the fact that both are palatable to livestock, their responses to grazing removal differ from each other, with *Hirpicium alienatum* increasing and *Ruschia robusta* remaining unaffected.

These differences in response to livestock exclusion suggest that there is no simplistic mechanism in which to predict the effects of removal of grazing pressure. It is impossible to execute a study at one level (e.g. looking at growth forms) and from the results make conclusions and predictions that will hold true on another (e.g. at the level of the individual). The interactions within this system are clearly quite complex, and defy the application of simple, deterministic models such as those forming the basis of equilibrium dynamics theories.

*Site factor effects on plant dynamics*

The positive effects of increased rockiness, upland topographical units and steeper slopes on some functional growth forms' abundances and diversity could be ascribed to the measure of protection from grazing due to the area being more inaccessible to livestock. At the same time, rockier areas provide less suitable substrates for other functional growth forms, which showed decreases in abundance and diversity. Lower areas and those with less steep slopes experience reduced water run-off, deeper soils, improved moisture retention and accumulation of nutrients, all of which would have promoted plant growth (*cf*. Alconada *et al*., 1993) and have been of benefit to seedlings of those functional growth forms that showed higher abundance and diversity in these areas. Plants in north-facing areas receive more sunlight, especially in the winter months –the main growing season in this area – and benefitted accordingly.

Other studies of vegetation characteristics in arid rangelands also show that factors such as topographical site and environmental factors play important roles in explaining species composition (e.g. Anderson & Hoffman, 2007; Osem *et al*., 2004). Milton (1995) showed that grazing exclusion did little to influence survival of seedlings in an arid Karoo shrubland, while the presence of "nurse" plants, which are important in facilitating the recruitment of seedlings in recovery of rangelands (Padilla & Pugnaire, 2006; Simons & Allsopp, 2007; Yeaton & Esler, 1990), was important. Even excluding livestock grazing for periods of a decade or longer may not be enough to effect a reversal of the changes observed as a result of long periods of grazing (Meissner & Facelli, 1999; Yayneshet *et al*., 2009). Only in much longer-term studies (e.g. Rahlao *et al*., 2008) does grazing exclusion prove to result in consistent vegetation change regardless of site factors, although these factors still influence vegetation cover and composition significantly.

Overall, abiotic site factors such as the degree of rockiness and the topography that the plot was situated in played more important roles in determining plant cover and the species composition and abundances of mature plants and seedlings than grazing or its exclusion. The complexity inherent in the variety of possible combinations of such factors resulted in unpredictability of the vegetation communities and their response to rest.

*Complex dynamics*

The use of an assortment of methods to observe change in vegetation dynamics yields a variety of results; these suggest that the system studied here does not exhibit simplistic or deterministic responses to the removal of livestock. While some plants (e.g. *Hirpicium* *alienatum*), life-stages (e.g. seedlings) and growth forms (e.g. leaf succulents as a group) seem to exhibit equilibrium-type responses to grazing exclusion, the majority do not (e.g. annuals, geophytes, stem succulents and non-succulent shrubs). Instead, it appears that landscape and environmental factors, such as rockiness and topography, do more to influence plant numbers and community composition. With a predominance of environmental effects, it can be surmised that the dynamics of this ecosystem are of a more complex nature.

The prediction of equilibrium theories of range management, *viz*. that the rangeland would experience some form of wholesale recovery after a rest from grazing to some sort of pre-utilisation state, has not occurred. Instead, heterogeneous landscape conditions and inter-specific variations in response to rest have resulted in a patchiness that allows the rangeland to retain its overall nature despite differences at lower scales (e.g. at the individual and guild level). Indeed, biotic interactions such as grazing are seen to affect vegetation at smaller scales, while on coarser scales the abiotic factors are more important (Bisigato *et al*., 2009).

The aim of conventional grazing theories is to keep both livestock and rangeland in an optimally productive state, based on the assumption of equilibrium rangeland dynamics. This relies on predictable and linear responses of vegetation to rest and grazing, which is not the case in this Succulent Karoo rangeland. Instead, heterogeneity of habitat and inter-specific variation in responses to the effects of biotic and abiotic environmental influences make such predictability difficult. Interactions between factors such as demographic inertia (Wiegand & Milton, 1996), grazing impacts on soil properties (e.g. Allsopp, 1999), variable forage selection by livestock (Weber *et al*., 1998) and the erratic rainfall patterns and inherent complexity of the rangeland system (Richardson *et al*., 2005) mean that spontaneous recovery of the communal rangelands to a condition observed in the neighbouring commercial farms by Todd and Hoffman (1999) remains unlikely to be achieved by livestock exclusion alone.

Rangelands should be managed in a manner that takes cognisance of the fact that these systems have complex interactions that determine their dynamics. This will require the application of detailed knowledge regarding the ecological and environmental constraints within the rangelands, which will need to be obtained from effective monitoring programmes.

Rather than the implementation of fixed grazing strategies based on simplistic and predictive equilibrium models of vegetation dynamics (*cf*. Hoffman *et al*., 1999; Milton & Dean, 1996; Tainton *et al*., 1999), management approaches should be informed by models that take the heterogeneity of the rangeland into account. This would include opportunistic grazing strategies and flexible stocking rates.

In order to develop such models, research in rangeland systems would need to further investigate the scope and nature of environmental factors that influence resource dynamics. This study clearly showed that site factors such as topography and rock cover have a strong influence on vegetation composition and abundance. The nature of these relationships could be more thoroughly explored. Further, an examination into the effects of precipitation on vegetation was beyond the scope of this study. Rainfall is considered to be one of the main factors influencing arid rangeland resources (Illius & O'Connor, 1999; Scoones, 1995). A longer-term study of the relationship between rainfall and vegetation – including periods of drought and periods of higher rainfall – could provide insights that, when combined with findings regarding site factors, would lead to more holistic and better integrated models of rangeland vegetation dynamics.

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# Chapter 4

# Local land-users' perceptions regarding rangeland management in an arid South African rangeland

## Introduction

Since Hardin's (1968) landmark paper on "the tragedy of the commons", it has been commonly accepted that communal rangelands, especially those occurring in Africa, are degraded and have low levels of productivity due to overgrazing (Rohde *et al*., 2006). In the last few decades, however, these assumptions have been re-examined (Abel, 1997; Briske *et al*., 2008; Illius & O'Connor, 1999). Along with the re-assessment of perceptions regarding rangeland function, condition and degradation, management recommendations have been re-examined. Whereas a rotational grazing system has been mooted as the only viable approach to rangeland management in South Africa (Hoffman *et al*., 1999a; Milton & Dean, 1996; Tainton *et al*., 1999), more recent studies indicate that a simple yet flexible strategy, incorporating knowledge of ecological and other parameters, is more appropriate (Briske *et al*., 2008; Rohde, 2005; Scoones, 1995). This knowledge can only be gleaned from effective monitoring programmes.

Experiential knowledge is increasingly being recognised as being invaluable in assisting in monitoring, understanding and managing various types of systems. A number of cases exist which have proven how accurate this form of knowledge is and how it can contribute to management practices (e.g. Allsopp *et al*., 2007; Barrios *et al*., 2006; Bosch *et al*., 1997; Calheiros *et al*., 2000; Fernandez-Gimenez, 2000; Mapinduzi *et al*., 2003; Samuels *et al.*, 2007). This is also in line with the evolution within rural development and agriculture of a mindset that a more participatory approach to both monitoring and management is necessary and desirable (Ellis & Biggs, 2001).

Traditional resource management in Africa appears to have evolved to exploit the opportunities and avoid the dangers inherent in the difficult environmental systems (Abule *et al*., 2005). Problems such as the increase in both human and animal populations, drought and a reduction in quality and availability of grazing have undermined the effectiveness of these systems, however, leaving pastoralists vulnerable and pressuring them to abandon this livelihood (Abule *et al*., 2005; Angassa & Beyene, 2003).

The communal rangelands of Namaqualand fall within the Succulent Karoo Biome (*sensu* Mucina & Rutherford, 2006), one of the biodiversity hotspots of the world (Mittermeier *et al*., 2004; Myers *et al.*, 2000). It has a high diversity of plant species (around 4 800 species), with approximately 40% of these being endemic to the region. It was the first arid area to qualify as a global hotspot for biodiversity (Brooks *et al.*, 2002), and as such warrants special conservation consideration. Currently, less than 4% of this vegetation type is conserved (May & Lahiff, 2007).

The Northern Cape province of South Africa, within which much of the Succulent Karoo occurs, has the third highest veld degradation index in the country (Hoffman & Todd, 2000). This assessment was based on perceptions of governmental officers involved in agricultural extension and conservation and was attributed to mining and the grazing of domestic livestock, which has been a major land-use in Namaqualand for the past 2000 years (Webley, 2007). However, up to 29% of the rangelands in which this grazing occurs, however, are largely untransformed and could contribute to biological diversity conservation (Mittermeier *et al.*, 2004).

Traditionally, livestock herders followed a seasonal transhumance herding strategy to better cope with the variability in forage availability as a result of the highly unpredictable seasonal rainfall patterns. However, since the mid-18$^{th}$ century, the inhabitants of the Namaqualand region have become increasingly restricted to small parcels of communally-owned land (Hoffman & Rohde, 2007). This forced the abandonment of the nomadic pastoralism that had previously been followed.

Assessment by herders and pastoralists of the rangelands within which they live is a traditional and on-going part of their life, as the welfare of their livestock, and therefore themselves, is dependent on the natural resource base around them (Abule *et al.*, 2005; Fernandez-Gimenez, 2000). The aim of this study was to therefore go about exploring the perspectives of the local inhabitants regarding the effectiveness of rest from grazing as a means of improving the condition of the rangeland. It was hoped to gain insight into what changes occurred in vegetation after livestock removal, what factors influenced vegetation characteristics and whether any alternatives to exclusion existed.

## Methods

### *Study area*

The participants were all inhabitants of the village of Paulshoek, located in the Leliefontein communal area of central Namaqualand, South Africa. The village is in the Kamiesberg escarpment, which rises between 900 – 1500 m above sea-level. The vegetation of the

Leliefontein commons is mostly classified under the Namaqualand Hardeveld Bioregion (Mucina & Rutherford, 2006).

In the Paulshoek area, stocking rates for livestock have averaged 5.6 ha per small stock unit for at least three decades (Hoffman *et al*., 1999a). This is far in excess of the 10 ha per small stock unit recommended by the Department of Agriculture (van der Poll, pers. comm.). This is a long-term average, however, as wide variability in animal numbers is linked to the fluctuations in annual rainfall, which determines availability of water and forage. Annual rainfall for the period 1999–2004 averaged 118 mm per annum, but it fluctuated between 84 mm and 201 mm, with co-efficient of variance of over 30%.

In 1999 a fence was erected as part of the Department of Agriculture’s LandCare programme, in order to keep livestock out of the Moedverloor area near Paulshoek (33º 20' S; 18º 17' E). The vegetation in and around the exclosure is Namaqualand Blomveld vegetation, dominated by succulent and deciduous dwarf shrubs (Desmet, 2007; Mucina & Rutherford, 2006). The existence of this exclosure provided an opportunity to explore perceptions of the effects of rest in this system by contrasting the grazed areas to those from which livestock was excluded.

*Interviews*

This study used a qualitative approach to collect data and describe findings within their context by providing in-depth details as related by a specific group or community (Babbie & Mouton, 2001). Typically, this research design features detailed encounters with the subjects of the study. Qualitative studies seek to explore differing opinions and presentations of the issues discussed, rather than trying to quantify opinions (Gaskell, 2000). This phenomenological approach provides a detailed understanding of people’s everyday experiences and knowledge (Mostyn, 1985) and allows individuals to relate their unique knowledge and experiences (Huntington, 2000).

The target group for the interviews comprised people who had experience relating to the herding of livestock. All of the respondents were either livestock owners or herders, or had at some stage been involved in herding. Most of the experiential knowledge discussed in the interviews was derived from the individuals’ personal experience gained during herding livestock.

During a visit prior to the survey period, the researcher approached potential interviewees to introduce himself and his research. Introductions were made by a fellow-researcher well-known to the interviewees due to their living and working in the community at the time. Upon introduction, the nature of the interviews was outlined and permission to conduct interviews with subjects was sought.

The selection of potential interviewees was based on two factors: proximity to the Moedverloor area, and special experience with livestock and plants. Those herding their livestock in closest proximity to the exclosure could be expected to have insights into the effects of rest on the vegetation. People with special knowledge of the vegetation in the area, e.g. amateur botanists and herbalists, were also specifically sought out.

The interviews were conducted in a semi-structured manner. Questions were constructed in such a manner that the asking of leading questions was avoided, maintaining the integrity of the study by not influencing the responses of the subjects in order to get answers that the interviewer would like to hear (Rubin & Rubin, 2005). Each interview aimed to explore themes linked to the effects that a rest from grazing would have on vegetation in the area. As an interviewee brought up a topic, further questions were asked in order elaborate on the issue.

All of the information gathered in this study was based on the personal experiences and knowledge of the interviewees. The perceptions presented here are thus of the interviewees' subjective view of the topic. While they may not be strictly factual, they can nonetheless be expected to bring much insight to the understanding of rest from grazing in arid rangelands (*cf.* Botha *et al*., 2008).

After obtaining consent, all interviews were recorded digitally, as this proved to be highly effective for capturing data. It ensures that all issues raised during the course of each interview are captured and can be included in later analysis and interpretation. All interviewees were native Afrikaans-speakers and the interviews were thus conducted in Afrikaans. The interviewing took place at the herders' stock-posts or homes.

The results of the interviews are to returned to the community through their local community forum. This platform exists for the purpose of organising and facilitating discussions regarding grazing management and other issues as necessary. It is also hoped that the research will be published in both the scientific literature as well as in Agricultural Research Council reports. This latter is used to improve grazing management in the region.

*Ethical considerations*

This study was designed and carried out according to Stellenbosch University's guidelines on ethical research, under which auspices this research was conducted. Ethics in research should aim for the subject, the researcher and the research itself to be protected. As such, it hinges upon informed consent and voluntary participation in the research, and confidentiality and anonymity.

According to the above-mentioned guidelines, participants have the right to privacy, confidentiality and informed consent. Consequently, each participant was informed of the nature of the study, given the option of whether to participate or not, and their consent was sought. They were given assurance that there would be neither negative consequences nor a reward if they participated. Participation hinged on free will, rather than any sort of coercion.

While the face-to-face interviews prevented absolute anonymity during data collection, subjects were assured that all information would be treated in a confidential manner. Upon receiving these reassurances, all subjects were willing to participate freely in the study.

*Data analysis*

The data were transcribed verbatim from the recordings. Analyses were then done using the method described by Botha *et al*. (2008). This involves identifying themes within the text of the interview and assigning a code to each theme. The code consists of a short phrase that summarises the theme related in a section of the transcription. Where more than one theme was mentioned in a specific section of an interview, as many codes as necessary were assigned to that section in order to ensure that all themes were captured. The data were coded and analysed in a simple spreadsheet.

In reporting the results, a superscript consisting of two numbers was used to indicate frequency of occurrence of the themes. The first superscript number indicates the number of times that the theme was mentioned (i.e. the number of times the code was counted) and the second indicates the number of interviewees that mentioned the theme in question. In this way, one can obtain an idea of the relative prominence of the various issues.

Codes that appear frequently, both in terms of the number of interviews that refer to them, and the number of times that they are mentioned in each interview, are widely recognised by respondents. Codes identified less frequently are either not of particular importance to the interviewees questioned, or are themes of which most interviewees had little experience or knowledge. Nonetheless, these often contain useful insights that were only known to a few interviewees (Botha *et al*., 2008). The superscripts in the results discussed here should thus not be interpreted as a means of ranking the codes.

**Results**

A total of fifteen persons were interviewed. Of these, eight were full-time livestock herders. Another two were herders who worked on an *ad hoc* basis for any livestock owner who had need of a herder for a period of time. These herders were responsible for ten of the twenty-four herds grazing in the Paulshoek area (Samuels *et al*., 2007). They also included the nine herds closest to the Moedverloor livestock exclosure.

Of the remainder, three respondents had been herders, but were now retired as they were too old to live at the stock-posts. One of these was an amateur botanist, the other an herbalist; they thus also had special knowledge of plants. The last two were both livestock owners and had considerable experience in herding, but also had other jobs and hired herders to look after their flocks.

All subjects barring one had also had other occupations at some time, such as working on the railways, at a telecommunications company or nearby mines. Most had extensive experience of livestock herding. Only three had spent less than ten years herding livestock, while the rest had between 20 and 40 years' experience. All had herded livestock as children, assisting with their parents' stock.

Six and a half hours of interviews were recorded. Three interviews lasted longer than 50 minutes, while the others ranged between ten minutes and 25 minutes long. The duration of individual interviews was subject to the interviewee's willingness to share information and the length of time they were prepared to spend in an interview. All three of the interviews that lasted over 50 minutes were with subjects who were not full-time herders, either with another job or retired. The interviews appeared to allow sufficient time to explore the topic, covering all of the questions in the interview schedule.

Five hundred and sixty-three themes were mentioned during the interviews, to which 74 unique codes were assigned. These codes were grouped into five main categories: (a) how herders assess rangeland condition; (b) factors influencing vegetation condition in the communal rangelands; (c) effects of rest on rangeland vegetation (particularly as observed in the Moedverloor livestock exclosure); (d) management and improvement of rangeland condition; and (e) the future of the Moedverloor exclosure.

*Assessment of rangeland condition*

The methods used by herders to assess the condition of the rangeland varied. To many, characteristics of individual plants, such as the foliage[10,6] and flowers[4,3] of the shrubs were important in assessing rangeland condition. A number of herders looked at the species occupying a certain area, notably toxic plants[4,3], species known to be palatable to livestock[7,4] (such as grasses[1,1]) and the germination of "opslag" (annuals and seedlings that emerge after rain events)[8,7].

Some respondents recognised rangeland vegetation in poor condition from the domination of these plant communities by "Kraalbos" (*Galenia africana*)[2,2], which was considered an indicator of degradation. While this species can serve as forage while green[2,2], it is sometimes unpalatable or toxic for livestock[3,3].

More than half of the herders interviewed did not always deem it necessary to consider vegetation at all in assessing rangeland condition. Instead, their assessment was based on observation of their livestock[16,9]. Healthy livestock provided an indication that the veld that was in good condition, while livestock vigour deteriorated when they grazed in rangeland areas that were in poor condition.

*Factors influencing rangeland condition*

The respondents were unanimous that the predominant factor influencing the health of the rangelands was rainfall[37,15], with good rains resulting in an improvement in veld quality. In times of drought, the veld quality would be reduced[6,6]. Overgrazing by livestock also negatively impacted on the vegetation[8,5]. Donkeys were identified as major culprits in overgrazing and decreasing veld quality[15,6], as they consumed more forage than smaller stock. Trampling and the development of footpaths[15,8] was observed where livestock densities were high, resulting in bare soil that was vulnerable to erosion during rainfall events[3,3]. The dust raised by livestock movements settled on leaves, reducing photosynthesis[1,1]. Grazing also reduced recruitment of seedlings due to flowers being eaten before seed could be set[3,2].

The variation in landforms encountered (e.g. slopes, hills, plains) was seen to influence vegetation condition[7,4]. Interviewees recognised that hills, slopes and rocky areas experienced less grazing and were generally in better condition that lower lying areas[2,2], due to a proclivity of sheep to grazing on flat plains. Soil texture and structure were also identified as playing a role in determining the vegetation composition[1,1].

Some respondents recalled years where plagues of insects such as locusts had been particularly damaging to the rangelands[2,2]. Also detrimental was the desiccation caused by winds[1,1] and extended periods of exceptionally high temperatures[1,1]. The vegetation condition could also be linked to the season[1,1], with winter being wetter and cooler and the summers hot. Late winter rains and rare summer thunderstorms were mentioned as having strong positive effects on the available forage for the next year[2,1].

Crucial to the use of any area for grazing was the availability of an adequate supply of good quality water for their stock[12,5]. A lack of water points restricted movement options. However, one interviewee warned that increased trampling around water-points may negatively impact on the rangeland[1,1]. Furthermore, livestock tended to become conditioned and accustomed to the vegetation in the specific areas that they regularly grazed in[11,6] and would fare poorly when moved elsewhere. Such livestock could only be moved after rains had fallen to rejuvenate the vegetation[2,1].

*Effects of rest on rangeland vegetation*

All respondents believed that the rest period of seven years was beneficial for the quality and availability of forage[37,15]. Some believed that rest may result in some changes in plant community composition[8,5], while others thought that such change was minimal and negligible[6,4]. Rest was seen to result in an increase in the abundance of seedlings[4,3] and "opslag" plants[7,5], and the return of grasses into the exclosure that were rarely encountered outside of it[10,6].

A number of participants felt that the long period without grazing had resulted in the plants becoming "wild"[13,9]. This is an undesirable state, as plants lose their vigour[3,3] and offer lower quality forage for livestock[12,7]. However, one positive effect was that that grazing exclusion at Moedverloor appeared to have resulted in senescence in some of the stands of "Kraalbos" (*Galenia africana*) that had for long dominated the vegetation in the area[5,4]. Some also noticed that the "Kraalbos" acted as "nurse" plants, facilitating the germination of and protecting seedlings under their canopy cover[4,3].

One respondent felt that the soil condition inside the exclosure had improved in the intervening time[1,1] and ascribed this to the improved vegetation condition that reduced erosion[1,1]. Other respondents did not notice any change to the soil properties as a result of livestock exclusion[6,6].

*Rangeland management and improvement*

All interviewees agreed that there was a need for some kind of rest to be included in their grazing patterns[40,15]. Historically, a form of rest and grazing rotation had been the norm[5,4], such as summer and winter grazing areas, or grazing different areas prior to and after harvesting of sowed crops. While this was no longer possible due to restrictions in the availability of land, respondents still practiced a sort of daily rotation, by herding their livestock in different directions each day[11,10].

The majority of respondents seemed to agree that a short period of rest (between three months and one year) was the most appropriate strategy[22,11]. Rather than be a rigid system based on calendar months, this should be done on an *ad hoc* basis[17,9], as dictated by the seasons and the frequency of rainfall[26,10]. A few herders believed that longer rest periods of one to two years[6,6] or even longer[6,6] might be appropriate.

Where veld had rested so long that it had become “wild”, it became necessary to introduce livestock in order to prune the vegetation and return it to a more vigorous state[17,9]. Such reintroduction should only occur after the plants had had opportunity to flower and set seed[4,4], after which the trampling of the livestock would stimulate germination of the seeds[10,6].

It was generally agreed that there was a need to establish other areas that could be rested (similarly to Moedverloor)[13,9]. However, several issues were identified that made this difficult to achieve. Some respondents felt that the coherency of the community had diminished somewhat, and that improved co-operation between herders needed to be re-established[10,4]. Others felt that implementation of rest areas would have to be enforced in some manner[2,2]. One respondent felt quite strongly that one could improve veld condition by collecting and sowing seeds of rangeland plants[5,1].

Problems mentioned included that the current grazing patterns did not include rotation any more[3,3] and there was poor management of the rangelands in general[1,1]. Some felt that there was not enough land available for the herders and their livestock[3,3], a problem that could be alleviated by the lease or purchasing of more land outside of the commons, especially towards the eastern, summer rainfall areas that the community had previously had access to[2,2].

*Future of the Moedverloor exclosure*

Most of the interviewees felt that the camp should be opened for some sort of grazing[14,8]. Some felt it should be re-incorporated into the rest of the commons and opened for grazing by any herders who wished to use it[5,5]. Others felt that it should be for some sort of specific use that all herders could benefit from. The suggestions for its future included the following:

- a camp where the rams could be kept separate from the herds to control breeding[7,5];
- conversely, animals that herders did not want breeding (such as older ewes) could be kept here[2,2];
- animals that were selected for sale could be kept here temporarily to fatten on the improved vegetation before going to the markets[3,3]; and
- in difficult times such as drought, each herder could put his weaker animals into the camp so that they could benefit from the good quality forage[3,2].

Any sort of grazing utilisation would, however, necessitate the provision of a watering point or borehole[2,2].

A few respondents felt that the area could be used for some sort of cropping. This included crops for human consumption[1,1], replanting with forage plants that were found locally[4,1] or planting pasture such as lucerne and lupine[2,1].

A number of interviewees related that they had already observed some herders using the exclosure for a short period just prior to the interviews[6,5].

## Discussion

*Extent and diversity of traditional knowledge in Paulshoek*

Identifying themes from the interview transcripts proved to be an effective methodology for exploration of the experiences and perceptions of Paulshoek's pastoralists. Collation and dissemination of the information in this manner was simple and efficient. It allowed the identification of issues of importance to the respondents, and provides insights into the indigenous knowledge systems of the study area. It also ensured that less prominent themes did not get lost during the interviews or subsequent analysis, allowing a broader impression of herders' perspectives to be constructed.

It appears that the interviews succeeded in capturing details regarding the herders' perceptions of the importance of rest from grazing in their pastoral system. Many of the perceptions expressed were held in common with other interviewees, with three themes being mentioned by each and every respondent and 15 being mentioned by seven or more of them (i.e. half of the subjects). There are clearly a number of issues that are important to all herders, with the result that knowledge regarding these is widespread and detailed.

At the same time, the diversity in the interviewees' responses is also evident. A total of 35 themes were mentioned by three or less interviewees. This suggests that the system is extremely complex and that there are a multitude of factors that herders need to take cognisance of in the course of practising their livelihoods.

*Comparisons to other traditional knowledge systems*

Many of the themes that emerged from this study are common to and widespread in traditional knowledge systems of other pastoralists, specifically those living in arid rangelands. Assessment of rangeland condition according to presence and abundance of toxic and palatable species, increasers (species that increase in abundance due to grazing pressure), grasses and annuals have all been observed in other knowledge systems (Abule *et al*., 2005; Angassa & Beyene, 2003; Fernadez-Giminez, 2000; Oba & Kaitira, 2006; Reed & Dougill, 2002; Solomon *et al*., 2007).

Livestock condition as a key indicator of rangeland health also seems to be widespread in other pastoral societies (Angassa & Beyene, 2003; Fernadez-Giminez, 2000; Reed & Dougill, 2002). As their animals play a pivotal role in their livelihoods, pastoralists clearly regard their well-being as of near paramount importance. Their concern is not so much with the rangeland's plant species, as the interactions between plants and their herds. Any loss in livestock condition is thus seen as evidence of poor forage resources or inappropriate grazing practices.

The consensus amongst Paulshoek herders that rainfall and drought are more important determinants of healthy rangelands than stocking rates appears to be universal amongst pastoralists (Abule *et al*., 2005; Bollig & Schulte, 1999; Fernadez-Giminez, 2000; Hussein *et al*., 1999; Oba & Kaitira, 2006; Solomon *et al*., 2007). Landscape heterogeneity (elevation, topography and aspect) and spatial and temporal variability of rainfall play key roles in determining the composition and health of rangeland vegetation communities. This variability is crucial as it leads to unpredictable shortages in the two key resources, *viz*. forage and water, and results in livestock mortality.

Perceptions of Paulshoek herders regarding rest periods and mobility as a means to exploit landscape heterogeneity are common to traditional herders in other arid systems. (Fernadez-Giminez, 2000; Solomon *et al*., 2007). As soon as a shortage of forage or water becomes evident, many herders immediately turn to migration in order to find sufficient reserves, and the use of short grazing periods based on intensity and seasonality of rainfall, and the employment of grazing reserves in times of drought, are common (Abule *et al*., 2005; Angassa & Beyene, 2003; Bollig & Schulte, 1999; Fernadez-Giminez, 2000; Oba & Kaitira, 2006; Solomon *et al*., 2007). These traditional practices gives plants relief during the crucial growing season, resulting in optimal production potential and maximum benefit to livestock when these areas are utilised again.

The recognition that different animals have different metabolic needs is also evident in a number of pastoralist systems (Abule *et al*., 2005; Angassa & Beyene, 2003; Oba & Kaitira, 2006). Paulshoek herders recognised the detrimental effect that donkeys (non-ruminants) had on the rangeland condition. They also noted that goats are better able to cope during droughts due to their ability to utilise habitats – especially steep or rocky areas – that are not favoured by sheep.

While traditional grazing systems are widely considered as being of value, they remain vulnerable to disintegration in situations of conflict, uncertainty, mismanagement, lack of participation within the community and shifts away from livestock towards other livelihood practices (Abule *et al*., 2005; Angassa & Beyene, 2003; Bollig & Schulte, 1999; Oba & Kaitira, 2006; Solomon *et al*., 2007). The Paulshoek pastoralists identified a lack of co-operation amongst community members and the disintegration of traditional grazing strategies; reinforcement of community coherency was seen as crucial to proper grazing management in the commons.

*Unique aspects of the Paulshoek traditional knowledge system*

The use of flowers as an indicator of rangeland condition is somewhat unusual amongst traditional knowledge systems. This can be ascribed to the prominence of the iconic displays that are characteristic of the region after rainfall, when perennial plants and especially annuals and ephemerals ("opslag") flower prolifically.

Another concept unique to the Paulshoek herders is the phenomenon of veld becoming "wild". While other pastoralists are aware that plant communities may be resilient and tolerant of grazing (e.g. Bollig & Schulte, 1999, Oba & Kaitira, 2006), the idea that rangelands require pruning by livestock in order to remain productive is not widespread in other traditions. Similarly, the stimulating effect of livestock trampling on seedling germination was not one shared by other knowledge systems. These positive effects of livestock grazing on rangeland health, while not seen in many ecological knowledge systems, is well-recognised in the scientific literature. Mearns (1996) cites several examples where the presence of livestock in the landscape is of benefit to tree, shrub or grass species.

*Value of indigenous knowledge systems*

Natural scientists remain hesitant to use social science methods to complement ecological studies and thus tend not to explore the knowledge of the land-users in their studies (Huntington, 2000; Robertson & McGee, 2003). Often the approaches are seen as not being scientifically robust enough to provide adequate and credible results. It is nonetheless well-documented that the knowledge held by those who interact daily with their environment is accurate and extensive (Aswani & Hamilton, 2004; Huntington, 2000; Ollson & Folke, 2001). The issues emerging from this study can be used to support and elaborate on studies that use a more traditional approach, as well as provide direction for future research. This is key to improving rangeland research and management by promoting sustainability (Bray *et al*., 2003; Warren & Cashman, 1988). As the understanding of the economic and social aspects of rangeland dynamics neglected in favour of ecological research, the integration of these fields show a lack of connectivity – a deficiency that needs to be rectified (Campbell *et* al., 2006; Dong *et al*., 2009; Havstad *et al*., 2007).

*Perceptions of other stakeholders*

Following Debeaudoin (2001), the following groups were identified as stakeholders in the management of rangelands: livestock keepers, the government (national, provincial and local departments of agriculture and the district municipality, as represented by extension officers), and professionals (e.g. agricultural, environmental and social scientists). A fourth group can be added to this list, non-profit and/or aid organisations, concerned with issues such as conservation, agriculture and development.

The South African National Department of Agriculture has three key management priorities regarding livestock grazing in Namaqualand. These are that livestock owners should: a) maintain a fixed and conservative stocking rate; b) operate a rotational grazing plan; and c) rehabilitate “degraded” areas by rest from grazing. This is often based on the assumptions that:

- livestock owners’ main objectives are to maximise profit – this is not always the case (Allsopp *et al*., 2007);

- rangelands are equilibrium systems requiring rotational grazing (Hoffman *et al*., 1999a; Milton & Dean, 1996; Tainton *et al*., 1999) – this view is increasingly being questioned (Briske *et al*., 2003; Buttolph & Coppock, 2004; Ellis, 1995; Scoones, 1995); and
- rangelands are overgrazed and degraded – this perspective is being re-examined (Abel, 1997; Illius & O'Connor, 1999).

The Northern Cape Department of Agriculture recommends a fixed stocking rate of 54 ha per large stock unit per annum (S. van der Poll, pers. comm.). This corresponds to approximately 10.8 ha per small stock unit per annum (*sensu* Tainton, 1981). The Department of Environmental Affairs and Tourism (2006) supports this as an appropriate long-term stocking rate, and suggests that exceeding this level for long periods will cause desertification. It views the communal rangelands of South Africa as being generally degraded.

Allsopp *et al*. (2007) found that professionals regarded the Leliefontein commons as being overstocked. A reduction of stock numbers to a fixed carrying capacity was seen as being essential to proper rangeland management. Furthermore, short-term rest on a rotational basis, founded on equilibrium theories of vegetation dynamics, was recommended. In a national study on land degradation, conservation and agriculture professionals working in the region viewed Namaqualand as being degraded (Hoffman *et al*., 1999b).

Conservation non-governmental organisations (NGOs) also view grazing as a threat to biodiversity in the Succulent Karoo. The Succulent Karoo Ecosystem Programme (2003) states that over two thirds of the area is severely degraded due to livestock grazing. It advocates a reform in communal and subsistence livestock herding practices towards a system that is environmentally and ecologically sustainable.

A study by the Human Science Research Council viewed the commonages in the Northern Cape as being degraded due to over-grazing (Benseler, 2003). The solution advocated was a commercialisation of the commons and a move away from traditional pastoralism to more intensive agricultural practices. So-called "emergent farmers" were purported to be uninformed and in need of training regarding grazing management.

The assumption that deviation from a fixed, long-term stocking rate will invariably lead to degradation is no longer universally accepted. Optimal grazing strategies will vary depending on site-specific factors such as environmental conditions, local property rights and market forces (Campbell *et al*., 2006). Moreover, the use of the word "degraded" is increasingly losing favour, as definitions of degradation vary depending on management objectives

(Behnke & Scoones, 1991; de Queiroz, 1993). Instead, landscapes are recognised as comprising a matrix of multiple land-uses (Thomas & Twyman, 2004).

The livestock herders' perceptions of appropriate management strategies differed from these expressed by government officials and professionals. The tendency of outside agencies has been to ignore local norms governing grazing practices and instead dictate fixed grazing strategies not adapted to local conditions (Allsopp *et al*., 2007; Rohde *et al*., 2006).

Conversely, herders did not identify a strict *pro forma* approach with a constant, conservative stocking rate and regular, prescribed rest periods as a necessity for management of the commons. Moreover, they did not see the rangelands as being necessarily degraded due to grazing pressure; instead, rangeland health fluctuated based on seasonal and climatic factors. While they identified over-grazing as having an impact on rangeland condition, rainfall and landscape heterogeneity were deemed to be far more important than stock numbers and rest periods. A more flexible and opportunistic management paradigm (*sensu* Scoones, 1995), based on spatial and temporal (especially seasonal) rangeland heterogeneity, seemed to be the norm. In the long term, this can be sustainable, if the institutions protecting resources remain intact and populations remain small and mobile.

An examination of the current status of grazing institutions and investigation into the reasons behind the perceived deterioration of rangeland management in the system is thus necessary. This would be augmented by exploration of past and current trends in the numbers of livestock, and strategies used by herders to vary livestock numbers in response to rangeland condition. More detailed knowledge of length of grazing and rest periods would also be appropriate to inform management interventions aimed at improving sustainability of the rangelands.

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# Appendix I

## Interview protocol

As a semi-structured approach was followed, the themes below were introduced for discussion. As the interview progressed, the interviewees' responses dictated the direction that the interview took.

**Greeting and introductions**

**Reminder to interviewee of purpose of research**

**Repeated reassurance of privacy and confidentiality**

**Repeated request to conduct and record interview**

**Biographical information**

- *Occupation*
- *Experience in livestock herding*
- *Other work experience*
- *Size of herd*

**Assessment of rangeland condition**

- *Vegetation characteristics*
- *Soil characteristics*
- *Other characteristics*

**Factors influencing rangeland condition**

**Effects of rest on rangeland**

- *Effects on vegetation characteristics*
- *Effects on soil characteristics*

**Rangeland management and improvement**

- *Need for rest*
- *Length of rest period*
- *Management / problems*
- *Other means of restoration*

**Future of the Moedverloor exclosure**

# Chapter 5

## The value of integrating scientific surveys and land-user perceptions to advise management strategies in an arid South African rangeland

### Introduction

In recent years, long-standing assumptions governing rangeland management have been revisited with a view to providing more appropriate measures dictating grazing strategies. It is no longer accepted as fact that communal rangelands are almost by definition overgrazed and degraded (e.g. Abel, 1997). Furthermore, management strategies that assume that biotic feedback is the primary determinant of vegetation composition are under review (Illius & O'Connor, 1999; Quirk, 2002). Most ecological theories now accept that arid rangeland systems are not at equilibrium; instead the relationship between livestock and forage is complex and extremely variable (Buttolph & Coppock, 2004; Ellis, 1995; Savory, 1988; Westoby *et al*., 1989). Strategies based on concepts such as rangeland carrying capacity, fixed stocking rates and regular rest periods (e.g. Milton & Dean, 1996; Tainton *et al*., 1999) are being replaced with more appropriate and opportunistic measures (Briske *et al*., 2003; Scoones, 1995). Briske *et al*. (2008) call for simple, flexible management approaches based on improved knowledge of ecological systems.

Conventional scientific methodologies used in rangeland research usually revolve around measures of species diversity and abundances, cover and productivity (Rohde, 2005; Todd & Hoffman, 1999). Plant characteristics such as toxicity and palatability towards livestock and their responses to grazing pressure are often also considered (e.g. Milton, 1994; Todd & Hoffman, 1999; Zaman, 1997). Changes in composition and cover away from some state considered to be the ideal are regarded as signs of degradation (Abel, 1997; Hoffman & Todd, 2000).

Hardin's (1968) prediction of inevitable degradation of common property resources appears to be inappropriate for many rangeland ecosystems (see Allsopp *et al*., 2007; Rohde *et al*., 2006; Samuels *et al*., 2007). It does indeed appear that outside factors can bring about the failure of traditional management institution. Political divisions, competition for an increasingly limited resource, land-use history and pressure from outside factors all weaken traditional management (Bennet *et al*., 2010; Moyo *et al*., 2008; Rohde *et al*., 2006).

However, conventional, modern management appears to be failing, while traditional practices seem increasingly to be valid in the context within which they developed (Walker, 2002; Warren & Cashman, 1988). Profit maximisation for the individual is not always the primary driver in communally owned systems (Abel, 1997; Allsopp *et al*., 2007; Ormazabal, 2003; Rohde *et al*., 2006). Instead of the free-for-all expected in the case of open access resources, utilisation is often governed by norms that include equity and sustainability. Thus, the commercialisation of common property so often advocated (e.g. Birdyshaw & Ellis, 2007; Markussen, 2008) is not necessarily a guarantee of sustainable resource use, nor the only means of achieving it.

Towards the end of the 1900s, rural development and agriculture have shifted towards a paradigm of improved participation in monitoring and management (Ellis & Biggs, 2001). Indigenous knowledge develops within a unique socio-economic and natural environment through a process of continued observation by land-users; it consequently plays a key role in traditional agriculture (Bosch *et al*., 1997; Warren & Cashman, 1988).

Rangeland pastoralists are continually engaged in a process of assessment of the resource base upon which their livestock depend, as their own welfare is ultimately reliant upon it (Abule *et al*., 2005; Fernandez-Gimenez, 2000). Environmental characteristics such as complexity and variability are well-understood and have been integrated into traditional management strategies (Calvo-Iglesias *et al*., 2006; Thomas & Twyman, 2004). The benefits of this experiential knowledge in effective monitoring are undeniable, as it has proven accurate and useful in advising management practices (Barrios *et al*., 2006; Bosch *et al*., 1997; Calheiros *et al*., 2000; Fernandez-Gimenez, 2000; Mapinduzi *et al*., 2003; Pretty & Smith, 2004). Such engagement empowers communities and increases the implementation of jointly-agreed upon interventions (Bray *et al*., 2003; Calvo-Iglesias *et al*., 2006; Fraser *et al*., 2006; Moran, 2004; Warren & Cashman, 1988).

Upon collecting indigenous knowledge, it can be used to complement scientific information (Bosch *et al*., 1997). Local knowledge can provide new research directions and expand the range of management actions that could be researched. Scientific research can then evaluate the problems and potential solutions identified in participatory surveys in order to advise on appropriate interventions. Integration of scientific and socio-economic perspectives will support local institutions, expand capacity and contribute to improved problem-solving in the management of rangeland resources (Howden *et al*., 2002).

*The Namaqualand rangelands, South Africa*

The rangelands of Namaqualand fall within the Succulent Karoo Biome, the world's most species rich arid environment and a biodiversity hotspot (Cowling *et al*., 1998; Mittermeier *et al*., 2004; Mucina & Rutherford, 2006; Myers *et al*., 2000). Namaqualand's low, winter rainfall has resulted in a unique and biodiverse plant community – with a high incidence of endemic species – that is adapted to grazing disturbances (Cowling *et al*., 1999; Desmet, 2007). Less than 4% of the Succulent Karoo is formally conserved, and it is found in an area classified by agricultural extension officers as being highly degraded (Hoffman & Todd, 2000; May & Lahiff, 2007). However, over a quarter of the Succulent Karoo is relatively pristine (Mittermeier *et al*., 2004); in these landscapes livestock grazing has been practised for 2 000 years, with spatial and temporal variability in forage availability resulting in transhumance being practised in pre-colonial times (Webley, 2007).

However, colonialism led to pastoralists abandoning nomadic life-styles, due to their being constrained to small areas of communally-owned land with the expansion of commercial farming since the 1700s (Hoffman & Rohde, 2007). Stock densities peaked in the 1950s due to favourable climatic and market conditions. They subsequently fell as a result of government-instituted destocking incentives to restore rangelands that were considered degraded (Benjaminsen *et al*., 2006), and the fencing in of commercial farms by white farmers able to take advantage of *apartheid*-era agricultural subsidies unavailable to coloured herders (Rohde *et al*., 2006).

Subsistence pastoralists found themselves marginalised as the combined effects of colonialism, *apartheid* and globalisation profoundly changed land-use patterns, confining herders and restricting mobility (Cousins *et al*., 2007). As a result, high stocking rates and a continuous grazing regime became the norm. This led to changes in the vegetation communities encountered on communal lands as compared to commercial farms in the area (Anderson & Hoffman, 2007; Todd & Hoffman, 1999).

With the globalisation of agricultural markets and the rise of new economic possibilities towards the end of the 20$^{th}$ century, commercial agriculture became less important in the local Namaqualand economy (Hoffman & Rohde, 2007). The exploration of alternative livelihood options such as nature conservation and tourism as means of adapting to Namaqualand's changing climate, land tenure and agricultural contexts have gone hand-in-hand with a decline in livestock numbers (Cousins *et al*., 2007).

With these changing conditions, an improved understanding of Namaqualand's socio-economic and environmental situations is important (Desmet, 2007). This requires proper support to institutions to ensure improved management of rangelands and diversification of livelihood options (Cousins *et al*., 2007). Such an in-depth understanding depends on the incorporation of both scientific and indigenous knowledge into an integrated system that will be able to provide advice during assessment, decision-making and implementation of management initiatives (Bosch *et al*., 1997).

To contribute towards an integration of scientific and indigenous knowledge in management of the Namaqualand rangelands, this study combined a vegetation survey determining the effect that livestock exclusion had on vegetation characteristics within the communal rangelands with a survey of land-user knowledge and perceptions regarding these effects. A comparison of the results of the standard scientific survey methodologies with those from the interviews was undertaken with the view to establishing whether similarities exist between the two knowledge systems, as well as to what degree they can complement each other in obtaining a more holistic understanding of rangeland dynamics. This also allowed for testing of the assumption that removal of grazing pressure will result in the restoration of degraded rangelands, as perceived and predicted by the governmental agricultural departments.

**Relating local ecological knowledge to scientific methodologies**

*Insights into vegetation dynamics*

There was a remarkable congruence between the results of the two methodologies regarding the effects of rest on the vegetation. Neither described unequivocal improvement nor deterioration of rangeland vegetation ascribed to the removal of livestock. The interviews corroborated the findings of the vegetation survey that rest improved grass abundance and forage availability (*cf.* increase of *Hirpicium alienatum* abundance and biomass in Chapter 3). While some growth forms showed changes in species richness, abundance and cover in the vegetation survey, these were the exception rather than the rule; the interviews also showed that rest from grazing did not result in unidirectional changes in the rangeland’s plant community.

Both methodologies agreed on the importance of environmental factors in determining vegetation characteristics. Rainfall, rather than rest, was identified in every interview as the primary factor driving rangeland condition. Both surveys identified site factors – specifically topography, slope and rockiness – as having critical influences on various characteristics of the rangeland vegetation.

The findings of both the conventional scientific study and the interviews suggest that the vegetation dynamics in the Paulshoek commons display both equilibrial and non-equilibrial responses. While some functional growth forms and species increased in abundance, richness or biomass following rest, others decreased or showed no change. The effects of rest on the vegetation in this rangeland are clearly complex, based on a number of factors, and thus difficult to predict. This is also reflected in the findings of Todd and Hoffman (1999; 2009)

Pastoralists recognise that landscapes display seasonal and spatial variability that influence vegetation characteristics and thus grazing capacity (Fernandez-Gimenez, 2000; Mapinduzi *et al*., 2003; Oba & Kotile, 2001). This and other traditional knowledge systems identify climate and landscape factors as being drivers of vegetation composition and condition, along with livestock grazing (e.g. Abule *et al*., 2005; Bollig & Schulte, 1999; Calvo-Iglesias *et al*., 2006; Fernadez-Giminez, 2000; Hussein *et al*., 1999; Mapinduzi *et al*., 2003; Oba & Kaitira, 2006; Solomon *et al*., 2007; Thomas & Twyman, 2004).

Ecologists and managers often treat study areas as homogeneous wholes. This may relate to the propensity for standard scientific methodologies to favour studies with simple designs and analyses – for example incorporating few variables and comparing means rather measures of variation – as these tend to render statistical hypothesis testing easier. A more careful approach to studies of such systems – an approach that includes a suite of environmental, social and economic variables – is called for instead.

*Repercussions for research*

Pastoralists' traditional knowledge systems regarding vegetation dynamics and grazing management (e.g. Abule *et al*., 2005; Bollig & Schulte, 1999; Fernadez-Giminez, 2000; Oba & Kaitira, 2006) show similarities to research findings and management interventions informed by non-equilibrium theories of rangelands (e.g. Briske *et al*., 2003; Briske *et al*., 2008; Buttolph & Coppock, 2004; Ellis, 1995; Savory, 1988; Scoones, 1995; Westoby *et al*., 1989). Herders' perceptions of the implications of grazing and rest for both livestock and rangeland resources are consistent with concurrent field surveys and experiments by conventionally trained scientists (Ayantunde *et al*., 2000; Katjiua & Ward, 2007; Oba & Kotile, 2001).

Since indigenous knowledge can estimate resource population dynamics accurately and cost-effectively (Anadón *et al*., 2009; Mapinduzi *et al*., 2003), it can be advocated as a standard tool to complement ecological surveys. However, differences in interpretation may arise. Herders in this study attributed changes mainly to environmental factors, while Todd and Hoffman (2009) consider livestock as important drivers in the system. While pastoralists and scientists are able to make comparable assessments of range characteristics and condition, interpretations of landscape stability and suitability for grazing often differ between the two approaches (Oba & Kotile, 2001).

Ecological assays generally focus on diversity and abundance measures; biomass and cover are used additionally for especially surveys that have an agricultural slant (e.g. Fernández-Lugo *et al*., 2009; Pykälä *et al*., 2005). Conversely, traditional knowledge systems do not necessarily base their assessments of grazing resources on a Linnaean species concept. Pastoralists may group plant species according to shared characteristics such as toxicity to livestock (Abule *et al*., 2005), or a single species may be known by two different names (Bollig & Schulte, 1999). Amongst Paulshoek herders, *Hermannia amoena* and *Hermannia cuneifolia* are perceived to be male and female plants of the same species.

A species-based approach to surveys that incorporate indigenous knowledge systems may thus prove problematic. Even in conventional scientific methodologies, species diversity indices are not always the most appropriate measure of vegetation responses in grazed landscapes; Pueyo *et al*. (2006) showed that plant community structure provide better indications of grazing effects. Pastoralists appear to be more concerned about qualitative characteristics of the rangeland and its vegetation than species diversity. Forage availability, palatability, and accessibility, spatial and temporal variability of rangelands and resilience to grazing pressure are all important to livestock herders (Fernandez-Gimenez, 2000; Mapinduzi *et al*., 2003; Oba & Kaitira, 2006).

While strict species diversity measures are inappropriate, adoption of a traditional pastoral classification system based on grazing potential may place biodiversity conservation objectives in jeopardy. Instead, integration of the two approaches may lead to the establishment of a classification system with features of both. Given the complexity of such socio-ecological systems, this process would prove time-consuming and challenging. However, it would provide a forum for engagement whereby multiple objectives might be able to be integrated effectively into monitoring and management activities.

A limitation of this study proved to be the finer scale of the botanical survey, when compared to the interviews. Future research in the area could integrate participatory rural appraisals. These could include vegetation surveys with groups of herders or individuals. By asking herders to look specifically at the factors measured in the botanical survey – *viz*. site factors, abundance, richness and cover – within the exclosure site, one might be able to obtain data that is more easily comparable to the conventional vegetation appraisal.

The congruency in the results from conventional scientific techniques and indigenous knowledge surveys shows that integration of the two methodologies is valuable for improving understanding of complexly interacting systems. However, the different approaches that the methodologies employ can create complications in interpretation of results. In order to achieve the clichéd comparison of “apples with apples”, it may be advisable to conduct explorations of indigenous knowledge as a precursor to the implementation of conventional ecological methods. Indigenous knowledge would be able to highlight problems and identify potential interventions. Standard scientific methods may be able to translate these issues into a broader range of suitable hypothesis for testing. This will improve the accuracy of models used to describe such systems and the spectrum and efficacy of suggested interventions, allowing the adoption of more appropriate measures for rangeland resource management.

*Implications for practice*

Management practices stemming from equilibrium models of vegetation dynamics (*cf*. Hoffman *et al*., 1999; Milton & Dean, 1996; Tainton *et al*., 1999) are based on a simplistic and predictive model of the interaction between grazers and vegetation, *viz*. that the removal of livestock will result in improvements to vegetation diversity, cover and biomass. Such grazing strategies advocate fixed stocking rates across designated landscape or vegetation units, regardless of rainfall or other environmental conditions. This was the thinking that informed the government policies that resulted in the destocking and fencing of vast areas of Namaqualand in the second half of the $20^{th}$ century (Benjaminsen *et al*., 2006; Rohde *et al*., 2006).

These practices are increasingly regarded as being inappropriate due to their ignoring the complexity and variability inherent in arid rangelands (Buttolph & Coppock, 2004; Ellis, 1995). The recognition of climate and landscape factors as crucial to understanding arid rangeland dynamics is reflected in the development of non-equilibrium models (Briske *et al*., 2008; Buttolph & Coppock, 2004; Ellis, 1995; Illius & O'Connor, 1999; Scoones, 1995). These models inform management approaches that take such heterogeneity into account by advocating opportunistic stocking rates and grazing strategies (Rohde, 2005).

Interviews with Namaqualand’s pastoralists corroborated evidence in the literature (e.g. Desmet, 2007; Webley, 2007) that rest and transhumance were integral to historic grazing patterns in a landscape that was resilient to such utilisation. However, the restriction of the inhabitants to small communal areas has prevented these traditional pastoral practices being followed. This confinement has resulted in poverty in the communal reserves (Hoffman &

Rohde, 2007; Rohde *et al*., 2006) and constrains the options of herders during droughts, reducing their resilience (Samuels *et al*., 2007). Paulshoek's pastoralists were desirous of a return to an opportunistic grazing system that could allow them to take advantage of the heterogeneity in grazing resources due to landscape and climate variability.

In order for the reinstitution of such a system to be effective, a number of issues would need to be addressed. Improved co-operation between herders and a strengthening of the formal and informal institutions governing grazing practices appear to be essential in Paulshoek, as in other traditional pastoral systems (Abule *et al*., 2005; Allsopp *et al*., 2007; Cousins *et al*., 2007; Rohde *et al*., 2006). Such a persistence of shared ecological beliefs and norms provides a basis for sustainable management of communal resources.

Another key issue identified by participants is the availability of land for grazing. A reduction in available land is a common side effect of colonisation and the move towards commercial pastoralism (Griffin, 2002; Grice & Hodgkinson, 2002; Hoffman & Rohde, 2007), with negative consequences for subsistence herders (Bayer & Sloane, 2002; Cousins *et al*., 2007). Clearly, settled pastoralism is inappropriate in such a spatially and temporally variable landscape (Ash & Smith, 1996; Danckwerts *et al*., 1993). Increasing the size of the commons available to such subsistence pastoralists would provide an ecologically sound manner in which to enable herders to take advantage of rangeland resource variation in time and space.

## Conclusion

It is clear from this study that the complexity of rangeland systems precludes the use of simplistic, predictive models in order to advise management. Such a predictive approach to rangeland systems would emphasise the effect of markets, government, scientists and non-governmental organisations on livestock numbers through forcing pastoralists to maintain prescribed stocking rates (Figure 5.1). The livestock would be perceived as determining the rangeland vegetation characteristics as described by an equilibrium paradigm. Little acknowledgement would be given to the effects of the pastoralists themselves, climate and landscape factors on the vegetation. The historical context within which the system exists, as well as the cultural context within which it evolved, are both largely ignored, as are the need for the pastoralists to interact with other players such as government and science.

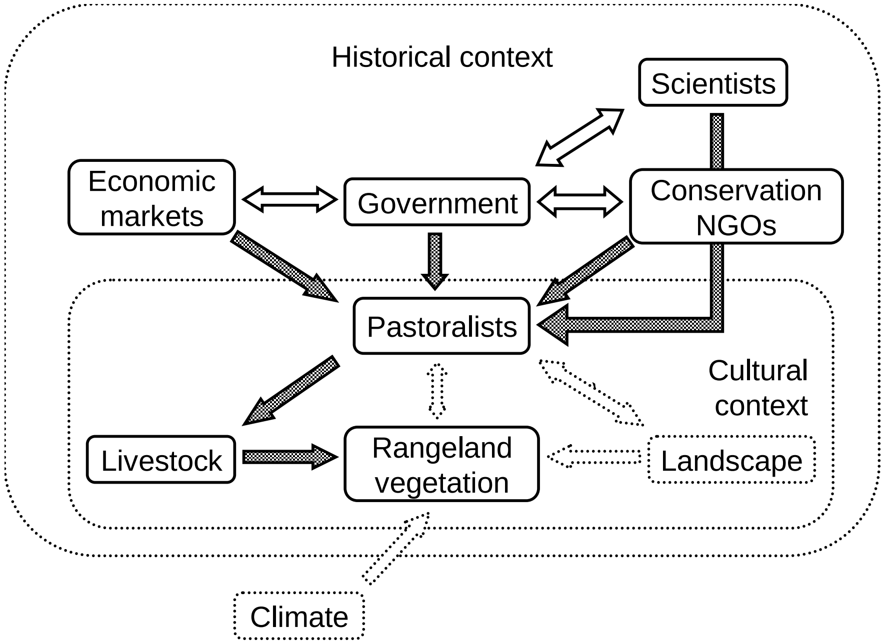


*Figure 5.1*. Conceptual model of a simple, predictive interpretation of the interactions between various factors in a rangeland system. Dark arrows indicate the nature of those relationships seen as most important; dotted arrows and boxes indicate relationships and factors not recognised as being of major consequence.

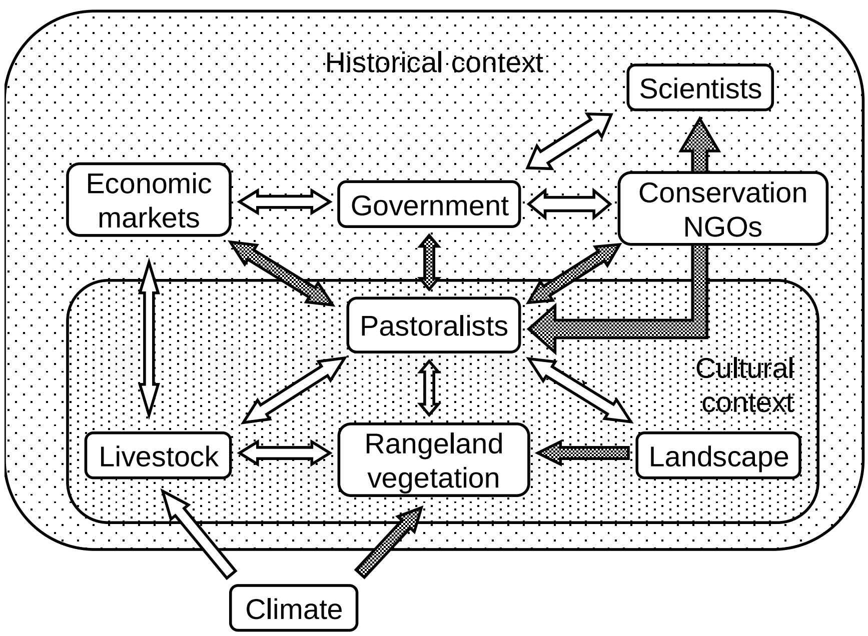


*Figure 5.2*. Conceptual model of a complex interpretation of the interactions between various factors in a rangeland system. Dark arrows indicate the nature of those relationships seen as most important; shaded boxes indicate factors recognised as being of major consequence.

An approach that recognises the complexity of rangeland systems would allow for more intricate interactions (Figure 5.2). Key to this conceptualisation are the reciprocal interactions between pastoralists and other stakeholders, and the recognition of the importance of climate and landscape factors in determining vegetation characteristics. The system is also seen within its proper historical and cultural contexts.

The complexity of the Paulshoek social and ecological systems, and the interactions between them, make it impossible to implement a generic, static management strategy. Grazing systems that link with traditional knowledge are more likely to take the variability of the natural, social and economic environments into account. Rangeland scientists should acknowledge the validity of local knowledge and perceptions of rangeland resources and incorporate pastoralists' knowledge into rangeland management systems – after all, they interact most directly with the resource base. Empowering the community through participatory monitoring and co-operative decision-making in this way will increase the adoption of such strategies, contributing to improved sustainability of interventions.

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