Fencing Impacts:
A review of the environmental, social and economic impacts of game and veterinary fencing in Africa with particular reference to the Great Limpopo and Kavango-Zambezi Transfrontier Conservation Areas

K. Ferguson & J. Hanks

Editors

100
1908 - 2008
UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Mammal Research Institute

Table of Contents

Acknowledgements 5

Editorial Note 5

List of Abbreviations 6

Foreword 11
(Daniel T Haydon)

Executive Summary 12
(Ken Ferguson & John Hanks)

1. Introduction

1.1 Introducing this review. 18
(Ken Ferguson)

1.2 Generic objectives of TFCA establishment and the importance of wildlife corridors 22
(John Hanks)

2. Fences and People

2.1 Transfrontier conservation in southern Africa: Taking down the fences or returning to the barriers? 26
(Marja Spierenburg & Harry Wels)

2.2 Governance and decision-making: Fencing in the Great Limpopo and the Kavango-Zambezi Transfrontier Conservation Areas. 36
(Mike Schoon)

2.3 The advocacy role of NGOs in promoting dialogue as a means of resolving conflicts resulting from veterinary cordon fencing in Botswana. 40
(Karen Ross)

2.4 The impacts of veterinary cordon fences on livelihoods and natural resource use in Botswana. 44
(Daniel McGahey)

2.5 Fences and conflicts in the Lubombo TFCA. 49
(Roelie Kloppers)

2.6 What do the local communities say about fences? 53
(Petronella Chaminuka)

3. Disease Control and Fencing

3.1 Current policies for epizootic disease containment in the southern Africa sub-region. 56
(Richard Burroughs)

3.2 New ideas that may impact on future fencing strategies in sub-Saharan Africa. 62
(Gavin Thomson)

3.3 Fencing along the Kruger National Park boundary. 66
(Dewald Keet, Lin-Marie de Klerk-Lorist, Roy Bengis & Ken Ferguson)

3.4 The newly proposed Laikipia disease control fence in Kenya. 71
(Richard Kock)

3.5 Zimbabwe's livestock disease control policy in relation to fencing. 75
(Chris Foggin)

4. Fencing Impacts on Ecosystems and Populations

4.1 The Scott Wilson 'fencing impacts' report: ten years on. 83
(Arthur Albertson)

4.2 Veterinary cordon fences and environmental change in northern Botswana. 99
(Daniel McGahey)

4.3 Fences and landscape scale degradation. 108
(Jem Perkins)

4.4 Environmental assessments of Botswana's fences 121
(Debbie Gibson)

4.5 Fences in Botswana: every fence should be judged on its own merits. 128
(Chris Brooks & James Bradley)

4.6 The relationship between fencing and the bushmeat trade. 134
(Peter Lindsey)

4.7 Impacts of fencing on the migration of large mammals in the Kruger National Park. 137
(Ian Whyte & Salomon Joubert)

4.8 Linkages, wildlife corridors and shortfalls in the KAZA TFCA. 144
(David Cumming)

4.9 Climate change and fencing impacts. 151
(Anton Seimon)

5. Species specific fencing interactions

5.1 Ground Pangolins and electric fences. 154
(Darren Pietersen)

5.2 Baboons and fencing in the Western Cape. 158
(Justin O'Riain & Tali Hoffman)

5.3 Mitigating the barrier effect of above-ground pipelines for moose (*Alces alces*) in northern Canada. 163
(*Mike Quinn & Bridget Dunne*)

5.4 Conservation fencing strategies in Australia. 168
(*Matt Hayward)*

5.5 Elephants and fencing conflicts in the GLTFCA and KAZA TFCA. 173
(Ken Ferguson & Mike Chase)

5.6 Kruger's elephants and fences: possible mitigation strategies. 181
(Rina Grant)

5.7 The use of electrified fences to mitigate human-elephant conflict: experiences from the Laikipia Plateau in northern Kenya. 185
(Max Graham & Tobias Ochieng)

5.8 A discussion of possible non-lethal methods to deter elephant damage to veterinary and game fences 193
(Loki Osborn)

6. Monitoring and planning the role of fencing in TFCAs

6.1 Monitoring fence permeability along the western boundary fence of Kruger National Park, South Africa. 196
(Ken Ferguson & Ferran Jori)

6.2 A spoor method for measuring fence crossing rates. 203
(Colin Bonnington)

6.3 TFCA integrated development planning processes and fences: 'babble, babble, toil and trouble'. 209
(Paul Bewsher)

6.4 Delineating and decommissioning of park and veterinary fences. 223
(Antony Alexander & Ken Ferguson)

6.5 Preliminary results on the permeability of veterinary fences to buffalo *(Syncerus caffer)* and cattle in Gonarezhou National Park, Zimbabwe.
(Timothy Dube, Amon Murwira, Alex Caron & Michel de Garine-Wichatitsky) 228

7. Land use options and fencing strategies

7.1 The impact of fences within the Kruger to Canyons Biosphere Reserve. 232
(Mike Peel)

7.2 The influence of fencing in the development and limitation of wildlife-based land uses in southern Africa. 239
(Peter Lindsey)

7.3 Conservation on private land in South Africa: management without boundaries? 245
(Matt Child)

7.4 The economic impacts of game and veterinary fencing 252
(Ken Ferguson)

7.5 Land use management on the border of Kruger National Park, the case of the Nghunghunyani buffer zone project 259
(Jotte van Ierland)

7.6 Nairobi National Park Wildlife Conservation Lease Project and the fencing problem.
(David. K. Ole Nkedianye) 263

8. Recommendations for the management of fences in TFCAs

8.1 Developing guidelines for the management and monitoring of fences. *(Ken Ferguson)* 267

8.2 Fencing and the 'Barrier-Effect': Research needs, innovations and knowledge gaps *(Ken Ferguson, Elissa Cameron & John Hanks)* 273

9. References

References for all contributions consolidated in a single list to avoid duplications 282

10. Appendices

10.1 Technical aspects of fencing *(Lyle Kelly & Tubby Hardman)* 318

10.2 TFCA up-date and extent of fencing in the GLTFCA and KAZA TFCA *(John Hanks)* 325

Recommended citation: Ferguson, K. & Hanks, J. eds., 2010. *Fencing Impacts: A review of the environmental, social and economic impacts of game and veterinary fencing in Africa with particular reference to the Great Limpopo and Kavango-Zambezi Transfrontier Conservation Areas.* Pretoria: Mammal Research Institute. Available at:http://www.wcs-ahead.org/gltfca_grants/grants.html

Acknowledgments

The Editors would like to extend their sincere gratitude to all of the contributors to this volume, particularly for the great efforts made to meet tight editorial deadlines. We believe that this truly multi-disciplinary effort will help to positively address some of the complex questions that have arisen with regards to 'fencing matters' over the last half century in Africa.

We would also like to thank Daleen Funston, Administrator, at the Mammal Research Institute, University of Pretoria for her assistance with financial matters.

Ken Ferguson would especially like to thank all those who have helped him in many ways during his recent 'fencing field work' in Kruger National Park, especially Dewald Keet, Roy Bengis, Rina Grant , Phin Nobela and Patrick Baloyi and all of the Kruger fence workers employed by the Department of Agriculture (South Africa).

We would also like to extend our sincere thanks to Professor Elissa Cameron, Director of the Mammal Research Institute, University of Pretoria, to whom this grant was awarded.

Editorial Note

In this review we have attempted to 'showcase' some of the best and most novel research that relates to the environmental, social and economic impacts of game and veterinary fencing in Africa. Fifty-two authors have contributed to this volume. However, our selection is by no means comprehensive as other researchers are dedicating much of their time and effort to this important topic. Although it may at first glance appear that certain contributions duplicate each other in terms of content, closer examination will reveal important differences in perspectives on a similar issue.

Whilst this review is intended to have a focal point concentrating on fencing issues in southern Africa with particular reference to two TFCAs, some of the contributions are from East Africa and two are from outside of the continent. We hope that all the contributions will help to stimulate interest and constructive debate around the issue of fencing and its impacts.

Due to time constraints the contributions have not benefited from being externally peer reviewed.

The views and opinions expressed in this report are strictly those of the contributors, except where otherwise stated or referenced.

Ken Ferguson and John Hanks, Western Cape, South Africa. May 2010

Copies of this report are available from Ken Ferguson: selousgame@hotmail.com and online at http://www.wcs-ahead.org/gltfca_grants/grants.html

List of Abbreviations

ACB	Anthropogenically Created/Constructed Barrier
ADC	Agricultural Development Corporation
ADMADE	Administrative Management Design for Game Management Areas (Zambia)
AfESG	IUCN/SSC African Elephant Specialist Group
AHCOF	Ad Hoc Committee on Fences
AHEAD	Animal & Human Health for the Environment And Development
APNR	Association of Private Nature Reserves
ASF	African Swine Fever
AU	African Union
AWC	Australian Wildlife Conservancy
AWF	African Wildlife Foundation
BFA	Biodiversity Foundation for Africa
BMC	Botswana Meat Commission
BMZ	German Ministry for Economic Cooperation and Development
BTB	Bovine tuberculosis
BOCOBONET	Botswana Community Based Organizations Network
CAC	Codex Alimentarius Commission
CAMPFIRE	Communal Areas Management Program for Indigenous Resources
CBNRM	Community Based Natural Resource Management
CBO	Community Based Organization
CBPP	Contagious Bovine Pleuropneumonia
CBT	Commodity Based Trade
CHA	Controlled Hunting Area
CIRAD	International Centre for Research, Development and Agronomy
CODEOSUB	Conservation and Development Opportunities from the Sustainable Use of Biological Diversity in the Communal Lands of Southern Africa
CONASA	Conservation of Natural Resources and Sustainable Agriculture
DAFF	Department of Agriculture, Forestry and Fisheries (South Africa)

DAHP	Department of Animal Health & Production
DBSA	Development Bank of Southern Africa
DCA	Damage Causing Animals
DEAT	Department of Environmental Affairs and Tourism
DEFRA	Department of Environment, Food and Rural Affairs
DFID	Department for International Development (UK government)
DNPWM	Department of National Parks and Wildlife Management (Zimbabwe)
DWNP	Department of Wildlife and National Parks
DVS	Department of Veterinary Services
EA	Environmental Assessment
EC	European Commission
ECTAD	Emergency Centre for Transboundary Animal Diseases
ELAND	Enterprise Linkage to Conservation and Development
EPSMO	Environmental Protection and Sustainable Management of the Okavango River Basin
ERL	Elephant restraining lines
FAR	fence across river
FIRM	Fence Interface Research and Monitoring group (MRI-University of Pretoria)
FISS	Fence Incident Surveillance System
FoNNaP	Friends of Nairobi National Park
FMD	Foot-and-mouth disease
GCM	Global General Circulation Climate Model
GEF/UNDP	Global Environmental Facility/United Nations Development Programme
GIS	Geographical Information System
GLTFCA	Great Limpopo Transfrontier Conservation Area
GMA	Game Management Area
GNP	Gonarezhou National Park
GPS	Global positioning system

HEC	Human-elephant conflict
HWC	Human-wildlife conflict
ICEMA	Integrated Community-based Ecosystem Management
ICRAF	International Centre for Research in Agroforestry
IECN	Integrated Environmental Consultants Namibia
IGF	International Foundation for the Conservation of Animals
ILRI	International Livestock Research Institute
IMP	Integrated Management Plan
IRBM	Integrated River Basin Management
IRDNC	Integrated Rural Development & Nature Conservation (NGO in Namibia)
JMB	Joint Management Board
KAZA TFCA	Kavango-Zambezi Transfrontier Conservation Area
K2C	Kruger to Canyons Biosphere Reserve
KCS	Kalahari Conservation Society
KfW	Kreditanstalt für Wiederaufbau (German Bank for Reconstruction)
KNP	Kruger National Park
KPNR	Klaserie Private Nature Reserve
KVTC	Kilombero Valley Teak Company
KZCDA	Kafue Zambezi Conservation Development Association
LIFE	Living In a Finite Environment
LITS	Livestock Identification and Trace-back System
LMH	Large mammal herbivore
LNP	Limpopo National Park
LTFCA	Lubombo Transfrontier Conservation Area
MCF	Malignant Catarrhal Fever
MET	Ministry of Environment & Tourism
M&EWG	Monitoring and Evaluation Working Group
MGR	Manyeleti Game Reserve
MSP	Maputo Special Reserve

MoU	Memorandum of Understanding
MPNP	Makgadikgadi Pans National Park
MRI	Mammal Research Institute (University of Pretoria)
NACSO	Namibian Association of CBNRM Support Organisations
NADP	New Agricultural Development Policy
NBF	Northern buffalo fence
NEPAD	New Partnership for Africa's Development
NGO	Non Government Organization
NNF	Namibia Nature Foundation
NNP	Nairobi National Park
NP	National Park
NPWS	National Parks and Wildlife Service
NRMP	Natural Resource Management Project
OIE	Office International des Epizooties – now the World Organization for Animal Health
OKACOM	Okavango River Basin Commission
OPWT	Okavango Peoples Wildlife Trust
PES	Payment for Environmental Services
PMU	Project Management Unit
PPF	Peace Parks Foundation
SADC	Southern African Development Community
SAFCAN	Southern African Community Based Organisations and Non–Governmental Organisations
SANParks	South African National Parks
SAP	Strategic Action Programme
SAREP	Sustainable Agriculture Research and Education Program
SDI	Spatial Development Initiative
SELZ	South-East Lowveld, Zimbabwe
SIDA	Swedish International Development Agency
SMART	Specific, measured, appropriate, researched, technology (fencing)
SSC	Species Survival Commission (IUCN)

SSW	Sabi Sand Wildtuin
TAD	Transboundary Animal Disease
TBNRM	Transboundary Natural Resource Management
TCC	Transfrontier Conservation Consortium Consultancy
TCL	Transvaal Consolidated Land and Exploration Company
TEP	Tembe Elephant Park
TFCA	Transfrontier Conservation Area
TDA	Transboundary Diagnostic Assessment
TLU	Tropical Livestock Unit (equivalent to 250Kg in weight)
TPNR	Timbavati Private Nature Reserve
TWF	The Wildlife Society
UNESCO	United Nations Educational Scientific and Cultural Organisation
UPNR	Umbabat Private Nature Reserve
USAID	United States Agency for International Development
USFWS	United States Fish and Wildlife Service
UTM	Universal transmercator
VAG	Village Action Group
VCF	Veterinary Cordon Fence
WCS	Wildlife Conservation Society
WMA	Wildlife Management Area
WTO	World Trade Organization
WWF-SA	World Wildlife Fund – South Africa
WWF-SARPO	WWF-Southern Africa Regional Programme Office
ZAMCOM	Zambezi Basin River Commission
ZAWA	Zambia Wildlife Authority
ZAZIBONA	Zambia Zimbabwe Botswana Namibia Community Association
ZNPWA	Zimbabwe National Parks and Wildlife Management Authority

Foreword

Professor Daniel T. Haydon, BSc.PhD.FRSE.
Faculty of Biomedical & Life Sciences, Ecology & Evolutionary Biology, Graham Kerr Building, University of Glasgow, G12 8QQ, Scotland, United Kingdom.
d.haydon@bio.gla.ac.uk

The diversity of contributions to this document underscores the myriad potential impacts of fences on both people and their livestock, and ecosystems and their constituents. In order to determine when and where to build fences, and how best to mitigate the interference resulting from them requires careful quantification of their impacts. But here is the difficulty. The impacts may be subtle, counter-intuitive, confounded, and manifest in places far removed from the fence location. Fences are just one more - often recent - change to environments that are undergoing numerous other forms of change, and to identify their impacts on systems that we care about requires dissecting and extracting signal from a complex cacophony of responses to other perturbations.

Ecology is often described as the study of the distribution and abundance of organisms. And a great deal of study it requires. Even enumerating individuals in a population, or prevalence of a pathogen amid a population often requires an intimidating and complex combination of hard work, sophisticated study design, and demanding statistics. Capturing the distribution of this abundance over landscapes is even harder, and relating the heterogeneities revealed to their correct drivers harder still. Now attempt to ascertain from individual members of these populations information about their condition, health, or stress levels and we begin to understand why progress in ecology and epidemiology often seems so hard-won.

Such apparently simple questions are genuinely hard. Answers must often be inferred from small samples that are frequently biased in complex ways that must be carefully corrected for, prior to any inference being made. Uncertainty is a constant and often over-sized companion with whom a good understanding must be made. All of this means that 'good' science is often difficult to do.

However, decision making in the midst of a diverse community of stakeholders, each with perfectly legitimate interests in different particular outcomes is when good science matters most. Just, sustainable and directed management policies cannot be formulated in the absence of a sound scientific appraisal of the available evidence base. Such an appraisal might lend clear support to particular policies; more likely, policies must be formulated cognizant of ambiguities in the evidence base, and management designed in a manner that can both add and adapt to our changing understanding of the systems we must live within.

This document represents an important contribution to the synthesis and appraisal of the evidence base surrounding this high-dimensional and complex issue. Its compilation is exactly the sort of stock-taking activity that is essential for assessing the effectiveness of current fence management procedures and determining future research priorities.

Executive Summary

Ferguson, K.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
selousgame@hotmail.com

Hanks, J.
Consultant, P.O. Box 254, Greyton 7233, South Africa.
hanksppt@iafrica.com

"Wildlife corridors designed to connect protected areas can also serve as biological bridges for vectors and the pathogens they carry" AHEAD-GLTFCA (2008).

The above quote encapsulates the dilemma that weaves its way through this review on the environmental, social and economic impacts of game and veterinary fencing. The veterinary fences erected since the 1950s in southern Africa, were and still are, meant to serve a purpose for the common good of the citizens of the countries within which they lie, by protecting national herds from disease (see Box 10.2 for an estimate of the extent of veterinary cordon fencing in southern Africa). The stemming of a transboundary animal disease outbreak is an expensive, time-consuming effort and it can lead to multiple deaths of both humans and animals. For example the current Rift Valley Fever epidemic in South Africa has led to a number of human fatalities (Khan, 2010). Indeed the rapidity with which this epidemic swept down the length of the country has spurred on the development of a South African vaccine bank for this and other diseases (Cape Times 2.5.2010). On another level, the multiplicity of African mammal-related disease transmission networks, which interact with veterinary cordon fencing (which represents an essentially static disease intervention strategy that intentionally disrupts the contact structure between wild and domestic animals and pathogens) requires more in-depth study (Kock et al., 2010). It is only relatively recently that there has been 'recognition *of a fundamental association between disease and environmental variables'* (Hess et al., 2002). The fact that pathogenic transmission events can cross a barrier such as a fence illustrates that changes to landscape structure and function (e.g. by imposing fencing) may affect the dynamic behaviour of the disease in question (McCallum 2008; Ducheyne et al., 2009; Reisen, 2010).

At the southern African wildlife/livestock disease interface, wildlife fences, in one form or another (i.e. to control diseases and/or to function as protected area biosecurity barriers) seem set to remain a part of the landscape. Or are they? This compendium does not represent an exhaustive array of research on the impacts of fences (and, more broadly, habitat fragmentation research), but it does give an insight into the multi-dimensionality of the impacts of these extremely simple physical structures that engender complex and radiating effects. To gain an understanding of this complexity is a prerequisite to ameliorating, where possible, the worst excesses of fencing in term of impacts on conservation efforts.

The Great Limpopo Transfrontier Conservation Area (GLTFCA) and the Kavango-Zambezi TFCA (KAZA TFCA) have a combined total area of nearly half a million square kilometres (Cumming, 2008; AHEAD, 2008), with an

ambitious vision of creating something new and yet diverse in terms of a conservation strategy. But, fulfilment of this innovative approach is called into question when fences appear to 'stand in the way'. The good news is that because fencing is so simple (but costly) to erect it should be relatively easily to take down (in theory at least), the 'scars' on the landscape can then heal post-fence removal. Alexander and Ferguson (6.4) show how, over a long period of time (over eight years thus far), fences can be successfully removed. The removal of the Kruger National Park's eastern border fence with Mozambique is a seminal event in the history of these types of barriers in southern Africa. This acclaim must be tempered by the fact that the removal of the fence will allow both animals and pathogens to repopulate Kruger's neighbour, Limpopo National Park.

The process by which fencing is removed, realigned or erected and governed is long and arduous and it is well explained in political terms by Schoon (2.2) and in practical terms by Bewsher (6.3). What emerges from these two contributions is that the involvement of stakeholders of all 'shapes and sizes' is critical to the success or otherwise of reducing the negative impacts of fencing. Just who are these stakeholders? Fencing issues are an exemplary illustration of 'top-down' and 'bottom-up' hierarchical scales mixing and meeting at critical junctures in the 'life history' of a fence, which, translates into the involvement of many diverse groups of people. Fences when viewed as a front-line defence against epizootic outbreaks are discussed by Burroughs (3.1), and Thomson (3.2) gives us some background detail into the *rationale,* perhaps flawed in some cases (see the section by Kock (3.4)) of a disease control fencing strategy and explanation of possible alternatives. Zimbabwe shows clearly how marked societal change can impact massively on fencing structures and wildlife/livestock related disease control strategies (Foggin 3.5).

Spierenburg and Wels (2.1) set fencing into its human cultural and historical dimension and illustrates once again that a fence may look simple but that its impacts can be wide reaching, and arguably, fence construction and use can be related to the quest for power and control by dominant social forces. In an environmental history context we can see that fencing, has been and is, a tool of land privatisation and appropriation that exists to delimit and exclude people and animals from state and private land assets, fences therefore 'seize' and fragment natural capital (the land; this 'dispossession of the commons' is happening in real time in areas where pastoralists are currently changing their lifestyles; see Nkedianye, 7.6).

Alternatively, one could argue that 'strong' fences reflect a strong and 'hands on' State. Ross (2.3) illustrates an example from Botswana, where over a period of three decades there has been controversy over the placing of veterinary cordon fences; just how these fences have impacted on the livelihoods of the Batswana is discussed by McGahey (2.4). 'Fence rage' may not be uncommon amongst rural people. Kloppers (2.5) chronicles the sad 'stand-off' between conservation aims and rural development that led to the destruction of a small, but critical area of Ramsar wetland in Kwa-Zulu Natal (South Africa) and he also documents the incredibly protracted negotiations relating to the building of a fence that would protect both people and animals as they traversed parts of the Lubombo TFCA.

Fencing can of course have a positive conservation purpose (Ferguson et al., 8.2). Brooks and Bradley (4.5) also make the extremely important observation that all fences have different attributes and impacts due to the different landscapes and environmental within which they are set and at times these

barriers may be a crucial adjunct to conservation efforts. Kruger National Park's western boundary fence is primarily a disease control fence but it also functions to demarcate the hard-edged boundary of the park and to reduce human-wildlife conflict as described by Keet, et al., (3.3).

On the other side of the fence, people are rarely asked what they think about a fence that restricts their movement. Chaminuka (2.6) asks some questions directly relating to human 'fence neighbours' and gathers some interesting replies. Various social studies appraising attitudes by people (amongst them some of the poorest people in South Africa) who live next to the to the Kruger National Park have shown that a level of goodwill and understanding of why the park should continue to exist (e.g. see Lagendijk & Gusset 2008), and this besides the fact that a fence separates local settlements from the park. Several years ago, Kruger management attempted to co-opt an element of local management and control into two trial sections of fence line, with generally promising results (B. Schraader, pers. comm. January 2009). Could new ways of enticing participatory co-management (between state and local communities) of the contentious Kruger fence be of future benefit to both park and people?

Van Ierland (7.5) explores ways that people could be brought into conservation around Kruger's border and how his communities 'biogas' work also raises the enticing prospect of a win:win situation, in that kraaling cattle at night is essential for collecting enough fresh dung to convert to 'biogas'. Kraaling should also decrease the amount of livestock killed by lions, which again occurs mostly at night, and hopefully at the same time decrease the rate of lion poisonings in the area. The win:win scenario would be that cattle are protected, free domestic gas produced, lions protected and less pressure on the riverine forests to produce charcoal in order to provide household energy.

But what is all the fuss about with regards to fencing? How do fences (game or veterinary) impact upon the environment? The answer is through multiple causal pathways. The veterinary fencing issue in Botswana is the most controversial and in some ways the most understood. Perkins (4.3) and Gibson (4.4) give us the hard facts, and it makes for sad reading. Albertson (4.1) charts the remarkable and contested Scott Wilson Report (2000) that set the scene for much discussion on the Botswana veterinary fences. McGahey (4.2) reminds us that there is still more to learn with regards to fencing impacts and his exemplary Ph.D. will do much to enlighten us. Lindsey (4.6) points out an obvious (so obvious it is often overlooked) negative attribute with regards to fencing impacts – that fence wire can sometimes be used for making snares thus increasing the bushmeat trade, damaging fence efficiency and increasing fencing costs. The impacts of fencing have also been felt in South Africa. Whyte and Joubert (4.7) estimate that Kruger's fence has been partly responsible for the decline of some large mammal populations, and yet it is not a 'black and white' issue as the park also has reaped some benefits from the fence (as mentioned above). Blue wildebeest (*Connochaetes taurinus*) seem to be a particularly fence 'sensitive' species, this species mobility is an adaptation to cope with drought and seasonal flux in resources, fences limit such seasonal movement and can lead to a variety of demographic effects that may involve deleterious changes in the age and sex structure of populations (see Gaillard et al., 2010 for examples of long-term demographic effects) as well as direct individual mortality at the fence itself. Therefore, movement and utilisation by large herbivores amongst heterogeneous landscapes that are rich in resource patches can enhance population growth rates and 'increase supportable

densities of animals' (Hobbs and Gordon 2010), homogeneity and fragmentation of landscapes (in part caused by fencing) engenders the opposite effect. Cumming (4.8) critically examines the need for wildlife corridors that may buffer fence sensitive species against population decline due, in part, to fencing.

Climate change effects on wildlife and livestock populations that inhabit semi-arid savannas may be compounded by the intransigent nature of fencing policies, especially, when it is considered that *'variable weather is the primary driver of changes in (large herbivore) population abundance, with the prevailing density level merely modifying its expression'* (Owen-Smith 2010). Seimon (4.9) discusses the great imponderable of how climate change may affect the role and impacts of fencing, and outlines some possible scenarios.

Fencing impacts can sometimes be overtly simple. Pietersen (5.1) shows how the thoughtless design of electric fencing is causing real problems for the rarely seen ground pangolin, and he offers us all a remarkably simple and yet effective solution. Baboons will almost always have the edge over fences, and yet, these amazing animals are now engaged in urban 'guerrilla' warfare in the suburbs and wine vineyards of Cape Town where fencing again plays a defensive role against humans and other primates as described by O'Riain and Hoffman (5.2).

A bigger issue, in at least a physical size sense, is the important role that fencing has on the behaviour of elephants in Africa. Ferguson and Chase (5.3) illustrate this with two very different 'elephantine' examples from KAZA TFCA and from Kruger. Grant (5.4) picks up the story on how to stop Kruger's elephants leaving the park and perhaps facilitating diseased buffaloes to exit through elephant fence breaks and infect local livestock. Electrification of a fence is one option to attempt to deter elephants going where they are not wanted and this has been tried and tested in Laikipia, Kenya as described by Graham and Ochieng (5.5). Osborn (5.8) confirms that in the case of elephants a holistic approach to stopping crop raiding and fence damage is the only one that is likely to be effective.

In order to comprehend the magnitude of fencing impacts we ideally need a robust monitoring system that can deliver good quantitative data. Ferguson and Jori (6.1) have designed a fence monitoring system for the Kruger fence based on the physical and geo-spatial nature of fence breaks. Bonnington (6.2) has used a different method based on spoor tracking along fences in southern Tanzania that are meant to protect teak plantations from wild animals. Dube et al., (6.5) have shown that quantifying and indentifying spoor tracks can create fence permeability statistics and potentially help to quantify the contact rates between wildlife and domestic animals, supposedly separated by a fence.

If the TFCA concept is to become a practical reality then TFCAs must have a comprehensive view of society and its role in the management and conservation of natural resources. Peel (7.1) shows us how stakeholders and the land use options they advocate in the proposed Kruger-2-Canyon biosphere reserve, may be affected by fencing. Land use is again the theme of Child (7.3) who examines in detail how private and commercial concerns and fencing strategies interlink. Herein lies a conundrum, Bothma et al., (2009) state that in South Africa their estimate of total investment in wildlife ranching infrastructure between the years 2001-2002 was a staggering US$ 1.6 billion, but, what percentage of this was used to further fragment landscapes by the use of fencing and conversely how often were fences removed in order to

amalgamate individual farms into conservancies. The risk of over-stocking with game, abetted by fencing (which retards 'natural' dispersal), so as to turn a fast profit, could have longer-term consequences for the sustainability of the industry. Lindsey (7.2) makes an important further contribution to the debate on the growth of the wildlife sector in southern Africa and specifically lays out the pros and cons of fencing in relation to wildlife use diversification.

Western et al., (2009) have shown that the sedentarization of pastoralists, with subdivision of land being enforced by fencing, leads to sharp declines of wildlife populations. Nkedianye (7.6) makes the critical 'leap' between land tenure-ship and the 'onward march' of fencing. The 'easement' policies of East Africa are proving to be of use in controlling the expansion of fencing, and yet, this policy may not be applicable to much of Southern Africa because of the high variability in State and Private land ownership in this region. It is also possible that 'easements' may start to permutate into different conservation strategic areas producing such hybrids as 'TFCA Easements' or 'Buffer Zone easements'. One thing is for certain, the impact and future role of fencing is inextricably linked to land ownership for the simple reason that barriers primarily function to keep people and animals in or out, which is the *sine qua non* of all private values.

Ferguson (7.4) attempts to view fencing in an economic perspective. Illustrating the international nature of anthropogenically induced barriers, for good or ill, are contributions from Australia by Hayward (5.4) and Canada by Quinn and Dunne (5.3). A global exchange of information on these barriers will be vital to moving forward towards mitigating and even undoing the habitat fragmentation related to fencing, railways, pipe lines, roads, human settlements and all other types of anthropologically created barriers (ACBs).

What can this review recommend with regards to the role and nature of fencing in TFCAs? Guidelines based on harmonised data and analysis would be a first step toward the development and integration of fencing 'problems' into TFCA governance structures (8.1). Perhaps other methods will evolve that will eventually see the lessening of the need for fences (Thomson, 3.2) and these potentialities are discussed in the last section by Ferguson, et al., (8.2). In summary we can conclude:

- Fencing is a major driver of habitat fragmentation, and perhaps of landscape epidemiology (e.g. Ducheyne et al., 2009; McCallum 2008). The spatial heterogeneity of landscapes that is initially created by environmental gradients (e.g. of rainfall) is to an extent 'tended' by large (and small and medium) herbivores and expressed in their own movement patterns and it is this disruption caused by fencing and other forms of habitat fragmentation that constitutes the greatest threat to semi-arid savannas.
- Some species (such as blue wildebeest) and ecosystems (particularly arid and semi-arid) are highly susceptible to the disruption induced by fencing.
- There is no generic set of impacts for all types of fencing, as this will vary with the types of fencing, extent, aims and purposes of the fencing and the species, ecosystems and diseased management regimes involved.
- It is essential that a holistic view is taken on the impacts of veterinary fencing. Conservationists must allow themselves to be swayed by the reasoning underlying those trying to protect national livestock herds

from diseased wildlife, or they must present realistic and workable alternatives.

- Further research is required particularly pertaining to the role of the spatially heterogeneous forces that 'push-pull' (Ogutu et al 2010) large herbivores across landscapes and that underpin the 'drivers' which motivate them to cross fences. The role of carnivore and herbivore 'drivers' of fence movement are likely to be different, but inter-related.
- The active role of fencing in blocking the transmission routes of pathogens also requires further attention. Landscape epidemiology in relation to pathogen distribution (and the social grouping of hosts) must be changed to some extent by habitat fragmentation (and wildlife corridors), how this occurs and how such answers may help to combat these diseases is of fundamental importance to conservation and human development in Africa.

1. INTRODUCTION

1.1 Fencing Impacts: A review of the environmental, social and economic impacts of game and veterinary fencing in Africa with particular reference to the GLTFCA and KAZA TFCA

Ferguson, K.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
selousgame@hotmail.com

Introduction

The multiple and complex, social, economic and environmental issues that are associated with game and veterinary cordon fencing in Africa (and the world) are now being investigated intensively (Somers & Hayward (*in press*) and the contributions therein). Fences represent a pervasive and increasingly important key 'anthropologically created barrier' (ACB) that sub-divides and fragments the 'natural' from the 'human-derived' landscapes in Africa and more specifically separates wildlife from livestock production areas and human settlements. Permeable fences allow a flow rate of large mammals that leads to problems associated with the primary intended functions of the fence i.e. the blocking of the pathways of wildlife-livestock disease transmission (an indirect form of human-wildlife conflict), and secondarily, by reducing the more direct aspects of human-wildlife conflict (e.g. human-elephant conflict).

The history of fencing policy in southern Africa would appear to be at odds with the more recently developed policies for developing long-term transfrontier conservation aims. Therefore, policy options for guiding fencing decisions must be explored and set within the context of disease containment options and, more broadly, conservation goals. It should also be made very clear that fencing in Africa should not always be seen to be at odds with conservation. Some fences 'protect' protected areas from encroaching human settlements, overgrazing by livestock and poaching. Similarly, veterinary cordon fences aim to insulate the national livestock herds (of both rich commercial and poor communal livestock farmers) of many countries from outbreaks of devastating epizootic diseases (devastating, in terms of animal health, human livelihoods and economic losses by the nation as a whole), if these fences were not present, would livestock farmers be calling for the eradication of all disease vector-carrying wild animals?

This '*Fencing Impacts Review*' should be seen as an initial 'stepping-stone' to the development of a more comprehensive knowledge base, related to the needs of fence management and maintenance, fence monitoring, and implementation of allied policies (such as wildlife corridor development) in transfrontier conservation areas (TFCAs). Ultimately, this should lead to the drafting of Transfrontier Fence Management Plans for individual TFCAs.

The conservation and developmental success of the Great Limpopo TFCA and Transfrontier Park (GLTFCA / GLTP) and the Kavango-Zambezi (KAZA) TFCA will depend upon a solid understanding of the complex issues surrounding approaches to the permissible mobility of wildlife and livestock. Park and

veterinary cordon fences in southern Africa have, since the 1950s been a part of the delimitation of wild areas and the diseases that may be contained therein. In the case of veterinary fences these structures bisect extensive areas of rangeland where domestic livestock and wild herbivores might otherwise co-exist or compete.

This review should help to facilitate discussion on these issues and increase the regional transfer of knowledge among stakeholders with regard to the long-term resolution of fencing issues. The harmonization of fencing policy and the exploration of viable, science-based alternatives among a TFCA's partner countries will be a complex and time-consuming process that will require the involvement of a variety of stakeholders representing divergent interests.

The remit requires a cross-sectoral review of the evidence pertaining to fencing successes and failures that can help to inform future actions and research. Recognizing and fully respecting the sovereignty of each country, this analysis aims to explore if there are means of improving collaboration between sectors and among the partner countries, on fencing issues and the social, political, economic and biological forces that shape them.

Background information and Terms of Reference of the review

The *Fencing Impacts Review* has been funded by an AHEAD-GLTFCA Seed Grant. The review will seek to stimulate the development of a strategic vision for cross border co-operation on fence management and propose some solutions to interface problems by examining crosscutting issues that affect the inter-relationship between 'natural' and human-derived landscapes.

Whilst it is considered desirable to remove whole/sections of fence to allow for the dispersal of large mammal species across transboundary protected areas such as from Kruger National Park (KNP) to Limpopo National Park (LNP), this 'release' can also facilitate disease transfer (e.g. foot-and-mouth disease (FMD) and bovine tuberculosis). Fences also play a critical role in the security of protected areas, both from the local community perspective (human-wildlife conflict) and park security (anti-poaching). It is this conundrum (the detrimental and beneficial role of fences), which has been acknowledged by conservationists, but haphazardly dealt with heretofore. No central, clear or collective policy strategies for fences that span the GLTFCA /GLTP or KAZA TFCA currently exist. This review aims to re-dress this imbalance.

The removal of sections of the KNP fence that borders LNP is a case in point, in that no disease risk assessment was undertaken prior to the removal of fence sections. Critically, until recently (Ferguson, 2009a & b; Jori et al., *in press*; section 6), there has been no overall generic monitoring system to ascertain the permeability of fences in any of the associated protected areas in the GLTFCA/GLTP or in other TFCAs. Therefore our knowledge of areas where 'fences are causing problems' (or in areas of repeated fence damage which may represent the 'gateways' to potential wildlife corridors) is largely anecdotal or data are collected unsystematically, if at all.

In an attempt to counter this lack of information, the Fence Interface Research and Monitoring (FIRM) group based at the Mammal Research Institute (University of Pretoria) with the support of funding from USFWS Project Afe-0401 and WWF-SA Project 1490 (Ferguson, 2009a & b) has already introduced a low cost fence permeability monitoring technique that now operates along the KNP's western boundary fence. This method standardizes data collation within a single 'fence' database and ultimately will lead to the development of adaptive management protocols on fencing issues at this hard-edge interface.

There is an urgent need to transfer these 'simple' types of monitoring technologies to other fenced areas within other TFCAs, in order for meaningful cross comparisons of data to be made and interface problems mitigated in a systematic manner.

Overall Goals of the Fencing Review Project

This multi-author review has been designed to represent a 'strategy toolbox' for sourcing information on planning, implementation and evaluation of the impacts of fencing policies (and alternatives). Conservation and the developmental progress of the TFCA concept will not proceed without taking into account the complex nature of the 'containment' (and 'release') of wildlife, livestock and people. The review should facilitate discussion and increase a regional transfer of knowledge between stakeholders with regards to the long-term resolution of fencing issues.

The eventual integration of fencing policy and the exposition of alternatives within the GLTFCA/GLTP (and KAZA TFCA) partner countries will be a complex and time consuming process that will require the involvement of a variety of stakeholders representing divergent interests. These stakeholders may require a review of the evidence pertaining to fencing and its impacts that can inform future direction and research in this area. The review should assist in stimulating the further identification of existing country fence related structures, the regional structures and international obligations, with regard to current fence policy and best and worst practice.

At the same time the benefits and risks associated with fencing policy and potential alternatives should be addressed (as an example of the diversity of fencing see Fig. 1.1). Recognizing the sovereignty of each country, the study explores means of improving collaboration between the partner countries with regard to fences, with emphasis on the sustainable development of TFCA initiatives.

Other Project Components

i) Disciplines deemed key to project success:

The project contributors have gathered information on fence policies and impacts both in an historical context and current innovations from published and unpublished sources. The contributions come from a wide range of disciplines e.g. veterinarians and social systems analysts.

ii) Disseminating results:

The final report, along with a comprehensive bibliography and a digital web-based archive of PDFs of key references, has been made available to the Wildlife Conservation Society, who will be responsible for further dissemination of this report within the AHEAD-GLTFCA Working Group, etc. Not all of the references contributed are available in PDF format.

iii) Planned involvement of local community members:

The report can be made available to community fora for example via the GLTP/GLTFCA Steering Committees where feasible.

iv) Local professional development facilitated:

The final report gives a holistic context to those involved in fencing issues and the expansion of transfrontier areas.

In conclusion this document explores the following issues:

- Fences (veterinary cordon, park and private) are an important physical environmental and social feature of the landscape in southern Africa and serve to separate wildlife from livestock and people, but, we recognise that there are many legitimate and diverse stakeholders involved at varying spatial scales.
- These fences are largely incompatible with the TFCA vision. However, we believe that the different sectors (livestock and conservation) could communicate more effectively on the impacts (intended and unintended) of fencing.
- TFCAs need fencing plans and monitoring/research programs directly addressing these issues.
- This review will help to inform the decision-making process in both GL and KAZA TFCAs, will assist in identifying problematic fencing structures in the TFCAs and will serve to promote the establishment of a broader TFCA fencing management plan.
- Risks/benefits and alternative options have been examined with regards to fencing issues.
- A fencing typology (systematic classification of fence impacts per type) needs to be developed that recognises the highly idiosyncratic nature and individual differences inherent in each fence type/location.

Figure 1.1. Penguin fence, Boulders, Table Mountain National Park, South Africa.

1.2 Generic objectives of TFCA establishment and the importance of wildlife corridors

Hanks, J.
Consultant, P.O. Box 254, Greyton 7233, South Africa.
hanksppt@iafrica.com

Generic objectives of TFCAs

A Transfrontier Conservation Area (TFCA) is a relatively new conservation paradigm, and is defined by the Southern African Development Community's (SADC) Protocol on Wildlife Conservation and Law Enforcement as *"the area or a component of a large ecological region that straddles the boundaries of two or more countries, encompassing one or more protected areas as well as multiple resources use areas"* (SADC, 1999). The 14 Member countries of SADC have taken the lead in the formal designation, establishment, and political recognition of TFCAs in Africa (Appendix 10.2). This is a significant conservation initiative, which can bring together a complex and diverse mosaic of land uses under one management authority, including national parks and game reserves, forest reserves, wildlife and game management areas, communal land and private land.

At a generic level, the main broad objectives[1] of TFCA establishment was summarised by TCC (2006) as follows.

- *Conservation of biodiversity.* The justifications to conserve biodiversity for human development and survival are well known. Africa's national parks and game reserves have vitally important roles to play in the *in situ* conservation of viable species in natural ecosystems. Unfortunately, these protected areas are increasingly being put under threat by human-induced land transformation and illegal harvesting. The well-established theory of island biogeography indicates that when an area loses a large proportion of its original habitat and especially when the remaining habitat is fragmented, it will eventually lose some of its species. It is thus clearly in the interest of species conservation to join together fragmented habitat patches into a continuum, a vitally important objective of TFCA establishment, and to manage large natural systems at the water catchment level rather than fragmented components created by artificial political boundaries[2].

- *Socio-economic development.* Travel and tourism is the fastest growing industry in the world. It is the foremost job creator of all industries within the SADC region where it is particularly well-placed to maximize foreign exchange earnings and provide new jobs in areas where there is high unemployment, a relatively unskilled labour-force and few alternative sources of employment. Although South Africa, Botswana and Namibia already have a reasonably well-developed tourist infrastructure, other countries in southern Africa have great potential for the development of new tourism opportunities, particularly Angola, Mozambique, Zambia and Zimbabwe. Much of this growth will be associated with nature-based or wildlife-based tourism, *including safari*

[1] Each TFCA will have more specific objectives, as set out later in this section.
[2] With each TFCA recognising the importance of biodiversity conservation, an additional objective, or a subset of this objective, is the role of well-conserved natural systems in the provision of ecosystem goods and services to southern Africa's rapidly growing human population.

hunting. The harvesting of natural plant products within SADC is worth at least US$250 million per year. The sustainable exploitation of these resources within appropriate areas of the TFCAs is an additional leading source of income. Many people living inside TFCAs have ready access to indigenous fruits, fibres for local crafts, and plants for traditional medicines. Using wildlife resources (both plant and animal) to benefit human populations at the same time removes incentives to develop the land for arable purposes or livestock herds, thus benefiting biodiversity conservation. With widespread poverty throughout many parts of Africa, socio-economic development should be one of the primary objectives for the establishment of the TFCA.

- *Promotion of a culture of peace and regional cooperation*. TFCAs can play a major role in building good relations between partner countries as they strive to cooperate on a range of mutually beneficial activities. With international boundaries all too often being the staging grounds for launching armed conflicts, an active commitment to promote a culture of peace and demilitarisation in these sensitive areas should be an objective of all partner countries.

- *Promotion of community interactions across borders.* Colonial boundaries were often designated without due considerations being given to the settlements and distributions of ethnic entities and cultural ties. Where appropriate, TFCA programs should articulate the facilitation of exchanges between ethnic groups separated by these boundaries, and restoration of severed cultural ties.

Most of the contributions to this review of the environmental, social and economic impacts of game and veterinary fencing in Africa will focus on localities in and adjacent to the following three conservation areas, the first of which will eventually become an integral part of a much larger TFCA.

1. **Great Limpopo Transfrontier Park (GLTP)** straddles three countries and joins together the Kruger National Park (South Africa), the Limpopo National Park (Mozambique) and the Gonarezhou National Park (Zimbabwe). The Transfrontier Park was formally established by a Treaty signed by Presidents Chissano, Mbeki and Mugabe on 9 December 2002. The GLTP has the same objectives as a Category II IUCN Protected Area[3] namely: *Large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.*
2. **Great Limpopo Transfrontier Conservation Area (GLTFCA)** has still to be established, and will be based on the core of the GLTP expanded to include the Banhine and Zinave National Parks in Mozambique with their interlinking communal areas, as well as various private and state-owned conservation areas in South Africa and Zimbabwe presently bordering on the Transfrontier Park. When formally established, the TFCA will have the same generic objectives as outlined at the start of this section.
3. **Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA)** A Memorandum of Understanding committing the five participating countries to the establishment of this TFCA of 287,132 km², was signed

[3] http://cms.iucn.org/about/work/programmes/pa/pa_products/wcpa_categories/pa_categoryii/

by the governments of Angola, Botswana, Namibia, Zambia and Zimbabwe on 7 December 2006 (see Box 1.2). The KAZA TFCA is situated in the Okavango and Zambezi River basins where the borders of Angola, Botswana, Namibia, Zambia and Zimbabwe converge. It is set to become the world's biggest conservation area and will include 70 protected areas, including national parks, game reserves, forest reserves, community conservancies and game/wildlife management areas, linked together by a complex mosaic of communal lands and private land (TCC, 2006; Cumming, 2008). Much of the KAZA TFCA falls within two of the world's 24 major terrestrial wilderness areas (Mittermeier, et al., 2003).

Box 1.2. KAZA TFCA Memorandum of Understanding

The mission of the participating countries in establishing the KAZA TFCA is set out in the MOU (December 2006) as:

To establish a world-class transfrontier conservation area and tourism destination in the Okavango and Zambezi river basin regions of Angola, Botswana, Namibia, Zambia and Zimbabwe within the context of sustainable development.

The primary objectives are to:

(i) Foster trans-national collaboration and co-operation in implementing ecosystems and cultural resource management;

(ii) Promote alliances in the management of biological and cultural resources and encourage social, economic and other partnerships among their Governments and stakeholders;

(iii) Enhance ecosystem integrity and natural ecological processes by harmonizing natural resources management approaches and tourism development across international boundaries;

(iv) Develop mechanisms and strategies for local communities to participate meaningfully in, and tangibly benefit from, the TFCA; and

(v) Promote cross-border tourism as a means of fostering regional socio-economic development.

Importance of wildlife corridors

When TFCAs were first openly discussed between neighbouring countries in the late 1990s, the "restoration of large mammal migration routes" was often cited as one of the main biological reasons for their establishment (Anderson, 2003). This has resulted in a certain amount of confusion, as there is no universally accepted definition of the word *migration* (Aidley, 1981; Hoare, 2009), although most authors do agree that migration occurs in response to changing seasons and is *predictable and repeated each year, with the animals returning to where they came from* (Sibley, 2001). It is important to separate this from *dispersal,* where animals move out of an area into a new range for a variety of reasons, but may not necessarily return. If they do return, the movement is not predictable or seasonal. Cumming (2008) has addressed this topic in

much more detail, recognising an additional important function for wildlife corridors as *adaptive response corridors* which provide for both fauna and flora to shift, or disperse, along ecological gradients in response to changing climatic conditions. His important contribution to this debate has been reproduced here this review in full in Section 4.8.

Whether it is migration or dispersal that it taking place, for the larger species of mammal, transfrontier wildlife corridors will have a vitally important role to play in regional conservation activities by presenting or consolidating opportunities for various species to move freely across international borders. Of particular significance in the KAZA TFCA is the movement of the African elephant (*Loxodonta africana*), a species of considerable economic and ecological importance to the region. Once established, the new TFCA will embrace the largest contiguous population of elephants in the continent, with northern Botswana alone having in excess of 150,000 elephants growing at 5% per year. There are an additional 50,000 in north-western Zimbabwe and 16,000 in north-eastern Namibia (TCC, 2006).

As elephant populations become more and more constrained so the need for 'safe corridors' between protected areas becomes even more important. There are considerable opportunities for elephants from Botswana to move north into Zambia and Angola once new corridors have been established, which has the potential to reduce to some extent the environmental and social pressures of their over-abundance in Botswana and Caprivi. Angola in particular will benefit from the natural movements back into that country through these corridors of a range of species, with elephant, buffalo (*Syncerus caffer*), giraffe (*Giraffa camelopardalis*), lechwe (*Kobus leche*), waterbuck (*Kobus ellisiprymnus*) and hippo (*Hippopotamus amphibious*) being some of the first to move along the Kwando River and adjacent areas. Large carnivores will also benefit from these opportunities to disperse into presently unoccupied areas.

As will be shown later in this review, the removal or re-alignment of existing fences, and the possible construction of new fences to protect human settlements and arable land should become an integral part of the planning of any new wildlife corridor. In areas where proposed corridors will have significant impact on local communities, extensive consultations with residents (especially farmers) must be incorporated into the planning and development processes, ideally linked to reducing human-wildlife conflict to an absolute minimum.

2. FENCES AND PEOPLE

2.1 Transfrontier conservation in southern Africa: Taking down the fences or returning to the barriers?

Spierenburg, M. & Wels, H.
Vrjie Universiteit, De Boelelaan 1105, 1081 HV Amsterdam, Netherlands and the Universty of Stellenbosch, Private Bag X1 Matieland, 7602 South Africa
mj.spierenburg@fsw.vu.nl; h.wels@fsw.vu.nl

Introduction

Nature conservation in southern Africa has always been an important political tool, at least since the advent of European colonisation. It played a role in fostering Afrikaner nationalism (Carruthers, 1995), - as testified by the name of South African's largest National Park, Kruger National Park - and during the years of apartheid in plotting a policy of political destabilisation of neighbouring countries (Ellis, 1994; Breytenbach, 1997; 2001; De Wet Potgieter, 1995). Conservation areas located on the national borders served as places through which weapons and saboteurs passed into neighbouring territories. As a result of its history, nature conservation often elicits deep-seated feelings of antagonism and distrust between wildlife authorities and local populations living in and nearby wildlife areas (Anderson & Grove, 1987), and between the neighbouring countries in southern Africa (Duffy, 2000: 43-66). At the local level this distrust was dealt with by excluding local communities from wildlife areas; physically through fences, and by excluding them from the management of these areas. However, when it became clear that this strategy was counterproductive, and had become socially unacceptable (see e.g. Adams & Hulme, 2001), conservation organisations started advocating strategies to generate benefits for communities living nearby protected areas and sometimes even community participation in the management of these areas. This new approach was referred to as 'moving beyond the fences' and was developed in the wake of the Bali declaration of 1982, and the 1987 report of the Brundtland Commission.

A more recent trend concerns bringing down the fences between countries in order to create Transfrontier Conservation Areas (TFCAs). Practically all international conservation organisations have embraced the concept of TFCAs (Aberly, 1999; Wolmer, 2003). The rationale for the support is that the boundaries of ecosystems generally do not overlap with national, political boundaries. Global threats to the interconnected ecosystems and migrating species allegedly require large-scale conservation efforts (Chapin, 2004: 22).

Especially in the south TFCAs are hailed as opportunities for economic growth, mainly through tourism development (Wolmer, 2003). By arguing that local communities living in or close to TFCAs will also benefit from this growth, TFCA proponents claim social legitimacy for large-scale conservation efforts. In this sense they propose to continue to 'move beyond the fences' which used to keep communities out. In this paper we will look critically at the use of fences in conservation practices in southern Africa, both in the literal sense and

semiotically. Do TFCAs indeed combine bringing down the fences between countries with moving beyond the fences to reach out to communities?

Fences and warfare: a brief history of wildlife conservation in southern Africa

In the late nineteenth, early twentieth century, larger game animals became increasingly scarce in southern Africa. This, according to Beinart (1987) contributed to a significant shift in attitudes towards the preservation of wildlife. Hunting for subsistence and gain gave way, amongst growing colonial elite, to 'the Hunt' as a socially exclusive pleasure pursuit. African rural dwellers, who had depended upon subsistence hunting, increasingly became defined as poachers and acted against as such. An important wildlife preservation strategy was the creation of protected areas/national parks. Members of local communities who dared to enter or touch any animal or other natural resource in protected areas, were immediately labelled as 'poachers', and heavily fined if caught. This policy was appropriately called the 'fines and fences-approach' or 'fortress conservation' (see e.g. Brockington, 2002). Wildlife management authorities and local communities developed antagonistic relations, and a negative form of exchange became more or less the norm: the communities 'poached' and 'trespassed' the boundaries and cut fences to express their protests, and wildlife managers 'hunted the poachers down'. In Zimbabwe this was taken literally, following the example of Kenya's strongman of the Kenya Wildlife Services, Richard Leakey (Leakey, 2001), in a 'shoot-to-kill'-policy (cf. Wels, 2003).

Poachers were Enemy Number One for conservation authorities. Reading auto-biographical accounts of game wardens, their preoccupation with poaching stares one in the face (see e.g. Davison, 1998; Stevenson-Hamilton, 1993; Kinloch, 1972). To get the conservation message across, the 'culprits' were juxtaposed to romantic notions of an unspoiled, virgin African wilderness which they were destroying (Adams & McShane, 1996). In line with their often militaristic background, conservationists often reverted to the reflex they were taught in the military which was to declare 'war on the poachers' (see e.g. Carruthers, 2001; Draper, 1998). Even today the training of game wardens is highly militaristic, and the camouflage uniforms they wear resemble military uniforms (see for good examples Leakey, 2001; Steele, 1992).

One of the most striking symbols of warfare in general is a (barbed wire) fence (Razac, 2002)[4]. The idea of barbed wire is taken from the thorn bushes, which were used all around the world for protection and to deter outsiders (Krell, 2002: 15). For instance, when Jan van Riebeeck landed in South Africa, the first attempt to protect his station was by erecting a hedge of *Brabejum stellatifolium*, the wild almond. With its 'dry and bitter' nuts the hedge became symbolic for the bitter segregation that has been part of South Africa's history ever since (Sparks, 1990: xv-xvi). The road from the 'natural' fence to barbed wire is a long one measured in time, but the effects of both have been the same: "barbed wire has always functioned in that paradoxical zone, between protection and division" (Krell, 2002: 160).

[4] In his book Razac describes the three 'heavy memories' associated with barbed wire, being the wiring of the American West, which ended the myth of the cowboy, the trenches of the First World War and the concentration camps of the Second World War.

In fact South Africa has the dubious 'honour' of being the first country where barbed wire fences were widely used in warfare, during the Anglo-Boer War of 1898-1901. "Keen to bring that conflict to a speedy conclusion, General Kitchener in early 1901 turned to a strategy of barbed wire and blockhouses, one that paralleled his other initiative, also involving barbed wire, the construction of what soon came to be called 'concentration camps'" (Krell, 2002: 49). Through this 'barbed wire-strategy' an immense space was brought under control, for which the British used about 3,700 miles of barbed wire (Netz, 2004: 64-67). Netz draws a gruesome parallel between hunting methods developed by the Boers after the introduction of barbed wire in South Africa. Boer hunters drove game into the barbed wire fences and when the animals got stuck there, they were easy to shoot. Along similar lines, during the Anglo-Boer War, Boers were driven towards barbed wire fences by the superior numbers and artillery of the British and when trapped against the wire, were caught. "The British counted their "bags"", a term used in hunting to indicate the number of animals killed (ibid: 68). Because of these connotations, barbed wire, and by implication fences, has become a symbol for human rights abuses and oppressive control mechanisms worldwide – see for instance the all familiar logo used by Amnesty International of barbed wire curled around a burning candle.

Fences have always been very popular in wildlife conservation: they served to protect the wildlife and to keep it separate from the people outside the fences. Fences have been part and parcel of much of the ideological upbringing of generations of conservationists, which, as noted above, has been characterised as a 'fines and fences-approach'. For local communities, the fence became the symbol of a conservation ideology that focused solely on the welfare of wildlife inside the fence and far less on the well-being of the people outside the fence (Hulme & Murphree, 2001).

In the second half of the nineteen-eighties it became evident that the fines and fences-approach was no longer socially nor politically acceptable, neither was it a sustainable way to manage and protect wildlife (McNeely, 1992). Not only was it too expensive in terms of deploying personnel and equipment, it also did not stop the poaching and further encroachment on wildlife areas. From then on wildlife managers and policy makers in the field of nature conservation started to proclaim a different approach that emphasised that communities had to become actively involved in wildlife management (Adams, 2004)[5]. Instead of an antagonistic party, communities had to become a co-operative partner. All kinds of projects were started in this vein, and some pioneering efforts, which had already started, now received official political backing and legitimisation. Conservationists in southern Africa were leading the way in this respect with ground-breaking projects such as ADMADE in Zambia (Gibson, 1999), LIFE in Namibia and CAMPFIRE in Zimbabwe (Kiss, 1990; Hulme & Murphree, 2001). The new approach was referred to as moving 'beyond the fences/boundaries'; the overall theme, for instance, of the Vth World Parks Congress held in Durban in 2003, was 'Benefits Beyond Boundaries'. Hence, the fence is still used as a symbol in communicating the new conservation ideology, but it is given a new meaning.

In wildlife conservation fences have always been a blessing and a curse at the same time. In Botswana Mark and Delia Owens mobilised the public against the government of Botswana by describing the devastating effects of a foot-

[5] Especially chapter 5, 'Poachers to partners'.

and-mouth disease fence on migrating wildlife in the country (Owens & Owens, 1985). In Australia the famous Dingo Fence, aimed at preventing dingoes (wild dogs) from eating sheep, stretches for some 5,309km through the Australian interior. "Enjoying a sympathetic relationship with the indigenous peoples, who incorporated it into their mythic stories, the animal, like its American counterpart, the coyote, was reconfigured by settlers into a mean and menacing creature. It is still possible to see dead dingoes hanging like trophies on the wire, a practice that parallels the (now diminishing) display of slain coyotes and other predators on the barbed wire fences of the American West" (Krell, 2002: 160)[6]. In a macabre parallel, local communities, including the Bushman or San who were once hunted down like animals (Gordon & Sholto Douglas, 2000), run up against fences that separate them from the natural resources they need to survive.

'Beyond the fences' indicates in a symbolically very powerful way attempts by conservationists to turn a metaphor of distrust into one of trust (Borrini – Feyerabend, 1997). The metaphor can be interpreted in (at least) two related ways. Firstly, by using fences in wildlife conservation, the authorities have protected the wildlife by immobilizing it. As Netz convincingly argues, "the purpose of barbed wire was to *prevent* motion" (Netz, 2004: 30, italics in original). However, especially with the success of the conservation of the elephant (*Loxodonta africana*) – a highly symbolic animal - in southern Africa, it has become clear that fences not only preserve wildlife, but also obstruct its mobility in search for greener pastures, in a destructive way (see e.g. Venter, et al., 2008). Increasingly, conservation organisations argue that the conservation of wildlife should not be confined to protected areas alone, but also take place outside of these (see Bhattacharya, et al., 2005).

The second interpretation of the metaphor is that it tries to convey the message to local communities that the wildlife authorities will reach across or even remove the fences which have been obstructing their relations since the early days of wildlife conservation in southern Africa. Instead of excluding communities from conservation areas, they are now considered stakeholders who, through the sharing of benefits from wildlife, will develop a stake in conserving it.

Taking down the fences: transboundary conservation initiatives

In the early 1990s a start was made with the dismantling of the system of apartheid. Within this context, aided by the different initiatives to reconcile local communities with wildlife managers, a normalisation of relations within the region could be initiated. The idea of promoting the creation of TFCAs, popularly referred to as ´Peace Parks', matched perfectly with the political feeling at that particular time. The late Anton Rupert, founder and president of the Peace Parks Foundation (PPF)[7], had the political acumen to recognise it: "After 1990, when former President Mandela was freed, I knew the time was right to proceed with cross-border [transfrontier parks]. This was not possible before" (cited in Ramutsindela, 2004: 63). The overall co-operative ideal was couched in romantic parlance about the way that the joint management of

[6] Another huge fence going through the Australian landscape is the Rabbit Fence, trying to curb and contain the spread of rabbits all over the country. This fence is symbolically used in a film about the eugenic practices in Australia until the 1970s. The film is entitled *Rabbit-Proof Fence*, directed by Philip Noyce (2002).

[7] Anton Rupert passed away on the 18th of January 2006.

nature "would heal old wounds" both at the state and community level (Koch, 1998). The PPF has formulated this threefold objective as follows: "to fund and facilitate the development of Transfrontier Conservation Areas, placing particular emphasis on the promotion of regional peace and stability, the creation of new jobs associated with the anticipated growth of tourism in southern Africa, and the conservation of biological diversity." "Involving local communities" was mentioned in a policy-document under the "specific objectives" (Hanks, 1997: 2,3).

TFCAs are supposed to present the ultimate form of taking down the fences. Literally, fences are taken down to allow the free roaming of animals across national borders. Figuratively speaking, the TFCAs represent attempts to break down the fences that have hindered community participation in wildlife conservation. These two aspects of breaking down the fences were celebrated in a recent feature of *National Geographic* on the Internet, with a digitalised film that opens with scene of barbed wire disappearing from view.[8] The idea behind the TFCAs is romantically referred to as the "dream of an Africa without fences". The same symbolism is used in a film directed by Karin Slater called "Road to Restitution", here we see former antagonists, i.e. community members and park wardens, reach through the wires of a fence to shake hands.

Or going back to the barriers?

In the 19th century, Cecil John Rhodes had the megalomaniac ambition to extend the British empire from the 'Cape to Cairo'. A famous cartoon shows Rhodes standing on the map of the African continent, taking a giant step from Cape Town to Cairo. Watching the maps showing the aspirations of the PPF for transboundary conservation brings one close to the sensation one has when looking at the cartoon of Rhodes. Noel de Villiers (in Wolmer, 2003: 264) even made an explicit link between Rhodes' ambitions and the TFCA-dream by saying that "Africa should endeavour to join all its game parks contiguously from Cape to Cairo". A more critical voice said that "TFCAs are driven by Cecil Rhodes clones - rather than seeing great expanses of red on the map [the colour of the British Empire MS/HW] they want to see a great wedge of green as their legacy to Africa!" (ibid: 266).

What do these ambitions mean for local residents? Are these endeavours to remove boundaries and fences at such a large scale indeed combined with efforts to reach across the fences or even remove the fences for them as well? A closer look at the experiences of residents living in or near the Great Limpopo Transfrontier Conservation Area (GLTFCA) shows rather mixed results. While residents in South Africa have successfully reclaimed part of the TFCA, and are benefiting from tourism development in their part of the Great Limpopo – though not optimally, as we have shown elsewhere (Spierenburg, et al., 2009) – the situation for the residents on the Mozambican side looks rather grim.

The GLTFCA is one of the largest TFCAs in the world, linking conservation areas in South Africa, Mozambique and Zimbabwe. This TFCA originally was supposed to become a multiple use area, which would especially help impoverished

8 http://magma.nationalgeographic.com/ngm/data/2001/09/01/sights_n_sounds/media.1.2.html (consulted May 8, 2010).

communities in communal lands in Mozambique. The map accompanying the original objectives of the GLTFCA shows that the communal lands originally enclosed in the TFCA-plan are much larger than the presently included Limpopo National Park (formerly known as the Coutada 16 Wildlife Utilization Area, located directly opposite South African Kruger National Park), Zinave National Park and Banhine National Park combined.

Just as in the other TFCAs, "funders and park planners hoped that through the use of participatory approaches local people would feel that they have a real stake in protecting wildlife" (Duffy, 2000: 44). On the Mozambican side, however, very soon the focus shifted away from the communal areas to Coutada 16, which was a Wildlife Utilization Area and has about 27,000 people living within its border. Soon after the signing of the TFCA agreement by the three governments involved, Coutada 16 was declared a national park and renamed Limpopo National Park. This was done without much thought about what that would mean for the communities living in the area. A World Bank consultant, who was initially involved in the TFCA remarked: "This was supposed to be a transfrontier *conservation area*, now it is becoming a transfrontier *park*, that is not the same thing, that is not what we had agreed upon. This was supposed to bring benefits to the local communities, but the way it is going now it will not."[9] The PPF brochure celebrating the establishment of the Great Limpopo reflects the change in policy:

> " …all a Transfrontier *Park* means is that the authorities responsible for the areas in which the primary focus is wildlife conservation, and which border each other across international boundaries, formally agree to manage those areas as one integrated unit according to a streamlined management plan. These authorities also undertake *to remove all human barriers* within the Transfrontier Park so that animals can roam freely." (SANP/PPF, 2003; emphasis added).

Turning the conservation area into a park could be considered an act of what Sibley calls 'spatial purification' (Sibley, 1995: 77). Representatives of various organisations (directly and indirectly) involved in the implementation of the TFCA[10] felt that the GLTFCA had become a matter of prestige for the PPF: it would be the largest TFCA on the continent and contains a national park of world fame. This might explain why the multiple use status of Coutada 16 was abandoned. To merge these two areas, the form of land use they are under had to be harmonised. The Kruger National Park was taken as a model for the entire TFCA. During presentations to Mozambican authorities and communities, PPF staff members presented the success of tourism in Kruger as an example of what the entire TFCA could become. They strongly suggested that the communities would benefit from these economic opportunities. However, by taking the Kruger National Park as a model for the Limpopo National Park, the communities living within the latter's borders became an 'obstacle' and 'undesirable'.

The majority of the people in the park live along the eastern and southern boundaries of the park. Seven villages with a total of about 7,000 inhabitants are located along the Shingwedzi River, which transects the southern part of the park. A study commissioned by the PPF concluded that the banks of the

[9] Interview at the World Bank, Maputo, 6 August 2003.
[10] Interviews in Maputo, April/May 2005.

Shingwedzi River also hold the greatest tourism potential.[11] To free the area for tourism, a programme was developed to resettle the 7,000 people along the Shingwedzi to an area to the south-east of the park. Both government officials in the Ministry of Tourism, responsible for the TFCA, and representatives of the PPF have insisted that no forced relocation will take place.[12] However, the new status of the area seriously impinges upon the communities' livelihood strategies. According to national parks legislation in Mozambique – based on the IUCN's Guidelines for Protected Area Management Categories (IUCN, 1994 in Aylward & Lutz, 2003) – cultivation inside national parks is forbidden. The communities along the Shingwedzi are allowed to continue farming the fields they had cleared before the declaration of the park, but they are not allowed to clear new ones. Most farmers rotate their fields every few years, and are worried what will happen if their current fields are losing their fertility. Furthermore, accessing the 'emergency pastures' used in times of drought has become illegal. The communities receive no compensation for wildlife damage, as one of the park's employees remarked: "This is now a national park, agriculture and cattle keeping officially is forbidden in a park, so how can we compensate for damage to things that are not allowed?"[13] As a result of the restrictions and increased damage, many people living along the Shingwedzi now believe that resettlement is inevitable (see also Milgroom & Spierenburg, 2008). A village headman formulated it this way:

> "They say that the resettlement is not forced, but that is not true. We are forced because we are no longer allowed to live our lives as before, we can no longer cultivate where we want, we can no longer take our cattle out to graze. Yes, we agreed to move, but we did not do so freely."[14]

The park is also impinging on another livelihood strategy, that of – illegal – migration to South Africa to look for (temporary) work on commercial farms and as servants in communities living next to the Kruger National Park. According to police officers of the Guarda Fronteira, the increased presence of wildlife and the fact that people now will have to cross two wildlife areas (including Kruger) with predator populations will deter possible migrants, as will the increased anti-poaching patrols. While TFCAs promote the transboundary mobility of tourists and investors, communities increasingly become immobilized and bounded (see also Hughes McDermott, 2002). The first step in this process was to deny them access to natural resources further afield and prevent them from crossing the border to pursue job opportunities. The second step has been to confine them to a new place outside of the park.

In other words, attempts are made to grant the mobile and transit tourist's exclusive right of access to the space of the national park. Contrary to the tourists, local people are considered 'undesirables', those who 'spoil' the image of a wild and pristine landscape (cf. Wels, 2004). The authorities interviewed kept repeating that "tourists and communities do not mix." Rangers and other park personnel are, as unobtrusively as possible for the tourists, constantly on the lookout for undesirables - often conveniently labelled 'poachers'. In the

[11] Interview with staff of PPF, April 2005, and with members of the Project Implementation Unit of the Limpopo National Park, May 2005.

[12] Interviews at the *Ministerio de Turismo*, Maputo, June 2002 and May 2005; and with a PPF representative, April 2005.

[13] Interview with a staff member of the Project Implementation Unit, May 2005.

[14] Interview in May 2005.

process the national and by implication *Public Park*, all of a sudden seems to have become a *private* space for tourists, who pay for the animals to stay instead of the people (cf. Sibley, 1995: xi).[15]

It seems that in the GLTFCA the fences were brought down mainly because they were believed to constrain nature conservation. It is therefore highly significant that the signing of the TFCA agreement by the governments of South Africa, Mozambique and Zimbabwe was celebrated by releasing 30 elephants from Kruger National Park into Mozambique: the basic assumption underlying the slogan of 'beyond fences' seems to be a recognition of motion as a new *sine qua non* in nature conservation. The very words '*trans*frontier' or '*trans*boundary' conservation areas seem to breathe this new interpretive mobility framework. Yet, while fences were removed to allow elephants to cross the border, the fences to keep communities out seem to have been resurrected in the case of the Limpopo National Park.[16]

Despite the proposed removal of communities from the park, the rhetoric of 'moving beyond the fences', i.e. community participation and development, has been maintained. The official website of the Limpopo National Park (www.limpopopn.gov.mz) states that: "Fundamental to the concept of the Limpopo National Park is the requirement that it contributes to the welfare of the people of Mozambique through sustainable eco-(and) cultural tourism development…"

In an interesting twist the head of the Project Implementation Unit of the TFCA in Mozambique, speaking at a press conference on the 23 May 2005, argued that the removal itself would be beneficial to the communities. Announcing the resettlement of the first 100 families in October 2005 – while in fact, the first villagers were moved only in December 2008 - he remarked:

> "(…) it is hoped that this will lead the remaining families to understand that the park will not damage their interests but will actually improve their lives. Families in this area can never rely on farming to escape from poverty: the soils are poor and the semi-arid climate guarantees that yields from agriculture will always be low." (Cited in Spierenburg, et al., 2006: 24).

A report by a consultant on possible resettlement areas denies this: "They utilise alluvial soils in the Shingwedzi valley which have higher agricultural potential than generally occurs in the region. They have access to vast areas of grazing for livestock and to other forest resources. (…) The villages have access to reasonable supplies of water in nearby rivers" (Impacto, 2005: 1).

The developments on the Mozambican side of the TFCA seem to justify the conclusion that (so far) much of the rhetoric about CBNRM in southern Africa has never materialised. Dzingirai concludes on the basis of a case study of CAMPFIRE in Zimbabwe that "with the support of global finance and its clients,

[15] The irony is that on the other hand local communities are often considered to be 'closer' to nature than the tourists. So who in the end defiles nature? (compare Sibley, 1995: 26-28. See also Neuman, 1998; 2000).

[16] Interestingly enough, those first translocated elephants returned to South Africa soon after their transfer, after which an area was fenced to serve as a sanctuary where translocated animals could acclimatise. The fences of the sanctuary were (partly) taken down after the opening of the Giriyondo border post allowing tourist to cross directly from Kruger National Park into the Limpopo National Park, because, as a park manager stated: 'Tourists do like to see animals in fences' (see Spierenburg, et al., 2008).

the state and private business are inviting communities to lay down their spears and traps and to take part in community-based wildlife conservation, in return for promises of control over wildlife, and revenue and other services generated from safari hunting in rural areas. It is an invitation which those communities, with years of experience of failed development, from the state especially, treat suspiciously, and often accept only with encouragement of environmental organizations. Rather than passing the benefits or the ownership of wildlife to indigenous communities, however, the new programme is allowing wildlife to be monopolized by the state and the private sector. (…) community conservation or even wildlife management are not what they seem or claim to be; they are not about conservation but are part of a strategy to continue the traditional disqualification, restriction or even total exclusion of rural people by the state and its partners" (Dzingirai, 2003: 259). CBNRM programmes often serve to bring communities in remote areas under the control of the state (Schafer & Bell, 2002) and introduce new stakeholders with entitlements to resources hitherto controlled – either *de jure* or *de facto* – by local communities (Spierenburg, et al., 2006, 2008).

It appears that not only local communities are disappointed with the results of community participation in nature conservation. Environmental organisations seem less and less keen to work with local populations and the hype of community involvement in nature conservation appears to be on a (steep) decline. Chapin (2004) claims: "Discussions of "natural" alliances between conservationists and indigenous peoples and the need to work closely with local communities, common just a few years ago, has largely disappeared" (Chapin, 2004: 18).[17] Chapin quotes a biologist from Conservation International working in Brazil, as having said that "Quite frankly, I don't care what the Indians want. We have to work to conserve the biodiversity" (ibid: 21).

Chapin argues that environmental organisations lack the knowledge and capacity to deal with development issues. Furthermore, community participation is a complex process, and may result in the realisation that the organisations' goals differ significantly from those of communities when communities choose their economic well-being over the preservation of natural resources. Conservation organisations translate this discrepancy as proof that local communities are not the good environmental stewards they were believed to be. The result is a growing distrust between conservation organisations and local communities. Chapin (2004) as well as Hutton, et al.,. (2005) even argue that the promotion of TFCA constitutes a deliberate move away from communities. Yet, organisations such as the PPF continue to promote their initiatives as resulting in benefits for local residents. At the same time, however, PPF staff appears to have little confidence in residents' abilities to participate in TFCA management; as shown by the statement from a PPF project officer: "For community representatives to participate on the actual management of a national park is something unfair to the community themselves. In most cases the people that are appointed to manage a national park have gone and done years of studying to gain a tertiary education. They're well qualified … I know a lot of critics are advocating for it [community

[17] This shift can be partly explained, according to Chapin (2004: 26), because of 'the presumption that biological science should be the sole guiding principle for biodiversity conservation in protected natural areas. This notion has produced a running debate between those who do not see human inhabitants as a part of the ecological equation, and those who argue for partnerships and the inclusion of indigenous and traditional peoples in protected area plans, both on human rights grounds and for pragmatic ecological reasons'.

involvement], but in my mind it is the same as having someone living next to an airport come and sit next to the air traffic controller…. You can't make them air traffic controllers" (in Tanner, 2003: 83).

Acknowledgements

We would like to thank the South Africa-Netherlands Research Programme on Alternatives in Development (SANPAD) for funding our research. Marja Spierenburg furthermore benefited from additional funding from the Transboundary Protected Areas Research Initiative, a program running under the auspices of the IUCN South Africa.

2.2 Governance and decision-making: fencing in the Great Limpopo and the Kavango-Zambezi TFCAs

Schoon, M.
Assistant Director, Complex Adaptive Systems Initiative, Arizona State University, 943 E Hermosa Dr. Tempe, AZ 85282, USA
michael.schoon@asu.edu

Introduction

Governance in transboundary conservation hinges on decision-making across borders, in particular an international frontier, but also levels of collaboration and cooperation between communities and protected areas, between provincial and national agencies, between game reserves, communal areas, and national park land, among others. In such transboundary environments, the resolution of collective action dilemmas – resolving the problems of coordinating institutional arrangements between partners – all comes down to the decision of where, when, and to what extent to collaborate. Whether conscientiously or not, all actors in a Transfrontier Conservation Area (TFCA) confront this cooperation conundrum in every conservation choice they make. Outsiders often assume that a TFCA means reaching consensus and cooperating on every issue, but this is as undesirable as it is unobtainable.

In seeking to provide pragmatic advice to policymakers and park officials, this brief intends to address real world management dilemmas regarding fencing in the Great Limpopo TFCA (GLTFCA) and Kavango-Zambezi TFCA (KAZA TFCA). In this pursuit, the policy challenge concerns making explicit what roles the joint management board of a transboundary protected area could play vis-à-vis the national park staffs. Particularly due to the higher transaction costs inherent in negotiating and coordinating decisions by consensus across an international border, not all decisions should be made through the international governing body. Instead, decisions made at the national park level or within groups of technical specialists can often lead to more efficient and effective outcomes. The challenge lies in determining the appropriate level at which to resolve crises and the appropriate degree of cooperation at these levels of governance. Decision-making will depend greatly on the location of the fencing and the rationale for the fencing. Fencing along protected area borders internal to a country differs from that along an international frontier. Likewise, decision-makers face a different calculus for fencing placed to minimize the spread of veterinary disease versus fencing to minimize international smuggling, the movement of people, or reduce human-wildlife conflict.

Resolving the challenges of governance

In resolving governance challenges within a TFCA, the national partners may choose to work together on interests vital to both parties (such as current efforts on veterinary disease control in the GLTFCA), may decide to keep the other parties informed about other issues (like single-country research initiatives) and completely do their own thing at a national or sub-national level (as is the case with local community relations in the GLTFCA). As one of the Great Limpopo Transfrontier Park Joint Management Board members (GLTP/JMB) stated, "We don't manage across the border. Both sides manage their own areas, and we (the Joint Management Board) try to coordinate their work." (SANParks interview, 04/19/2007).

In more practical terms, the analysis of transaction costs can be used to help discern the appropriate level of cooperation at various levels of governance. Because transboundary collaboration generally requires governing by consensus rather than unilateral authority, decision-making across borders amplifies many of the costs of governance. Decisions in transboundary conservation may ultimately take on many aspects of international governance regimes. Decision-making of multiple actors often requires unanimity. This limits the specificity of many arrangements because choices may be limited to a politically acceptable set of options rather than a broader range of choices. While self-organized governance arrangements can emerge at sub-national levels, most international arrangements require complex negotiations. The multiple-level negotiations often require approval at national levels before international talks can proceed, resulting in a two-stage, iterative political game (Putnam, 1988) with decision-making occurring simultaneously at multiple levels of governance.

The increases in communication, the additional time needed to come to agreement, the expense of multiple rounds of meeting, and the inability to optimize in some cases all lead to an increase of costs in transboundary governance. Likewise, monitoring and enforcement costs often increase, both because of the larger spatial scale and because of the difficulties in coordinating groups from each country or creating an enforcement unit with enforcement authority in multiple jurisdictions. Additionally, as Levin (1999) notes, feedback loops often loosen at broader scales and have more variables leading to ambiguity in cause-effect relationships. In sum, the costs of coordination of more actors in a more complex and heterogeneous environment all result in an increase in transaction costs when going transboundary.

The additional costs and challenges emerge in virtually every aspect of transboundary conservation. A quick scan of the JMB minutes for either the GLTP or KAZA TFCA provides examples of ongoing discussions with very slow progress on the creation of border posts, the addition and removal of fencing, the building of bridges to connect the parks, and many other border issues. Additionally, the GLTP has several sub-committees on fencing related topics ranging from veterinary disease to border security to conservation. Interviews with many sub-committee members often gave examples of the additional transaction costs of working across the border and through the JMB. One instance comes from the comments from a member of the veterinary disease sub-committee, one of the most active and progressive groups. Even in this group, the member noted that "there is a lot of talk but no action. We have no money to pursue some of our initiatives, so every meeting we just discuss what we would like to do. We don't actually do anything." (GLTP veterinary sub-committee, 06/19/2007). This is not an indictment of the joint management board or any of the sub-committees, rather it acknowledges the costs and complexity of managing across borders.

The importance of broader governance levels

Noting that transaction costs generally increase as governance moves to broader scales is not meant to dissuade such a move. Instead, it points to the urgency of comparing the costs and benefits of the move. Polycentricism – the idea that multiple centres of decision-making that function autonomously on some issues and act as part of an interdependent system for others (McGinnis, 1999) – and Panarchy – the nesting of adaptive cycles across both time and space (Gunderson and Holling, 2002) – both demonstrate the importance of

moving to broader governance levels as needed. They also demonstrate the importance of only moving up a level when advantageous. Even if transaction costs increase when moving up a level, it may still be a worthwhile decision if the benefits of aggregation grow faster than the costs.

In comparing the benefits and costs of moving up a level, the wide range of transaction costs faced by several groups of actors' needs consideration. Typical discussions of transaction costs look at the cost of doing business between government officials. Changing levels of governance, however, changes the cost-benefit calculus for many others as well. In the case of a transfrontier park, the decisions may at first seem to affect the costs of decision-making through collaboration for the transnational representatives. However, the decisions made by a JMB, for instance, also impact other officials, who may be at lower levels within the parks or officials in other governmental agencies such as international water groups, customs and border control, and so on. For instance, TFCA decisions can ripple through the decisions made in co-management groups for the contractual parks. In the past it has changed the budgetary decisions of provincial park authorities by changing land use plans and modifying tourism plans (South African provincial park staff, 06/23/05). The decisions may also change the cost equations for tourists and researchers, for better or for worse, by making cross-border movement more difficult or by increasing the length of time of the research permit process. The use of transaction costs to guide decisions is not meant as a call for detailed cost-benefit analyses for every decision, but rather to serve as a conceptual guide for how to operationalize the decision-making process and how to discern the appropriate level of governance for a wide range of challenges.

Diversity in TFCA decision-making

To summarize, in decision-making in a transboundary environment, no panacea approach exists (Ostrom, 2007). Transboundary conservation officials, NGO advocates, local community members, national and provincial government officials, and other actors in TFCA decisions must walk a fine line between generalizing from past experience elsewhere and taking contextual clues into account. Designing and implementing institutional arrangements is difficult and takes scientific and place-based knowledge, experience, and time. It also requires an adaptive governance approach of viewing policy decisions as experiments in need of continual refinement. The diversity of situations in southern Africa's transfrontier conservation initiatives provides multiple laboratories for experimentation and can facilitate region-wide learning.

With respect to the specific question of what level of cross-border cooperation to achieve, the approach above is not meant to be simplistic or naïve and it acknowledges that politics constantly buffets decision-making. Where possible, the intuitively obvious question to always ask is "Do the benefits of collaborative efforts outweigh the costs?" Unfortunately it does not always get asked. This question helps to re-examine the calculus in polycentric terms and eliminates much of the push for greater cooperation for no better reason than simply to cooperate. Instead, the lessons of polycentricism and robust institutional design encourage a more nuanced approach. In response to some disturbances, cooperate fully. In other cases, communication only with cross-border counterparts is the more appropriate level of interaction. Sometimes, working autonomously will generate the best solutions, either because local specificities require different responses or because a variety of potential solutions may work. Response diversity enables learning and better responses

to future disturbances. Within a country, as well, some actions will work best from the national level and others at a provincial level, some at a policy level and others at a bureaucratic level, some from within the parks and others from outside. The effectiveness of a particular level of cooperation in response to a plethora of challenges and opportunities which inevitably arise as TFCAs develop and the type of governance structure best suited to manage these issues will vary enormously. Fencing in and around TFCAs is likely to remain a contentious issue, and will continue to present governance and decision-making conundrums for the JMBs.

2.3 The advocacy role of NGOs in promoting dialogue as a means of resolving conflicts resulting from veterinary cordon fencing in Botswana

Ross, K.
Box 13478, Mowbray 7705, Western Cape, South Africa
karenross@mweb.co.za

Of the five countries in southern Africa that lie within the proposed Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA), it is Botswana that has the most complex and controversial history of fence construction for which Botswana's Ministry of Agriculture has come under much scrutiny and criticism from the conservation lobby and civil society. That being said, there are also some encouraging developments in recent years, resulting in better dialogue and greater transparency, which is worth detailing as a good example of the importance of advocacy in resolving similar issues. Since colonial times veterinary fences have been erected in Botswana to control livestock diseases and quarantine cattle from wildlife. Cattle are a prominent cultural and economic feature of the country, and for hundreds of years small-scale livestock rearing has co-existed relatively benignly with Botswana's remarkable wildlife resource (Barnes, et al., 2001). But the introduction of European Union (EU) trade subsidies has resulted in a proliferation of veterinary cordon fences, built to control the spread of diseases from wildlife to cattle, most notably foot-and-mouth disease (FMD), in order to comply with the strict EU & World Organisation for Animal Health (OIE) import regulations (Conservation International, 1989) so that Botswana may qualify for this lucrative EU trade subsidy (Environmental Investigation Agency, 2003).

Since then biologists and conservationists have become increasingly concerned at the negative impacts that these fences have had on Botswana's wilderness areas, by direct impacts on wildlife populations through death on fences by cutting access to critical water and forage, and through the fragmentation of their home ranges, as well as the loss of wilderness areas to livestock farming (Albertson, 1998; Keene-Young, 1999).

From the 1950s to the early 1980s veterinary fences were erected mainly in the southern and central parts of Botswana, adjacent to the Kalahari, and without thought about their impact on the wildlife in these areas. The best known of these was the Kuke fence, which was constructed in 1958 as the first full veterinary cordon fence in Botswana. Over the years the fences took a massive toll on animals whose traditional migration routes to water had been sealed off, and the Kuke fence in particular had a critical impact on the Kalahari wildebeest (*Connochaetes taurinus*) migration (Williamson & Williamson, 1984). There are also a number of qualitative accounts of losses of other species such as Kalahari carnivores, red hartebeest (*Alcelaphus buselaphus*) and zebra (*Equus quagga*) (Owens & Owens, 1984). Wildlife film-maker and conservationist Rick Lomba recorded some of the wildebeest deaths in a hard-hitting documentary entitled "The End of Eden".

The fence along the international boundary between Botswana and Namibia was constructed in the early 1960s and disrupted wildlife movement between the two countries, again, showing how, in arid land ecosystems, such

movements play a critical role in species survival (Martin, 2003). Having noted the negative impact of fences that interrupted wildlife access to water, it should be also recognised that during the early 1980s the Southern Buffalo Fence was built around the lower edges of the Okavango Delta. This fence has been useful in keeping livestock out of the Delta, which is a designated "Livestock Free Zone", and since the Delta's wildlife is contained within a wetland it has not had the same type of negative impacts on wild animals as have other cordon fences.

Lomba continued his lobbying and advocacy efforts with a US-based campaign against the erection of fences in Ngamiland (and around the Okavango Delta). This area in the early 1980s was to be part of a World Bank program called Livestock II, which laid out a plan to make Ngamiland, the northern Botswana wilderness home to the Okavango Delta, the next major beef export zone. Since FMD is endemic in the abundant buffalo (*Syncerus caffer*) populations of this area, this called for extensive veterinary fencing which would have large negative impacts on wildlife populations. Despite these lobbying efforts to stop the erection of the Northern Buffalo Fence and the Caprivi Border Fence, their construction went ahead.

However, more recently some encouraging initiatives have taken place, such as the formation of the Ad Hoc Committee on Fences (AHCOF). This was the first forum for discussing fence related issues, both within government (between the Ministries of Agriculture and Wildlife that had conflicting interests and in the past) as well as between government and NGOs. The minutes of these meetings, which took place over a five-year period from 1988 to 2003 are filed at the Department of Environmental Affairs, Gaborone. Through the period that AHCOF was active the first ever fences corridor in Botswana was created –by means of a vital 50km stretch of the Caprivi Border Fence which was removed adjacent to the Kwando River thus allowing animal movement between the Okavango region and the Caprivi area. This only partly alleviated the impact of the Caprivi Border Fence on Namibia's wildlife, as described by Martin (2003), who noted that the numbers of buffalo, roan, sable, and tsessebe in the Caprivi all seemed to have declined sharply since 1995. Prior to this time these animals were deemed to have been relatively abundant. The decline in these populations followed the most recent wave of construction of veterinary control fences and occurred immediately after the construction of double electrified fences along the western and northern sides of the international border between Botswana and Namibia, the strongest evidence that these veterinary control fences impact wildlife (Martin, 2003).

When an outbreak of contagious bovine pleuropneumonia (CBPP) occurred in Ngamiland in 1995 (starting in the extreme north-western corner of Botswana in an area called Xaudum), it resulted in the sudden erection of hundreds of kilometres of fences in many parts of Ngamiland in a bid to stop the spread of this disease (Ross, 1997).

As reported by FAO (Amanfu, et al., 1998):

"A logical strategy was put in place to contain the spread of the disease by forbidding cattle movement from the infected zone towards free areas and to perform a massive vaccination campaign ahead of the disease front. The vaccine used was the T1 SR strain and it was administered to thousands of cattle in an emergency vaccination campaign. However logical the strategy and correct the implementation plans were, they failed to contain the disease. CBPP soon spread to regions where the vaccination had been performed.

Subsequently, an ultimate massive slaughter strategy was put in place and all the cattle population in the infected zone was destroyed. This enabled Botswana to regain its CBPP-free status by the most rapid way but at a high initial cost".

The emergency erection of these fences failed to stop the movement of cattle and thus the spread of CBPP, and the entire cattle herd of Ngamiland, some third of a million animals, had to be destroyed (Amanfu, et al., 1998). This was a sobering reminder of the negative impact of animal diseases, and the potential difficulty that transfrontier conservation may face (with regards to transboundary animal diseases) due to the fact that the CBPP outbreak had originated in neighbouring Namibia. Just as concerning was that in a single year, most of the fences needed to institute "Livestock II" had been put in place.

Due to these developments, in the late 1990s Conservation International (CI) called for an Environmental Audit (EA) of all the Ngamiland fences that had been rushed into place during the CBPP emergency, a study for which Global Environment Facility funding had been secured. Whilst the Ministry of Agriculture rejected CI's request, the Ministry decided to commission their own study, funded by British Aid and the Government of Botswana; now known as the Scott Wilson Report (2000). The study was detailed, and the process was closely followed by a multi-sectoral Reference Group consisting of some 20 agencies. At the end of the process the Scott Wilson Report (2000) clearly showed that the Ministry of Agriculture's preferred option of expanding the Cattle Export Zone into Ngamiland, which was termed Option 3 (and following the idea of Livestock II) was environmentally, economically and socially the least sound land use option. At that time CI also held the first "Regional Workshop on Fences" (Conservation International, 1989), which was well attended by the countries that are now partners in the KAZA initiative. The Scott Wilson Report (2000) also recommended a review of the veterinary fence on the Botswana/Caprivi border, suggesting its partial removal as well as realigning the northern buffalo fence along the boundary of Controlled Hunting Area NG/13. To date this action has not taken place. The economic findings of the Scott Wilson study were supported by CI's own cattle/livestock economics study (Barnes, et al., 2001).

In 2003 it was announced that Option 3 was being pushed through Cabinet by the Ministry of Agriculture. Outraged that the conclusions of the EIA process that CI had tracked so closely were being ignored, a small group of NGOs comprising the Kalahari Conservation Society (KCS), the Hotel And Tourism Association of Botswana and CI joined forces and took a petition to the President of Botswana, as representatives of Civil Society on a matter where EA findings were being ignored. The then President, His Excellency Mr. Festus Mogae, heard of these concerns, and called for a halting of the Parliamentary debate pending further consultation and the completion of a World Bank study on cattle economics. It should be noted however, that although this livestock study was completed in 2007, its findings have still not been released to the general public. Thus it is unclear how the results of the study were used to inform Parliament on the validity or otherwise of the Scott Wilson Options 3 & 4. During this time attention was also raised also within the broader civil society by a series of articles by Ian Michler, which were published in *Africa Geographic* (including Michler, 2008).

Thanks to the findings of the Scott Wilson study, submitted to Government in 2001, the Ministry of Agriculture took the decision to entirely remove two Ngamiland veterinary fences deemed to be no longer required for disease control purposes, which was progress indeed. In 2003 the entire Setata fence was removed, some 210km, and in 2005 a 66km stretch of the Nxai Pan was removed (KCS, 2005). It was therefore a great surprise when, in 2007, the alarm was that the de-commissioned Setata fence was being re-built (this is part of Option 3) in response to a new FMD outbreak. Some NGOs and conservationists once more gathered forces – as they considered that much progress made in the past decade was at stake.

This time the conservation lobbying group was even larger, involving international groups such as the WILD Foundation of the USA, the Environmental Investigation Agency of UK, and the 'Bateleurs' of South Africa. A petition was sent to the President, a tenure now occupied by His Excellency Lt General SK Ian Khama, calling for a halt in construction of the Setata fence and the proposed formation of a wildlife corridor (see WILD Foundation web-page, 2009). Whilst sections of the Setata fence still stand, which is still of some concern and the subject of on-going monitoring, there is now a 70km wildlife corridor in place. The President also mandated that a group be formed in Botswana which will monitor this and other fences, participants include the Ministry of Agriculture, the Ministry of Wildlife, the Department of Environmental Affairs, and a conservation NGO presence, mainly represented by KCS. However, at a meeting with President Khama in April 2009, he asserted that any conservation NGO could participate with this group, now known as the "Fences Task Force".

Encouragingly, consultation is now easier with government officials in the Ministry of Agriculture and the Veterinary Department, and there is a certain degree of transparency, whilst officials in Veterinary Services and the Ministry of Agriculture are more knowledgeable of the complexity of ecological systems, and more willing to look at mitigation and alternatives. There is now widespread talk of Commodity Based Trading (CBT) to be the new paradigm with which to market livestock products in wildlife areas that contain diseases such as FMD (FMD Project, 2008). It would be useful if Namibia's Ministry of Agriculture, Water and Forestry conducted a pilot project on how best to integrate the communal areas north of the red line, with the more commercial south/central areas, into one economic unit and for Botswana's Ministry of Agriculture to collaborate with Namibia on the need to integrate Botswana's red line with Namibia's.

The Presidential mandated "Fences Task Force" is an interim replacement of the AHCOF, and there is a possibility that AHCOF could become re-instated. It has been a long and sometimes bitter conflict between the needs of animal disease control and the well-being of wildlife in Botswana, but it appears we are moving into a new era of communication.

2.4 The impact of veterinary cordon fences on livelihoods and natural resource use in Botswana

McGahey, D.J.
Consultant, Cardno Agrisystems Ltd, Oxford House, Oxford Road, Thame, OX9 2AH, UK.
daniel.mcgahey@cardno.uk.com

Fences and livelihoods in Botswana

Livestock development policy in Botswana has historically been targeted at international markets resulting in policy interventions that emphasize national rather than local priorities, favouring concerns for commercialization over rural livelihoods and the environment (Sporton & Thomas, 2002). To protect the export-orientated livestock sector from recurrent disease risks posed by neighbouring countries and wildlife areas, the nation is now divided by a network of veterinary cordon fences (Fig. 2.4.1). Much of this infrastructure has been developed with little *a priori* planning and negligible consultation with communities, ecologists or land-use planners (Perkins et al., 2002). Until recently, for example, no environmental impact assessment (EIA) has been conducted prior to the construction of any veterinary fence.[18] Few, if any, veterinary cordon fences follow the boundaries of existing land-use plans for their entirety. At best fences block communication links, cut cattle-posts off from arable lands and villages; at worst some even dissect entire villages (Hobbs, 1981). While the ecological consequences of veterinary fencing in Botswana have been documented widely (Williamson & Williamson, 1985; Mordi, 1989; Pearce, 1992; Perkins, et al., 2002), far less work has focused on impacts upon livelihoods and natural resource use in rural areas (exception being a brief examination by Hobbs, 1981; Scott Wilson Resource Consultants, 2000).

In spite of the lack of specific research on the implications of veterinary fences for rural livelihoods, actual impacts on society have begun to emerge. Research concerning community adaptation to drought in Botswana emphasizes how fencing prevents people from exercising coping strategies such as taking meat and goods to markets, while livestock movements between cattle-posts and arable lands are curtailed reducing access to draught power and milk at villages (Hitchcock, 1995 & 2002).

Studies of natural resource use at the wildlife/livestock interface found that fences have denied some communities access to natural resources, marginalising natural resource-based livelihoods and escalating resource conflicts (Mbaiwa, et al., 2008; Mbaiwa, 2004). However, far more research is needed, particularly detailed work investigating the extent to which veterinary fences have modified people's access to, effective use and management of, natural resources. Furthermore, a thorough analysis is needed of the broader implications of these changes for the sustainability of rural livelihoods and resource use, as well as for future fence planning.

[18] Legislation regarding EIA has recently been strengthened and several assessments have been completed in the last 10 years (see e.g. Scott Wilson Resource Consultants, 2000). However, under current animal health policy state veterinarians retain exclusive powers to construct 'emergency' fences upon communal land anywhere in the country.

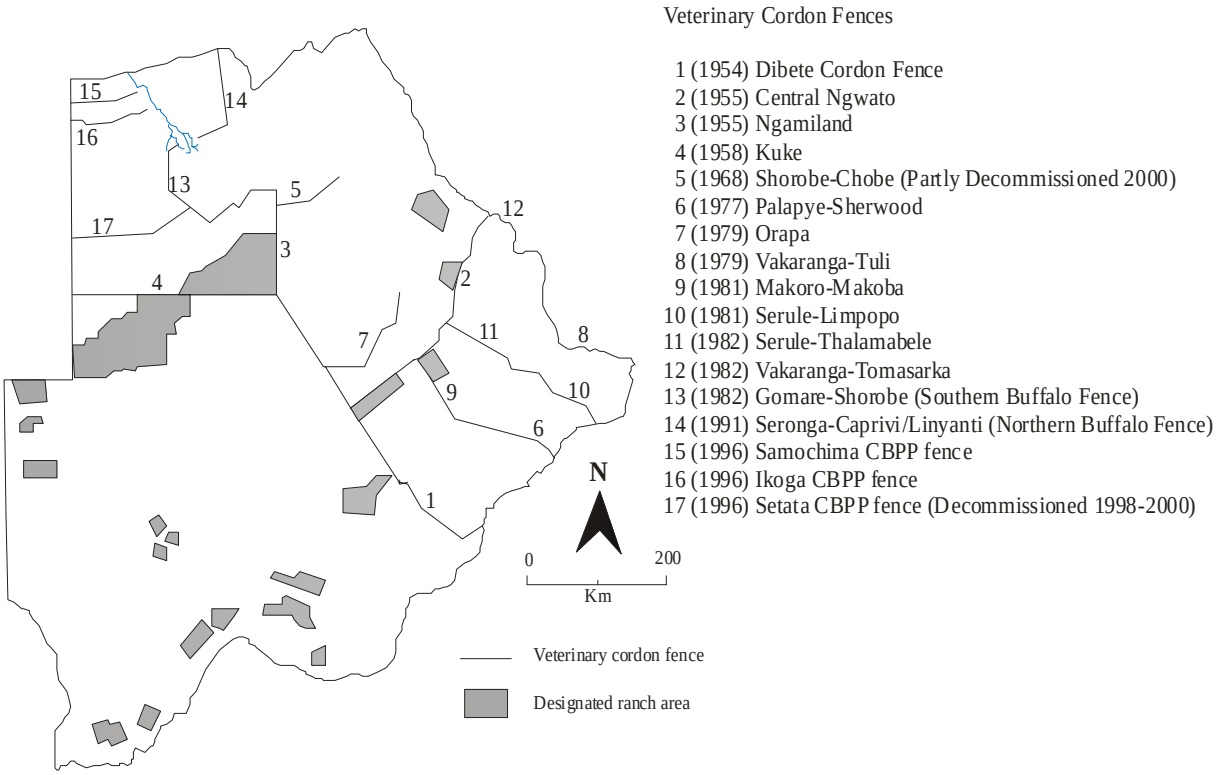


Figure 2.4.1. Botswana's veterinary cordon fences and fenced ranch blocks 1954-1996 (source: adapted from Perkins, et al., 2002).

The case of the northern buffalo fence

An analysis of these issues in relation to fence planning is timely given that recent prospects for further developing the wildlife-based tourism sector in Botswana through the creation of a Transfrontier Conservation Area (TFCA) will involve the removal and realignment of some fences (Conservation International, 2006). Notwithstanding significant research gaps that remain regarding the likely risks to animal and human health (Osofsky, et al., 2008), a thorough understanding of the long-term costs of fencing for communities at the wildlife/livestock interface will be vital to ensure that these changes work with, rather than against peoples' resource relationships. The case of the northern buffalo fence (hereafter NBF) provides an opportunity to explore these issues in detail.[19] Situated in north-western Botswana, the fence is designed to prevent the transmission of foot-and-mouth disease (FMD) from wild buffalo in the Okavango Delta wetlands to domestic cattle (Fig.2.4.1). The NBF was Botswana's first veterinary cordon fence to involve a community consultation exercise prior to construction.[20] In 1991, work was completed on the southern section of the fence after six years of planning and consultation,

[19] Much of the following case study material emerged from a doctoral study of veterinary cordon fence impacts upon rural livelihoods and resource use between 2004 and 2008 among communities living adjacent to the northern buffalo fence (cf. McGahey, 2008).

[20] During the early 1980s consultation and planning for fences such as the southern buffalo fence typically involved a flight along the route previously drawn on a map by DAHP officials (H. Benson, pers. comm.), with little or no consideration for current land use plans or people's resource relationships. Fence construction campaigns were also rapid, especially if conducted during disease outbreaks. For the Makoba cordon fence, for example, DAHP officials made their proposed plans known in December 1980 yet by March 1981 the fence was almost complete (Hobbs, 1981).

during which the veterinary department had commenced construction at least once, and the proposed fence alignment had changed four times (Lomba, 1991). Although the decision to fence or the design of the barrier was non negotiable, the community did manage to agree a more favourable alignment in terms of resource access than that initially proposed. However, after settling on an alignment that appeared to satisfy the interests of local people, land use planners and veterinary department, officials reverted to a route previously consulted over without returning to inform the community. The final alignment was motivated more by national political interests over retaining donor support for the expansion of commercial ranching in the region in the face of continued environmental lobbying, rather than people's natural resource access rights (McGahey, 2008). This has caused feelings of betrayal and widespread resentment towards the fence (Conservation International, 1998).

The fence impacted both positively and negatively on rural livelihoods. Prior to the construction of the fence people lived in a series of small settlements dispersed throughout the region with open access resources communally owned, and resource access negotiated through social relations at the community level. However, settlement patterns and livelihoods had begun to change as people were encouraged to resettle around several government service centres, and livelihoods shifted from a dependence on natural resources towards mixed agro-pastoralism. Although the quantity and diversity of gathered food declined, all groups retained a strong cultural attachment to these activities and a small number of households remained dependent upon the natural-resource base after refusing to resettle. The fence directly impacted upon the resource relationships of these people, enclosing some key resource areas (McGahey, 2008). Reduced resource access, coupled with the lack of transparency during the consultation process has disenfranchised the community from the aims of the fence, causing local resentment towards enclosure which is seen as accompanying preservationist conservation policies in a gradual process of land dispossession and detachment from wildlife-based natural resource use (ibid, chapter 7).

The NBF fragmented and isolated wildlife populations causing declines in a number of species to the west of the fence (Chase & Griffin, 2009; Mbaiwa & Mbaiwa, 2006). At the same time community-based natural resource management (CBNRM) initiatives have increased in the region and nature-based tourism now accounts for forty-per cent of employment opportunities (Hoon, 2004). Nationally, there are over 80 community conservation organisations, most of which are involved in joint-venture partnerships with private safari companies who manage the land on behalf of the people and share economic returns. Many of these larger trusts manage these relationships on behalf of a collection of villages, creating conflicts over management and benefit sharing. Although some community trusts have invested in productive assets which may benefit the wider community, few households derive livelihood benefits unless directly employed by the trusts or joint-venture partners. Educational constraints mean that competition for unskilled employment opportunities is high.

More recently the situation has improved through the establishment of several ecotourism ventures led and managed by individual village trusts. The potential for these initiatives to become mainstream wildlife viewing destinations, however, has been limited by fence-induced declines in the diversity of wildlife, causing frustrations towards the NBF among many people, especially Basarwa groups (McGahey, 2008). For example, with assistance

from local NGOs, the marginalised Basarwa have been supported to establish a cultural ecotourism camp, yet this is marketed by the joint-venture partner as a one night addition to a client's trip making '*a perfect complement to the wildlife viewing camps of the Okavango Delta and Linyanti*'. Mbaiwa, et al., (2008) note the Okavango Polers' Trust, a community venture involving wildlife tours in dugout canoes or *Mokoro*, have experienced similar marketing problems. Elsewhere, entire communities have been denied access to CBNRM opportunities by the southern buffalo fence (Mbaiwa, 1999). By extending state control over natural resources the fence has weakened community access and control over wildlife, thus privileging a narrow form of CBNRM involving joint-venture partnerships with private safari companies. Veterinary fencing, alongside the establishment of protected areas, has served to alienate communities from their ancestral lands and escalated tensions over resource use between people and the state (Mbaiwa, et al*.,* 2008).

One of the positive implications of fencing for livestock farmers is that enclosure has reduced stock loss through straying and stock-theft, especially in remote border regions. Most owners practice a 'herd release' form of pastoral management relying on water demands to attract cattle back from the dry savanna pastures. During the wet season herding demands are far higher as cattle can stray for days, accessing water from the many ephemeral waterholes that cover the landscape. Fences have created a useful barrier to these movements, with maintenance roads providing access routes to track lost livestock. The increased presence of veterinary personnel along fences at gate camps or on maintenance patrols often provides a source of additional intelligence regarding the location of lost livestock.

The fence has also had an impact on people's vulnerability to environmental change. In addition to recurrent droughts, fires, disease outbreaks and economic risks associated with tourism, people cope with various natural hazards associated with dependency on seasonal floodwaters of the Okavango Delta. The Delta is subject to an annual flood event, which takes place during the dry season (August-September) and is largely dependent on rainfall in the Angolan highlands. The area inundated changes annually and inter-annually with long term variability ultimately determined by external climate changes and El Ninõ/Southern Oscillation (ENSO) effects (McCarthy, et al*.*, 2003). As a result, the flooded area can vary from an annual minimum of between 4,000-6,000km^2 to an annual maximum of between 6,000-12,000km^2 (Wolski & Murray-Hudson, 2006). Flooding is also spatially dynamic with floodplain morphology naturally changing due to sedimentation, channel blockage and avulsion (McCarthy & Ellery, 1998). Flood regimes therefore change annually and inter-annually, and channel desiccation can occur irrespective of overall flooding trends.

Analysts of societal vulnerability to natural hazards emphasize the importance of access qualifications in determining the ability of people to engage their optimal risk management strategies (Wisner, et al., 2004). Local community members, particularly village elders, lament the loss of enclosed natural resources previously used during times of environmental stress. These people have experienced poor flooding and prolonged droughts in living memory and used migration to access social support networks and natural resources now enclosed by the fence (McGahey, 2008). Livestock farmers also used herd mobility to access water or grazing and have now adapted by digging shallow wells, resulting in more sedentary grazing patterns. These changes have increased reliance upon economic diversification and state support schemes to

cope with natural environmental variability (Wilk & Kgathi, 2007). Concerns over the increased vulnerability of water-dependent livelihoods caused by fencing have intensified since people living adjacent to the southern buffalo fence have experienced a permanent loss of flood water resulting in the collapse of flood-recession farming systems (cf. Bendsen & Meyer, 2003; Mbaiwa, 2004).

Conclusion: implications for planning

Inadequate forward planning and consultation for veterinary fencing has resulted in alignments that fail to account for people's resource access rights and natural resource relationships. For people living at the interface between wildlife and livestock in Botswana, veterinary fences have restricted access to, and control over natural resources. This has served to further marginalise natural resource-based subsistence livelihoods, contributing to existing trends towards increased reliance on agro-pastoral production. By reducing the diversity of wildlife on community lands, fencing has pre-empted the means by which people can benefit more directly from nature-based tourism. This has served to extend state control over wildlife, privileging a simplistic form of CBNRM involving the lease of enclosed land to the predominantly foreign-owned nature tourism sector. Finally, by restricting resource access and mobility, fencing has increased societal vulnerability to environmental risks and hazards. This is of particular concern for people whose livelihoods are highly dependent on water availability in the Okavango Delta region, where long-term channel desiccation can occur irrespective of trends to overall water abundance.

The NBF will require realignment with the creation of the Kavango-Zambezi TFCA, thus providing an opportunity to address many of the resource conflicts that have emerged in the region. Realignment should revolve around findings emerging from a thorough environmental and social impact assessment and decision makers should seek to engage local communities early and ensure that the interests of all resource users influence the planning process, particularly socially marginalised groups. In the long term, given the constraints to natural resource access and livelihoods outlined above, veterinarians should work with communities to devise more innovative fencing solutions to the disease management problem which allow more integrated land use options, within the limits of current international animal health policy. This could involve the creation of community-managed enclosures to compartmentalize livestock, provided such solutions worked with, rather than against, existing agro-pastoral systems.

Acknowledgements

Research referred to throughout this section in McGahey (2008) was funded by the Economic and Social Research Council, Natural Environmental Research Council and Hertford College, Oxford. My thanks are extended to the people of Beetsha and Gudigwa for taking the time to participate in the research and to the Department of Animal Health and Production for granting a permit to conduct this study.

2.5 Fences and conflicts in the Lubombo TFCA

Kloppers, R.
Wildlands Conservation Trust, P.O. Box 1138, Hilton 3245, South Africa.
roeliek@wildlands.co.za

Borders, boundaries and fences at Lubombo

The Lubombo Transfrontier Conservation Area (LTFCA) was planned in the late 1990s and endorsed by the governments of Mozambique, South Africa and Swaziland in March 2000. This TFCA comprises five mini Transfrontier Parks, each with its own dynamics, conservation objectives and fences (Fraser, 2009). The first and largest of these aims to establish a link between the Maputo Elephant Reserve in Mozambique and the Tembe Elephant Park and Ndumo Game Reserve in South Africa (Fig. 2.5.1). It will re-instate the ancient migratory route of the Maputo-Futi-Tembe Coastal Plains elephant (*Loxodonta africana*) along the Futi-corridor and, it is hoped, unlock the tourism potential of the area to foster local growth (Kloppers, 2003; van Aarde & Jackson. 2004).

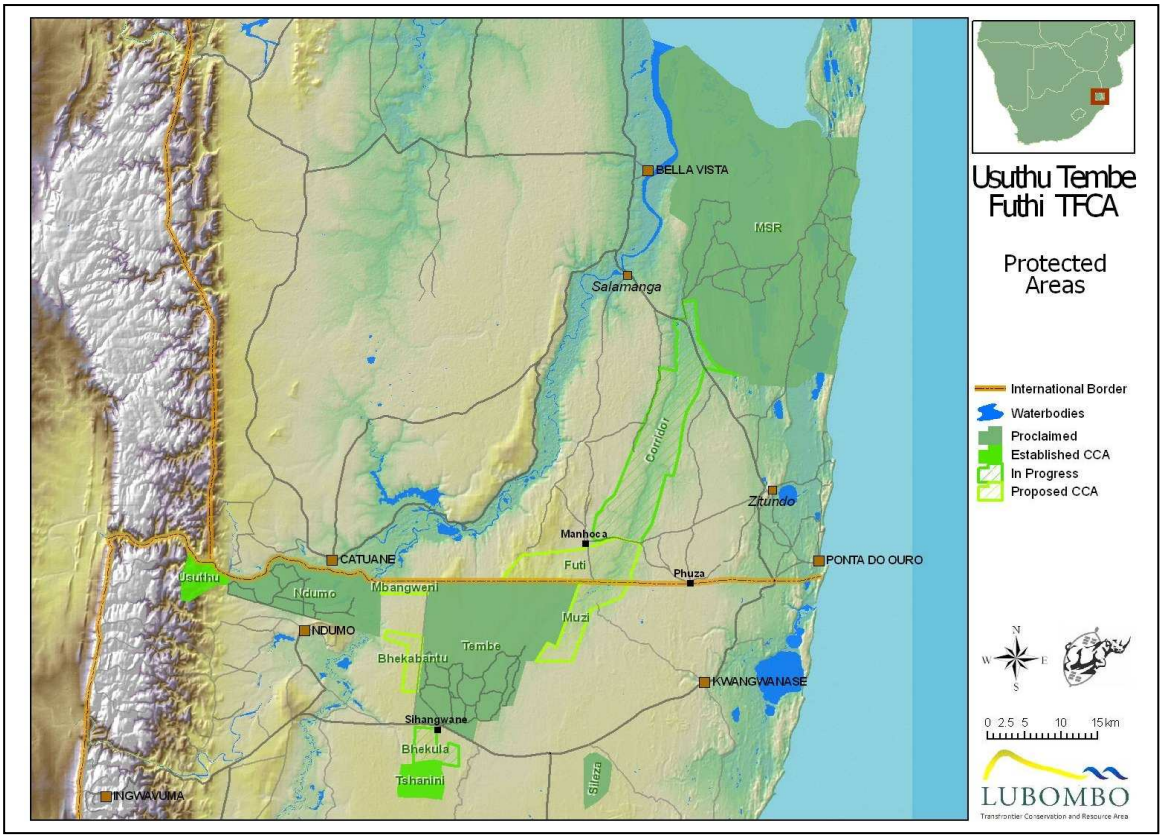


Figure 2.5.1. Lubombo Usuthu-Tembe-Futi Transfrontier Conservation Area

However, it has never had much legitimacy at the local level. At the base of local opposition to the larger conservation area are disputes over land ownership and access to resources and conflicting perceptions on 'people in parks' in South Africa and Mozambique. The history of the fences that

demarcate imposed borders and boundaries in the area tells the story of this unfolding conflict. These fences are; the MacMahon Fence, the Ndumo fence and the Tembe fence. After a brief discussion on the history of placing these fences, consideration is given to the current dynamics around the removal of these fences and the placement of new ones.

The MacMahon fence

In 1875, the President of France, Marshall MacMahon, imposed the first artificial border on the Maputaland landscape. This border cut straight through the Tembe-Thonga Chiefdom, placing half the subjects of the Tembe Chief under British rule and the other half under Portuguese rule. The line on the map was only fully fenced in 1989, after Mozambican independence (1975) and an ensuing internal war that caused the displacement of thousands of refugees (Webster, 1991; McGregor, 1998). The fence still stands and nowadays represents the border between the Republics of South Africa and Mozambique and the ethnic boundary between Zulus and Shangaans (Kloppers, 2006).

The Ndumo fence

Ndumo Game Reserve was proclaimed in 1924, but not fully fenced until the late 1960s. The reserve is relatively small (12,000ha) but has been proclaimed as a Ramsar site and is home to over 400 bird species. The Mathenjwa and Tembe communities who were forcibly removed from the area during the 1960s claimed their land back after 1994 and two separate titles, one for each claimant community, were restored on the land in 2000 (Jones, 2006; Impey, 2006). As part of the settlement agreement the conservation authority was to enter into a co-management agreement with the claimants and plans needed to be put in place to ensure local people would benefit from eco-tourism activities inside the Reserve. Government also made R17 million available for related socio-economic development projects. At the time of writing, the co-management agreement is yet to be developed and the local community has seen no benefit from their land. This is the root cause of recent land invasions, dealt with in more detail below.

Tembe's fence

Tembe Elephant Park was proclaimed in 1983 to protect the last free roaming elephant population in KwaZulu-Natal. The Park was established on request from Chief Mzimba Tembe after escalating complaints from his people of crop damage caused by elephants in the Sihangwana sand forest. Tembe is in fact the first contractual Park in South Africa and was established with the explicit goal of protecting people from elephants. The northern border of the Park initially remained unfenced, allowing elephants, which seasonally migrated from the Maputo Elephant Reserve to Tembe, to continue natural migration patterns. However, rangers recorded increased incidences of elephants with bullet and snare wounds contracted as they migrated into the Mozambican warzone and in 1989 a decision was taken to fence the northern border of the Park. The new fence trapped a substantial portion of the elephant population inside a sensitive habitat, which they historically only visited for short periods of the year (Morley & van Aarde, 2006; Matthews, et al., 2001 & 2002). The fenced in and growing elephant population has caused a major headache for Park officials and scientists who fear that one of the largest protected tracts of the sensitive and endemic Maputaland Centre of Plant Species Endemism might be disappearing at the hands of the elephants. As a result, Park officials have endorsed plans for the establishment of the TFCA into Mozambique, as well as plans for creating corridors with Ndumo Game Reserve and for the

establishment of new community owned reserves where elephants would be able to roam.

Tearing down old fences and putting up new ones: the Ndumo fence line

The establishment of Ndumo Game Reserve and Tembe Elephant Park created a small borderland community in South Africa on a 5km wide strip of land along the Mozambique border. Initially only a very small group of people, the population steadily grew with the settlement of refugees from the Mozambican war. Although there were never any formal refugee camps established in KwaZulu-Natal, government did grant amnesty and citizenship to refugees who settled in South Africa in the late 1980s. Today there are some 150 households (less than 1000 people) in this area, called Mbangweni after a prominent chief who historically ruled this land. Recent research has shown that more than 80% of the people currently living in this area moved there during the Mozambican war (1975-1992) and that only a very small percentage were forcibly removed from Ndumo Game Reserve (Kloppers, 2006; Jones, 2006). However, the new community has created a united front demanding access to resources inside the reserve and adamantly opposing any efforts to establish a corridor through their land to link Ndumo Game Reserve with Tembe Elephant Park. The latter has been blamed on crime syndicates operating in the area and smuggling drugs, stolen cars and other contraband through this relatively unprotected border.

Life in Mbangweni is indeed harsh. There is no ground water or arable land and most locals undertake daily trips across the border into Mozambique to collect water or to farm small parcels of land. Government has also not provided any support and the only school was donated by the conservation agency as part of its efforts to better relations with the local people. This relationship has consistently worsened after the land claim in 2000 as the community became increasingly aggrieved at not benefitting from land restored to them. The fence has not only come to symbolise the conservation agency, but government at large and the community beliefs that the only way to get development and force government to listen to them is to ring what is locally referred to as the Ndumo fence line. In 2008 the local community, disillusioned by promises of development and delivery, pulled down 11km of the eastern fence of Ndumo and invaded the reserve. Using guns and dogs they decimated game in the area east of the Pongola River and forcibly took control of the area. They have since moved into the area and started to farm along the Pongola Floodplain, not needing to travel to Mozambique to access water or arable land any longer. The conservation agency has been unable to do much about the invasion as the climate has become increasingly militant with rangers and their families threatened by local militia. At the time of writing the fence remains down and it appears that the eastern portion of the reserve has been lost for conservation. With that plans for creating a corridor to link Ndumo Game Reserve with Tembe Elephant Park have also been abandoned, placing the fate of Tembe's habitat and elephants squarely on a successful link with the Maputo Elephant Reserve.

People inside and people outside of parks

The biggest conundrum faced by planners on the South African side of the LTFCA was how to deal with the people living in the Futi Corridor – the area of land between the Rio Futi and Rio Maputo that was to link the Maputo Elephant Reserve and Tembe Elephant Park (Fig. 2.5.1). Unlike the case in most countries on the continent, game reserves in South Africa are fenced entities with no people living inside except for those responsible for managing the

reserves. The forced removal of people to set aside pseudo-wilderness areas lies at the origin of many land claims and conflicts on land ownership in South Africa. This mentality has been exported in planning for the TFCAs and the first question everyone asked was what to do with the people living in the Futi Corridor. Mozambican analysts were adamant that no action was needed. They strengthened their case when they alerted planners in South Africa to the fact that there were some 30,000 people living inside the boundaries of the Maputo Elephant Reserve. It would seem that South Africa was about to enter the world of 'outside of the fence' thinking on people and parks, but then, at almost the same time, Tembe Elephant Park introduced new inhabitants that seemed to close the door on any link with Mozambique. In 2001 the conservation agency introduced six lions from Pilanesberg (originally from Etosha) to Tembe Elephant Park. Mozambican officials were up in arms – whereas people historically lived with elephants and welcomed the amalgamation of the two parks, local people now viewed with suspicion any talk of a larger TFCA. It seemed the introduction of lions killed all aspirations of expanding space for elephants to the north and, at the time of writing, this is still unresolved. However, ground has been gained with the erection of a two-strand elephant restraining line along the Futi Corridor. The new fence restricts elephants in Mozambique to the eastern side of the Rio Maputo, still allowing local people access to the river. Initial assessments have shown that the elephant restraining line has limited human-elephant conflict in this area and that local people have been convinced that conservation authorities could control elephant conflict and possible crop damage. This would have been the ideal time to push for dropping fences, but for the new inhabitants of Tembe who now number some 30 individuals.

Since the northern fence of Tembe Elephant Park could not be dropped, scientists have looked for new solutions to control the growing elephant population. In 2008 an internal elephant restraining line was erected inside Tembe Elephant Park to keep elephants out of the sensitive sand forest habitat. This was done in conjunction with a contraception program. However, all those involved agree that these are mere 'holding mechanisms' and that the only real solution for Tembe's elephants is to expand the space over which they could roam. At this stage expansion to the west is complicated by land invasions in Ndumo and to the north by fear amongst local people of Tembe's recently introduced carnivore population. This has ignited new plans for expansion to the east and south. In both these directions work is already underway to secure land for conservation – to the south a new 4,000ha community conservation area is being established and to the east a buffer-zone that could provide some much needed options for expansion. As new fences go up in Maputaland, hope remains that old ones could soon come down.

2.6 What do the local communities say about fences?

Chaminuka, P.
University of Limpopo, School of Agricultural and Environmental Sciences, Private Bag X1106, Sovenga, 0727, South Africa.[21]
petronella.chaminuka@wur.nl

Introduction

Using information collected from over three years of interaction with rural communities on the north-western side of the Kruger National Park (KNP), we present here some insights into how these rural communities perceive the KNP fence. The information was collected through community workshops, focus group discussions, key informant interviews and a survey of 540 households, 270 of which owned cattle. In one of the workshops held in March 2010, several questions pertaining to how communities perceive fences were put up for discussion. Thirty seven participants, from six villages attended this workshop. Participants were divided into three groups; cattle and crop farmers (14), youths (14), and tourism business entrepreneurs (9). Each group discussed the questions and gave feedback in a plenary session where there was further discussion of the issues.

Studies by Els (1995), Mabunda (2004), and Anthony (2007), have reported different findings in attitudes of communities towards the KNP, which vary between different villages and over time. Anthony (2007) found that attitudes varied from positive, neutral to negative. Negative attitudes toward KNP were as a result of damage causing animal (DCA) problems and inadequate maintenance of the KNP border fence. These previous studies focused on the attitudes and perceptions of rural communities towards the KNP. This contribution focuses on the attitudes and perceptions of these communities toward the existence of the KNP fence.

Perceptions on the role of fences

Contrary to prior expectations that rural communities had a negative attitude towards the KNP fences, we found that community members did not in fact have a problem with the fence per se, but rather the fact that the fence did not successfully keep damage causing animals (DCAs) from crossing over into people's fields and the grazing land. Discussion about the KNP fences inevitably led to discussion on crop destruction and livestock depredation, and the losses that these communities have suffered due to lack of compensation payment. Despite these problems the communities pointed out that that they do not have a problem with the KNP fence and there was a general agreement on the need for the fence. We however, found that there were differences in understanding of the purpose of the KNP fences amongst community members.

Table 2.6.1 shows that the farmers were aware of the role that fences play in disease control. This supported our earlier findings from the survey of 270 cattle farmers, that revealed that 86% of the farmers were aware of the redline zone for disease control. In the workshop, the farmers indicated that

[21] This work is part of a PhD project generously funded by the AHEAD seed grants program, Wageningen University and the International Foundation for Science.

they were aware that the fence around the KNP was owned by the Veterinary Section of the Department of Agriculture. They further explained that the KNP staff had communicated through the Hlanganani forum that the fence did not belong to the KNP and hence responsibility for its maintenance did not lie with the KNP. The farmers indicated that the poor state of the KNP fence had resulted in significant losses to the communities through livestock depredation, crop destruction and loss of human life. Similar to findings by Mabunda (2004), these communities view the KNP as a national heritage site to be proud of, and also appreciate the biodiversity conservation role of the park. The farmers cited two plant species that were previously available locally, but have since been destroyed and can now only be found inside the park.

Table 2.6.1. Community responses to questions pertaining fences.

Why is there a fence around the KNP?	**Groups responding**
To prevent dangerous animals from crossing to our areas	*All groups (100%)*
Prevent animals with infectious diseases from the park to cross and infect our cattle; especially buffalo	*Farmers only (33%)*
To preserve nature	*All groups (100%)*
To prevent people from entering the park for poaching	*Youth only (33%)*
To protect the community from KNP animals	*All groups (100%)*
What would happen if the KNP fences were brought down?	
Good things	**Bad things**
People will get access to meat	*Wildlife will kill domestic animals*
More access to residential, grazing and cropping land	*Wildlife will kill people*
Free entrance to the park	*Diseases would spread*
Availability of traditional medicine	*Elephants would damage our crops*
Get access to more firewood and mopane worms	
We could start income generating projects that need larger amounts of land.	

Communities on the northern borders of the KNP are characterized by high unemployment rates, poverty, high dependence on natural resource based livelihoods and limited livelihood opportunities (Chaminuka, et al., 2008). Whilst it is generally perceived that by being close to the KNP these communities derive benefits through employment and business opportunities, the extent to which these communities has been able to benefit economically from the KNP is limited (Mabunda 2004; Chaminuka, et al., 2008).

The KNP and the fence around it impacts both positively and negatively on the livelihoods of these rural communities. Workshop participants were asked whether or not the KNP fence prevented them from undertaking some activities to earn income. By a show of hands in the plenary, 20 out of the 37 participants (54%) agreed that the fence did in fact hinder their opportunities to generate income. There was consensus on this view in the farmer's group. This is despite the fact that the farmers also acknowledged the role the fence

played in disease control. In the youth group and the tourism entrepreneurs groups, consensus could not be reached on whether or not the fence prevented communities from performing some income generating activities. It was pointed out that whilst the fence did prevent people from accessing some natural resources, it also presented opportunities to earn income from tourism related businesses. We however, observed that compared to the other sides of the KNP such as the Paul Kruger and Numbi gates, next to the Punda Maria gate there was almost no visible tourism related business, except for the craft shop at Punda Maria, and two small privately owned lodges.

When asked what would likely happen should the KNP fence be taken down, the communities cited both the good and the bad. Table 2.6.1 shows that most of the perceived advantages that would accrue to local people, if the KNP fence was removed, have to do with access to land and land based resources inside the KNP. This was also echoed in discussions where one of the participants said: *'The KNP should not take down the fence because it is there to preserve the national heritage, they should only move it into the park for some kilometres inside to allow us to have more land'.*

The poor state of the fence and the problem of DCAs are considered to create obstacles to improving livelihoods, pursuing economic diversification particularly with regards to crop and livestock farming (Anthony, 2007). From the survey, we found that about 25% of cattle households lost cattle to depredation between and including June 2005-June 2008. Some (13%) of the households without cattle cited problems with wildlife as the main reason that they would not want to own cattle. About 23% of the cattle farmers were of the view that they were disadvantaged by being within the redline zone. The reasons for this included that it limited their opportunities for livestock marketing (32%) and also increased the risk of disease and livestock depredation.

Conclusion

Although there are some benefits that are associated with the KNP, the costs of being adjacent to the KNP for some members of the community are far higher than the benefits. Maintenance of the KNP fence is not only important for disease control and wildlife, but it may be in the best interest of all parties for the KNP fence to be maintained since wildlife also faces risk of extermination outside the park. Farmers suggested that they should be trained and employed to patrol the fence for some nominal fees. This would reduce problems of depredation whilst generating additional income for the households. Repairs of damaged fences and responses to reports of lions escaping the park should be treated as a priority by the KNP.

3. DISEASE CONTROL AND FENCING

3.1 Current policies for epizootic disease containment in the southern African sub-region

Burroughs, R.
Centre of Veterinary Wildlife Studies, Faculty of Veterinary Science University of Pretoria, P.Bag x04, Onderstepoort, South Africa.
Richard.Burroughs@up.ac.za

Introduction

Most countries within the southern African sub-region use a combination of international standards and national legislation and regulations as the basis for their own disease control strategies. The most important of these international standards, is the International Organization for Animal Health (OIE). The OIE defines the mechanisms whereby countries can trade with each other in animals and animal products on an acceptable risk basis. Each country would then consult the current version of the Terrestrial Code of the OIE (it is revised on a regular basis), and formulate import policies for animals or their products that are of interest. The Code regulates many diseases, but not all and specifically not all the diseases that may be of relevance to the sub-region. Importing countries can then request certain guarantees from the country of origin that the products have either been tested free of a particular disease, or have originated from a geographical zone that is recognized to be free from that particular disease. Test results would have to be backed up by written acknowledgement from the veterinary services of the country of origin that the tests are adequate and correct. Furthermore, with regard to disease free or disease control zones, the exporting country is able to submit detailed surveillance information to the OIE on the status of this zone, and if accepted by the OIE, would be made available on the OIE website. It thus becomes an important criterion for trade, specifically with regard to foot–and-mouth disease (FMD). Fences, identification of animals and movement controls thus form a core component of an OIE recognized disease control zone. In terms of OIE rules, an outbreak of, for example, FMD has to be reported within 24 hours of laboratory confirmation of the event, even if this occurs inside a controlled area or buffer zone, irrespective of whether this affects the particular disease free status of the country or not.

In addition to this, individual countries impose internal restrictions (based on their own animal regulatory legislative framework) for the control of certain diseases, which would be to the benefit of trading partners. If the disease has only regional significance, and the distribution of the disease is linked to a specific arthropod vector, then that disease is not likely to be defined by the OIE, e.g. Corridor disease (although this has similarities to and is related to East Coast Fever). Within the sub-region, all animal and animal product movements are generally subject to a Veterinary Import Permit, with the possible exception of the movement of dogs and cats between certain countries.

Related to fencing, a compartment is a specific unit or series of units that is adequately fenced or contained, which can be considered free of a disease

within the accepted infected geographical distribution area of that disease, provided that adequate biosecurity can be maintained. The sub-units can be in different areas, provided that each has adequate and similar biosecurity, and that the methods of transport or communication of the products between the sub-units, within an infected area, are equally biosecure.

Harmonization of policies is a stated goal of regional cooperation, but is often difficult to achieve, given difference in disease, disease control strategies and control capacities in the sub-region. South Africa relies on the OIE process to define the disease control zones (Fig.3.1.1), as necessary, as well as its Animal Diseases Act. From a wildlife perspective, the role of infected buffalo as carriers of FMD and Corridor Disease, and to a lesser extent Tuberculosis and Brucellosis, are central to disease control policies that affect the borders of South Africa.

South Africa

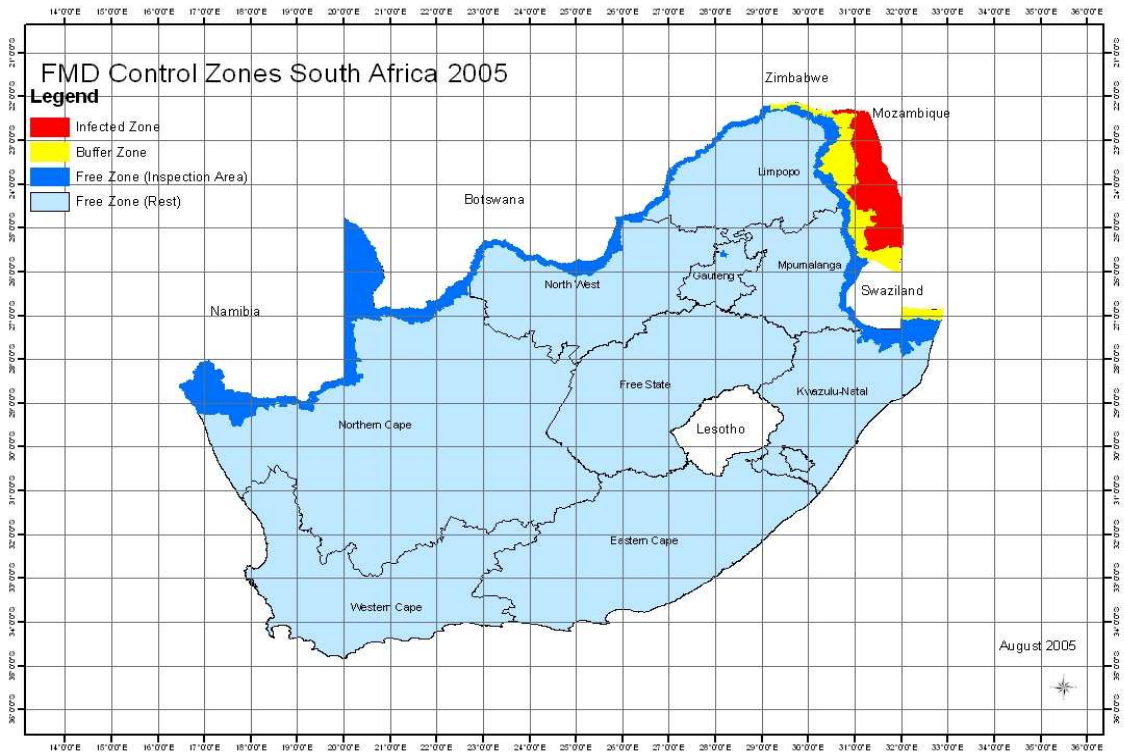


Figure 3.1.1. Disease control zones in South Africa.

South Africa is defined by the OIE as a country that is FMD infected, with a FMD free zone without vaccination. The Infected Zone is a fraction of the size of the free zone – it extends from the Crocodile River in the South up to the Zimbabwe border, and some distance along the Limpopo towards Messina. Around this infected zone is the Buffer Zone that extends from the Swaziland border, around the Kruger National Park (KNP), and along the borders of Zimbabwe, and ends at the beginning of the Botswana border. This buffer zone is split into 2 sections: a narrow FMD vaccinated zone, and an unvaccinated zone. Vaccination within the vaccinated zone occurs at the moment twice annually, but is likely to be increased in frequency to three times per year. Vaccinated cattle are branded, and cannot leave this zone, unless for direct slaughter at approved and designated abattoirs situated on the periphery. The land use is that of both communal land and commercial

livestock ranchers, depending on the area. Active surveillance for FMD occurs within this surveillance zone.
The rest of the country is thus classified as FMD-free. In addition to this, there is an additional "Inspection Zone" around the total perimeter of the country in which additional active surveillance takes place.

The perimeter of the KNP is fenced to exclude buffalo (*Syncerus caffer*) movements from out of this area, but is challenged by elephant (*Loxodonta africana*) breakouts on occasion. An exclusion fence extends along the Zimbabwean border, but along the Botswana, Namibia, Swaziland, Lesotho and parts of Mozambique border, this is largely a cattle-type fence. This is challenged by illegal movements of livestock and products.

With the exception of rhino (*Diceros bicornis* and *Ceratotherium simum*) and elephant, no free movement of hoofed animals occurs from the infected zone to the free zone unless a strict series of quarantine and testing protocols have been adhered to. Buffalo are allowed only in certain parts of the Buffer Zone. Movement can occur from the buffer zone to the free zone only under State Veterinary supervision, and under specific conditions. Manned control points exist to control the movement of animals, but the movement of livestock out of this area is not common, unless for direct slaughter. Disease-free buffalo (i.e. FMD, Corridor, bovine tuberculosis, brucellosis or a specific combination thereof) exist in game farms or parks outside of the controlled zone.

Movements of animals and animal products in general from Zimbabwe and Mozambique are strictly controlled, while those from countries with a perceived lower disease risk such as Botswana, Namibia, Swaziland and Lesotho are less strictly controlled. Other diseases in South Africa are controlled by policy as defined by national legislation, with power devolved to nine autonomous and separate provincial veterinary services for execution by their provincial and local veterinary services.

Other than the branding of animals within the vaccination zone of the buffer zone, no mandatory identification system of animals exists in South Africa. Surveillance for controlled diseases is performed on a regular basis.

Namibia

Namibia has similar disease control approaches to that of South Africa. They are also classified as an FMD infected country, with a FMD free zone without vaccination (3.1.2). Similarly, their infected zone is relatively small, consisting of the Caprivi Strip. FMD-infected buffalo occur in this area, but are not allowed out. Movement of cattle is restricted, and movement of animal products can only occur under certain conditions. The borders of this area are designated by fences, as are the international borders with Angola and Namibia and South Africa. The FMD Buffer Zone extends across the northern sections of the country, and includes the Etosha National Park. Active surveillance for FMD and Contagious Bovine Pleuropneumonia (CBPP) occurs in this region. This area is largely community based agriculture, with the exception of the Etosha National Park. No FMD-infected buffalo occur in this Buffer Zone. Slaughter of cattle only occurs at two designated abattoirs after a mandatory quarantine period - one abattoir in the Infected Zone, the other in the Buffer Zone.

Annual vaccination for CBPP occurs in this area. Rigorous control of animal and animal products into the southern FMD-free zone occurred at the so-called red-line fence, with specific designated quarantine zones. The status of this red-line has recently been revoked as the result of an absence of FMD outbreaks and reduction of CBPP cases, with control shifting to the Angolan border.

Revised control measures for that region will be introduced, particularly as CBPP and FMD occur in southern Angola.

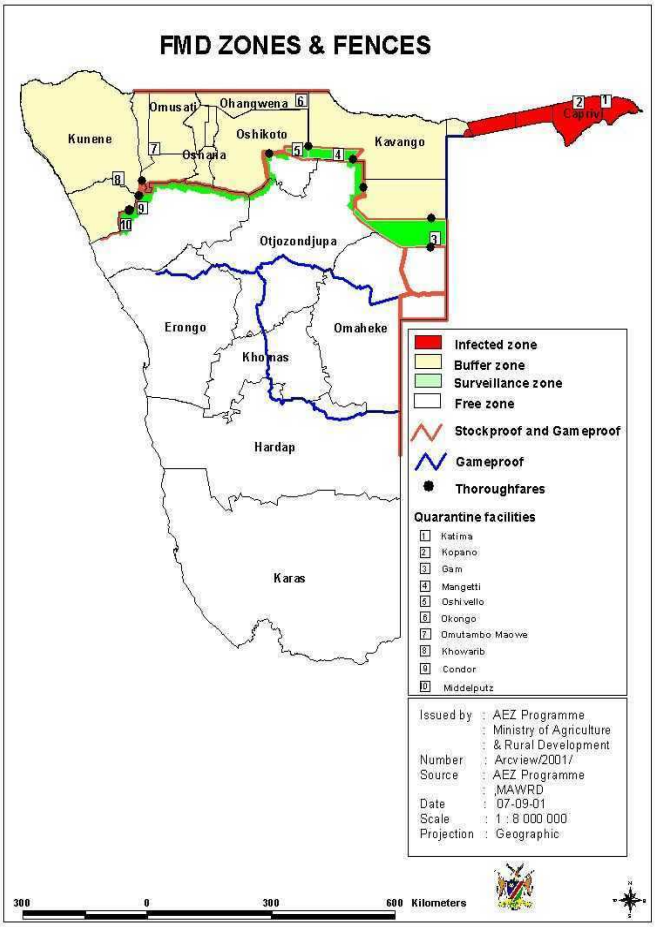


Figure 3.1.2. Disease control zones in Namibia

Other diseases are controlled according to current disease legislation, and export occurs from the current FMD-free zone. Within this zone, all livestock on commercial land are identified as they are moved using a sophisticated mandatory ear tag system that has direct electronic links to various government departments.

Two herds of disease-free buffalo exist outside of the FMD Infected Zone. Disease control strategies are decided by a strong centralized Veterinary Department, and are executed at regional state veterinary level. Surveillance for controlled diseases is performed on a regular basis.

Botswana

Botswana has a similar disease control approach to that of South Africa – a combination of OIE recognized disease free zones and nationally controlled programmes (Fig. 3.1.3). With regard to their FMD status, they are FMD infected, with a FMD-free zone without vaccination. Trade with neighbouring countries that also have FMD-free zones is thus relatively simple. The FMD control zones are in 2 major areas. The northern most regions consists of a central wildlife area, comprising the Okavango ecosystem and parks such as Chobe to the north. This area has populations of buffalo that are both FMD infected and *Theileria parva* (Corridor Disease) infected, and are separated

from the FMD-free zone by fences that restrict movement of animals and livestock from within this area.

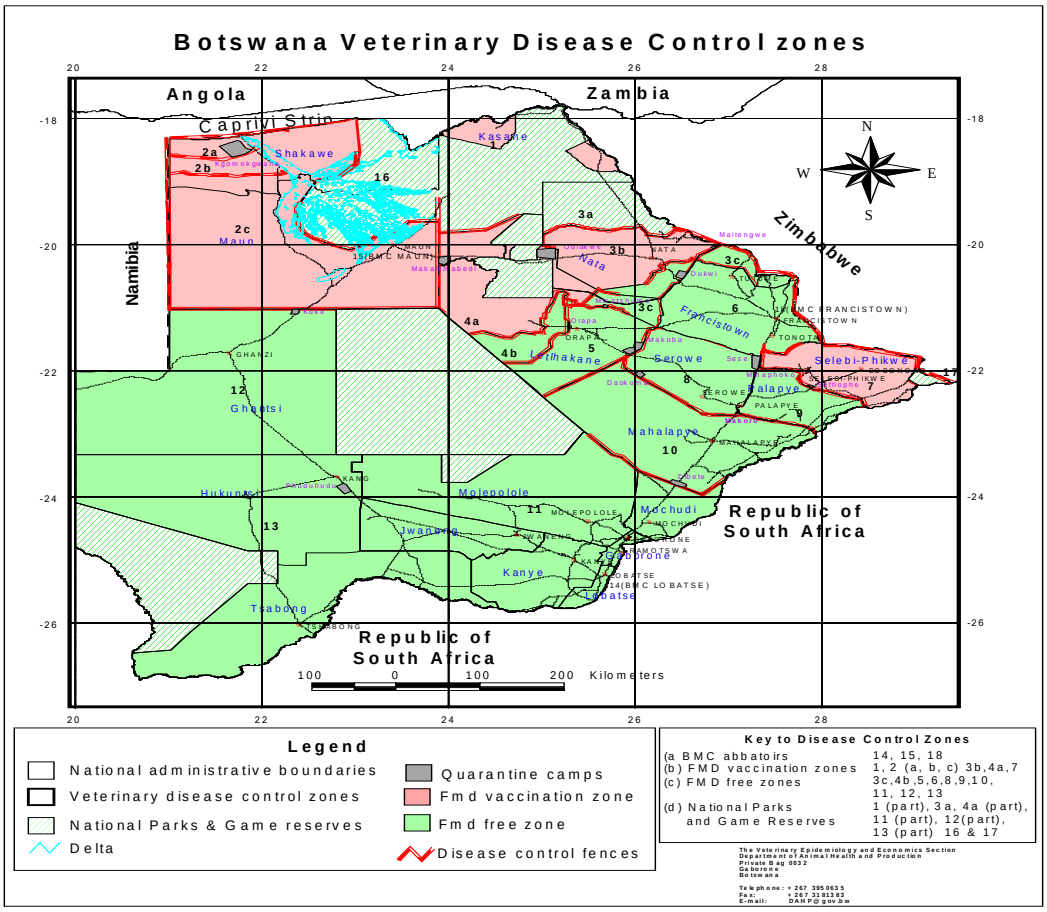


Figure 3.1.3. Disease control zones in Botswana

Around this area is the FMD vaccination zone, which is equivalent to a buffer zone. Here strict vaccination protocols are implemented, consisting of vaccination of cattle three times per year, and strict movement controls within this region and from it. Fences border this region, and also form distinct areas within it that do not allow free movement of livestock and wildlife. There are designated quarantine camps that animals are contained in before they are moved from the vaccinated zone to zones of less control for purposes of slaughter, for example.

A second vaccination zone has been declared in the south eastern corner of the country on the borders with Zimbabwe, around the Tuli Circle area. There are no fences separating Botswana and Zimbabwe here, and there are no buffalo in this region, but it has been the site of FMD outbreaks in what was previously part of their FMD–free zone. This area is likely to be incorporated into the Greater Mapungubwe Transfrontier Park.

The fence between Botswana and Zimbabwe is being strengthened along the Shashi River in attempts to prevent the unwanted incursion of potentially FMD infected cattle from Zimbabwe into Botswana. Botswana has OIE listed freedom for CBPP. In addition, Botswana employs a sophisticated animal

identification strategy for every animal – each animal is dosed with a bolus that contains a unique microchip identification number which permanently resides in the rumen.

All international trade occurs only from the FMD-free zone. There are no buffalo outside of the endemic FMD infected area. Disease control strategies are decided by a strong centralized Veterinary Department, and are executed at local state veterinary level. Surveillance for controlled diseases is performed on a regular basis.

Zimbabwe

Zimbabwe has endemic FMD in many areas of the country, largely as a result of a lack of movement controls of infected cattle. Historically, FMD was contained in Infected Zones in the South-Eastern Lowveld, with buffer or protection zones around it. No defined disease control zones are currently maintained for FMD. Buffalo in Zimbabwe are carriers of both FMD and *Theileria parva*, although there are some FMD-free buffalo in some areas, e.g. South East of Bulawayo, where the herds are contained behind fences. CBPP does not occur in Zimbabwe. Tuberculosis and brucellosis are also controlled diseases within the national beef herd. In buffalo, tuberculosis has recently been described in a TFCA, probably acquired from infected buffalo from South Africa.

Where necessary, disease control is maintained at outbreak level, as defined by national legislation and policy. The OIE process is adhered to as far as export of certain products is concerned, and compartmentalization as a policy is adopted for certain meat products. Policy is decided at a central national level, with responsibilities delegated directly to local provincial veterinary authorities. Surveillance is performed for a number of diseases as the need arises.

Angola

Diseases control policies are defined in terms of national legislation and policy at national level, and executed by local veterinary authorities. Reporting to the OIE occurs. CBPP exist in parts of southern Angola, but no OIE defined control zones exist in that area for these two diseases. FMD has occurred sometime in the past, according to the information available on the WAHIS website. Tuberculosis and brucellosis are also controlled diseases, but the status of these two diseases in the TFCA area is not known. No known movement controls exist for livestock in that area.

Zambia

Disease control policies are defined by national legislation and policy at national level, and executed by local veterinary authorities. An organized cattle farming industry exists. Anthrax, brucellosis, tuberculosis, Theileriosis, trypanosomosis and FMD occur in Zambia, but no OIE accepted control zones exist for these diseases. CBPP occurs as well, but is confined to one or two zones. FMD occurs in one more zones within the country. All are notifiable diseases, and are controlled according to legislation and policy. Disease surveillance for these and other diseases are regularly performed, and reported on a regular basis to the OIE. Tuberculosis is endemic in free-living lechwe (*Kobus leche*) in the Kafue area. Free-living buffalo are carriers of both FMD and Theileriosis. Compartmentalization and control for some disease exists.

3.2 New ideas that may impact on future fencing strategies in sub-Saharan Africa

Thomson, G.
TAD Scientific, P O Box 1607, Brooklyn Square, Pretoria 0075, South Africa
gavin@tadscientific.co.za

Introduction

Fencing is an ancient tool for controlling animal movement. Its use in the management of animal diseases is more recent but in southern Africa it has been applied for more than a century, e.g. in attempts to limit the spread of the Great Rinderpest Pandemic of 1896-1904. There is no doubt that for directly transmitted infectious (i.e. contagious) diseases fences can be effective in their management as long as they are not permeable for susceptible species of the disease in question. Obviously, for non-contagious diseases such as those transmitted by vectors, fences have limited value. This is an important point with respect to the argument presented below because the flying insects that transmit an array of animal diseases in tropical and sub-tropical Africa may fly or be carried by air currents over enormous distances.

The essential argument over fences used to manage animal diseases in southern Africa?

Many infectious agents that cause high-impact diseases of livestock (these are frequently, together with important zoonoses, collectively referred to as transboundary animal diseases [TADs]) co-evolved with the huge numbers and diversity of wild animals historically endemic to the sub-continent. Some of these infections cause more serious disease in domestic livestock than they do in their natural mammalian hosts. The net result is that livestock production in sub-Saharan Africa is confronted by an unparalleled range of TADs. These diseases individually and collectively represent hazards that the rest of the world is loath to import and they therefore have major effects on the potential to export animal commodities and products from sub-Saharan Africa and, thereby, retard rural development.

Although the technical background to the argument about fencing in southern Africa – as will become apparent below – is complex, for illustrative purposes it can be reduced to two broadly opposed positions. The veterinary fraternity argues that separating infected animal populations from those that are susceptible is a prerequisite for managing contagious TADs and, in particular, for establishing areas free from particular TADs for which fences are indispensable. Present international practice requires that only once freedom from TADs is achieved in a particular location can a wide range of high-value products derived from animals be exported to regulated markets. Conversely, environmentalists contend that in many parts of southern Africa where large numbers of wildlife and pristine, biodiverse environments still exist (the conservation of which is vital to future mankind) the value – both environmental and monetary through tourism – of biodiversity conservation far exceeds that of livestock production. Therefore, the ecologically disastrous effects of veterinary fences cannot be justified. This argument is at present particularly acute in and around some of the 13 transfrontier conservation areas (TFCAs), covering more than 1.2 million km^2, under development in

southern Africa. The vision with respect to TFCAs is 'the establishment of a network of protected areas that link ecosystems across international borders and create wildlife dispersal routes between them or in certain circumstances link them' (www.peaceparks.org).

Factors affecting access to international markets for products derived from animals

The current emphasis on fencing for animal disease management, foot and mouth disease (FMD) particularly, is a direct consequence of international standards imposed by the relevant international standard-setting body of the World Trade Organisation (WTO), *viz.* the World Organisation for Animal Health [OIE]. These standards – contained in the OIE's Terrestrial Animal Health Code (OIE, 2009a) – unfortunately do not accommodate integrated biodiversity conservation and animal disease management required for market access of animal products in some agro-ecological settings, e.g. in areas where pastoralism is an established and ecologically sound practice, and in and around TFCAs.

Standards for management of animal diseases are currently founded almost exclusively on a geographic approach. The geographic approach, in turn, is based on the understandable desire to eradicate TADs, preferably worldwide but at least regionally. The problem is that the vast array of TADs prevalent in sub-Saharan Africa are often endemic to wildlife populations and – with the remarkable exception of rinderpest – are not eradicable because the technologies required to achieve that goal, never mind the resources, do not yet exist (Thomson, et al., in preparation).

The net result is that in southern Africa hundreds of thousands of kilometres of fencing (see Box 10.2) have been erected to establish FMD-free zones in order to enable access to high-value beef markets for portions (zones) of some countries in the region (Scoones, et al., in press). Botswana, Namibia and Zimbabwe (prior to 2002) have all benefited from access to beef markets of the European Union on this basis. Rural development in these countries has been underpinned in the process and, understandably, agricultural authorities now desire to extend the fencing systems to increase the extent of FMD-free zones, including into areas where large numbers of wildlife are present.

Access to international markets for products derived from animals, however, is also dependent on a number of factors other than the animal health status of the locality, the most important being assurance that the products for export are safe for human consumption. Internationally, food safety and management of animal disease spread fall under an umbrella agreement between WTO member countries, *viz.* the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). Standards for these two complementary aspects (food safety and prevention of animal disease spread) are set by two different bodies: in the case of food safety by the Codex Alimentarius Commission (CAC) and for animal health, as already indicated, by the OIE. Inexplicably, these two standard-setters base their standards on different principles. In the case of CAC the basis is that production processes need to ensure that the end product is 'safe' for human consumption while for the OIE the guiding principle is that safety is achieved by ensuring that the locality of production is free from TADs. This dichotomy presents a particular problem for export of animal commodities and products. Obviously, an integrated set of standards would be more appropriate to achievement of the goal of the WTO which is to minimize impediments to free trade.

To some extent this anomaly in standard setting is overcome by inclusion of the principle of equivalence in the SPS Agreement (Article 4). In effect this means that if alternative approaches and measures can be proven to be 'equivalent' to those recommended by international standard-setting bodies, there should be no fundamental impediment to their adoption by trading partners. This has recently been used to overcome a long-standing dispute between the European Union and the USA with respect to livestock products (European Community, undated). The question therefore arises as to whether there could be alternative approaches to ensuring access to markets for animal products other than on the basis of the locality of production being free from TADs, e.g. through adoption of the same principles applied by the CAC? Food safety assurance is universally based on the HACCP (hazard analysis critical control points) approach which is also eminently applicable to management of animal disease hazards.

In 2004 the argument was advanced that many products are safe to trade internationally irrespective of the animal health status of the locality of production because, as long as the products are derived from healthy animals, they inherently pose minimal risk of transmitting infectious agents (Thomson, et al., 2004). The label applied to this approach was 'commodity-based trade' (CBT). Advocacy of CBT by influential bodies such as the British Government's Department for International Development (DFID) initially met with vigorous opposition from the OIE. Subsequently, however, CBT has progressively been accorded wider support and a recent study conducted on behalf of the OIE with financial support from DFID and published on the OIE's website, has shown that de-boned beef produced from healthy animals (i.e. beef from which the bones and lymph nodes have been removed) poses a 'very low risk' of transmitting FMD irrespective of the disease status of the locality of production (OIE, 2009b). This finding supports an earlier paper which argued that this is the case not only for FMD but for a range of other TADs including rinderpest, contagious bovine pleuropneumonia, Rift Valley fever, Congo-Crimean haemorrhagic fever and bovine spongiform encephalopathy [BSE] (Thomson, et al., 2009). The same can be shown for many other products derived from animals, in particular processed dairy products and a variety of processed meats. Importantly, CBT also provides the opportunity for products derived from wildlife to access international markets to a far greater extent than hitherto, i.e. it would create greater opportunities for sustainable utilization of wildlife. These issues are vital to ecologically sound rural development necessary for poverty alleviation.

From the above it is clear that the requirement for almost all products for export having to be derived from areas recognised as free from FMD and other TADs is an unnecessarily narrow interpretation of international trading requirements. The 'equivalence principle' outlined above provides the Southern African Region – or any other region for that matter – with a wide range of alternative approaches as long as they are technically sound. This implies that fences required to delineate and protect FMD-free zones are not an essential requirement although, unfortunately, the misguided notion that they are has become established in the psyche of veterinarians and official veterinary services worldwide.

The requirement for balanced rural development

A consequence of the enduring stand-off between animal health authorities and conservationists in southern Africa is an escalating dilemma over how best to

balance the apparently contradictory needs of livestock development and those of biodiversity conservation and tourism. This comes down to a fundamental question: Are fences that may be ecologically damaging an absolute requirement for commercialisation of livestock production and access to high-value markets?

Based on the position presented above the answer to this question is clearly 'no'. However, theoretical possibilities need to be transformed into practical reality and that is where the focus of future endeavour needs to lie. There are two further requirements that need to be understood if progress is to be achieved. Firstly, the fact that fences are not an absolute requirement for accessing export markets does not mean that all fencing designed to control animal diseases can be dispensed with. Fences may, for example, in some strategic situations be necessary to limit the impact of specific diseases on livestock production. Secondly, and specifically in the context of TFCAs, international and regional agreement, resulting in practical guidelines, are needed to enable groups of countries contributing to TFCAs to act collectively towards ensuring biodiversity conservation without jeopardising trade in livestock commodities and products in one or more of the participating countries. Chapter 5.3 of the current (2009) Terrestrial Animal Health Code dealing with the SPS Agreement from the OIE perspective is not adequate to this purpose. However, a regional body such as SADC is in an ideal position to rectify this deficiency, specifically for application to TFCAs of the Region.

Conclusion

The argument made here is that non-geographic approaches to management of animal disease spread through trade – enabled by the concept of CBT, Article 4 of the SPS Agreement and Chapter 5.3 of the Terrestrial Animal Health Code, 2009 – provides a basis for objective re-examination of the need for existing fences and, more importantly, creates the possibility for new multidimensional approaches to integrated land-use planning. So, for example, land-use plans for the enormous area covered by the Kavango-Zambezi TFCA and the even larger Zambezi River Basin could incorporate livestock-based enterprises, including product processing, without the need to build long fences that divide ecosystems and Ramsar sites. The technical basis for achieving this objective, while not ideal, is established: What is needed now is development of practical ways of implementation, including re-evaluation of existing and planned fencing systems.

3.3 Fencing along the Kruger National Park boundary

Keet, D., Bengis, R. & de Klerk-Lorist, L-M.
Office of the State Veterinarian, Directorate of Animal Health, Department of Agriculture Forestry and Fisheries, P.O. Box 12, Skukuza, Kruger National Park, South Africa

Ferguson, K.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
selousgame@hotmail.com

Introduction

The extent and type of the protected area interface that adjoin domestic livestock production areas is an important animal disease risk factor (Bengis, 2005). The interface may be linear, as along a fence line, or patchy, reflecting the habitat preferences of a disease host. It may be focal e.g. at a shared water point, or diffuse, where range and resources are shared, as in savannah pastoral societies. A diffuse interface has the greatest risk for animal disease transmission, which may be bidirectional, with diseases traditionally seen in livestock entering wildlife populations, or indigenous wildlife infections crossing over into livestock. Both scenarios have potentially serious implications. Fencing therefore becomes a critical barrier between the natural and human dominated areas.

A brief history of KNP fences

For nearly half of its existence the Kruger National Park (KNP) has been bounded (sometimes partially or wholly) by varying lengths and types of fence. Starting in the early 1960's the Government of South Africa, following several outbreaks of foot-and-mouth disease (FMD) in 1958, decreed that the risk of FMD spreading to neighbouring livestock production areas that lay west of the KNP had to be curbed (Bengis, et al., 2003; Joubert, 2007). Although the primary rationale towards fencing the western boundary of KNP came primarily from a desire to control FMD, the KNP management at the time encouraged the act of fencing as a means of protecting animals from external influences. Between 1947 and 1953 the KNP lost thousands of animals from the Pretoriouskop area that vacated the park after the temporary abolition of the veld burning regime. Such losses had a dramatic impact on the Parks Board's view of fences. An annual report from the early 1960s stated that 'the fence was one of the most progressive steps ever in the protection and control of our wildlife populations' (National Parks Board Annual Report 1960; quoted in Joubert, 2007). Only later could the KNP management admit that the fence created problems of an 'overwhelming nature...despite its many advantages' (Joubert, 2007).

In 1969 the simple western boundary 1.8m standard cattle fence was replaced by barbed wire which was considered adequate to contain most game species. This further attempt at the containment of disease (by means of a north-south orientated western boundary fence that runs for over 400km) is bi-directional in intent, although in practice controlling disease flow towards the human domain takes precedent as a matter of national economic importance. This western boundary fence has always been under the management of the Department of Agriculture, Forestry and Fisheries (DAFF; or its antecedents) even though the 'owner' of any fence in South Africa is determined by land

tenure and the fence owner has legal obligations to all adjacent owners in terms of damage and public liability that may result from a degraded fence.

Prior to the erection of the western boundary fence in the early 1960s, construction of boreholes (105) were systematically placed throughout the western populations range and fire policies were implemented that stimulated 'green' nutritious grazing patches). These 'incentives' were an overt attempt to keep wild animals within the park boundaries (Brits, et al., 2002; Joubert, 2007). It could be argued that the provision of artificial waterholes and dams along the planned route of the fence was the first 'virtual' fence and the original catalyst in disrupting westerly migrations (out of the park) of certain species in an attempt to 'acclimatise' them to a sedentary or rerouted migratory way of life.

After the western fence was erected much of the park became effectively isolated from the rest of the progressively human dominated, greater Kruger ecosystem. Smuts (1982) commented that the 'effective size of the park is gradually shrinking'. Carruthers (1995) points out that the onset of the 'isolation' (by habitat fragmentation) of the KNP, pre-dates fences, and was largely due to mechanisms such as human population increases (released by a decline in malaria outbreaks and the eradication of the tsetse fly) in the Lowveld in the 1930s to the 1950s and also the exclusivist policies of the park management at that time.

In 1977 a small section of the western boundary fence was up-graded (replacing the 'Snyman' fence) to an 'elephant-proof' fence which was not entirely successful and in 1984 electric fences became the barrier of choice for the western fence.

The western boundary fence received an upgrade to electric fence status that was completed in 1999 at a cost of R12 million. The next year, floods devastated the electric fence and caused R7 million worth of damage. Increased permeability to large mammals, in parts of the western fence, was exacerbated by the floods, and damage by elephant (*Loxodonta africana*) in particular meant that the electric fence no longer became a viable option. Has the fence done its job with regards to the containment of FMD? Between 1983 and 1999 no outbreaks were recorded. However, from 2000 to 2009 six outbreaks have been recorded with four being directly linked to buffalo (*Syncerus caffer*) escaping through elephant fence breaks (Grant, et al., 2007).

The eastern boundary 'elephant-proof' cable fence, which runs parallel to a national boundary (with Mozambique) for 350km, was erected by KNP authorities and completed in 1976. This fence has often had connections with the South African military and indeed its rationale was to prevent intrusion by guerrillas into the country. Bizarrely, at one stage, in the mid to late 1970s it was recommended by the Transvaal Provincial Administration and the army that an impenetrable sisal barrier should be grown close to the eastern fence in order to stop these guerrillas from entering the park – a trial patch was quickly thwarted by elephants and the idea thereafter abandoned (Joubert, 2007).

Kruger fencing for the 21st Century

Currently a new form of non-electrified elephant proof fences is being constructed along the western boundary. The 'I' Beam fence is 2.45m high (see Figs. 1 and 2) and will eventually replace the existing fence from the Komati to Limpopo Rivers a total distance of 480km. There have been two reports thus far of elephants climbing over the new fence, apparently by

pushing down on the 13mm cables at the mid-point between the 60m spaced restraining posts. The tension of these cables allows for the fence to upright itself once the elephants have crossed. The new fence costs approximately R100,000 per kilometre (excluding recurrent maintenance). The fencing network adjoining the KNP boundary is currently managed by DAFF and maintained by 80 tradesmen and three Animal Health Technicians. The owner(s) or manager(s) of the fence that encompasses private or provincial reserve along the western fence (some 30% of the total western fence) where buffalo are kept, are responsible for the erection and maintenance of appropriate fences (according to the Act on Animal Diseases; Act 35 of 1984, Article 20).

Although the new 'I' Beam fence is designed to be people friendly in that it can be easily climbed over. It must be remembered that the fence is a disease control barrier created to stop the movement of livestock and wild animals, especially buffalo, and it is not designed to exclude people.

Much of the permeability exhibited by wild animals through the existing fence is encountered at drainage lines that bisect the fence. These sections of fence are recurrently damaged by flooding and are inherently structurally weak due to the sandy substrate that the fence has to span. In order to counter these weak spots large nylon 'fishing nets' up to 20m high (costing up to R250,000) have been spanned across major rivers and some of the smaller drainage systems (Fig. 3.3.3). The net across the Klein Letaba River functions well during the dry season with animals appearing to be reluctant to approach the net. During heavy flooding the net in Fig. 3.3.3 was damaged due to the collapse of a concrete ballast weight.

The KNP fence is an essential component of the disease control strategy that aims to limit the impact of certain diseases on the livelihoods of local people, the economic fortunes of the country as a whole and the health of the Kruger ecosystem. With up to 2 million people living within a 50km radius of the western boundary of the park (Pollard, et al., 2003), it is safe to assume that this structure will be an important bulwark against transboundary animal disease transmission for the foreseeable future.

Figure 3.3.1. I Beam Drawing: Courtesy Department of Agriculture (Engineering)

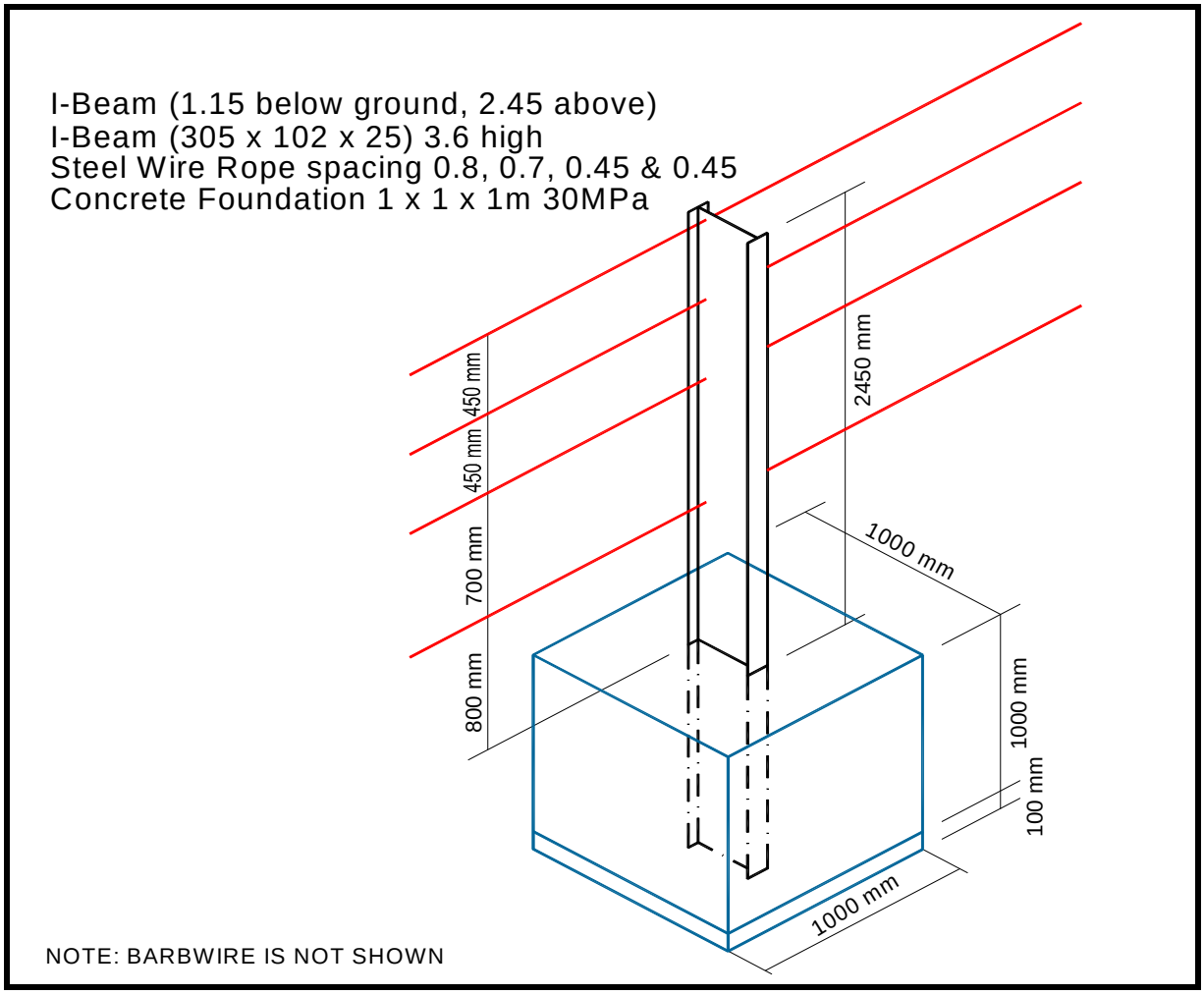


Figure 3.3.2. I Beam drawing: Courtesy Department of Agriculture: Engineering

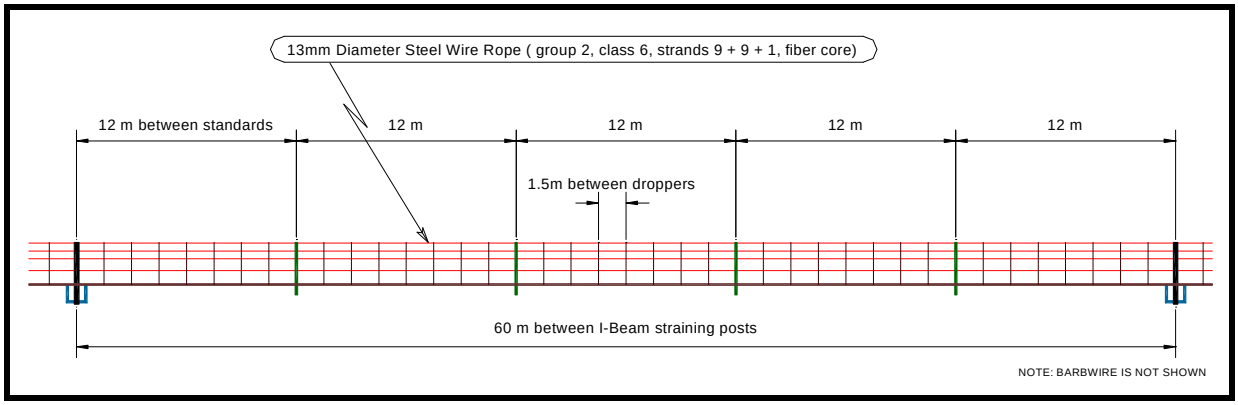


Figure 3.3.3. Net Barrier across Klein Letaba River (Photo credit D. Keet)

3.4 The newly proposed Laikipia disease control fence in Kenya

Kock, R.A.
Senior Wildlife Veterinarian, Wildlife Health Programme, Conservation Programmes, Zoological Society London, Regents Park, London, U.K.
richard.kock@zsl.org

Background

Laikipia district is split into marginal crop and range land (75%) and high potential crop and range land (25%), the latter predominately in the south west. On average there is ~50 TLU (Tropical Livestock Unit) per km^2 for livestock and ~ 20 TLU (equivalent) for wildlife. Livestock are marketed both locally and to the urban centres of Nairobi and Nakuru. There is a range of 400 to 1,200mm rainfall annually within the district varying by locality and season. Vegetation types range from grassland to shrubby or bushed grassland to shrubland, the latter dominated by *Acacia* spp. and leleshwe (*Tarchonanthus camphoratus*). The plateau is defined to the north and west by the Great Rift Valley and has adequate water arising from its southern boundaries, the Aberdares situated to the south west and Mount Kenya to the south east. There is a mosaic of land use in Laikipia including areas for military use, horticulture, pastoral systems, ranching, fenced livestock, mixed livestock and wildlife, fenced wildlife, and cropland, small holdings and a few towns. The trend over recent years has been sale of large land parcels, resulting in increasing subdivision and settlement and a steadily increasing human population, particularly in the south.

Majority of livelihoods are based on casual labour associated with ranching and the tourism industry, with relatively low human density and large scale ownership of land. Pastoral communities, which are relatively few in number, utilise mostly northern parts of the district, seasonally and their herds comprise mainly cattle and goats. Numbers of wildlife and biodiversity remain remarkably stable in the district with ~ 60,000 individual large mammals persisting over the last 30+ years. This is untypical of the general trend in Kenya, which has shown steady declines in wildlife population in both protected and unprotected areas, with losses amounting to 70% of the population of large mammals during this period. (WRI, 2007)

In addition, Laikipia has become a significant refuge for one of the largest elephant (*Loxodonta africana*) populations remaining in the country. The zone is a popular tourism destination with high quality accommodation, dramatic scenery and excellent and diverse wildlife viewing.

Why the pressure for livestock disease control?

African agricultural markets are not immune to globalisation and commercialisation. There is considerable pressure for both given the rapidly increasing population and high demand for meat protein. African rural livelihood research now recognises the importance of putting present patterns of natural resource use within wider political, social and economic contexts. Whilst opinion is divided over current trends of rural agricultural development and natural resource use it is clear that agricultural production remains central to development plans of the African countries. This is written into national and regional economic development strategies and related documents. In southern

Africa commercialised livestock production is facilitated by the construction of veterinary cordon fences in order for livestock products to be classified free of disease for international markets. By restricting the mobility of rural livelihoods, disease quarantines and veterinary cordon fences have had potentially detrimental effects on both rural livelihoods and natural resources. However, the nature of these impacts remains largely unexplored, academically and this lack of clarity is encouraging the trend towards agricultural development at the expense of natural resources.

The situation is no different in Kenya, where there is a significant opportunity cost of land kept under mixed wildlife and livestock systems due to negative impacts of wildlife on livestock and agro-economy. This is especially true where there is potential for dry-land agriculture. Nationally there is an estimated 48% net loss in income from pastoral livestock economy due to competition, conflict and disease impacts relating to wildlife (Norton-Griffiths, 2007). This is exacerbated by fewer wildlife income generating opportunities (hunting and cropping is illegal) in Kenya when compared to other countries in sub-Saharan Africa. The result of this policy is inadequate compensation from the wildlife sector for the loss of livestock or agricultural income associated with integration. To compound this situation, nationally, tourism revenues largely accrue to state enterprises and a small number of landowners and entrepreneurs, the latter providing tourism services, often living in urban centres or abroad. Therefore socio-economic arguments are strongly in favour of a shift in land use in Laikipia to livestock and agriculture, especially where economic gain is the main criteria for land use designation and if benefits to the ordinary Kenyan are a primary consideration.

Justification for the integrated wildlife - livestock system

The argument for retaining integrated land use and against fencing is equally compelling but for different reasons (Kock, 2005). This is based on the acute need for land to support biodiversity conservation in Kenya and in the region and Kenya's commitment to the Convention on Biological Diversity (CBD) and other international conventions, and not least the importance of sustaining a renewable ecologically viable resource underpinning Kenyan economics for centuries to come. Kenya retains one of the highest levels of biodiversity on the continent. Laikipia and the Northern rangelands are unusual in their relatively stable wildlife population and high densities. In addition there is a track record of successful development of private sector and community conservancies. This has been achieved at very low cost to the state purse unlike the state conservation areas, which are heavily subsidised. There would be much stronger arguments therefore favouring conversion of state protected areas to livestock and agricultural use rather than reverting Laikipia to primary agricultural use. This status and the improving trend towards more equitable benefits accruing from wildlife in Laikipia is increasing the justification of the mixed system, especially in the more agriculturally marginal areas, although these tend to be peripheral to or, outside Laikipia district itself. Tourism remains a strong economic sector and Laikipia should continue to contribute significantly. There are also strong ecological arguments for a mixed system with conservation not only of wildlife but other environmental components e.g. ecosystem services provided by well structured fertile soils and optimal vegetation cover, critical for nutrient cycling, and animal diversity and ultimately the whole contributing to buffering against climate change and other man made perturbations.

What are the arguments for improved disease control?

Laikipia plateau is excellent rangeland. It was a premier livestock rearing area in past times and until the 1980s benefited from an export trade which is why there has been an interest in re-establishing strong livestock economy. This in turn has led to discussion on establishment of a disease free zone (Fig.3.4.1), due to its natural boundaries and reasonable transport infrastructure, lending itself to biosecurity and the supplying of both national urban markets and livestock export markets. The debate has been ongoing for the last decade and with an upsurge of interest more recently. The need for a disease free zone relates to Kenyan exclusion from trade opportunities due to the persistence of controlled diseases, in particular, foot-and-mouth disease (FMD), which remains one of the most critical wildlife – livestock interface issues not because the disease has an impact at the local level but due to its effect on trade in livestock and livestock products (Thomson, et al., 2003, 2004).

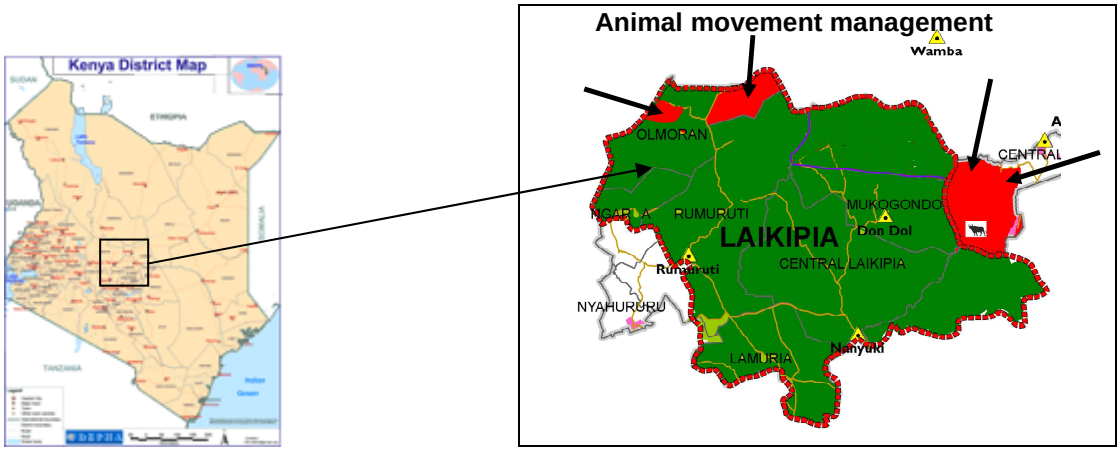


Figure 3.4.1. Map of the proposed fenced disease free zone in Laikipia District of Kenya. (Map courtesy of Tom Omenda).

In Africa, buffalo (*Syncerus caffer*) are a reservoir for FMD virus, and kudu (*Tragelaphus strepsiceros*) and impala (*Aepyceros melampus*) are regularly infected amongst other species. Buffalo, which have passed through damaged fences (e.g. after elephant), are often associated with index cases in cattle herds with subsequent livestock movement leading to epidemic spread in disease free zones. In African traditional pastoral societies, the disease is endemic and under these conditions outbreaks are rarely reported, as there is minimal impact. In this circumstance wildlife FMD is not an issue. This is not the case for more intensive systems like dairy or export beef. The main methods of control currently in Africa are based on separation of wildlife and livestock, vaccination, movement control, quarantine and slaughter (stamping out). Vaccine production is complicated by the need for viral typing and appropriate strains incorporated into vaccines. SAT 1, 2 and 3 occur in Kenyan buffalo herds in all areas and are a consistent threat to unexposed cattle (Bronsvoort, et al., 2008). FMD is endemic in Laikipia and surrounding districts with frequent outbreaks. Under the current trade rules this is the main constraint for development of the Kenyan livestock industry and particularly in Laikipia which has abundant wildlife.

Commodity Based Trade as an option to support the status quo

International animal health standards designed to facilitate safe trade in livestock and livestock products are set by the Office international des épizooties (OIE). A core principle is the need for countries to eradicate important transboundary animal diseases (TADs) to reduce the risk of exporting disease to trading partners (Thomson, 2004).

The goal of global eradication of most TADs is unachievable for the foreseeable future, other than in the case of rinderpest, and this prevents many countries from engaging in international trade under WTO rules, especially developing nations. Disease free zones have been seen as an alternative approach and have worked in certain southern African states where land use policy is more applied and communities largely settled.

An alternative to the seeming necessary exclusion of wildlife, which is not a widely acceptable option amongst Kenyan political community, is commodity-based trade (CBT) and this approach is proposed. This requires the formulation of international animal health and food safety standards based on the fact that different commodities pose very different risks when it comes to spread of human and animal pathogens. Therefore, the risk mitigation strategies required are equally commodity dependent. Thomson (2003) and others concluded that more focused commodity standards would improve access to international markets for all countries, especially those in the developing world without the need to disrupt the rangeland ecosystems which have potential for multiple land use and in particular conservation of natural resources. For this objective to be realised requires credible and independent certification. The response of Government to the concerns raised over the suggested fencing is reassuring and advice is apparently being heeded and the matter will not be forced, at least not for the foreseeable future. Further lobbying especially in Europe for CBT is warranted, as this will provide the best options for both wildlife livestock and people in Laikipia.

Conclusion

There is growing pressure for change in land use in the Laikipia district largely around the desire to re-establish a livestock export industry and for social and economic reasons. The lack of flexibility in the international trade regulations with respect to FMD and the resistance to a perfectly rational argument for CBT currently leaves little option for government, if it wishes to pursue this development option and with respect to disease control, other than fencing and creation of a disease free zone without buffalo, and other wildlife species.

To counter this, the importance of Laikipia to biodiversity conservation in Kenya and Africa is high, and on economic grounds alone more legitimate even than state protected areas, given its security and stability at little or no cost to the taxpayer. The shift to community run conservation is increasing the justification for this approach and will provide a more sustainable and resilient ecosystem for the future.

3.5 Zimbabwe's livestock disease control policy in relation to fencing.

Foggin, C.
Wildlife Veterinary Unit, Department of Livestock and Veterinary Services, P.Bag BW 6238, Borrowdale, Zimbabwe.
chris@kigelia.net

Introduction

Control of major animal diseases in Zimbabwe has followed a difficult course. For many years there has been an excellent legislative basis for effective disease control by the Government Veterinary Authorities (The Animal Health Act and its associated gazetted Regulations/Statutory Instruments) and, when adequate resources were available, the country was able to export beef to the European Union for more than a decade, under a preferential trade agreement, which required stringent disease monitoring and controls. This was principally to control foot-and-mouth disease (FMD) using a combination of movement controls and vaccination; the animal movement controls were facilitated by government-administered fencing.

In recent decades the resources made available by central government to the Veterinary Authorities have been severely curtailed and, in addition to this, there has been a relatively emotive, land-reform process and reduced ability for law-enforcement. The result of this has been a severe breakdown of the veterinary controls, including fencing, to the extent that animal disease control is now based on tactical, rather than strategic considerations, as and when resources are made available, either by the Zimbabwe government, or by international aid agencies and foreign governments. The integrity, construction and maintenance of disease control fences have been some of the primary casualties in this process.

Historical aspects (prior to 1980)

From the early days of European settlement in Zimbabwe (formerly Rhodesia) animal disease played a major role in the nation's development. Rinderpest, in the late 1800s, and East Coast fever (*Theileriosis*) were the most important diseases of livestock that were introduced in the early colonial period. In addition, *Trypanosomiasis* was always present where the tsetse-fly vector could survive, though the distribution of this disease was greatly reduced for many years following the rinderpest pandemic which wiped out much of the buffalo and antelope populations on which tsetse-flies fed.

FMD was first diagnosed in the country in 1931 and subsequent research traced the source of this disease to buffalo, which were shown to be caused by virus types SAT 1, 2 and 3. By 1979 there had been 62 outbreaks of this disease, all but a handful of them in the south-eastern Lowveld of Zimbabwe (Condy, 1979). Even after the role of buffalo in propagating this FMD had been established, there was no national effort to construct fences to separate cattle and buffalo because this contact was reduced by the presence of tsetse fly which limited the cattle populations in areas where buffalo were left, relatively undisturbed. Indeed, much of the rationale for cattle owners to voluntarily limit the contact between the species was due to the fact that buffalo also carry the organism responsible for the fatal (to cattle) form of *Theileriosis* (Corridor

disease), *Theileria parva lawrenci*, a disease transmitted to cattle through ticks.

In this period, the control of FMD was based on human-contrived infection or *aphthisation* of cattle in the infected focus, and the prohibition of movement of cattle out of the infected zone, as well as the non-infected surrounding area, by the establishment of law-enforcement/veterinary cordons. These cordons made use of natural features, pre-existing farm fences and fences constructed for that immediate purpose (Condy, 1979). The Animal Health Act of Zimbabwe was promulgated in its present form in 1960 and amended a number of times since then. Section 16 of this Act makes provision for the Minister of Agriculture to order the construction of veterinary fences (plus gates and grids) both on state and private land. If the latter is shown to be of some benefit to the owner of the private land then up to half of the cost of construction of that fence may be recovered from the owner by the state. Importantly, the Act states that no person shall remove, or impair the efficiency of any of these fences, unless it is with the written permission of the Minister.

The most extensive use of fencing in this period of the country's history was to control the spread of tsetse fly, particularly in the north and south-east of the country adjacent to lightly-populated wildlife areas which did not experience winter frosts. During the 1960s there was a severe incursion of tsetse-fly into the south-eastern Lowveld, and vigorous measures were undertaken to protect cattle on the ranches in the region. *Cordon sanitaires* were instituted to stop the onward movement of tsetse-fly; these were established by the erection of fences and the elimination of some species of wildlife in these corridors (primarily elephant, buffalo, kudu, bushbuck, warthog and bushpig, while buffalo and elephant were displaced 'outside' of the fence) by hunters employed to carry out this task. Some areas of these *cordon sanitaires* were also cleared of bush to reduce suitable habitat for the tsetse-fly. Additional measures included ground spraying of residual organochlorine insecticides, including dieldrin and DDT (Boyt, 1979)

In the 1980s these environmentally-destructive methods were replaced by more selective techniques involving the mass deployment of tsetse-attractant 'targets' impregnated with residual pythrethroid insecticides (Connor & Van den Bossche, 2004). This method no longer required the use of fences and the old game fences fell into disrepair, though fence-lines, consisting only of metal or termite-resistant wooden poles can still be seen in some areas.

The situation between 1980 and 2001

In the late 1970s, when the Unilateral Declaration of Independence period of Rhodesia/Zimbabwe was coming to an end and added together with the effects of external economic sanctions, moves were made to export beef to overseas markets. This required control of FMD with standards having to conform to the World Organization for Animal Health (OIE) Code. These methods were based on the concept of sequestering FMD into infected zone, or zones, and surrounding these with FMD-vaccinated-buffer and surveillance zones. However, even prior to this, as a result of agitation by cattle owners, the eradication of buffalo from ranching areas in the south-eastern Lowveld had been initiated.

The first buffalo destruction regulations were gazetted in 1979 (Government notice 325) which required the killing of all buffalo in certain districts in the country. This was extended in 1986 under Statutory Instrument 278, whereby

all buffalo outside designated Parks and Wildlife Areas were to be destroyed. However under Section 2(iii) of this, the Director of Veterinary Services could, with the approval of the Minister, make exceptions. This allowed for the formation of FMD-free buffalo herds and, subsequently the creation of Conservancies with FMD-infected buffalo (see later).

The first buffalo fences were constructed, with assistance of European Union funding, around Gonarezhou National Park and subsequently around some of Hwange National Park. Thereafter, the line of the game fence was amended to include much of Binga and Gokwe districts and ultimately extended into Mhangura district in the north and north-west of Zimbabwe. The intention was to continue this buffalo fence around the whole north-eastern border to the Ruenya River, but the last 400 km of this fence was never constructed because funding was no longer available (Fig. 3.5.1). These game fences were designed solely to separate buffalo and cattle. They were erected to a height of only 1.2m, and consisted of 3 lines of 7-strand cable interspersed with 3 lines of high-tensile steel wire. Fence standards and straining posts were made of railway-line and set in concrete, 1.0m deep. There was no electrification of these game fences.
Other, standard, 5-strand cattle fences were constructed to delineate the surrounding "vaccinated" or "red" zone, and adjacent to that the "surveillance" or "green" zone. In the former, cattle were vaccinated every 6 months against FMD, while in the "green" zone, restrictions were placed on the movement of cattle, *i.e.* cattle could only be moved into the "clear" zone when they could be shown to be serological-negative for FMD.

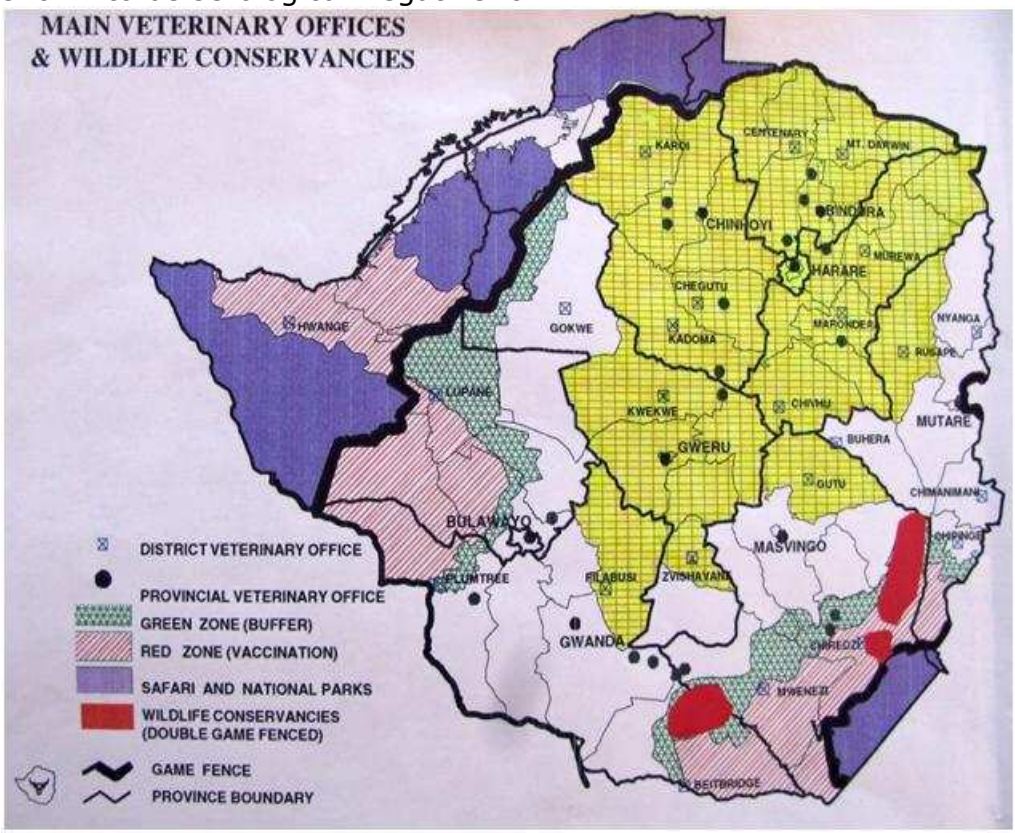


Figure 3.5.1. FMD control zones and game fence construction (thick black-line designates completed fence, thin black-line, never completed).

A short section of fence was also constructed along the eastern border with Mozambique, near the city of Mutare. Subsequently, a long section of game

fence was built by the Botswana Veterinary Department along the border with Zimbabwe; this is also shown in Fig. 3.5.1).

Export of beef to the European Union was initiated 1985 and continued until 2001. These exports were interrupted briefly when outbreaks of FMD occurred. There were 11 outbreaks of FMD in cattle in the 17 years 1984 to 2000, half of which occurred in the "vaccinated" zone. The other outbreaks occurred in the "surveillance" and "clear" zones and were the result of small residual groups of buffalo, or cattle which had remained persistently infected with FMD-virus. Investigations carried out during these episodes showed that a very low proportion of FMD-infected cattle could carry the virus for up to 42 months after being clinically affected with FMD (Anon., 1994).

In the seven years following the Buffalo Destruction Order some 4,500 buffalo were shot or relocated into wildlife areas (Foggin & Taylor, 1996). Vagrant buffalo continued to appear far outside the wildlife zones, despite the fencing, and a few, small residual herds of buffalo have remained in these areas.

Not all landowners were pleased to lose their buffalo and an undertaking was made to restock some areas with FMD-free buffalo. This was done under a programme initiated in 1975 and, in 2009, 23 such properties remained registered. In Zimbabwe, unlike South Africa, "disease-free" buffalo were tested only for FMD. FMD-free buffalo may be "free-ranged" behind a double fence; the specifications for this type of fencing are detailed by Foggin and Taylor (1996), and consist of an inner 1.2m, 6 strand cattle-type fence and an outer 1.9m high, 10-strand fence. If not free-ranging, FMD buffalo have to be herded by day and confined in an approved facility at night. Modifications to these specifications have been made over the years, in the light of experience in the responses of buffalo to fences.

In 1993 the decision was made to allow selected Wildlife Conservancies to keep FMD-infected buffalo and, in the next three years, four of these received permission to hold buffalo, all within the "red" or "green" zones. Again, a double fence was required, and again the specifications were modified over the years in the light of experience. An example is the fence around the Bubye Valley Conservancy in the south of Zimbabwe which consists of double fences, 10m apart, with a corridor cleared of all vegetation except grass between them. The outer fence is 2.0m high with 12 strands of barbed wire. The inner fence is 2.2m high with 22 strands, comprising 9 barbed wire strands alternating with 9 high strain strands, plus 3 cables (6mm in diameter) between 0.4 and 1.2m height. The inner fence also has 4 electrified wires between 0.2 and 2.1m above ground.

The Bubye Valley Conservancy fences are patrolled daily by guards stationed every 10km, as well as at the river crossings; these guards are also responsible for maintenance and clearing the fence lines of vegetation (K. Leathem, pers. comm.; Fig 3.5.2).

Figure 3.5.2. Bubye Valley Conservancy's double fence.

Save Valley Conservancy was the first Conservancy to have buffalo, which were released into the main body of the Conservancy in 1995. There the fencing differed from the above; the inner fence was only 1.2m high and the outer fence only 1.9m. In 1997, within a few months of the completion of a risk assessment which indicated the risk of a FMD outbreak adjacent to the Conservancy was very slight (Sutmöller, et al., 2000), an outbreak of the disease occurred. Subsequent investigation revealed that the risk assessment was flawed in that the role of antelope, specifically kudu and impala had been under-estimated. Kudu in particular are able to jump over a 1.9m fence and they are also susceptible to, and able to transmit, FMD infection though they do not remain carriers of the virus beyond a few months (Hedger, et al., 1972). It was concluded that this species, or possibly impala, had transmitted the virus to cattle by jumping over the fence when actively infected (Hargreaves, et al., 2004). This hypothesis was strengthened by the finding that 48.1% of 351 kudu, and 15.6% of 647 impala tested in the Save Valley Conservancy between 1998 and 2005 were sere-positive for FMD (C.M. Foggin, unpublished data).

After this incident, sections of the outer fence were raised to 2.2m in height to try to prevent these species from exiting the conservancy.

In 2001, one-and-a-half years after Zimbabwe's "fast-track" land reform process was initiated an outbreak of SAT 2 Foot-and-Mouth disease occurred in cattle in a "beef export" FMD-control zone. The outbreak was first seen in a feedlot near the city Bulawayo, but was traced back to ranches moderately close to the Bubye Valley Conservancy, although no link was ever established. Even at that stage, control on illegal movement of cattle was becoming difficult to enforce and the disease spread widely throughout Matabeleland Province,

and thereafter further into the southern half of Zimbabwe. Beef exports to Europe then ceased and have never been resumed.

The status of disease control fences from 2002 to 2010

As the Land Reform process was applied throughout Zimbabwe there was much illegal movement of cattle in the country, even between FMD-control zones and the previous export zone. This was clearly demonstrated by FMD appearing in foci far removed from where it was known to be present. Coupled with this, many fences were destroyed or stolen. Often the wire was used for the snaring of wildlife and massive losses of this valuable resource have been experienced throughout Zimbabwe (Lindsey, 4.6). There also occurred in recent years an absolute and relative decline of financial resource provisions which meant that repair and maintenance became almost impossible. Not all fence damage is caused by human factors, there are large lengths which are elephant damaged especially when there are water scarcity problems and elephants tend to disperse through fences.

The government fences were not spared and, despite the Department of Veterinary Services' best efforts to maintain them; it has been considered a losing battle. Reconstruction of 300km of the 1.2m game fence, in Matabeleland North Province, was undertaken in 2003/4 but it was vandalized and removed shortly after it was erected (S. Chug, pers. comm.). A similar situation occurred with the game fence in the south of Gonarezhou National Park in Masvingo Province in 2005. Efforts to maintain these control fences have been virtually abandoned until greater stability and law-enforcement is deemed possible. This includes the cattle fences demarcating the previous "red" and "green" zones. No detailed assessment of the government disease-control fences has been carried out recently, apart from a section of the Matabeleland North fence which, at the time of inspection, consisted only of railway-line fence poles, some of which had also been removed (S. Choga, pers. comm.). It is likely that very little of this fencing within Zimbabwe remains intact.

In some wildlife areas under the control of the Parks and Wildlife Management Authority of Zimbabwe cattle are presently grazed in close association with buffalo. In Gonarezhou National Park there are some 3,000 to 4,000 cattle in the park at any one time. Not only does this create a great risk of the spread of FMD but, with recent confirmation of bovine tuberculosis in the south of that Park in February 2009 (de Garine-Wichatitsky, et al., 2010), there is a very real danger of this disease infecting cattle.

Some of the Conservancies were also hard hit in terms of fencing losses. At least one quarter of the perimeter fence of the Save Valley Conservancy no longer exists. Aerial game counts have been conducted annually, in the late dry season, in this Conservancy. In 2009 nearly 14,000 head of cattle were counted within the previously double-fenced area, up from 8,000 in the 2004 game count. Apart from buffalo which have shown a modest increase, the populations of most species of wildlife in the Conservancy have been reduced; some by more than half of the 2004 population estimate (Joubert & Joubert, 2009). There has been large-scale settlement in the south of the Conservancy and much clearing for dry-land cropping. This settlement has not been sanctioned by government, but appears to be tolerated. In the course of this, at least one quarter of the 350km perimeter fence has been completely removed (G. Connear, pers. comm.). Much of the rest is severely degraded and human/wildlife conflict around the Conservancy has increased as a result.

Only the Bubye Valley Conservancy in Matabeleland South has been able to keep good control of its fence and any damage to this fence is quickly rectified (K. Leathem, pers. comm.).

The Department of Veterinary Services has been greatly deprived of resources to carry out its vaccination programmes, including the FMD vaccinations around the wildlife areas. Such vaccinations should be undertaken every 6 months in order to be effective. The situation has been ameliorated by international organizations supplying vaccine, especially the Food and Agricultural Organization. However much of this vaccine is used to control outbreaks of FMD, and relatively less for routine vaccinations in areas where it is required.

Since the end of 2001, until the end of 2009, FMD has occurred in all 8 rural Provinces of Zimbabwe as well as the two urban Provinces of Harare and Bulawayo; *i.e.* in 45 of the 59 districts of the country (Anon., Information Management Unit, Division of Livestock and Veterinary Services, 2010). This has mainly been a result, initially of the removal of fences and thereafter the inability to police the illegal movement of livestock throughout the country. The most severe situation occurred between 2002 and 2004, and has been relatively improved since then as outbreaks have been brought under control by vaccination.

The way forward

The initial impetus must be in bringing FMD outbreaks under complete control by strategic vaccination of cattle adjacent to area where buffalo occur and bringing the illegal movement of livestock to a stop. Outbreaks of FMD may still occur away from the buffalo reservoir of the disease because there may be a few cattle still carrying the virus elsewhere. These outbreaks would have to be controlled by vaccination and quarantine, as before.

In addition, the remaining areas of Conservancies left for wildlife production should be clearly stated by government and then demarcated by adequate fencing. All cattle, and people illegally settled within those areas should then be removed. This would also be the case for those Parks and Wildlife areas in which cattle are now present.

Thereafter a review of the policy of FMD disease control should be undertaken. A starting point may be the Risk Assessment conducted by Sutmöller and Anderson in 1998. This indicated that northern buffalo control fence should be retained (now requiring resurrection) but that the design should change to eliminate the use of intermediate high-tensile steel strands of wire, because these are invariably stolen. There should only be vaccination of cattle within the fenced (buffalo) area. Around Gonarezhou in the southeast of Zimbabwe the consultants believed that a more substantial fence should be considered (at least in the south) because of the danger of the entry of bovine tuberculosis. This disease has now arrived in Zimbabwe in the intervening years anyway.

In the south-east Lowveld of Zimbabwe the mosaic of land-use has changed considerably in the last 10 years. There is more subsistence farming and cattle herding on land that was previously reserved for extensive cattle ranching coupled with the disappearance of most of the wildlife that was previously there. However, there has also been an increase in the number of, and area of some, Conservancies. In addition, the development of the Transfrontier Conservation Areas (TFCAs) has placed more emphasis on wildlife production as well as intensification of crop production, with small-scale irrigation schemes to replace some of the subsistence, dry-land cropping. One proposal,

therefore, is to extend the FMD wildlife or "infected" zone to include a much greater area of the south-east Lowveld other than the present Conservancies and Gonarezhou National Park. This area could be demarcated by fences of varying standard, depending on the challenge and risk posed by wildlife transmitting disease over in any particular section: anything from a conventional cattle fence to a full 2.4m high, cable-reinforced and electrified fence to retain all species. A proportion of this fence-line already exists, albeit severely degraded in places.

Cattle and buffalo should always be separated by fences, whether totally inside or on the periphery of any expanded "infected'" zone. Where a high antelope population is present the fence should be adequate to retain these species because of the possibility of FMD (and TB) being transferred, especially by kudu. Fences of greatest importance would have to be inspected and maintained daily, as is the case for some Conservancy fences at present. The desirability of leaving all fence construction and maintenance in the hands of private enterprise, with government auditing, could be debated. Certainly, acceptance of such fencing by those affected by it is paramount. Cattle within the enlarged infected zone would have to remain there, unless going for slaughter. Surveillance of the cattle within 20km of buffalo would require weekly checking. Regular vaccination of cattle would be done only in areas of greatest risk (the Sutmöller and Anderson risk assessment questioned its overall efficacy in controlling FMD). Fig. 3.5.3 shows one proposed fence line to designate any expanded infected zone. However, this concept needs urgent and wide debate both within government and with all other stakeholders.

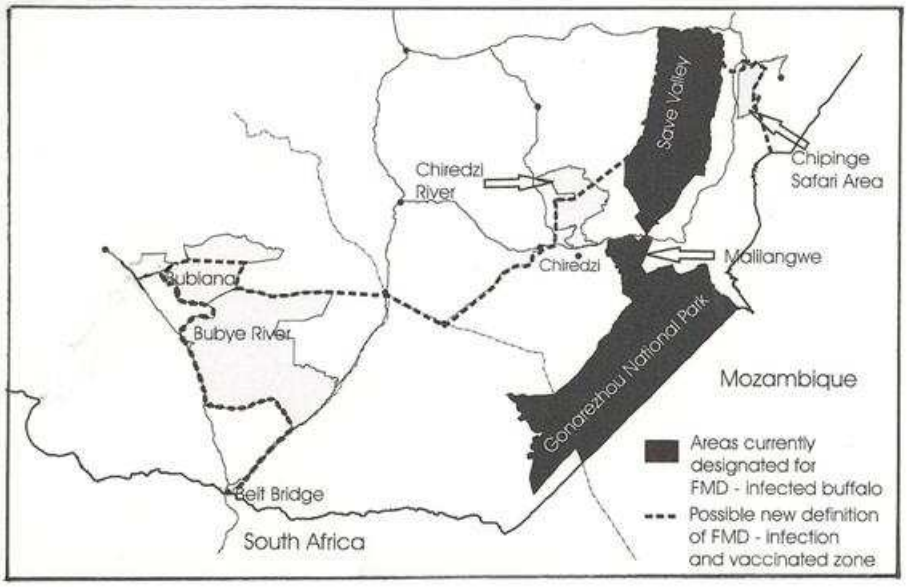


Figure 3.5.3. Possible fence line for expanded FMD-control zone in south-east lowveld.

Conclusion

Zimbabwe is emerging from a turbulent period which has had major impact upon animal disease control in general, and fences in particular. With stabilization will come the opportunity to re-assess disease control policies, including the role, design and alignment of fences, in line with new concepts of rural livelihoods, conservation and TFCAs. A massive injection of resources will, however, be required before any new concepts could be translated into change on the ground.

4. FENCING IMPACTS ON ECOSYSTEMS AND POPULATIONS

4.1 The Scott Wilson 'fencing impacts' report: ten years on.

Albertson, A.
Arthur Albertson Consulting (Pty) Ltd. P.O. Box 00352, Gaborone, Botswana.
arthur.albertson@gmail.com

Tourism vs. livestock macro-economics

The conflict in Africa between the opposing interests of the commercial cattle sector and the wildlife / tourism sector is nowhere more starkly apparent than in North-West Botswana, otherwise known as the Ngamiland District. World-renowned for its free-ranging wildlife populations, which migrate seasonally between the Okavango Delta and the surrounding sandveld, this region is the 'epicentre' of the country's tourism industry. Travel and tourism, including associated support providers, currently comprises 10% of national GDP and generates revenues in excess of Pula 300 million annually (Government of Botswana, 2010). The tourism industry has been identified by the Botswana Government as an "engine of economic growth" and the optimization of this rapidly growing sector is now pivotal to policies aimed at diversifying the country's economy away from dependence on minerals. By comparison, the livestock industry's contribution to GDP has consistently declined over the last 10 years. It now stands at 1.7% (Government of Botswana, 2010) and due to high levels of recurrent expenditure, of which a large proportion is related to disease control, the livestock industry is a net economic liability for the Botswana Government.

Although the 'macro-economics' now weigh heavily in favour of tourism as opposed to livestock production as a development priority for the Ngamiland District, livestock production still enjoys a disproportionate level of support at local and national planning levels. This is partly explained by the involvement of many officials, policy makers and their primary beneficiaries - some of whom are also decision-makers - in private and personally profitable cattle enterprises. Government funded livestock support services, easy access to loans, the tax deductibility of personal livestock-related capital outlay and operating expenditure and the high prices paid by the Botswana Meat Commission (BMC) are amongst the factors that contribute to the profitability of commercial livestock production at an individual level.

Only a very small proportion of cattle owners in Botswana are engaged in commercial production. The poor economic performance of the livestock sector at a national level is frequently blamed on a lack of commercialization of the traditional communal sector that owns the majority of the national herd.

Fencing policies associated with livestock commercialization

A number of agricultural policies are associated with the promotion and establishment of the commercial livestock sector, in particular private fenced ranches outside of existing commercial production areas in unfenced communal areas, some of which still contain important wildlife habitats.

The *Fencing Component* of the New Agricultural Development Policy (NADP) of 1991, for instance, advocates the fencing of communal rangelands to "*combat*

land degradation" and *"improve productivity."* However it also enables individual's not necessary resident in the affected rural areas to obtain exclusive grazing rights to commonage areas. The implementation of this Policy, as a successor to the Tribal Grazing Lands Policy of 1975, has been widely criticized for its social and environmental impacts, which have included loss of wildlife habitats and displacement of traditional pastoralists and communities of hunter-gatherer origin (Selolwane, 1996; White, 1992).

The implementation of the NADP in Ngamiland has been enabled under a three-phased fenced ranching implementation programme affecting a large part of Southern Ngamiland, approved by the District Land Use Officer in 1998 (Scott Wilson, 2000. The proposed implementation of "Toteng - Sehitwa phase 2" in the wildlife management area NG5 (see Fig.4.1.1), has been accompanied by consistent political pressure from Maun-based businessmen and district land use planning officials. This pressure continues today, as evidenced by a new 2009 proposal for ranching in NG5 (Landflow Solutions, 2009). This is despite strong support from the Office of the President for its continued protection, a clear recommendation against any fencing within NG5 by the Department of Wildlife and National Parks (DWNP) and repeated requests by surrounding local communities, dating back to 1983, to benefit from wildlife utilization in NG5 (Government of Botswana, 2007).

This programme is also closely linked to national disease control policies. In Ngamiland, an area subject to foot-and-mouth disease (FMD) outbreaks, the creation of an FMD free zone, through the implementation of new veterinary fences, is regarded by the Department of Veterinary Services (DVS, previously known as the Department of Animal Health & Production (DAHP)) as a necessary prerequisite to the ability of the ranch owners to sell cattle at a premium to the BMC for export. Such a new zone would also enable livestock owners operating unfenced cattle posts to sell cattle to the BMC at higher prices.

Popular support for the implementation of veterinary fencing in Ngamiland has been won amongst the general farming community of Ngamiland. This appears to be on the basis of two factors: firstly the fear of imposed disease-related movement controls and culling operations and secondly, the prospect of the Maun BMC abattoir reopening and being able to purchase cattle at export-related prices as opposed to the lower prices offered for sale for the local market.

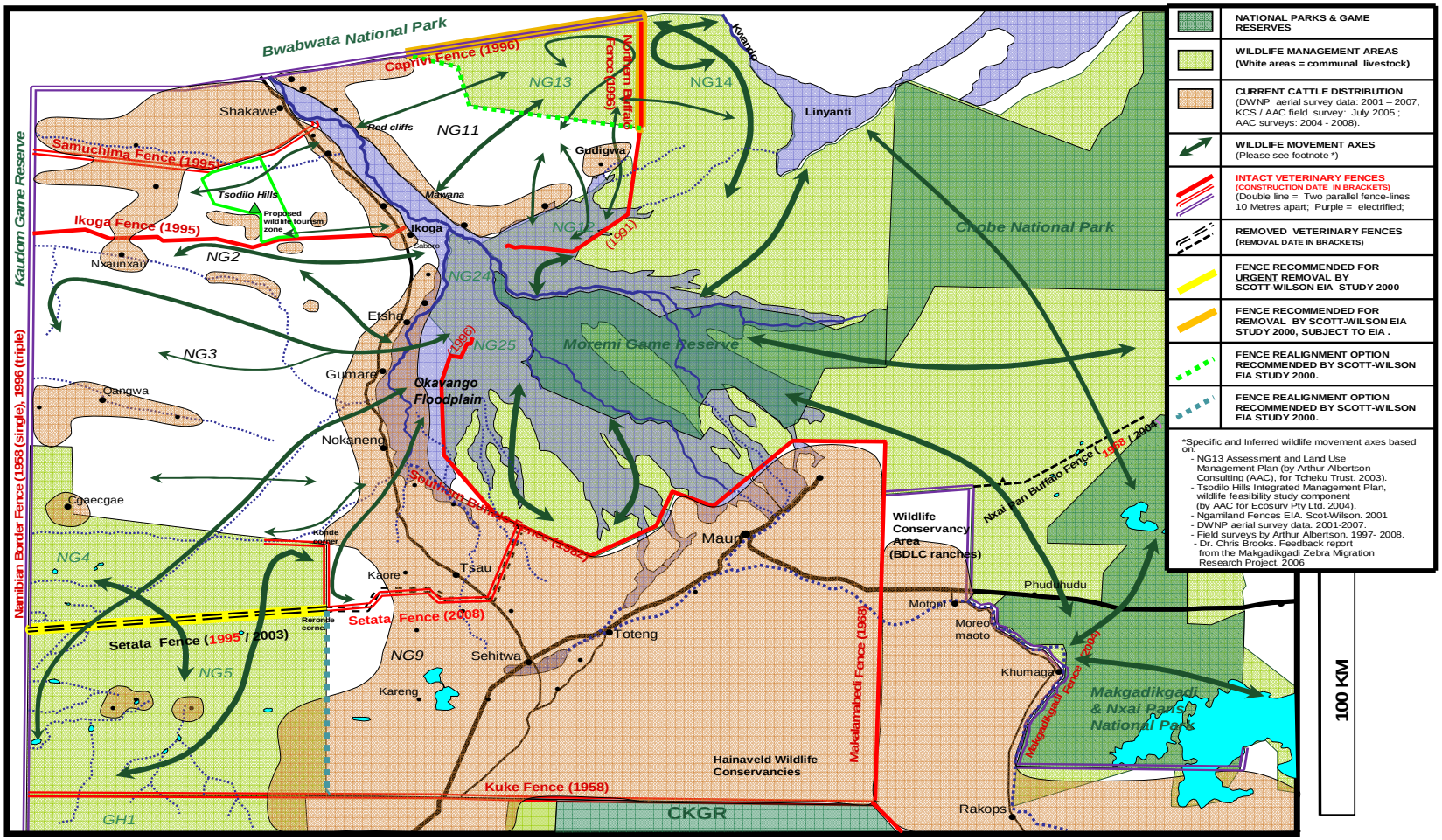


Figure 4.1.1. North-west Botswana (Ngamiland District): veterinary fences vs. wildlife movement patterns.

The commercialization drive has been promoted under the banner of the general cultural and livelihood importance of cattle to the majority of Batswana and the importance of 'disease control' to the livestock sector as a whole. However, while cattle are indeed important to the culture and livelihoods of a portion of the rural population located in the areas affected by veterinary fencing, very few of these local residents are engaged in the commercial production that the fencing policies are geared towards.

The Scott Wilson EIA study found that in localities such as Cgae-cgae, a predominantly Jun/hoansi Bushman community severely impacted on by the Setata fence, only 14 out of 110 surveyed households owned any cattle. Of these households, five had less than 10 cattle and five had between 10 and 30 cattle, with only four households owning more than 30. Very few derived any kind of livelihood benefit from cattle herding under the *Mafisa* system and the majority derived their primary livelihood income from Government relief programmes (e.g. labour-based public works, destitute rations), CBNRM (safari hunting), subsistence hunting / gathering and craft production (Scott Wilson, 2000).

It is also pertinent to note that cattle-keeping communities have existed in Northern Botswana for several hundred years, despite the existence of commercially significant diseases such as FMD and Contagious Bovine Pleura Pneumonia (CBPP). The cattle keeping communities adjacent to the eastern Setata fence, at Molatswane, Makakung, Mapeno and Semboyo complained that the fence reduced access to grazing and water resources to the north of the fence, particularly during droughts (Albertson, 2005; Scott Wilson, 2000).

National disease control policy

The disease control policy implemented today by DVS has its origins in the veterinary policies first introduced by the British prior to Botswana's independence. It was under the advice of foreign veterinary epidemiology experts that the infamous Kuke fence was constructed in 1958. In 1964, 1970 and 1982, many thousands of wildebeest perished along this fence, which cut off traditional wildlife access to dry season ranges around the Okavango and the Boteti River (Williamson & Williamson, 1984). The hartebeest (*Alcelaphus buselaphus*) and wildebeest (*Connochaetes taurinus*) populations of the South-Western System (i.e. Central and south-western Botswana), estimated at 290,000 and 250,000 respectively in 1979 (Government of Botswana, 2003), plummeted in numbers in the early 1980s, primarily due to the combined effect of drought and fences. At an estimated 18,354 and 4,530 for hartebeest and wildebeest respectively in the 2007 dry season (Conservation International, DWNP, 2007), these populations are showing no sign of recovery towards historical numbers despite improvements in anti-poaching measures in protected areas such as the Central Kalahari Game Reserve.

After the construction of the Kuke and other fences in the late 1950s, several waves of fencing development, notably in 1968 and the early 1980s saw the proliferation of fences across Botswana. These fences were constructed as straight impermeable barriers, often hundreds of kilometres in length, running across largely uninhabited, cattle-free ranges. Reports of wildlife population die-off were often associated with these new developments.

In 1991 the development of the Northern Buffalo Fence, linked to an ambitious plan for the development of commercial ranches west and north of the Okavango Delta, under a proposed World Bank Sponsored project called Livestock III resulted in wildlife mortalities which were reported on by film-maker Rick Lomba. Conservationists were highly critical of the *Lome Protocol*, a preferential trade agreement with the EU believed to have directly promoted the expansion of fencing programmes northwards into the Okavango delta sub-region (Lomba, 1991; Williamson, et al., 1994).

The DVS bases its current disease control policy on the requirements of the OIE (World Organization for International Animal Health) *terrestrial code*. Botswana is accordingly divided up into various OIE-approved control zones. Cattle within the FMD Free Zone, which is located south of the Kuke fence, can be sold at a premium to the BMC for export. Cattle within the FMD vaccination zone, located north of the Kuke fence, can only be used for the domestic market subject to veterinary controls. According to chapter 2.2.10 (Foot and Mouth Disease) of the OIE terrestrial code, internal fencing is not required within an FMD vaccination zone, but it is required that such vaccination zones be separated from declared FMD free zones *"by a surveillance zone, or physical or geographic barriers, and animal health measures that effectively prevent the entry of the virus."* The fences located within the Ngamiland District therefore are accordingly unnecessary if the objective is not to expand the existing FMD free zone further northwards, beyond the Kuke fence.

The persistent policy of promoting fencing within the Ngamiland FMD vaccination zone therefore appears to be motivated by the potential for the creation of a new FMD free export zone, rather than solely for the protection of the existing FMD free zone south of this District. In order to acquire OIE approval for a new FMD free zone in Ngamiland, Botswana would have to satisfy the OIE of its ability to prevent the movement of any potential FMD vectors into such a new zone from the current FMD infected zone (located to the north of the Southern Buffalo Fence). An examination of these underlying motivations for the implementation of veterinary fencing in Ngamiland and the associated commercialization efforts is important in understanding the nature of the persistent threats posed by the cattle industry to remaining wildlife habitats in Northern Botswana.

Fencing impact misconceptions

A number of misconceptions undermine popular understanding of the true nature of fencing impacts on wildlife in Ngamiland District and the appropriate interventions required to resolve the fencing issues. The Ngamiland fences require analysis on a 'per case' basis. The Southern Buffalo Fence for instance does, despite its persistent impact on giraffe (*Giraffa camelopardalis*) and other species (Fig.4.1.2), serve the useful purpose of keeping cattle out of the Okavango Delta. From a disease control point of view, the fence also limits the risk of contact between FMD carriers such as buffalo (*Syncerus caffer*) and cattle. In contrast the Northern Buffalo Fence and Setata fences are ineffective as disease control measures as it bisects largely uninhabited cattle-free wildlife habitats and the fence is generally opposed by local communities (Albertson, 1998 & 2005; Landflow Solutions, 2009; Scott Wilson, 2000). The fences bisecting wildlife habitats prevent home range movements to a wide variety of resource areas /

sites (not limited to surface water resources only) and movements that are required in response to changes in environmental conditions due to for example drought and fires.

Figure 4.1.2. Giraffe trapped on southern buffalo fence, 1998. *Photo: Yssel du Plessis*

Fences interfere with non-migratory herbivores as much as migratory herbivores, through stress effects related to the prevention of access to key resource sites (e.g. grazing, minerals licks, pans, waterholes) which lie within defined territories or home ranges, the separation of social groupings in particular calves and juveniles from adults, direct injury related to lateral collisions with fences and injury or entanglement related to attempts to cross over or pass through a fence.

Contrary to the common belief that elephant (*Loxodonta africana*) and "famous jumping species" like kudu (*Tragelaphus strepsiceros*) are not constrained by the veterinary fences (Government of Botswana, et al., 1998), mortalities related to fence entanglement or injury in these species has been observed (Albertson, 1998).

The prevention of access of water-sensitive species such as zebra (*Equus quagga*) and some wildebeest populations, to dry season water resources, is popularly perceived to be the only significant impact. However, it is the prevention of access to adequate forage areas, which is of comparable, or greater significance to most large wildlife species affected by fences in semi-arid environments. Seasonal declines in the abundance and nutritional quality of forage resources and dynamics related to the spatial availability of forage resources, which is affected by the low and highly variable and erratic rainfall patterns that characterize Ngamiland, requires a high level of movement flexibility. Furthermore, the ability of populations to deviate from normal movement patterns in order to optimize use of resources under favourable environmental conditions, which are often 'patchy' in their geographic availability, or to access key sites to avoid impending population declines (e.g. due to localized droughts), is also a vital long-term survival requirement.

Compounding the difficulties in assessing on a 'snap-shot' basis the full potential range of short-term and long-term impacts on wildlife populations, are the behavioural tendencies of wildlife in proximity to fence-lines. Wildlife typically avoid vehicles travelling along fence-lines and the sight and smell of artificial materials in particular chemically-treated wooden poles is also a deterrent. The tendency of predators to use fence-lines to trap prey and the lack of vegetation cover along the cleared cut-lines on either side of the fence-lines, which exacerbates physical stress levels in animals in an already weakened and dehydrated condition, are also factors causing wildlife to make contact with fences only intermittently spatially and over time.

Wildlife contact with fence-lines is consequently more likely to occur at night or in the cooler hours of the day (i.e. early morning or late afternoon). Movements often are limited to a zone within a perpendicular distance of between 15 to 100m from the fence-line, with parallel game trails often clearly evident from the air along fences causing high levels of movement interference (Albertson, 1998, 2002, 2005, 2008; Government of Botswana, 1998; Scott Wilson, 2000).

In terms of assessing the physical evidence of wildlife-fence interactions, a number of human-induced and natural factors also undermine such investigations. Apart from the factors deterring wildlife fence contacts, stressful or physically harmful fence contacts is seldom evidenced by observable damage to fencing wires or carcasses alongside fence-lines. Veterinary crews also frequently remove any carcasses found alongside fence-lines and dispose of them at sites away from the fence. Carcasses are also removed by predators (Government of Botswana, 1998; Albertson, 1998, 1999, 2000, 2002). Wind also plays a significant role in obliterating spoor evidence of wildlife-fence contact (Albertson, 2008).

Wildlife "build-up" in the form of large groupings of stationary animals clearly positioned closely alongside fence-lines - as has often been conceived in the past by officials of the DVS as a necessary prerequisite for any mitigation action – this is not necessarily a reliable indicator of severe movement constraints on local wildlife populations (Albertson, 2000).

The 1995 CBPP campaign and its resultant wildlife impacts

In February 2005, CBPP entered northern Ngamiland by means of the illegal movement of cattle from an adjacent infected area in Namibia. The disease rapidly moved southwards and this was followed by a decision to construct three "emergency" CBPP control fences, namely the Samuchima, Ikoga and Setata fences. The fences did not achieve their stated purpose and by March 1996, the entire Ngamiland district was declared an infected area. A total of 320,000 cattle were culled to prevent further spread of the disease. Double electrified fences were erected in the same year along the western and northern boundaries with Namibia.

The Government decided to compensate affected communities for the loss by restocking a third and providing monetary compensation for two thirds of livestock lost. The Minister of Agriculture at the time, Roy Blackbeard also took the decision to extend the Northern Buffalo Fence northwards to join the new Caprivi fence. Only the western border fence and the border fence west of the Okavango River was already fenced - the three CBPP fences, the Caprivi fence

and the Northern Buffalo Fence extension all cutting across unfenced terrain. Approximately 80% of the Caprivi fence-line was constructed through cattle-free wildlife habitat across a border area regularly traversed by wildlife and hunter-gatherer Bugakhwe communities moving between Namibia's West Caprivi Game Reserve and the Okavango region. The Northern Buffalo Fence extension was constructed through an entirely cattle-free area and approximately 70% of the Setata fence bisected an uninhabited cattle-free area. No impacts studies were conducted prior to the construction of the new fences.

Severe disruption to wildlife movements shortly followed the construction of the fences. The impacts were most acute along the southern side of the Setata fence where mortalities of wildebeest, zebra, hartebeest, gemsbok (*Oryx gazella*) and giraffe were reported by S. Ludbrook (Natural Resources Management Project, support to DWNP) and D. Mughogho (DWNP) internally to their organizations. Local conservationists Dr. Karen Ross and the author drew attention to the wildlife impact issues related to the new fences by lobbying Government and other stakeholders. Dr. Ross's efforts were crucial to the formation of the Ad Hoc Committee on Fences (AHCOF), a multi-stakeholder Government and NGO group formed with the objective of advising Government on solutions to the impact issues.

Early efforts to mitigate environmental impacts of Setata CBPP fence

Independently and under the auspices of the Okavango Peoples Wildlife Trust (OPWT), the author undertook extensive monitoring of the Setata and Northern Buffalo Fences in an effort to communicate the reality of the ongoing daily impacts on wildlife to the authorities. The AHCOF proposed an option for realignment of the fence further north along the boundary between NG5/NG4 and NG3. The DWNP and DAHP communicated the realignment option to the Cgae-cgae community but gave no indication of any immediate plan to mitigate the impacts of the existing fence. Frustrated by what appeared to be the DWNP's inability to influence any timely mitigation action, the author then directed his communications to the then Vice President of Botswana, Lt.Gen. S.K.I. Khama, now the honourable President of Botswana, who also served as the patron of the OPWT.

Local communities affected by the fence expressed their opposition to the fence at the highest levels of Government. A letter addressed by the Chief of Xai-xai and the Village Development Committee, dated 1 June 1998, indicated as follows: *"...We are asking for the removal of the Setata Fence immediately, without delay, to prevent mortality of wildlife by the fence this winter season. With regard to the re-alignment option along the boundary of NG 4 and NG3 from Tsau, we are totally against it, because it will have the same effect as the Setata Fence by blocking wildlife migrations and tampering with community activities."*

The Botswana Vice President responded in a reply to the Cgae-cgae Chief, dated the 12 June 1998 that a decision had been taken to *"lay down the fence so that wildlife can pass through."*

On the 15 July 1998, DWNP Regional Wildlife Officer Dan Mughogho in an internal communiqué to his Director, validated the concerns expressed by the author and

the Cgae-cgae community by reporting: *"mortalities due to physical stress and entanglement on the fence...as suspected, a massive build up of a variety of wildlife species was observed. Almost all on the southern side of the fence."*

Mughogho further states that: *"The majority were trotting along the fence in either an east or westerly direction. It was obvious from the observations that these animals were desperately trying to cross the fence to go north."*

The Botswana Government then issued a Directive on the 18 August 1998 for DAHP to put together a multi-stakeholder team to monitor the Setata fence to determine its effect on wildlife populations. The assigned team, which included the DWNP, DAHP, the author (OPWT) and the Cgae-cgae community was tasked with monitoring the fence for a period of *"at least one month,"* and given a mandate to drop the fence where wildlife build-up was observed. The Team had identified a total of 68km to be dropped, but the team leader, a representative of DAHP, only permitted 34km to be dropped, as 2 - 3km gaps alternating with the standing sections. This action was completed in August 1998.

The OPWT objected to what it felt was "an unnecessarily small total of dropped sections". Wildlife impacts continued to be monitored by the author and spoor assessments revealed that wildlife were hesitant to cross over the dropped sections. Objection was also raised to what was felt were incorrect and misleading statements in the joint report submitted by the team leader, a DAHP official (Government of Botswana, et al., 1998). The author later conveyed his concerns to the Vice President concerning the objectivity of the monitoring and mitigation effort led by DAHP and continued to report on the observed impacts. In reply the Vice President indicated in a letter dated 16 December 1998 that a decision had been made that an EIA be carried out given the *"predominance of wildlife resources in NG5."*

The "retroactive" Scott Wilson EIA of Veterinary Fences in Ngamiland

The EIA of the veterinary fences in Ngamiland, undertaken between June 1999 and October 2000, was commissioned by the Botswana Government *"in response to publicity generated by the construction of a number of veterinary fences to control the outbreak of (CBPP) in 1995"* (Scott Wilson, 2000).

The terms of reference called for a number of interlinked outputs with the primary objective of finding compromised solutions acceptable to the interests of the diverse stakeholder groups involved, in particular: environmental audits of the existing fences; an EIA for the linking of the Southern and Northern Buffalo fence; a strategic environmental assessment of the livestock disease control policy; guidelines for future fences EIAs and an environmental management plan for the Ngamiland fences.

Guided and managed by a multi-stakeholder reference group chaired by the DWNP and DAHP, the study involved extensive consultations and studies of the livestock and wildlife / tourism sectors, and the affected communities, rangelands and wildlife populations. The various study components were undertaken by multidisciplinary teams with relevant qualifications and experiences in their respective fields of expertise.

The findings of the environmental audits concluded as follows for the following selected fences (Executive Summary, Scott-Wilson EIA of veterinary fences in Ngamiland, Final Report, 2000):

Setata Fence: Pg viii: "Due to evidence of high wildlife pressure upon the western side of the fence (west of Reronde), and adverse changes in some wildlife populations, this section should be removed completely and the ground rehabilitated. The eastern portion is less critical from an environmental point of view and may be maintained and included in district agricultural planning, providing stiles and gates as required by local communities." ..Pg xvi: "This is the most controversial fence and its removal or realignment is urgent." It was also concluded that the fence was ineffective as a disease control measure.
Northern Buffalo Fence: Pg viii: "The (NBF) should be maintained but realignment along the southern boundary of NG13 should be considered in consultation with communities."
Caprivi Fence: Pg ix: "The removal of the eastern section of the fence along the northern side of NG13 should be considered in consultation with local communities. Pg xvi "..to re-establish wildlife movement and allow for the development of trans-boundary tourism and resource management."

Four "policy options" for livestock disease control were considered in the final assessment (see Figs. 4.1.3 – 4.1.6):

Option 1: A modified status quo with Setata fence aligned along the northern boundary of NG5 to join the Namibian boundary.

Option 2: Modified status quo incorporating the findings of the EIA: removal of the western Setata fence and realignment of the NBF.

Option 3: Creation of an FMD free zone to the south and west of the Okavango Delta providing opportunities for beef export. Joining and upgrading of Southern Buffalo and Ikoga fences to a double, electrified fence joining up with the Makalamabedi fence.

Option 4: Creation of a smaller FMD free zone with western Setata fence realigned to follow the eastern NG5 boundary.

The study further advises as follows: *"In the event that a decision is made <u>not to</u> create an FMD free zone, Option 2 represents the better environmentally and socially acceptable option." "In the event that a decision is made <u>to create</u> an FMD free zone, Option 4 would be more ecologically sound, socially equitable and with better net benefits than Option 3."*

The report concluded that in Option 1 and Option 3, the realigned east-west fences would "lead to reduced (wildlife) populations and eventually to local extinction," and threaten wildlife tourism development in Western Ngamiland.

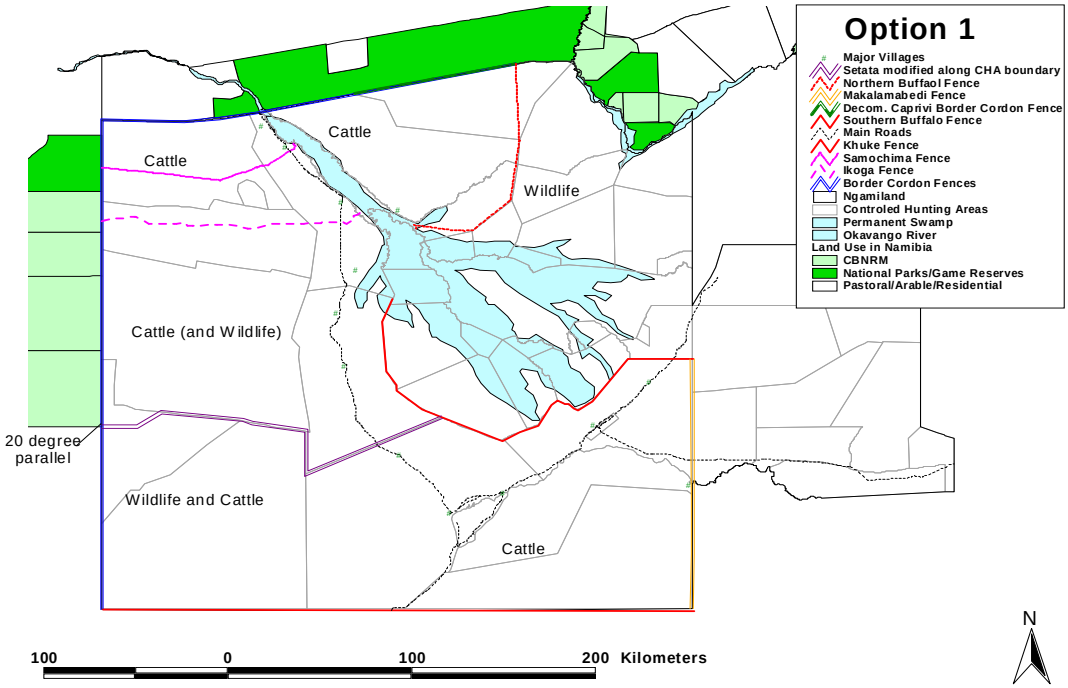


Figure 4.1.3. Option 1 considered in the Scott Wilson EIA study.

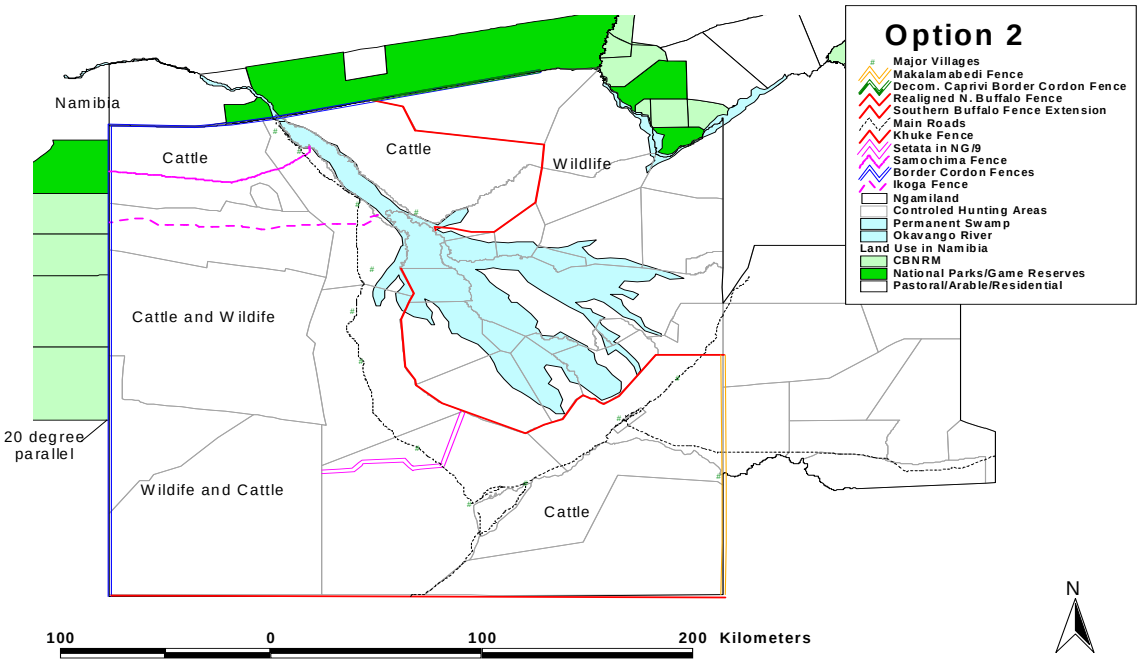


Figure 4.1.4. Option 2 considered in Scott Wilson EIA study.

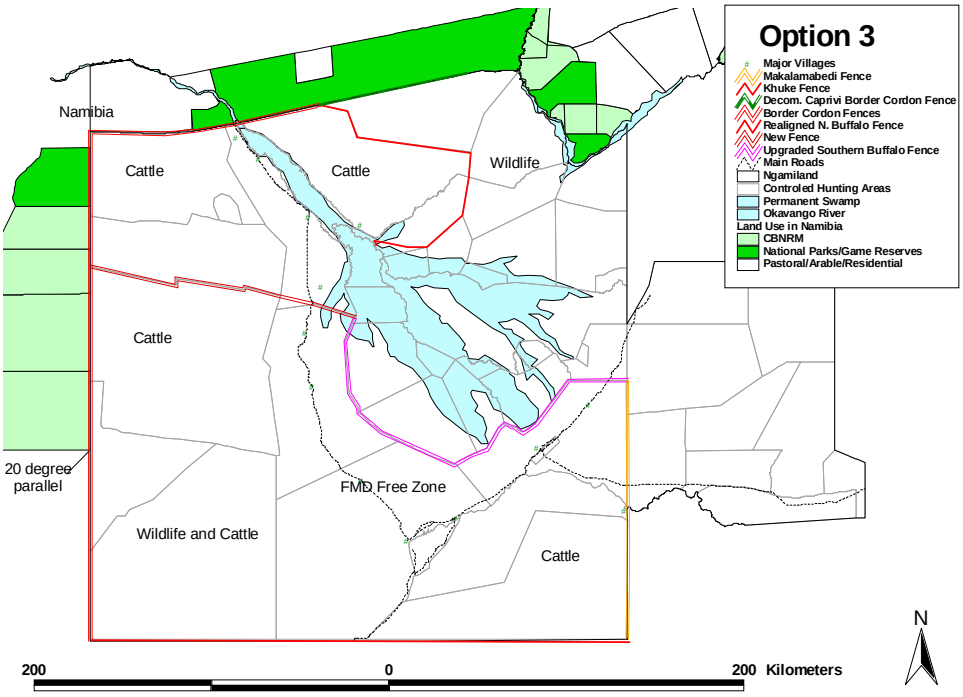


Figure 4.1.5. Option 3 considered in Scott Wilson EIA study.

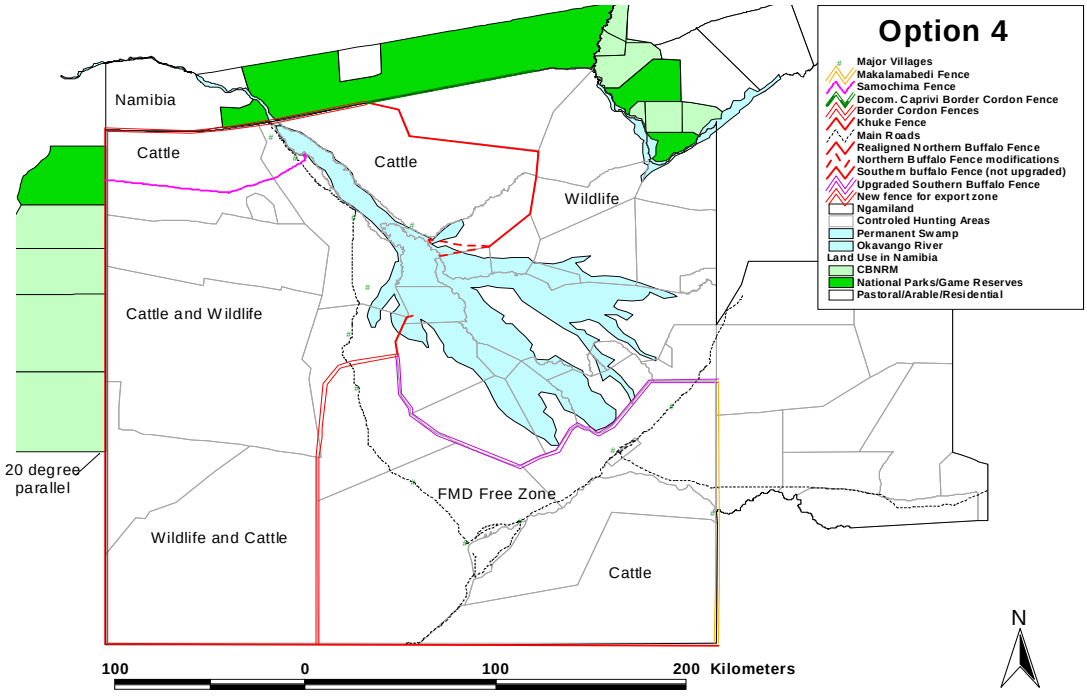


Figure 4.1.6. Option 4 considered in Scott Wilson EIA study.

Implementation of the Scott Wilson EIA recommendations

Although the recommendations were endorsed by the Reference Group and the AHCOF, no immediate action was taken by DAHP to implement the EIA's recommendations. This was due to a lengthy review process by the Ministries concerned.

Between 2001 to 2003 the author continued to inform the Botswana Government of the ongoing impacts along the western Setata fence and Northern Buffalo Fence while the Ministry of Agriculture, in contradiction to the endorsements, made it clear that it favoured Option 3 (F. Monggae (KCS)., pers. comm.). In 2004 the author submitted a proposal to the Kalahari Conservation Society (KCS) Board for the sponsored removal of the western Setata fence and the Nxai Pan Buffalo fence (a decommissioned, dilapidated fence reported on by the author in 1998). This was followed by a directive issued to the DAHP for the immediate removal of the Nxai Pan fence and for the clearing of remaining materials from the Setata fence (which had already been removed by late 2003). The DAHP removed both fences at a cost of Pula 845,000 and Pula 120,000 respectively.

Preliminary investigations carried out by the author after the removal of the fences on behalf of KCS in July 2005 indicated, inter-alia, that elephant, zebra and wildebeest had resumed their normal movement patterns south of the old Setata fence-line into NG5, setting a favourable precedent for wildlife population recovery (Albertson, 2005).

The reconstruction of the Setata Fence

By 2007, no further progress in the implementation of any of the primary EIA recommendations had been made, and it was still unclear which of the recommended options (i.e. Option 2 or Option 4) would finally be adopted by Government for implementation. Also significant was the apparent acceptance by the DVS of the removal of the entire Setata fence-line, with no indication provided to any stakeholders that its partial or full reconstruction would be essential for disease control, the Scott-Wilson study having already disposed of this issue to the satisfaction of all stakeholders involved in the study, including the DVS.

In November 2007, a shock cabinet directive was issued for the reinstatement of the entire Setata fence as a double cordon, following an alignment similar to that in the Option 1 advised against by the Scott Wilson study**.** This decision had shortly followed a report by DVS in October 2007 of an outbreak of FMD north of Tsau in the vicinity of the old Setata - Southern Buffalo Fence intersection. The stated rationale for the reconstruction of the Setata fence was that it was necessary as an emergency FMD control measure. Work for the clearing of cut-lines for upgrading both the fences was tendered in late 2007.

As part of the Directive, an appointed DWNP-DAHP "Task Team" visited Cgae-cgae in January 2008 to present the alignment, which was proposed to follow the northern boundary of Ng5 and then run directly through the centre of the village. After vehemently objecting to this alignment, the community agreed to a suggested alternative alignment that would loop around the north of the village (pers. com. Cgae-cgae Thlabololo Trust, 2008). No EIA was undertaken on the final alignment and construction work commenced from the Namibian border and the Southern Buffalo Fence towards the centre of the proposed alignment (Albertson, 2008).

Having been alerted to the Directive in late 2007, the author immediately commenced lobbying the Government in support of the Scott Wilson recommendations for the alignment of the fence to run down the eastern boundary of NG5, as opposed to it following the northern boundary of NG5. This was recommended in order to avoid cutting off the primary wildlife movement corridor between Ng4/5 and the Okavango delta.

In the absence of any EIA study on the new fence the Scott Wilson EIA study served as the only existing scientifically credible and suitably objective guideline for fencing policy and impact avoidance in South-West Ngamiland. It was also pointed out in a number of communications by the author in January and February 2008 that the western portion of the fence as proposed, was unnecessary due to:

- the absence of potential FMD vectors such as buffalo to the west of the Southern Buffalo Fence;
- the absence of livestock and unlikelihood of any contact between the isolated cattle population of Cgae-cgae and the cattle populations around the eastern fence portion;
- the fact that FMD had already spread to southern Ngamiland and that there was no longer any rationale for erecting the fence as an "emergency" in the absence of an appropriate EIA study.

After continued lobbying efforts, supported by other conservationists, the Office of the President confirmed in writing in June 2008 that a decision had been made to halt the construction of the fence, with the Task Team mandated to continue monitoring the impacts and implement mitigation measures. The author undertook a survey in August 2008 in which high levels of wildlife impact were noted in the vicinity of the Reronde and Konde corners of the remaining fence portion. Mortalities of gemsbok and giraffe were later confirmed by DWNP. In late 2008 and 2009 the author wrote to and met with the Chairman of the DWNP-DVS Task Team, Dr. Neo Mapitse, to appeal for the implementation of mitigation measures in the form of two 10m wide gaps in the Reronde and Konde corners of the fence. It was pointed out that the measures could be implemented on a precautionary basis and that this could be done so at negligible cost. The Task Team has undertaken a number of seasonal "surveys" in 2008 and 2009 but to date there is still no indication of any plan to implement mitigation measures. In conclusion, if the recommendations of the Scott Wilson Report - which do not support the fencing of the eastern and northern boundaries of NG5 to the north of Reronde - are to be disregarded by DVS, the only practical solution, compliant with the requirements of the EIA Act of 2005, would be to undertake an independent EIA of this portion.

Other current and potential fencing impacts undermining wildlife / tourism sector

Cattle population distribution, as evidenced by DWNP aerial surveys, has not significantly changed since the time of the Scott Wilson EIA study. Large areas of Western Ngamiland are infested with the poisonous plant *Dichapetalum cymosum* ('Gifblaar' or 'Mogau') and a TGLP ground water survey conducted in 2004 advises that Area 5 (NG5) is "extremely unsuitable for ranch demarcation."

The Botswana Tourism Board is actively supporting the development of community based photographic tourism in NG4 (ecologically dependent on its linkages with NG5 and NG3). The communities of NG3 have also requested support from the DWNP for a change in land-use from livestock grazing to wildlife management area. The opportunities for further CBNRM and tourism development in Western Ngamiland are significantly better today than they were in 1999 / 2000.

With one main exception, that being a renewed proposal for a 100km X 50km fenced cattle ranch along the northern boundary of the Kuke fence in NG5 and to a lesser extent NG9, the *Review of the National Land-Use Map* by Landflow consultants (Landflow, 2009) recommends a number of positive developments, with the potential to promote the recovery of Botswana's declining wildlife resource base and assist in improving the livelihood income of rural communities, namely:

1. *A change in the status of NG11 from livestock to community Wildlife Management Area on account of the poor suitability of the area to livestock production, community prioritization of CBNRM and potential for further expansion of the CBNRM / tourism sector.* This would contravene the recommendations of the Scott Wilson study, for the realignment of the Northern Buffalo Fence along the NG11 / NG13 boundary as a compromise between the opposing interests of the DWNP and DVS stakeholders involved in the study. However, given the potential for negative impacts on wildlife movements between NG13 and NG11, and the growing interest in CBNRM as opposed to livestock development amongst resident communities, a more pragmatic approach would be the complete removal of the Northern Buffalo Fence, as implied by the proposal for change in land-use.

2. *A change in the status of NG3 from communal livestock grazing to unfenced game ranching based on an open system of wildlife boreholes.* This proposal may be compatible with the existing DWNP plan for the change in land use to a community WMA. The author is currently engaged in developing a proposal for linking current and potential wildlife areas in Botswana (namely NG8, Ng4, Ng5, GH1 and the Tsodilo Hills World Heritage Site, with adjacent conservation areas in Namibia. A M.Sc. thesis by B. Tucknott has already established that the communities would support a trans-boundary conservation area in NG3, linking the Okavango Delta to Namibia's Kaudom Game Reserve and the Nyae-Nyae conservancy. WWF has already indicated its interest in the concept (Chris Weaver, Personal communication, 2008).

The *Review of the National Land Use Map* Final Report is still under review at Ministerial level. While some of the proposals appear to be well justified, those relating to the proposed reductions in the sizes of several WMA in the Kgalagadi and Ghanzi Districts, as well as the proposed ranching block in NG5 were motivated on the subjective basis that they are needed as *"further compromises towards the cattle industry"* (e.g. Landflow, 2009 p.160). These particular proposals contradict the expressed needs of many of the local communities involved in, or interested in CBNRM, the recommendations of the DWNP (e.g.

Government of Botswana, 2007) and the Scott Wilson EIA study of 2000 (recommending Option 4 and the preservation of the WMA status of NG5).

These proposals also contradict the existing Government policy and planning framework which is increasingly aimed at diversifying the rural economy and promoting tourism diversification and geographic expansion where it is feasible to do so. Key proponents of these development objectives include the *Revised Strategy for Rural Development of 2002*, *The Tourism Act of 1992* and the *National Development Plan 10 (2010)*. The demand for private land acquisition, as an underlying motivation for the fencing policies and proposals that continue to plague Botswana's remaining wildlife habitats is clearly spelled out in this excerpt from the LandFlow report on p. 67:

> *"A new factor that limits land allocation is the lack of available land for the creation of new ranches. It is estimated that only 4,500 to 5,500 additional ranches can be created within the available space in the country. This situation may only be altered if standard ranch sizes are significantly decreased, or if the system of land tenure is altered. Neither solution would be politically acceptable to current land-holders...*
> *Communal lands in some areas have been sub-divided and fenced in the recent past to encourage a shift from the traditional multi-use system to a cash-trade orientated system. This has brought dissention among the people, mainly those in lower income levels, because wealthier and batter educated people with more cattle tend to acquire the tribal ranches, but hang on to their traditional cattle post areas.."*

4.2 Veterinary cordon fences and environmental change in northern Botswana

McGahey, D.J.
Consultant, Cardno Agrisystems Ltd, Oxford House, Oxford Road, Thame, OX9 2AH, UK.
daniel.mcgahey@cardno.uk.com

Fences and environmental change

Overgrazing by domestic livestock within communal rangeland areas is widely perceived as a major threat to biodiversity, declining rangeland productivity and degradation in Namibia (Kuiper & Meadows, 2002), South Africa (Hahn, et al., 2005) and throughout sub-Saharan Africa in general (Vetter, 2005; Rowntree, et al., 2004). Increased enclosure, structural land use change, and sedentarisation has dramatically increased resource pressure in these areas as governments pursue policies encouraging land privatisation, sedentary infrastructure, and the fencing of communal pastures (Sporton & Twyman, 2002). At the same time major changes in rangeland science have resulted in wider acceptance of non-equilibrium ecological concepts and maintaining livestock mobility is now seen as essential for the future sustainability of dryland savannas (cf. Niamir-Fuller, 1999; Fratkin & Mearns, 2003; Homann, et al., 2004). As a result, understanding the ecological consequences and causes of restricting herd mobility by rangeland fragmentation is now being highlighted as an important research agenda (Vetter, 2005; Boone & Hobbs, 2004; Boone, et al., 2005; Stokes, et al., 2006).

Veterinary cordon fences represent one persistent constraint to herd mobility and fences in northern Botswana have curtailed the movement of people and livestock resulting in more sedentary resource use (McGahey, 2008, chapters 6 & 7; McGahey, this volume). At the same time veterinary fences severely restrict the movement of wildlife, particularly large mammal herbivores (Chase & Griffin, 2009). However, we know very little about how the fence-restricted resource relationships of people, livestock and wildlife are impacting upon the natural environment (exception of McGahey, 2001). That said contrasts in vegetation communities are particularly conspicuous across some veterinary cordon fences in Botswana, especially older fence-lines. An assessment using earth observation data by Ringrose, et al., (1997), for example, attributed fence-line vegetation contrasts across the southern buffalo fence (circa. 1982) to the restriction of migratory wildlife. Yet far more research is needed; particularly more detailed ecological studies to determine the extent to which grazing has effected species composition across veterinary fence-lines.

Assessing fence-line environmental change

Fence-lines represent natural grazing experiments whereby the effects of different grazing regimes and management practices can be monitored (Todd & Hoffman, 1999). The spatial variability of vegetation communities can be altered by grazing animals confined by fences and this has been observed in Australia (Pickup, et al., 1998; Graetz & Tongway, 1986), and elsewhere (Boone & Hobbs, 2003). Several studies have attempted to assess fence-line contrasts in vegetation communities using ground-based transects. Trodd & Hoffman (1999) used these across fence-

lines dividing commercial farmland from communally grazed areas in South Africa. They targeted areas of comparable vegetation, soil and topographic characteristics and found significant changes in the abundance of palatable and unpalatable species of both grass and shrubs between plant communities (ibid). However, very little work has focused on the impact of large scale barriers such as veterinary cordon fences which dissect areas of communal rangeland and wildlife reserves. This section describes the results of detailed ecological surveys conducted across the northern buffalo fence (hereafter NBF) between land grazed by wildlife and communal land predominantly grazed by livestock. The fence was used as a natural grazing experiment to determine the extent of structural changes to vegetation communities at the landscape scale.

Study area

The NBF is located in north-western Botswana and its southern sections were constructed in 1991 (Fig.4.2.1). The fence was extended to join the Namibian border fence after a disease outbreak in 1996. The vegetation is dominated by tree and shrub savanna, giving way to dry deciduous woodland (predominantly *Baikiaea plurijuga*) to the northeast (Ben-Shahar, 1998). *Colophospermum mopane* dominates the vegetation on calcareous or sodic soils, while *Terminalia sericea, Combretum molle* and *Baphia massaiensis* shrubland is found on sandy soils. The ground-based survey involved a series of transects conducted orthogonal to the fence-lines and at set distances along them. A 75km sample route from Sandaroka channel to Dishokora cattle post was used for survey purposes. In total 16 sites were sampled along the NBF (Fig.4.2.1) at approximately 5km intervals. In order to avoid the confounding effects of landscape heterogeneity, the precise location of these adjacent sites was subjectively positioned within similar patches of vegetation, following reference to a vegetation map derived from a land cover mapping excise (see McGahey, 2008: chapter 9). Study sites were distributed such that they covered the majority of areas where fences come close to the study villages and cattle posts, along with regions some distance from settlements and cattle posts. If cross-fence changes observed with distance along the fences correlates with known settlement patterns or wildlife population increases, the areas of contrasting vegetation communities could highlight resource pressure resulting from fence enclosure.

Several studies have documented that the zone of maximum interaction of wildlife species with a fence starts at 30m (Lewis & Wilson, 1977). Observations along the NBF revealed similar well used animal tracks at approximately 30-40m from the fence. To assess the impact of herbivory either side of the fence a series of 30m line intercept transects were conducted at distances of 30m, 100m and 150m either side of the veterinary fence (Fig. 4.2.2). Tree density was also recorded at each sample point within a series of 30 by 30m quadrates using an arbitrary 3m level to distinguish shrubs from trees (for a more detailed discussion of these methods see McGahey, 2008).

In order to evaluate significant differences in fence-line vegetation communities, T-tests for independent means assuming unequal variances were conducted on the vegetation cover data. The statistical analysis focussed on both the total cover changes and individual species cover changes. In addition, the significant

differences in annual and perennial grasses, as well as increasing or decreasing species of shrubs and trees were assessed across the fence-lines.

The classification of species into each of these characteristic categories was facilitated following reference to several sources (cf. van Oudtshoorn, 1999; Coates Palgrave, et al., 2002; van Vegten, 1981; Moleele & Perkins, 1998).

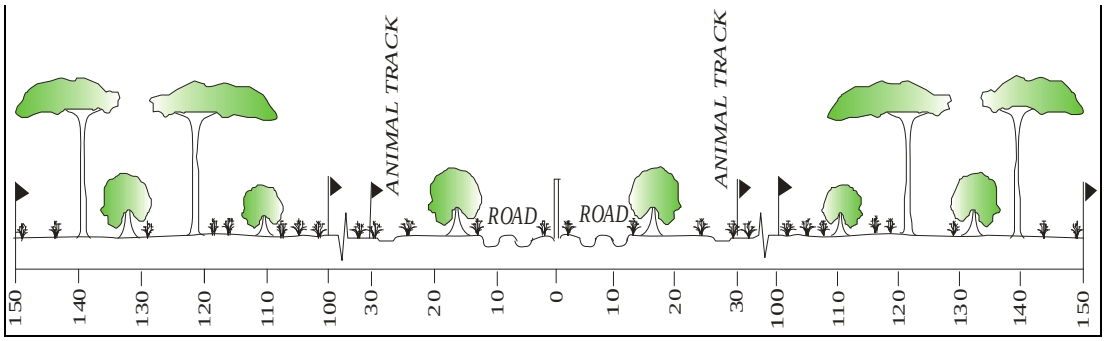


Figure 4.2.2. Diagram illustrating location of sample points along cross-fence transects. Line intercept transects were 30/50/ 150m each side.

Fence-line vegetation changes

Vegetation data showed a significant reduction in total cover to the east of the NBF (Table. 4.2.1). There was no significant difference in the mean total cover of tree, shrub or grass species across the NBF, but the mean total cover of shrubs, grasses and trees was lower on the eastern side of the fence for all three variables. The cover of annual grass species did not differ significantly either side of the fence. However, the cover of perennial grasses was slightly lower (significant at the 0.1 level) to the east of the fence.

Table 4.2.1. Mean cover and density changes of several indicator species groups across NBF. T-test statistics illustrate significant fence-line changes.

Indicator/species group	NBF east	NBF west	Test stat	df	*P*
Bare ground	63.5	58.1	2.1	94	0.05
Shrub cover (<3m)	23.8	26.4	-1.3	93	NS
Grass cover	13.6	15.8	-1.2	80	NS
Tree density (>3m)	4.1	5.6	-1.4	93	NS
Annual grasses	6.4	6.1	0.3	75	NS
Perennial grasses	5.9	8.1	-1.8	93	0.1

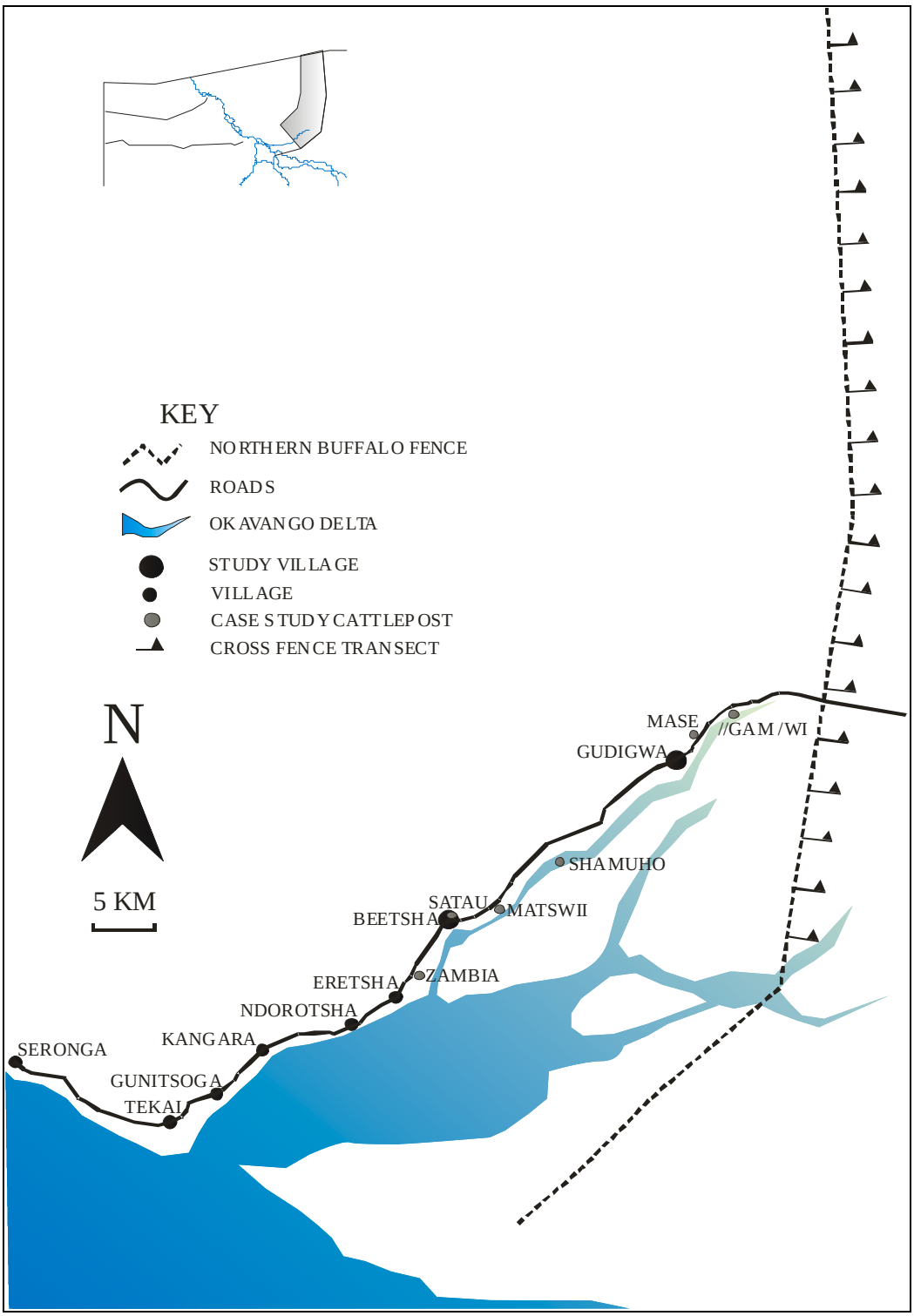


Figure 4.2.1. Location of sample points for cattle posts and fence-line ecological surveys in NBF site.

Species diversity changes across the NBF

A total of 44 different species were identified on both sides of the NBF. Species diversity was slightly lower on the eastern side of the NBF, with 42 and 38 different species identified to the west and east respectively. When separating the differing species found into growth form categories (e.g. shrub, trees, annual grass, perennial grass and creeping grass), a further 4 species were not present (2 east and 2 west) on both sides of the fence. These were all mature trees above the arbitrary 3m level (Table 4.2.2). However, none of the species that failed to be present on either side of the fences were common species contributing to more than 0.5 per cent of cover as a percentage of the cover of all taxa.

Table 4.2.2. Species diversity and growth form changes across NBF with % cover as a % of cover of all taxa signifying importance of species.

Species not found to the east	Growth form	% cover as % of all taxa
Pterocarpus angolensis	<3m Shrub	0.18
Dichapetalum cymosum	<3m Shrub	0.05
Boscia albitrunca	<3m Shrub	0.28
Acacia fleckii	<3m Shrub	0.04
Acacia nigrescens	<3m Shrub	0.28
Acacia eriolobia	>3m Shrub/Tree	0.07
Combretum apliculatum	>3m Shrub/Tree	0.04
Pterocarpus angolensis	>3m Shrub/Tree	0.02
Species not found to the west	Growth form	% cover as % of all taxa
Setaria sphacelata var. sphacelata	Perennial grass	0.03
Panicum maximum	Perennial grass	0.006
Guibourtia coleosperma	>3m Shrub/Tree	0.07
Combretum hereronense	>3m Shrub/Tree	0.02

Two alternative explanations exist to explain these patterns. Could the reduced eastern cover changes be indicative of fence restricted wildlife herbivory or could reduced grazing following exclusion of many native ungulates be causing increased cover to the west? Furthermore, would more detailed investigations identify species and vegetation community changes across the fence facilitate interpretation of veterinary fence impacts?

Species and community changes across the NBF

The results of the more detailed analysis of shrub species cover changes over the NBF revealed that the main shrub species could be divided into those which showed increased cover to the east and those which showed decreased cover to the east (with the exception of *Ochna pulchra*, see Table 4.2.3). Of the decreasing shrub species *Baphia massaiensis* and *Grewia* sp. were significantly different. The main shrub showing a significant increase to the eastern side of the fence was *Terminalia sericea*, a species known to react well to disturbance (Hipondoka & Versfeld, 2006). Although the cover differences seen in other species listed were not significant, the total increasing and decreasing shrub mean cover changes were significant at the 0.05 level (Table 4.2.3). Figs. 3 & 4 illustrate the cross-fence changes seen with the cover data from the total mean cover of each group

of increasing or decreasing species. These graphs highlight sites roughly between 20 to 50km and 75km north from Sandaroka as areas of major fence-line contrasts in vegetation community structure. Sites from 20 to 50km relate to an area between approximately S18°34 E23°01 and S18°18 E23°02. The site 75km north of Sandaroka relates to an area near Dishokora cattle post at approximately S18°06 E23°01.

Table 4.2.3. Mean cover changes of main shrub species found either side of NBF illustrating clear division of species into increaser or decreasing groups. The significance of these changes is illustrated by the t-test statistics.

Decreasing shrub species	NBF east	NBF west	Test stat	df	*P*
Bap. mas	2.0	6.9	-3.1	55	0.01
Col. mop	6.6	7.4	-0.3	92	NS
Bau. pet	0.2	1.1	-2.3	51	NS
Grewia sp.	0.3	0.9	-1.8	71	0.1
Com. apl	0.7	0.9	-0.5	92	NS
Increasing shrub species					
Ter. ser	7.5	4.8	1.8	90	0.1
Lon. nel	2.4	1.5	0.8	80	NS
Com. mol	1.7	0.9	1.1	73	NS
Bur. afr	1.5	1.0	0.8	90	NS
Neutral shrub species					
Och. pul	1.1	1.1	0.1	89	NS
Total increasing shrubs	13.0	8.2	2.3	83	0.05
Total decreasing shrubs	24.5	31.3	-2.2	84	0.05

Tree density changes across the NBF

There were no significant changes in the density of the five most common tree species over the NBF (Table 4.2.4), though *T. sericea* decreased in density to the east in its mature form. Similarly all other species except *Colophospermum mopane* decreased to the east.

Table 4.2.4. Mean density changes of main tree species found either side of NBF. The significance of the change is illustrated by the t-test statistic.

Tree density changes	NBF east	NBF west	Test stat	df	*P*
Ter. ser	1.5	2.4	-1.3	82	NS
Com. mol	0.0	0.4	-1.4	48	NS
Bai. plu	0.3	0.4	-0.4	94	NS
Bur. afr	0.7	1.1	-1.1	80	NS
Col. mop	1.5	1.1	0.4	84	NS

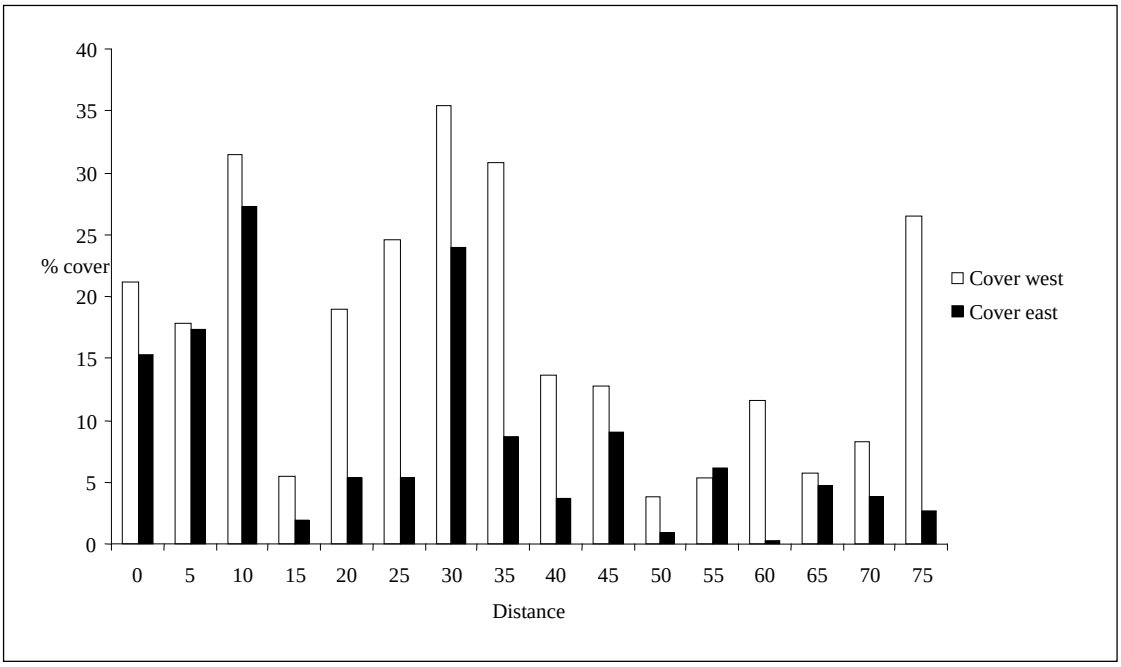


Figure 4.2.3. Mean cover changes of decreasing shrubs showing lower cover on the eastern side of the fence at several sites.

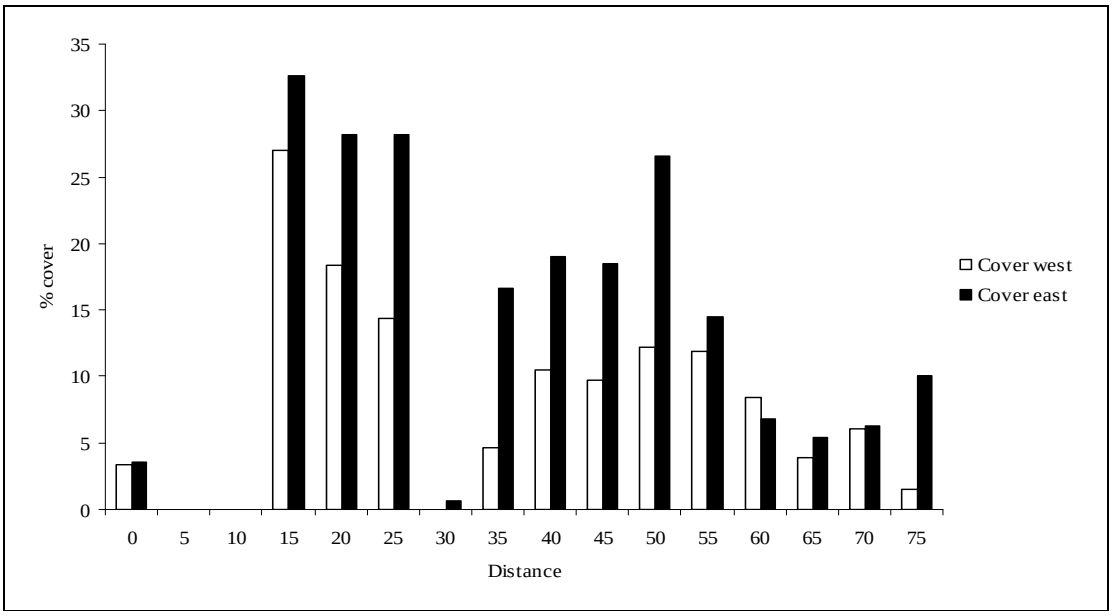


Figure 4.2.4. Mean cover changes of all the increasing shrub species combined showing sites of major fence-line contrast.

Grass cover changes across the NBF

The cover of most annual and perennial grasses changed little over the fence-line although 3 out of 4 annuals increased slightly to the east and 3 out of 5 perennials decreased slightly to the east. However, the cover of the highly palatable perennial grass *Digitaria erianthia* was significantly lower to the east of the fence which will have contributed to the significant difference at the 0.1 level of total perennial grass cover in Table 4.2.5.

Table 4.2.5. Changes in cover of main annual and perennial grass species found along NBF. Significance of the change was assessed using t-tests for independent means assuming unequal variances.

Annual Grass Species	NBF East	NBF West	Test Stat	df	*P*
Ari. ads	2.5	2.3	0.5	91	NS
Ari. sca	0.5	1.0	-0.8	60	NS
Pog. squ	2.9	2.7	0.4	85	NS
Sch. kal	0.5	0.2	1.4	68	NS
Perennial Grass Species	NBF East	NBF West	Test Stat	df	*P*
Ari. mer	0.2	0.3	-0.3	82	NS
Era. leh	2.0	2.1	-0.1	88	NS
Sti. uni	0.3	0.2	0.7	90	NS
Bra. bri	0.3	0.3	-0.2	82	NS

Conclusion: interpreting changes

The results of the assessment of fence-line vegetation change indicate that veterinary cordon fences in northern Botswana are influencing vegetation dynamics at the rangeland scale. Vegetation changes across the NBF are manifest in statistically significant reductions in total vegetative cover and lower perennial grass cover to the east of the fence. Species diversity also decreased to the east of the fence, although none of the absent species were common species overall. Significant increases in the cover of *T. sericea* to the east of the NBF was also indicative of increased disturbance, and analysis of spatial changes in increaser or decreaser shrubs revealed an area of particular fence-line contrast between S18°34 E23°01 and S18°18 E23°02.

These results raise an important question: what factors are driving these cross-fence vegetation changes? Livestock mobility has declined in the area and cattle are now kept at a series of permanent cattle posts dotted along the delta fringe (McGahey this volume). Although livestock numbers are increasing, at present the population has yet to reach pre-cull levels. Thus, livestock grazing is unlikely to be a widespread factor influencing ecological change at the fence-line. Wildlife, on the other hand, graze both sides of the fence, and have been seriously curtailed by the NBF. Enclosure is known to have dramatically altered the diversity and population of species found on the western side. To add to this the population of large mammal herbivores (LMH) such as elephant (*Loxodonta africana*) to the east of the NBF is said to have increased (Cumming & Jones, 2005), causing concern over the excessive utilisation of woodlands in the region (cf. Ben-Shahar, 1995; 1998).

The significantly reduced vegetation cover to the east of the NBF, along with the increased cover of *T. sericea*, would appear to be wildlife-induced changes. Previous studies of fence-line vegetation change across veterinary cordon fences in Botswana, found reduced tree density cover on the wildlife side to be indicative of over-utilisation by migratory animals curtailed by the fence (Ringrose, et al., 1997). However, the study fell short of quantifying changes to the species level, or assessing the temporal dynamics of these land cover modifications, due to the limited spatial and temporal resolution of their observations.

Work by Ben-Shahar (1995; 1998) attempted to identify structural elements of changes resulting from the over-utilisation of woodland by elephants in northern Botswana. The studies found that *Acacia erioloba* woodland is little affected by elephant damage, while *C. mopane* woodland is subject to obtrusive damage without any major change in tree density and significant declines in *B. plurijuga* woodland are driven more by fire than elephant damage. Thus, ecological change by LMH such as elephant are difficult to detect in overall cover or density measurements, and best observed using height or a proxy disturbance measurement.

In spite of the difficulties identifying specific wildlife drivers of ecological change, it is clear that fence restricted wild herbivores can cause undesirable shifts in vegetative cover (van de Koppel & Rietkerk, 2000). Habitat fragmentation by large-scale barrier fences reduces access to landscape heterogeneity, thus excluding large herbivores from key resources, and increasing the potential for overgrazing (cf. Boone & Hobbs 2003; Boone, et al*.,* 2005). Furthermore, the increased cover of *T. sericea* to the east of the NBF could be a result of reduced cover, as the species is known for its ability to increase following reductions in herbaceous cover (Hipondoka & Versfeld, 2006).

In summary, veterinary fences are contributing to environmental changes in northern Botswana and reduced wildlife mobility at the wildlife/livestock interface appears to be a significant driver of structural vegetation change. Further work is needed to monitor these changes over time in order to isolate permanent environmental changes from inherent system dynamics. At the same time planners should explore solutions to the veterinary fencing and disease management problem that are more permeable to non-target species or allow greater wildlife mobility.

4.3 Fences and landscape scale degradation

Perkins, J.
Department of Environmental Science, University of Botswana, P.Bag 0022, Gaborone, Botswana.
perkinsjs@mopipi.ub.bw

Introduction

Fencing has become a prominent feature of southern African rangelands and in many ways has added a relatively new and powerful fifth dimension to semi-arid savanna ecosystems, that as a result are no longer just determined by rainfall, nutrients, fire and herbivory. Fencing is unfortunately a highly political factor, driven by a number of ultimately conflicting national and international agendas, with a profoundly negative cumulative and seemingly irreversible impact upon the landscape. It can take many forms, including that of veterinary cordon fencing for disease control, fencing for problem animal control, game and cattle ranch fencing, fencing of roads and arable lands, as well as the fencing of national borders for security purposes. The spatial scale at which each type of fence operates is quite different, with the fencing of national borders providing one of the earliest examples of marked fragmentation of southern African rangelands at a regional scale. Within the fenced borders of Botswana, fencing for disease control has done much to define the course land use planning can take, setting new constraints upon wildlife and livestock movements, and significantly altering the way in which ecosystems are not only defined, but also function.

Ranch scale fencing, in both the game and livestock sectors has further fragmented the landscape. An attempt has been made to re-instate the mobility of ungulates, via an intensive system of borehole water point and paddock provision, however, the spatial and temporal scales involved are ill suited to the realities of semi arid ecosystem functioning. Perhaps most damaging of all, fences through their permanent nature and cumulative effects, have helped to remove any grander design or vision for the way in which both wildlife and livestock systems can function. The mobility over whole ecosystems that sustained the large free populations of wild ungulates and the rural people that depended upon them, have been relegated to the history books by sustained phases of fencing, leading many to even question the accuracy of the reports that make reference to the once vast herds of game in the Kalahari. The failure to effectively manipulate the one factor we can control, the areas over which livestock and wildlife are free to roam, but instead to build upon past fence layouts as if they were an integral part of ecosystem structure and functioning, means that we are poorly prepared to face the new challenge of climate change, through effective biodiversity conservation and poverty alleviation.

The Kalahari System

The border fence with Namibia in 1954 and South Africa in 1964 removed the Orange River from wildlife movements into and out of the Kalahari ecosystem and provides one of the earliest examples of regional scale fencing related fragmentation in southern Africa. These fences pre-date any quantitative studies

of wildlife movements, such that the true nature of wildlife mobility in southern Africa can never be known (DHV, 1980). The key ungulate populations in the Kalahari are known to be highly mobile in response to the green flush of grass that follows spatially and temporally highly patchy rainfall and fire events (Pratt, 1967). Reports of large scale movements, or migrations, particularly during droughts, are found in the records of early travellers and provide some insights, as do the observations of early Game Wardens. For example, repeated die-offs of wildlife have occurred along the fenced border of the Molopo River, with Liversedge reporting that "..*It was noticed that many of the places where the border fence had been damaged coincided with a water installation or dam on the South African side of the border. It is also interesting to note that although there was an increase in the number of springbok and hartebeest on the border no gemsbok were seen. The fact that eland and wildebeest were the species that were most common along the border and that they were in the worst condition does seem to suggest that a lack of water was responsible for the movement. Possibly a century or so ago the game moved south to the Orange River in really bad times..."* (Liversedge, 1969; p.3).

One of the earliest fences for veterinary disease control was the Kuke fence which was erected in 1958 by the British Protectorate Government of then Bechuanaland. The only hope for the economic development of the country was seen as beef cattle (Debenham, 1954), with the separation of buffalo (*Syncerus caffer*) populations in the higher rainfall north of the country from livestock populations in the drier regions to the south essential for the control of foot-and-mouth disease (FMD). The Kuke fence that runs across the top of the northern boundary of the Central Kalahari Game Reserve effectively separated Kalahari wildlife populations from the Okavango Delta System (DHV, 1980) and it has remained intact ever since. After its erection severe droughts, which are endemic to Botswana, resulted in heavy mortalities of wildebeest (*Connochaetes taurinus*) and the effective exclusion of zebra (*Equus quagga*) from the northern Kalahari (Silberbauer, 1981). Indeed, *"The effects of fences on migratory species is a cause for concern and the construction of further fences should be a matter for consultation after investigating the probable consequences of the fences on wildlife"*(Blair Rains & McKay, 1968; p.57).

Independence in 1966 and a lucrative beef subsidy with the then European Community in 1972, which effectively pays ninety per cent above world beef prices for Botswana beef, necessitated thousands of kilometres of inter-connected veterinary disease control fences in the 1970s and 1980s, that cordoned off the rangeland into small insular parcels of land. As a result the country is effectively divided into 17 zones with double or single cordon fences as boundaries (Fig. 4.3.1). These together with general movement restrictions and quarantine camps along them, control the intra zonal movement of livestock and other animals.

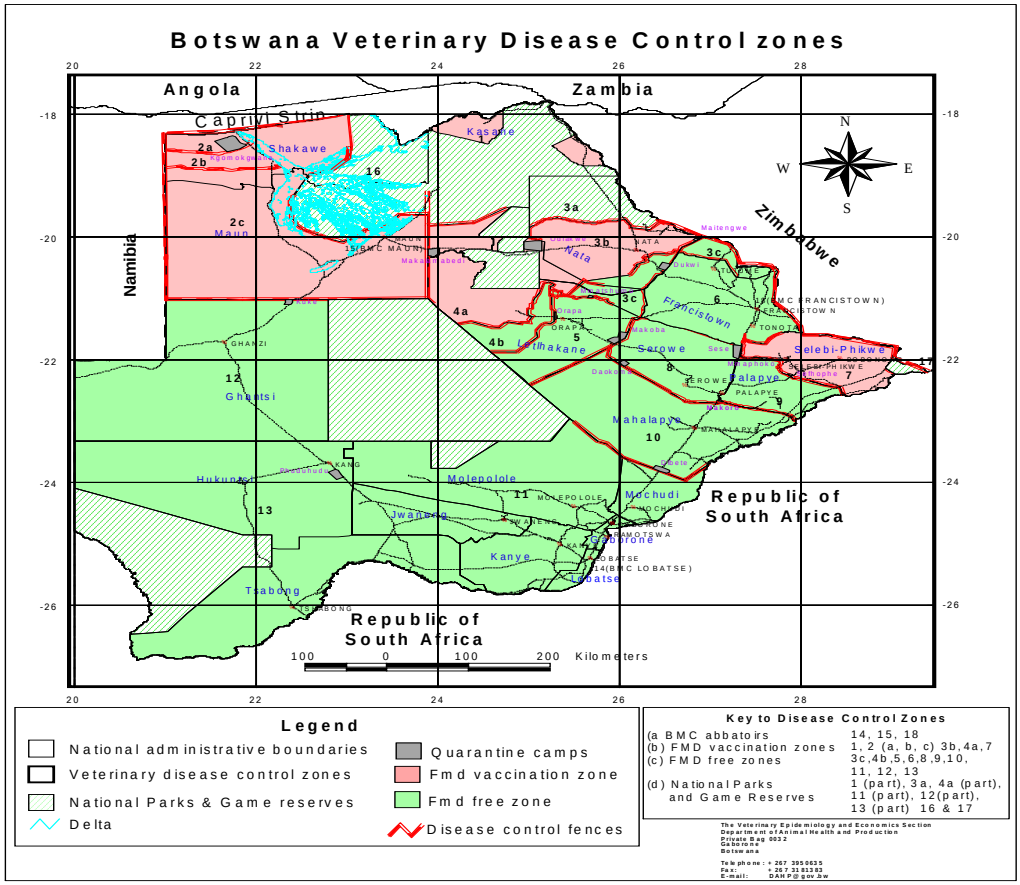
Consequently, the Limpopo System was effectively isolated from the Kalahari System by the combined effect of these cordon fences in the eastern Kalahari, while the linkage with the Makgadikgadi System was finally sealed in 1996 by the erection of the Phefodiafoka fence that closed a gap through the north eastern CKGR to Lake Xau/Mopipi Dam (Williamson, 2002) (Figs. 2 & 3). The fences had in fact channelled the Kalahari wildebeest into this area at the time of the 1982 -

86 drought, leading their population (Williamson & Williamson, 1981, 1985ab; Williamson, et al., 1988) as well as that of hartebeest (*Alcelaphus buselaphus*), to be drastically reduced (see Tables 4.3.1 and 4.3.2) (Lindsay, 1992; Spinage & Matlhare, 1992). In this respect, the Kalahari wildebeest is exceptional in that it is able to meet its water requirements from plants, especially tsamma melons (*Citrillus lanatus)* and the gemsbok cucumber *(Citrillus naudianus),* in the dry season (Murray, 1988; Lindsay, 1992) but when this crop fails, during for example prolonged drought, it needs to reach surface water.

Table 4.3.1. Reports of wildebeest mass movements and die-offs (from Lindsay, 1992; p.62)

Year	Description	Source
1930	Mass die-offs in eastern Botswana	Campbell, 1978, 1981; Child, 1972
1941	Movements towards and deaths along the Molopo River	Spinage, 1992
1962	Large numbers moving east along the Kuke fence	Silberbauer, 1981
1964	Carcasses in CKGR, die-off of >15,000 along Boteti River	Silberbauer, 1981; Child, 1972
1969	Movements towards the Molopo (and Orange?) River	Williamson, et al., 1988
1970	Die-off at Lake Xau	Child, 1972
1979-80	Migration through CKGR to Lake Xau	Owens & Owens, 1986
1980	Movements towards the Molopo (and Orange?) River	Williamson, et al., 1988
1981-84	Movements towards the Molopo (and Orange?) River	Williamson, et al., 1988
1983	Major die-off of >52,000 at Lake Xau	Williamson & Mbano, 1988
1985	Die-off of >5,000 at Lake Xau and Mopipi movements towards the Molopo (and Orange?) River. High mortality in Kalahari Gemsbok NP, South Africa	Calef, 1985 -from Lindsay (1992) ; Williamson & Mbano, 1988; Knight, 1991

Figure 4.3.1. Botswana Veterinary Disease Control Zones (From Department of Animal Health and Production, Ministry of Agriculture, Gaborone).



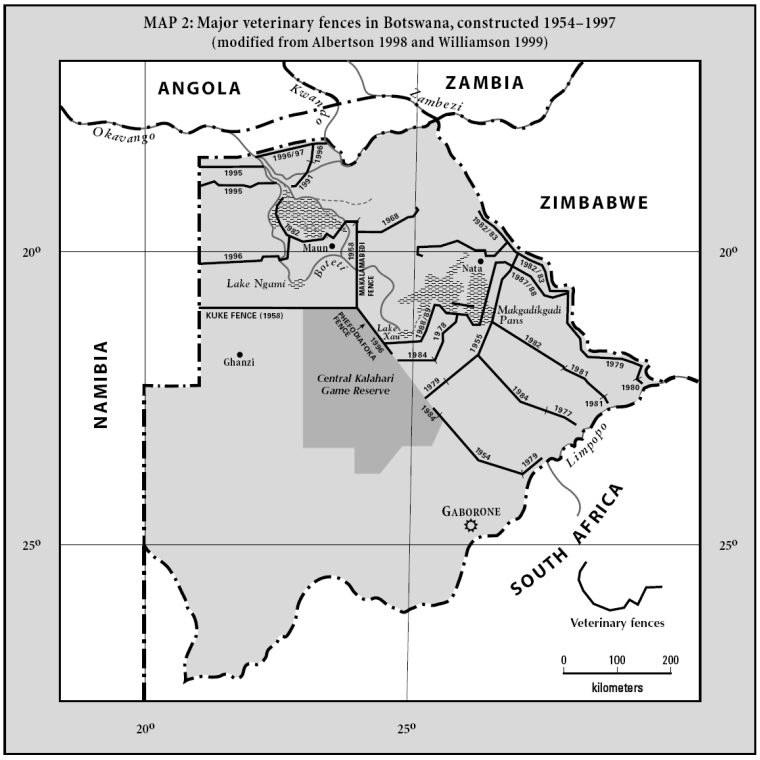


Figure 4.3.2. Veterinary cordon fences (From Williamson, 2002).

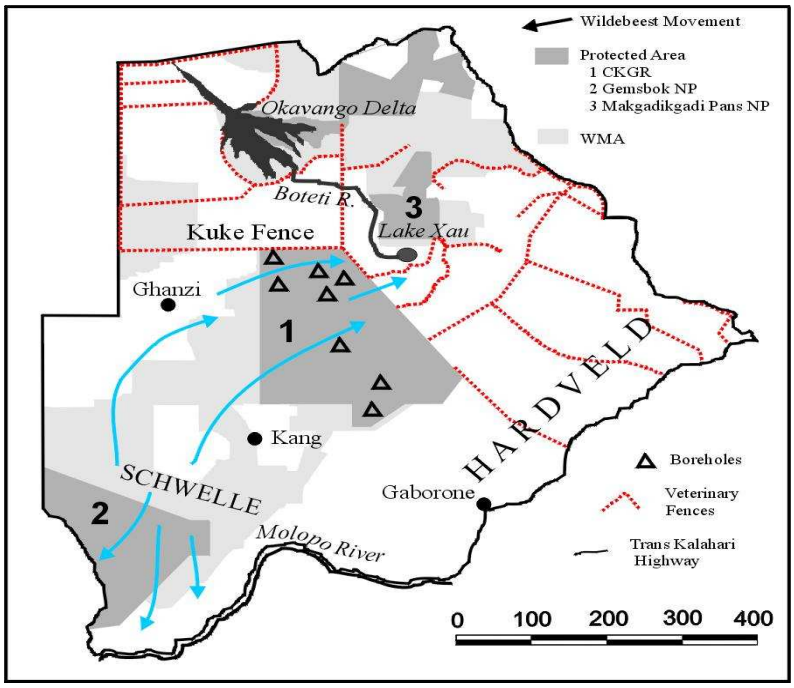


Figure 4.3.3. Wildebeest movements in the Kalahari.

The fundamental problem in the Kalahari ecosystem has been that while the Kalahari wildebeest and other key ungulates follow a predominantly NE-SW movement along the rainfall gradient axis, the veterinary cordon fences in general, but also fenced ranch blocks financed by the World Bank and USAID in particular (Odell, 1980), have bisected it. This is surprising as the key actions necessary for the conservation of the Kalahari ecosystem were explicitly stated in the first quantitative assessment of the Kalahari wildlife resource, the CountryWide Animal and Range Assessment Project (DHV, 1980), that was commissioned by the European Community in the 1970s. This study pointed out that:

*"...the Kalahari appears to be a single system in which the Schwelle running northwest-southeast through the middle of the region forms an axis, about which are centred the greatest animal numbers." (*DHV, 1980; *Volume IV; p.21).*

'What is certain is that the two very large populations of hartebeest and wildebeest display one outstanding characteristic: mobility....It must be assumed that this nomadism is one of the preconditions of their success which means that to curtail it is to risk what might well prove massive reductions in their populations.' (Volume IV; p.22).

DHV (1980) emphasised that *"....the integrity of the Kalahari as a major wild animal system is at high risk. The key to its integrity is the Schwelle. The greater part of the game herd - the hartebeest, wildebeest, ostrich, springbok and kudu - require both access to the Schwelle and freedom of passage across it. Likewise it will be the site of much of the livestock expansion of the immediate future. …….. Tremendous damage to the game resource could be done for the sake of a very small gain by the cattle industry."* DHV (1980) Vol. I (p.38).

Most critically, DHV (1980) made the point that, *"Enhanced game use is seen as the best way to raise the standard of living of the greatest number of people in the Kalahari, particularly those who are the poorest."* (DHV (1980) Vol.I *(p.45).*

The trends in the aerial survey data collected by the Department of Wildlife and National Parks in the Kalahari reveal that gemsbok (*Oryx gazella*) populations are thriving and eland (*Tragelaphus oryx*) populations appear stable (Table 4.3.2). By contrast, the populations of wildebeest and hartebeest, which once made up a significant proportion of wild animal biomass in the Kalahari have not recovered from their precipitous declines in the 1980s. Springbok (*Antidorcas marsupialis*) populations in the Kalahari have shown a sustained decline, possibly due to their preference for grazing areas shared with cattle, and open pans, both of which have made them easy to hunt (Verlinden, et al., 1998). The fenced livestock areas in the Kalahari now support healthy populations of kudu (*Tragelaphus strepsiceros*), common duiker (*Sylvicapra grimmia*) and steenbok (*Raphicerus campestris*), amidst a heavily bush encroached landscape.

Table 4.3.2. Trends in wildlife numbers in the Kalahari and Makgadikgadi.

Species	1978	1994	2003
Wildebeest (Kalahari System)	315,058	17,934	16,698
Hartebeest (Kalahari System)	293,462	44,737	44,629
Gemsbok (Kalahari System)	71,423	85,368	91,130
Eland (Kalahari System)	18,832	11,757	24,024
Springbok (Kalahari System)	101,408	67,777	24,795
Zebra (Makgadikgadi)	100,295	20,863	12,314
Wildebeest (Makgadikgadi)	53,000	-	8,500
Buffalo (Northern System)	72,290 (1987)	29,037	33,305

Source: (DHV, 1980; DWNP, 1994a & b, 2003: and Perkins & Ringrose, 1996; Scott Wilson, 2002).

Failure to conserve key refuge areas for wildlife, through the strategic use of fencing and optimal land use planning, has removed the one resource, diverse and healthy populations of Kalahari wildlife, that was both independent of surface water and largely drought resistant. As a result large tracts of savanna are effectively empty of both large herds of wildlife, that cannot reach them because of the layout of fences, and also livestock, that cannot be kept there due to the lack of suitable groundwater. The primary biomass in these areas, while unutilised by large herbivores is available to fires, with extensive areas of the Kalahari burning in the dry season as a result.

The Kalahari System appears set to fragment further due to the further provision of fenced livestock and game ranches, fenced infrastructure – the proposed Trans Kalahari Railway, and the increasingly fenced Trans Kalahari Highway, problem animal control fences (100km of the SE Transfrontier Kgalagadi Park and a portion of the eastern and southern boundary of Khutse Game Reserve) and also the expansion of cattle posts into key wildlife areas (Schwelle). Indeed, Botswana is rapidly heading towards the fenced and fragmented look that most of Namibia has (Fig.4.3.4) and in many ways is desperately trying to reverse.

Figure 4.3.4. Fences in Namibia (from Eckardt, unpublished)

The Makgadikgadi Ecosystem

The Makgadikgadi Pans wildebeest and zebra populations that show a seasonal migration from their wet season grazing area on the western edge of Ntwetwe Pan in the east to the dry season grazing along the Boteti River in the west, also suffered severe losses in the 1980s drought (DHV, 1980) (see Table 4.3.2). The arrival of the floodwaters in the Boteti River, from the Angolan highlands, via the Okavango Delta, provided essential surface water to Makgadikgadi zebra and wildebeest, in the late dry season, and to Kalahari wildebeest during droughts The Kalahari wildebeest are otherwise independent of surface water. All die-offs related in fact to the lack of grazing around water, accentuated by competition with livestock and people, rather than the lack of surface water itself (Parry, 1987a; Williamson & Mbano, 1988).

The Makgadikgadi Pans ecosystem has today been further separated from that of the Kalahari ecosystem by the erection of the Game Proof Fence along its western (Boteti River) and southern boundaries (Scott Wilson, 2002). A major justification for the erection of the fence was the need to separate livestock and predator (lion) populations and reduce depredation, as the natural barrier that was provided by dry season flows in the Boteti River ceased in 1991 (Scott Wilson, 2002; see also Hemson, et al., 2009). Protagonists of the fence declared that the Boteti River would never flow again and that the Game Proof Fence was the only effective way forward, and were critical of a CBNRM wildlife based alternative along key sections of the River (for example, as expressed in Sefe, et al., 1997). The Boteti River has flowed for the last two years with the fence constraining wildlife access to it and CBNRM activities along it, while the cattle lobby has sought to use the fence to increase the spatial extent of the EU export zone available to beef cattle.

In both the Kalahari and Makgadikgadi ecosystems the key to understanding the drastic reduction in the size of their key wild ungulate populations has been the failure to protect their key refuge areas - the Schwelle (Kalahari ecosystem) and the Boteti (Kalahari and Makgadikgadi ecosystem). Kalahari wildlife can move around fenced ranch blocks but the veterinary cordon fences provided a continuous barrier that served to channel wild ungulates into high conflict zones with people and livestock (DHV, 1980; Perkins & Ringrose, 1996)). Consequently, the natural phenomenon of drought related mortality that Kalahari wildlife populations experience, were greatly accentuated, by the veterinary cordon fences (Spinage & Matlhare, 1992). The reduction of wild animal biomass experienced has resulted in a major loss of protein and impoverished livelihoods, which many rural communities in the Kalahari are still suffering from and are grappling to understand. A potential win:win balance between the beef and wildlife sectors has therefore been lost due to the permanence that the layout of veterinary disease control fencing has taken in the Kalahari and the movement restrictions it has imposed.

Remarkably, the veterinary cordon fencing has been necessary to secure access to the EU beef market and preserve the beef subsidy, which the EU regards as a form of development assistance or aid (Perkins & Ringrose, 1996). The connectivity between the huge die-offs of Kalahari wildlife and veterinary cordon fences, the extreme poverty experienced in those areas today and the loss of hunting and gathering as an effective way of life in the Kalahari ecosystem is rarely made. Indeed, EU support for the wildlife sector, through infrastructure development and finance on the one hand, appears to be in direct contradiction to the consequences of its provision of a beef subsidy and conditional stringent controls on wildlife and livestock movements on the other.

The Northern System

In the Northern System, the Southern (1982) and Northern (1991 and 1996/97) buffalo fences have provided an effective east-west divide to wildlife movements and were condemned in some circles (for example, Lomba, 1991). The gap in the buffalo fence, necessitated by the permanent swamps, allows for some movement out of the Delta, particularly of zebra and wildebeest, although many fail to return (Scott Wilson, 2000). Much of western Ngamiland is therefore devoid of wildlife, except for isolated herds of elephant (*Loxodonta africana*) and gemsbok, due to the Buffalo fence. Fragmentation of western Ngamiland itself occurred through the erection of three east-west trending fences following the outbreak of Contagious Bovine Pleuropneumonia (CBPP) in 1995 (Scott Wilson, 2000).

The Okavango Panhandle is dominated by subsistence agriculture and fishing, such that its communities are amongst the poorest in the country. Crocodiles and hippos occur along the Okavango River, and are despised by most local communities, for the loss of life and livelihoods they incur, while elephants cause crop damage and the occasional loss of life. The Okavango Panhandle Management Plan (NRP, 2001) identified that wildlife based economies were the most potentially viable in terms of alleviating poverty through CBNRM activities, and that it was essential for local communities to benefit from tourism ventures in the area. In the case of both the Boteti and the Okavango Rivers the communities that live along them are isolated by fences from the wildlife resource that offers the greatest potential to improve their livelihoods and well-being.

Apart from border fences, the dominant motivation for fences in important wildlife areas in Botswana remains the livestock sector. However, in the Northern System arable agriculture is also leading to fragmentation and degradation of the landscape, as is the case with the existing Pandamatenga Farms and the proposed development of the Northern Plains. The Pandamatenga Farms were initially developed in the early 1990s (Arup Atkins, 1990), and will soon be subject to a road and drainage improvement scheme (Ehes, 2007) and may be complemented by a new agro-commercial integrated development scheme in the Northern Plains that utilises water piped down from the Zambezi River (CAR, et al., 2009). The Pandamatenga Farms are already fenced and the planned extensions to them, together with the proposed development of the Northern plains will threaten trans boundary movements of elephants and buffalo between Botswana and the neighbouring wildlife areas in Zimbabwe (Kazuma Pan Hwange and the Matetsi Safari Area).The southernmost limit of roan (*Hippotragus equinus*), sable (*H. niger*) and tsessebe (*Damaliscus lunatus*), the numbers of which have all declined in recent years, together with the only habitat for oribi (*Ourebia ourebi*), will also be impacted upon by the proposed agro-commercial integrated development scheme (CAR, et al., 2009).

Livestock ranches and cattle posts

The history and nature of Botswana's ranching programme has been comprehensively covered elsewhere (see Sandford, 1983; Perkins & Ringrose, 1996). Significantly, initial attempts to commercialise cattle-keeping, via cattle holding grounds and fattening ranches in the 1950s in the north-east of the country, the so-called Northern Crown Lands (Blair Rains & McKay, 1968), failed, in spite of the input of considerable capital for borehole drilling and fencing, and the conversion of large tracts to leasehold status. Indeed, problems were such that by the early 1960s the ranches had been abandoned. Despite this fate, the past forty years of official policy in the livestock sector has consistently followed the twin pursuits of privatisation and commercialisation, with expansion dependent upon the advent of deep drilling borehole technology and fencing.

By contrast cattle posts comprise a borehole, kraals - fenced or thorn bush enclosures where the cattle are kept at night, and the, often adjoining, huts of herders. Under the cattle post system, the 'borehole is the herder' (Jerve, 1982). It is a remarkably simple system, with routine herding confined to the collection and kraaling of animals around the water-point at dusk, and their subsequent release in the morning, in a daily cycle that is clearly adapted to avoid working in the extreme heat of the Kalahari days, and is more generally based upon the minimum expenditure of energy (Abel, et al., 1987).

Permanent grazing around point water sources (boreholes) creates a distinct pattern of impact via the piosphere effect (Lange, 1969), where bare ground (0-200m), gives way to bush thickened habitat (200m – 2kms+) and ultimately a 'grazing reserve' (in many areas the grazing reserve has in fact been replaced by thick bush). Large tracts of rangeland are today a complex mosaic of fences and piospheres, clearly visible on satellite images (Fig.4.3.5).

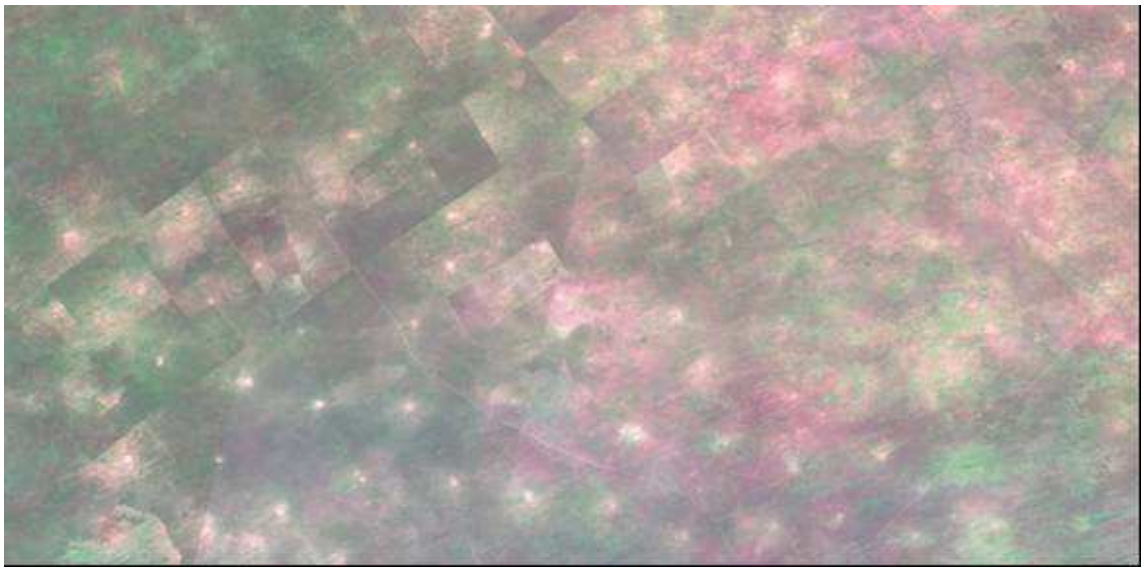


Figure 4.3.5. Kalahari piospheres and fences (after Eckardt, unpublished).

Open, unfenced piospheres do not pose a barrier to wildlife movements, although Leeuw, et al., (2001) quantified the impacts of water points and livestock on the distribution and diversity of wildlife in the arid pastoral rangelands of northern Kenya. They observed a negative association between livestock and wildlife that they believed to be attributed to the impact of people associated with livestock rather than the impact of livestock itself (Leeuw, et al., 2001). The same inverse relationship between livestock and game densities appears to be found in Botswana, perhaps emphasising the need for key wildlife refuge areas to be essentially livestock free (e.g. the core area of the Schwelle and key areas along the Boteti River).

Ottichilo, et al., (2001) compared cattle densities around the Maasai Mara in Kenya in order investigate possible competition between cattle and wildebeest, and the latter's over eighty percent decline from about 119,000 in 1977 to about 22,000 in 1997. They attributed the decline to the loss of former resident wildebeest wet season grazing, calving and breeding ranges to agriculture (Ottichilo, et al., 2001). It is a result that clearly has important implications for land use planning and management in and around the Schwelle, which constitutes the Kalahari wildebeests wet season calving area, as well as a vital resource area for most plains game (DHV, 1980).

Conclusion

The Botswana Government has received much criticism for both the wildlife die-offs that occurred in the 1980s and the failure to maintain hunter and gatherer populations in the Kalahari. This is despite the fact that both of these outcomes are in fact directly related to the provision of veterinary cordon fences and so called development assistance from the EU, under the Cotonou Agreement. Indeed, wildlife population densities are now so low in the Kalahari ecosystem that hunting is no longer viable and the ecotourism potential of large tracts of land are at an unprecedented low.

The debate over fences has become so polarised that veterinarians are understandably reluctant to even entertain re-alignments, with their future plans for disease control the polar opposite of many conservationists vision of re-instating mobility over large tracts of rangeland. With wildlife densities so low in the Central Kalahari Game Reserve in particular, and the Kalahari ecosystem in general, it will be increasingly difficult for the Botswana Government to justify to a politically powerful cattle lobby, why such large amounts of land are being set aside for wildlife conservation. Indeed, further landscape scale degradation and fragmentation of the Kalahari ecosystem seems inevitable.

It is disheartening that the ecological requirements necessary for the effective conservation of the Kalahari wildlife resource have been known since the 1970s (DHV, 1980; IFAD, 1991), but have not been acted upon. It was inevitable that significant tracts of rangeland would become inaccessible to wildlife as Botswana developed rapidly, secured its borders and expanded its livestock industry. In this respect the wildlife populations counted in the 1970s simply could not be sustained today as the area of rangeland available to them has declined markedly. However, the manner in which fencing for disease control has unfolded has delivered an unnecessarily severe and irreversible blow to the key populations of Kalahari ungulates, with very little overall gain to the livestock sector and most critically to rural livelihoods. Sustainable development over extensive areas of rangeland, and a win:win balance between the livestock sectors and wildlife has been compromised. Indeed, the longest wildebeest migration in Africa has been lost together with a valuable source of protein and income generation for the rural communities found there.

In this respect it is not fencing as a source of snares, increased accessibility or fragmentation of rangelands that perhaps should be decried the most, but rather the indifference with which the international community in general, and the EU in particular, has played upon the cultural and political advantages of promoting the beef sector in Botswana, regardless of its ecological and socio-economic consequences. The network of veterinary cordon fences in Botswana means that the protected areas have not maintained ecosystem integrity and functioning such that the Government is now locked into expensive and risky forms of manipulative wildlife management (*sensu* Caughley & Sinclair, 1994), such as fencing and borehole provision. Ironically, the spectacular loss of wildlife in the Kalahari and Makgadikgadi ecosystems, precipitated by the requirements for disease control fencing by the EU beef subsidy, has in turn given rise to a number of often donor assisted projects to seek ways to try and improve rural livelihoods and achieve sustainable development. The layout of fences has shrunk the spatial and temporal scale of such projects and all but removed the broader vision of expanding the role that wildlife can play in the achievement of national and district development goals.

As Taylor & Martin (1987) put it: *"Under pressure from beef importers, it would be all too easy to adopt a policy that attempted to make the entire country disease free for cattle production, regardless of land capability. Wildlife populations would be reduced to those in a few heavily cordoned enclosures, grudgingly accepted to satisfy the conservation lobby. There is little reason for the developed world to influence land use in the marginal areas [of Zimbabwe] especially if it is short-term economic exploitation at the expense of land."*

Climate change may make the difference but the ecological realities of development in the Kalahari seem destined to be continued to be ignored. Fencing in all its forms, but most crucially veterinary cordon fencing for disease control, remains an integral part of this development path, diametrically opposed to mobility over large areas that the effective conservation of sizable herds of wild ungulates requires. The abiotic factors that ultimately drive the Kalahari ecosystem cannot be manipulated or constrained by fencing, which is why the looming crisis in biodiversity conservation, poverty alleviation and sustainable development is likely to be unprecedented.

4.4 Environmental assessments of Botswana's fences

Gibson, D.
P.O. Box 25476, Windhoek, Namibia.
deb-col@iafrica.com.na

Introduction

The construction of fences in Botswana has been taking place since the 1950s in response to European Union (EU) beef export requirements which enable Botswana to benefit from preferential trading agreements with the EU. Fences have been used to create zones to control foot-and-mouth disease (FMD) (Thomson, 1999) by preventing contact between wild ungulates and domestic livestock (Sutmöller, et al., 1999). The negative impact of some of the veterinary fences on wildlife has been significant, cutting migration routes and, critically in drought years, access to seasonal water and feeding grounds. The "mass die-offs" and resultant population declines of wildebeest (*Connochaetes taurinus*), zebra (*Equus quagga*) and other large mammals has been well recorded (Williamson & Williamson, 1981, 1984; Williamson, et al., 1988; Masunga & Kegoeng, 1998) but on-going disruptions of migratory routes, habitat damage and fragmentation and mortalities on fences continue to be a source of concern and controversy (DAHP, et al., 1998; Mouchel Consulting & Price Waterhouse, 1997; Mughogho, 1996).

Ngamiland veterinary fences

In 1995 there was an outbreak of Contagious Bovine Pleuropneumonia (CBPP) in north-western Ngamiland. The Government of Botswana responded by constructing two fences (the "Samochima" and "Ikoga" fences) in northern Ngamiland. Additionally, double electric fences were erected along the western and northern boundaries with Namibia (Fig. 4.4.1) despite objections by NGOs and communities in the Caprivi (Weaver, 1997).

The fences were intended to prevent movement of cattle and divided the area into zones relating to levels of infection. The fences were ineffective, however, because in order to avoid quarantine or mortality of their stock, some owners moved their animals away from the infected zone through weak spots in the barriers. This led to a rapid spread of the disease southward and although a third ("Setata") fence was erected, the disease continued to spread. Finally, in 1996, the government ordered all cattle to be eradicated. Around 320,000 were killed, to be replaced or compensated for once the spread of the disease had been stopped.

Considerable adverse publicity followed the erection of these fences as a result of the impacts on wildlife populations and the Government of Botswana commissioned the assessment of environmental impacts of the fences on wildlife, conservation and natural resource management. This was the first EIA to be carried out on fences in Botswana.

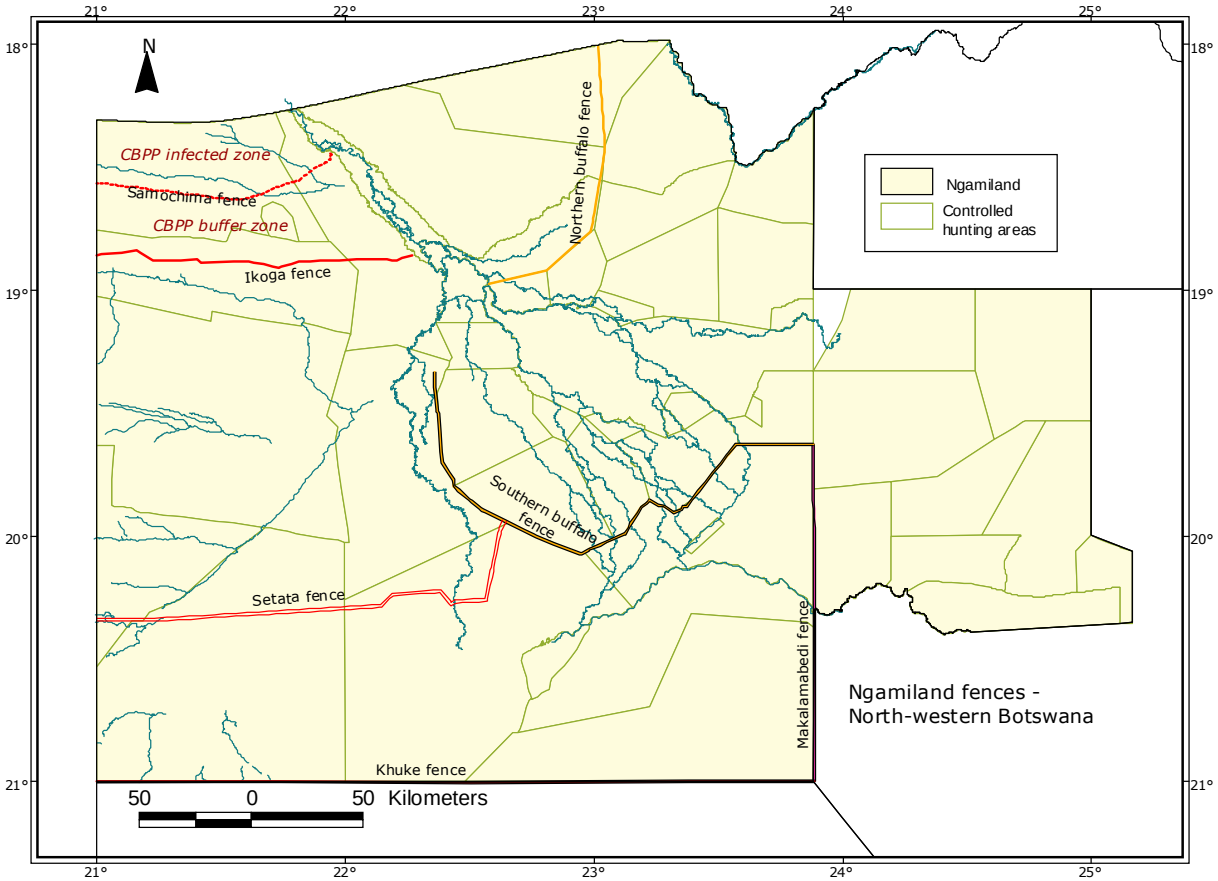


Figure 4.4.1. Veterinary control fences in Ngamiland

The work placed emphasis on comprehensive consultation with representatives from a variety of stakeholders and communities (Scott Wilson, 2000a). Presentations, issue papers, reviews and publicity formed part of the process. Additionally the EIA teams used a variety of methods including aerial surveys of wildlife, wildlife population analysis, assessment of wildlife-friendly fences, livestock disease risk assessment, as well as satellite imagery of fire scars and land use assessment to provide detailed information. Cost benefit analyses and socio-economic studies were included and rapid impact assessment matrices were used to compare different fence route options.

The outputs (Scott Wilson, 2000b) comprised:

1. Environmental Audits of existing fences (Samochima, Ikoga, Setata, northern buffalo and Caprivi cordon fences).
2. Strategic Environmental Assessment of the policy of fencing to control cattle disease in Ngamiland.
3. Environmental Impact Assessment for joining the northern & southern buffalo fences.
4. Guidelines for EIAs of future veterinary fences.
5. Environmental Management Plan for veterinary fences in Ngamiland.

The environmental audits (Scott Wilson, 2000c) showed that some of the existing fences had more significant impacts than others and that an additional proposed

fence joining the northern and southern buffalo fences would be environmentally disastrous (and impractical) (Scott Wilson, 2000e). On the basis of the EIA, four policy options for livestock disease control in Ngamiland (Scott Wilson, 2000b; 2000d) were proposed as summarized in Table 4.4.1.

The Makgadikgadi National Park game proof fence

Although long-distance movements of wild animals occur opportunistically and irregularly in the central and western parts of Botswana, the Makgadikgadi Pan National Park is unique in supporting true seasonal migrations of large mammals (Parker, 1975; Kgathi & Kalikawe, 1993). In the dry season, large numbers of zebras and wildebeest inhabit the wooded grasslands along the Boteti River, which forms the western boundary of the Makgadikgadi Pans National Park (MPNP). At the onset of the rains, these herds move east immediately, making their way to the grasslands bounding the pan (Fig. 4.4.2). Should the rains fail, the animals return to the Boteti where many die in the dwindling pools (Mughogho, 1998; Masunga, 1998). Other migrations in the area, such as those from the Okavango Delta to the Makgadikgadi/ Nxai Pans Parks have been constrained by a decommissioned fence that was never removed.

In the past the migrating herds spent the dry season along the length of the Boteti River, crossing when grass within the Park was burned or depleted to reach additional grazing to the west. The river, which was a partial barrier between wildlife and adjacent farm lands, dried up completely by 1991. Reduced to a few pools in the river bed, this restricted the area available to water-dependent wildlife and by the end of the dry season the pools dwindle and animals die. The drying of the Boteti enabled animals to move freely between the farming settlements and the park and human-wildlife conflict increased significantly and in particular, the predation of domestic livestock by lions (*Panthera leo*) and damage to crops by elephants (*Loxodonta africana*).

An estimated 23,000 people, mainly subsistence farmers, were living near the Park in 2001 with around 30,000 head of cattle. A survey of households in the area showed that 92.2% owned cattle and 59% relied on mainly livestock for their livelihoods (Gupta, 2004). About 70% of the community also grew crops for personal consumption. Losses of both livestock and crops by wildlife could often significantly impact on rural welfare and people reacted by shooting, snaring and poisoning wild animals.

In addition to impacts of wildlife on livestock, the lack of any kind of barrier between the Park and farmlands enabled cattle to move into the Park. Excessive numbers of cattle had led to over-grazing, farmers regularly moved their animals as much as 20km into the Park to graze. The obvious outcome was competition with wild grazers and overgrazing in their dry season range within the Park, but it also reduced the aesthetic value of the Park for tourism.

The fence around the MPNP was commissioned by DWNP largely to resolve these conflicts (this move would also expand the *de facto* area under FMD control zone status) and a "double electric" fence was selected as the preferred design.

Table 4.4.1. Options for alignment of fences.

	Description	Cost benefit implications	Environmental Impacts	
			Positive	Negative
Option 1	Setata fence removed and replaced by one following land-use boundaries. Buffalo fences not joined.	-1.9% of original maintenance costs. Positive impact on equity & resource distribution	Free movement in area of Setata fence	Reduced access for wildlife to & from Delta: reduced wildlife populations & local extinctions
Option 2	Most of Setata fence removed. Northern buffalo fence realigned & Eastern end of the Caprivi Cordon fence removed to accommodate wildlife movements. Buffalo fences not joined	-19% of original maintenance costs. Positive impact on equity & resource distribution.	Wilderness value maintained, land use boundaries, settlements & land forms not dissected	
Option 3	Samochima, Ikoga & Setata fences removed. A new fence erected to link the western border with the southern buffalo fence. Northern buffalo fence & Caprivi fence as in option 2. Buffalo fences not joined.	16.6% of original maintenance costs. Significant cost & benefit implications. Benefit to cattle owners, not poor people	Free access for movement over large area. Wilderness value maintained, land use boundaries, settlements & land forms not dissected	Reduced access for wildlife to & from Delta: reduced wildlife populations & local extinctions. Likely incursion of cattle posts leading to reduced wildlife & options for CBNRM. Increased risk of disease spreading south. Reduced tourism potential.
Option 4	Samochima fence unchanged. Ikoga & Setata fences removed. A new fence erected from the middle of the Khuke fence to join with the southern buffalo fence. Buffalo fences not joined.	24.1% of original maintenance costs. Significant cost & benefit implications. Benefit to cattle owners, not poor people	Improved tourism potential. Wilderness value maintained, land use boundaries, settlements & land forms not dissected	Disease control more difficult.

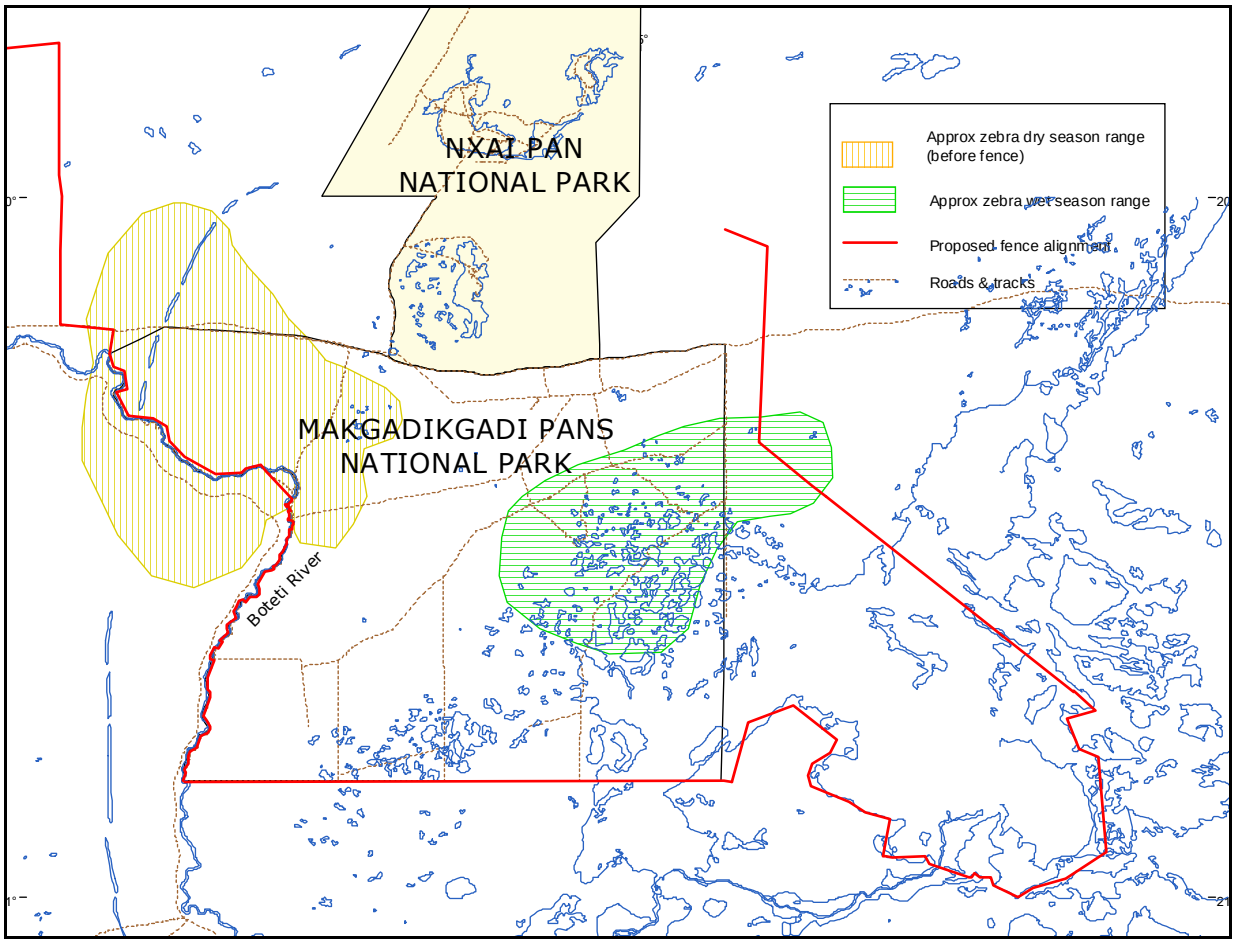


Figure 4.4.2. Makgadikgadi Pans National Park showing proposed fence alignment and wet and dry season ranges of zebra and wildebeest

The design of the fence followed a proposal for a "give and take" fence along a section of the Boteti River (Ferrar, 1995) and in early discussions between DWNP and communities it was agreed that the fence would zigzag along the whole river. With a change of personnel in DWNP, however, the final route of the fence was changed so that the entire river would be fenced out of the Park except at Khumaga and two lodges (Fig. 4.4.3). This alignment was approved by Cabinet on condition an EIA was conducted. An Environmental Appraisal was started in 2002.

Instead of a full EIA, an Environmental Appraisal started in 2002 comprised (Scott Wilson, 2002) a four-month long desk study made up of literature reviews, consultations with stakeholders, communities, NGOs, government and political representatives. The issues were identified and impacts on wildlife, habitats, land use, archaeology, tourism, Community Based Natural Resource Management (CBNRM) and social development were considered. An economic assessment was carried out.

Figure 4.4.3. Map showing the fence alignment in relation to the Boteti River

It was made clear that while making compromises with communities in aligning the fence it would be crucial to consider conservation objectives and to avoid cutting off wildlife populations from essential resources, reducing access to water or increasing the risk of being trapped by fire. The EA was commissioned to ensure that the fence would not cause an environmental and social disaster.

Two alternative options were proposed: (1) leaving the area unfenced but with increased problem animal control, increased control of illegal access by people and livestock and increased law enforcement and (2) alternative routes for the fence with mitigation measures. The mitigation measures included the installation of additional water supplies (crucial to the survival of the zebra population (Brooks, 2005)), the development and implementation of water and fire management plans prior to the fence construction and increased Park management resulting from the conversion of the Park into a fenced system.

Few of the mitigation measures were put in place. As a result there have been serious impacts, particularly on wildlife and habitats, namely:

1. Alternatives for the alignment of the fence were not accepted and most of the Boteti River is excluded from the Park.
2. Alternative water points along the full length of the river were not provided to spread the dry season range for wildlife although a single additional borehole was sunk several years later. The number of potable water points available to wildlife was reduced from 57 to 22 in only two sites
3. No attempt was made to preserve trees in the dry riverine forest along the Boteti while bulldozing a 40m wide strip for the fence
4. There are no water, fire or fence management plans and no emergency measures plan
5. Animals are trapped between the two fences and eventually die of thirst as there is no way of letting them out (Fig. 4.4.4).
6. Animals get caught in the fence when trying to escape from predators
7. Animals die trying to reach traditional water sources that are now inaccessible. In 2005 a failure in rains caused zebras to return from their wet season range and over 300 zebra died of thirst along the fence (Fig. 4.4.5).
8. The fence is unsightly and detracts from the tourism value of the Park
9. CBNRM activities involving use of the Park are no longer an option.

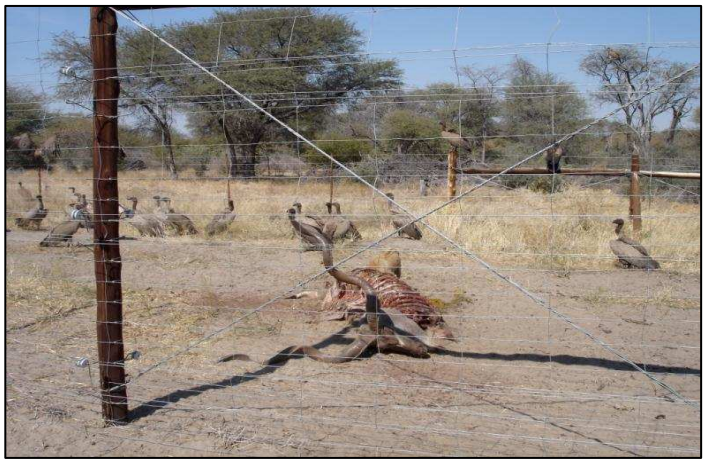


Figure 4.4.4. Kudu trapped between double fences

Figure 4.4.5. 300 zebra died along this fence line in 2005.

4.5 Fences in Botswana: every fence should be judged on its own merits

Brooks, C. & Bradley, J.
School of Biological Sciences, University of Bristol, Woodland Road, Bristol, UK.
Chris.Brooks@bristol.ac.uk and James.Bradley@bristol.ac.uk

Introduction

Thanks to a combination of good, systematic land use planning and a low human population, with limited surface available water and poor soil fertility, Botswana is blessed with some of the largest land use conservation zones within Africa that still serve as functional entities. Most protected areas in Africa were established before there was an understanding of ecosystem dynamics and the resource requirements of wildlife populations, so that most of these protected areas do not serve as functional, independent systems. These habitat constraints cause wildlife to leave their protective boundaries in search of seasonal resource requirements bringing them into conflict with people (DeFries, et al., 2007).

The Okavango / Chobe / Makgadikgadi complex (the Northern Conservation Area) is one of the last few remaining functional ecosystems on the continent. The area is conserved through an interconnected series of National Parks, Game and Forest Reserves and Wildlife Management Areas that surround and connect these protected areas. The northern conservation area, at 85,000km^2, encompasses both wet and dry season resource utilisation zones and therefore reduces the relative levels of conflict between people and wildlife within this part of Botswana.

Human-wildlife conflict (HWC) is however still prevalent around the periphery of the conservation zone, with the Makgadikgadi region identified as having the highest levels of human-wildlife conflict across the whole country in the early part of this century (Department of Wildlife and National Parks (DWNP), unpublished). The principal cause of this conflict was the lack of any defined land use buffer zone along the western boundary of the Makgadikgadi Pans National Park (MPNP) or actively managed buffer zone to the east and south of the park.

The Makgadikgadi Complex

The western boundary of the MPNP is formed by the Boteti River, an outflow of the Okavango Delta that, until recently, had not flowed since 1991. The drying of the Boteti River removed the physical barrier between people and livestock living on the western riverbank from the high density of wildlife on the eastern riverbank. Transgression of the park boundary by both livestock and wildlife lead to extensive incidents of HWC and competition for resources between livestock and wildlife. While depredation of livestock by lions created an embittered local community, who felt they received no benefit from the national park (Hemson, 2004; Gupta, 2006).

Continuous complaints by local communities living along the Boteti River led the Government of Botswana to develop a 'conflict' fence along the line of the Boteti River so as to segregate wildlife from people and livestock. The proposed development of the fence, which was eventually erected in 2004,

was highly contentious, with conservationists unsure of its impact on the local wildlife population, or the fence's potential effectiveness for mitigating the conflict. The fence forms an effective physical barrier for most species, but is not a predator proof fence. It is designed as a double fence with a 1.2m high cattle fence on the western community side and a 2.1m high electrified wildlife fence to the eastern park side, with neither fence dug into the ground.

The MPNP is home to one of the largest remaining mass migrations of zebra (*Equus quagga*) and wildebeest (*Connochaetes taurinus*) within Africa. During the dry season the migratory herds are resident along the Boteti River, attracted by the only permanent source of surface water in the Makgadikgadi. The arrival of the rains in November / December cause the herds to move east towards the open grassland plains of the Makgadikgadi salt pans, where they remain until the rain-fed ephemeral pools evaporate.

The annual east-to-west migration is mostly contained within the national park, with a significant portion of the wet season range moving beyond the park's eastern boundary into an adjoining wildlife management area (Brooks, 2005). Movement of zebra and wildebeest west of the Boteti River was limited, but still evident, with a sub-population of wildebeest moving southwest of the Makgadikgadi region towards the Central Kalahari Game Reserve. This was potentially a relic of the great Kalahari wildebeest herds that died around Lake Xau in the late 1970s (Williamson, et al., 1988).

The Makgadikgadi population of both zebra and wildebeest had been in decline since the 1950s, with several drought associated mass die-offs in the 1950s and 1960s responsible for the majority of the decline (Estes, R. pers. comm. & unpublished reports). Zebra population estimates ranged from 22,748 ± 2,287 (Graham, Dawson & Parker, 1974) in 1974 to 100,295 (DHV, 1980) in 1978 although it is likely that a figure somewhere between these two estimates is correct for the time. However, it is clear that since the drying of the Boteti River in 1991 the population of both zebra and wildebeest have showed further decline, with zebra numbers dropping from an estimated 36,000 in 1991 to less than 15,000 in 2001 (DWNP, BASIS, 1991, 2002) while the wildebeest population had plummeted from over 100,000 in the 1950s (A. Campbell, pers. comm.) to just 17,000 in 1999 and only 3,500 in 2002 (DWNP, BASIS, 1999, 2002).

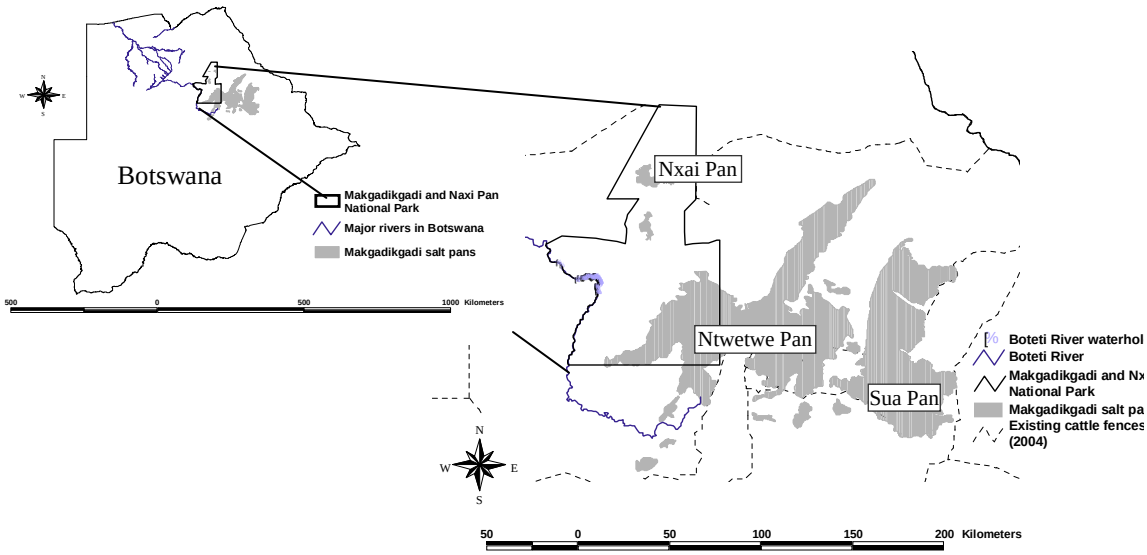
The cause of the more recent decline in the 1990s was attributed to resource limitation during the dry season being regulated by two main factors: limited water availability and competition with cattle for access to resources (Brooks, 2005). Both zebra and wildebeest were forced to adopt a central place foraging strategy (Orians & Pearson, 1979) around the limited water points along the Boteti riverbed. There was a direct overlap in spatial range and resource preference between cattle and both zebra and wildebeest, while resource availability was low with less than 6 g/m^2 of available sward within a 6km range of the Boteti water points (Brooks, 2005) thus encompassing the three factors required for resource competition (Prins, 2000).

Zebra may have been able to escape some of the impacts of the competition for resources by extending their foraging range up to 35km, much further than had previously been recorded in Africa (Hack, East & Rubenstein, 2002). Zebra remained within their foraging patch for an average of four days and up to a maximum of seven days, enduring considerable physiological constraint to access preferred resources beyond the zone of conflict with both cattle and

wildebeest (Brooks, 2005). Resource availability at these more remote areas was on average six times greater than close to the riverbed, with zebra found to preferentially select patches with a better than average resource availability of 70g/m^2 (Brooks, 2005). Wildebeest remained closer to the riverbed, directly competing with cattle for the remaining resources and may have suffered to a greater extent than zebra from resource limitation.

It is clear that the prevalence of HWC along the Boteti River was having a significant negative impact. The question was – would the fence help improve the situation or compromise the wildlife populations even more?

Figure 4.5.1. The Makgadikgadi and Nxai Pan National Park in central, northern Botswana.



The fence was meant to zigzag along the dry Boteti riverbed, partitioning water points evenly along the riverbed's length between those for wildlife and those for people and livestock. The difficulty in this approach was aggravated by uncertainty over whether the river would flow again, washing away sections of the fence, and also by the clumped distribution of water points along the riverbed. The water points were used by livestock during the day and by wildlife at night with neither zebra nor wildebeest lingering around the water points for any period of time. They descended en-masse in the evenings, drank quickly and departed. In response, lions adopted a simplified predation strategy of waiting at the water points for the zebra and wildebeest to come in to drink. When the migration departed to the open grasslands in the wet season, lions switched from targeting wildlife to livestock, with only a small sub-population following the migratory herds (Hemson, 2004).

Although the water points were evenly divided, the final alignment of the fence excluded all access for wildlife to the majority of the riverbed. The fence was aligned to the east of the riparian woodland inside the National Park crossing the riverbed at only three points for short (500m to 5km) sections. This has led to extensive elephant (*Loxodonta africana*) damage to the remaining riparian woodland with declining habitat availability for bushbuck (*Tragelaphus*

scriptus) and impala (*Aepyceros melampus*) close to the riverbed. The final alignment went against the advice of an independent environmental assessment (Scott Wilson & Ecosurv, 1991) with regards to concerns over the possible dangers of the river flowing again. Ultimately, these concerns were proved valid as the river started to flow again in 2009.

From observations of 15 GPS and 10 VHF collared zebra, one third of the zebra were found to graze to the west of the Boteti River at some point during the dry season but only 4% of their preferred foraging patches were selected here (Brooks, 2005). Wildlife have been found to be affected by human disturbance along rivers in Africa (Fritz, et al., 2003), while zebra have also been found to be excluded from foraging resources by human disturbance in east Africa (Wordon, Reid & Gichohi, 2003; Young, Palmer & Gadd, 2005) and it is possible that high levels of human activity outside of the park compelled both zebra and wildebeest to select foraging resources within the park. Meanwhile, cattle were recorded moving up to 5-6km into the national park on a daily basis, while also selecting areas outside of the park (Brooks, 2005).

Impact of the fence

When the fence was erected in 2004 there was extensive concern over its immediate impact. In the first year after its erection 88 zebra were found dead within the riverbed close to the fence during the latter part of the year, with a further 254 found between January and March in 2005 when there were poor rains. The principal cause of death was related to dehydration, exhaustion and lion predation (Reed & Sautereu, 2005). Of the 254 zebra found dead in 2005, 247 of them were found at one point along the fence. They died trying to move to the west of the riverbed but were stuck within a poorly aligned alcove created along the fence. It is possible that this represented a sub-population of zebra within the migratory herd that historically always resided to the southwest of the park. A remnant Kalahari wildebeest population was also resident in this area. A high incidence of mortality along the riverbed was not, however, unusual. Previous to the development of the fence 55 zebra were found dead in the riverbed in 2002 with 84 found dead during 2003. The cause of death was primarily related to lion predation, with increased rates of death related to exhaustion during summer months with failed rains.

Ongoing research in the MPNP suggests that the fence has met its aims of reducing resource conflict between livestock and wildlife. Removing cattle from the National Park has lead to a significant increase in resource availability, for zebra and wildebeest, close to the Boteti's water points (and now flowing river). Zebra and wildebeest are now found within the riverbed during the daytime and are spending longer periods of time in the riverbed drinking and resting. The mean foraging distance of selected grazing patches has decreased from 17km in 2003 to 10km in 2009, consequently reducing the required foraging effort. Zebra are also now actively grazing within 5km of the riverbed, an event which had not been observed prior to the erection of the fence. The reduced physiological constraints on zebra have been reflected in improved yearling recruitment rates. Prior to the erection of the fence the yearling recruitment was 14 per 100 adult females and is now 20 per 100 adult females. However, the time frame from 2004 to 2010 has also been associated with increased annual rainfalls and a longer residence time in the wet season home range.

However, the fence has not been as successful at mitigating human-predator conflict as lion (*Panthera leo*) continue to kill livestock at high levels (G.

Maude, pers. comm.). As the fence is not predator proof, lions cross under the fence to predate on livestock before moving back into the park for safety after the attacks. Increased rainfall has reduced the natural prey density for lions along the Boteti with the zebra and wildebeest increasingly resident in their wet season range. In order to help control the impact of conflict, farmers use the holes under the fence to monitor for signs of lion activity and subsequently target lions which have crossed the fence. Ultimately the fence has not reduced the level of conflict in the area but actually made lions easier to kill (Maude, G., 2010). More time is, however, required to continue to assess the current upward trend in the zebra and wildebeest population as well as the negative impacts upon predators, in relation to the fence.

Conclusions

Overall, the success of the initial aims of the fence is mixed. It has proved very effective at mitigating the resource competition between wildlife and cattle but has not been as effective at reducing human-predator conflict. The hard edge between such high densities of wildlife and adjacent human populations is a significant problem. There is no buffer zone between them to act as a form of land use mitigation, while forms of direct mitigation through Government paid compensation have been ineffective at appeasing the local communities. The fence should have been constructed to be predator proof. This may have helped mitigate this form of conflict, undoubtedly the continued loss of livestock through lion depredation still results in an embittered rural community that receives little benefit from wildlife.

By erecting fences around wildlife areas, communities become cut-off from wildlife and the benefits that wildlife may provide (the indirect benefits of wildlife-based tourism for example). It is essential to ensure that "separation" of wildlife and people does not hinder "integration" of culture and nature in the landscape, so that people can benefit from tourism, and still practise other land uses such as pastoralism and agriculture (Lamarque, et al., 2008).

Along the length of the Makgadikgadi fence local communities have the right to request the government to re-align the fence. Such proposals initially fell on 'deaf ears' but have been increasingly well received in recent years and would allow the communities to receive some benefit from the adjoining wildlife. One proposed realignment would pull the fence back across the riverbed into the community areas and therefore create wildlife watering points in front of any future community operated safari camp.

The Makgadikgadi fence was initially viewed by conservationists as a potential ecological disaster but this has not proved to be the case. The levels of conflict were sufficiently high along the hard edge of the MPNP that a barrier was considered a feasible way of reducing HWC. If the fence had not been erected, we surmise that the zebra and wildebeest population may have declined even further. By helping to conserve and protect the migration, there is a hope that direct and indirect benefits through tourism could help appease rural communities. Without the fence, this option would not have been available.

While the erection of the Makgadikgadi fence may prove to be a conservation success, the decommissioning of a further fence in the Makgadikgadi system has the potential to be even more beneficial. The 'Nxai Pan' Buffalo Fence was erected in 1968, to the north-west of the Nxai Pan National Park. Measuring 100 km in length, it cut off an important migration route between the Okavango Delta and the Makgadikgadi system. It is not known what impact

this had on wildlife population levels as little research has been undertaken in this remote area. However, in the late 1990s the fence was recognised as no longer serving any veterinary purpose, and was officially declared a 'decommissioned' fence (Albertson, 1998) before finally being removed in 2000. Bartlam-Brooks, et al., (2010) found that zebra had re-established their migratory movement between the Okavango Delta and the Makgadikgadi. Further evidence of the importance of this route has been confirmed by Chase (pers. comm.), who has recorded elephant movements along the same paths used by the zebra. The ability of the zebra population to respond to this change and re-establish a migration that had been cut-off for 40 years should provide hope to many conservationists across Africa.

Fences can be an effective form of conflict mitigation, but should be combined with a larger land use planning approach. Fences can segregate wildlife from people and livestock. However, without land use buffer zones, the hard edges of protected areas can still lead to HWC. The relative benefits and negative impacts of fences must be carefully assessed so that each fence is judged on its own merits.

Acknowledgements

We would like to thank the Department of Wildlife and National Parks, Botswana for research permits and technical support. We would also like to thank The Dulverton Trust, the Rufford Foundation, the Walt Disney Company Foundation, Columbus Zoo, San Antonio Zoo, the Gilchrist Educational Trust, Ken Moore, Wilderness Safaris Wildlife Trust, the Rory and Elizabeth Brooks Trust, Oregon Zoo, the Sophie Danforth Conservation Biology Fund, the Whitley Wildlife Conservation Trust, the Sir Richard Stapley Trust, Ideawild and other private donors for funding the research.

4.6 The relationship between fencing and the bushmeat trade

Lindsey, P.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa.
palindsey@gmail.com

The bushmeat trade

The bushmeat trade represents a major threat to wildlife populations in parts of Africa, resulting in widespread local extinctions, particularly of large-bodied species (Fa, et al., 2000; Wilkie & Carpenter, 1999). The majority of work on bushmeat in Africa has focussed on the forest regions of West and Central Africa (e.g. Noss, 1998; Wilkie, et al., 1998; Bowen-Jones & Pendry, 1999; Fa, et al., 2002; Robinson & Bennett, 2002; Bennett, et al., 2007). Outside of those areas, research on bushmeat has been limited largely to isolated studies in East Africa (notably around the Serengeti [Loibooki, et al., 2002; Ndibalema & Songorwa, 2007] and in parts of Kenya [Fitzgibbon, et al., 1995; Okello, 2004; Wato, et al., 2006]). TRAFFIC (the wildlife trade monitoring network) conducted a broad review of the bushmeat trade in southern Africa in the late 1990s (Barnett, 1998), and some work has been done on the topic in Zambia (e.g. Lewis & Phiri, 1998; Lewis, 2007), Namibia (Vaughn & Long, 2007) and Zimbabwe (Lindsey, et al., in press). Otherwise, there has been little attention on the issue in southern Africa, perhaps due to a misconception that bushmeat hunting is a sustainable, subsistence phenomenon in the region (Barnett, 1998). There are, however, indications that the bushmeat trade represents a serious conservation threat in parts of southern Africa (Lewis & Phiri,1998; du Toit, 2004; Lindsey, et al., in press a and b).

In southern Africa, the bushmeat trade appears to be an incipient threat which manifests more severely under conditions of political instability, weak management of protected areas, and where mechanisms for communities to engage in and benefit from natural resource management are inappropriate or absent (Lindsey, et al., in press b). In Mozambique, for example, illegal hunting for the bushmeat trade during and immediately after the civil war caused dramatic reductions in wildlife populations in protected areas (Hatton, 2001; Barnett, 1998). One of the legacies of the civil war in Mozambique was the continued reliance of rural communities on natural resources, including bushmeat for survival, slowing the recovery of wildlife populations in many areas (Barnett, 1998; Lindsey, in prep). Similarly, in Zimbabwe, during recent political instability associated with the land 'reform' programme and the occupation of wildlife ranches, illegal hunting surged resulting in dramatic declines in wildlife populations on private land (du Toit, 2004; Lindsey, et al., in press a).

The role of fencing

Fencing can impact on the bushmeat trade both positively and negatively (Lindsey, et al., in press c). On a positive level, the construction of perimeter fencing can assist in the control of illegal hunting. The barrier created by a fence can reduce the movement of wildlife from protected into unprotected lands. In addition, the clearing of a bare patch of earth on the inside of fence-lines enables anti-poaching guards to detect the footprints of illegal hunters

who may have passed into a protected area. Fencing as an anti-poaching strategy is particularly important for areas containing high-risk, valuable

wildlife such as black (*Diceros bicornis*) and white rhinoceroses (*Ceratotherium simum*). However, poorly-designed fencing can exacerbate illegal hunting by providing a massive supply of materials for the construction of cable snares. Cable snares are a widely used method for hunting bushmeat, and are particularly undesirable from conservation and animal welfare perspectives. Snares are indiscriminate and virtually all mammal species of a sufficient size (>3-5kg) are affected, including species generally not considered food items (e.g. wild dogs (*Lycaon pictus)*, hyaenas (*Crocuta crocuta* and *Hyaena brunnea*), baboons (*Papio* spp)) (Lindsey, et al., in press a). Snaring is wasteful, and <15% of snared animals are successfully extracted by illegal hunters, the remainder rot or are eaten by scavengers (Lindsey, et al., in press a). Similarly, in the Central African Republic, 27% of animals killed in snares are wasted (Noss, 1998). Snaring results in slow deaths or horrific injuries in cases where animals manage to break snares, leaving them with a tight ligature on a limb or on their neck. Snaring is effective; large numbers of animals can be killed in single snare lines and if left uncontrolled, wildlife populations can be decimated rapidly. Finally, snares are difficult to detect and so controlling their impact represents a major challenge (Lewis & Phiri, 1998).

Steel wire, barbed wire and cable of the kinds used to construct wildlife fencing are ideal materials for making snares. In Savé Valley Conservancy in Zimbabwe for example, >84,000 snares were removed by anti-poaching teams during an eight-year period following the onset of the land reform programme, most of which were comprised of wire stolen from the fence (Lindsey et al., in press). On the western boundary of Kruger National Park in South Africa, thirteen millimetre cable is frequently stolen by illegal hunters to make snares designed to catch large species such as buffalo (*Syncerus caffer*) (Ferguson et al., 2010). The theft of fence material can significantly increase maintenance costs and also reduce the efficacy of a fence as a barrier to wildlife, and particularly large species such as elephant (*Loxodonta africana*) which are commonly implicated in crop-raiding in areas adjacent to parks (Ferguson et al., 2010).

In parts of Africa where wire is less readily available, illegal hunters are forced to use alternative methods which may be easier to control. In central Mozambique for example, illegal hunters use steel gin traps which if confiscated by anti-poaching scouts are costly and difficult to replace (Lindsey, et al., in press c). Care is required when constructing fencing to ensure that the materials used cannot readily be used for snares. Kinked mesh fencing (such as Bonnox™ or Veldspan™) is less easy for illegal hunters to turn into snares. Though the initial investment in such fencing may be more costly than a traditional steel-wire fence, savings through reduced incidence of theft of wire and loss of wildlife in snares are likely to more than compensate for the additional expenditure. In the Zululand region of KwaZulu-Natal in South Africa, the high incidence of snaring has encouraged most ranchers to use mesh fencing (Lindsey, et al., 2005).

Negative community perceptions towards fencing can also play a role in driving illegal hunting. Preservationist conservation strategies employed by some colonial and post-colonial governments relied on fencing to exclude rural people from the natural resources that they had historically utilized (Els, 2002). Consequently, in some areas, wildlife fencing represents both a

functional and symbolic barrier which is negatively perceived by local communities (Spierenberg & Wels, 2006). Antagonism created by the presence of a fence can encourage vandalism of or theft of parts of the fence, and contribute to the illegal extraction of resources from a wildlife area (Lindsey, et al., in press c). Conversely, if designed appropriately and in consultation with communities fencing can play a positive role in neighbour relations by minimizing human-wildlife conflict (Lindsey, et al., in press c). Prior to the construction of a fence, both environmental and social impact assessments should be conducted. Communities are more likely to accept fences if they are provided with a stake in the management of the barrier (e.g. through employment associated with fence maintenance) and of the enclosed wildlife resources.

In summary, fencing can play a key role in reducing illegal hunting but only if the correct materials are used and if communities are consulted and engaged positively in the development and maintenance of the barrier.

4.7 Impacts of fencing on the migration of large mammals in the Kruger National Park

I.J. Whyte[1] & S.C.J. Joubert[2]
[1](*Private Consultant retired from South African National Parks.* ian@mpu.co.za)
[2](*Private Consultant retired from South African National Parks.* sollie@telkomsa.net)

Introduction

The fencing of the Kruger National Park (KNP) was long held as an ideal by its earlier managers, but this was not a universally accepted option. Some foresaw the problems that might arise. *"The fencing of the Park's western boundary must surely lead to a splitting of the game population in the Eastern Transvaal Lowveld, eventually leading to the extermination of all game in the vast area adjoining the Park, and to the serious material reduction of many species inside the Park"* (Mackenzie, 1955). The opinions of the respective "interested and affected parties" involved in the respective fencing issues have been well documented by Joubert (2007) and therefore need no repetition here.

Col. Stevenson-Hamilton, first Warden of the KNP stated that "*… I am certain that sooner or later, some means must be found to confine the game to the Park if we are to ensure the existence of all species*," (Stevenson-Hamilton, 1945). This opinion was endorsed by Stevenson-Hamilton's successor (Sandenbergh, 1947), and was again reiterated by Brynard & Pienaar (1961) who wrote that "*… while the fencing of the southern and western boundaries progressed slowly, it was seen how a long-cherished ideal was materializing, it was realised more and more that this is one of the most progressive steps ever in the protection and control of our wildlife populations, the curtailment of poaching and the preservation of our rare animal species*". This view resulted particularly from the fact that migrant wildebeest and zebra populations in the western parts of the Central District (CD) of the KNP migrated out of the Park when the summer rains started. The seasonal availability of water opened up favoured habitats to the west of the KNP's boundary. Earlier declines in wildebeest (*Connochaetes taurinus*) numbers were attributed to their persecution while they were outside the Park (Stevenson-Hamilton, 1945). The fact that these animals regularly left the KNP in large numbers was also a cause for concern for government veterinarians due to possible disease outbreaks in domestic livestock originating from wild herbivores.

History of boundary fencing in KNP

As early as 1930, farmers on the southern boundary had been supplied with wire and poles to erect fences to protect their crops from the depredations of wild animals, particularly hippos (*Hippopotamus amphibius*). This scheme had failed for various reasons (Nel, 1951). The first fence erected was a stretch of 25km between the Sabie and Nsikazi rivers which was funded by the then Department of Native Affairs in 1957 (c.f. Joubert, 2007). The next fence to be erected was along the western boundary of the CD. Prior to the erection of this fence, it was well understood that water provided the main stimulus for migration in this area. In winter the game came south from the areas to the west of Orpen to the winter grazing areas in the south eastern parts of their

range where they drank from the Sand River. Once the summer rains had started and surface water was again available, they moved back to the north-west (Pienaar, 1960 in: Whyte & Joubert, 1988). It was also well understood that the fencing of the boundary would cut them off from their favoured drinking sites in the Sand River in the dry season. The National Parks Board (1955 in Joubert, 2007) felt therefore that they could not recommend the fencing until the "water problem" had been resolved inside the Park. This implied that alternative water sources would have to be created in the areas immediately to the east of the boundary. These were provided in 1962/62 in the form of dams and boreholes in the vicinity of the proposed line of the western boundary, and included Ngwenyeni Dam, Airforce Dam, Ntswiriri Dam, N'wanetsana Dam, the pit dams at Ripape and Tswaene, and the Shiteveteve and Timbiteni windmills.

Severe outbreaks of foot-and-mouth disease (FMD) occurred in the KNP in 1958, which finally prompted the Department of Veterinary Services to commence with the erection a game deterrent fence along the western boundary between the Sabie and Olifants Rivers. Work on this fence commenced in 1959 and was completed in 1961 (Pienaar, 1982)

Fencing of the rest of the western boundary, and also the southern and northern boundaries was completed by July 1961 (Joubert, 2007). The northern boundary at that time ran along the northern bank of the Luvuvhu River. Fencing the eastern boundary between the Crocodile and Sabie rivers commenced in 1962, and the eastern boundary between N'wanetsi and the Olifants River was completed in the same year. Thereafter, stretches of fence five miles to the north and south of the Shingwedzi were completed. A new fence to the west of the Nsikazi River was erected in 1967 to cut off the area which was to be de-proclaimed as a result of changes to the Selati railway line.

During 1973 the authorities in Mozambique erected a fence along the eastern boundary from the Sabie River northwards to Mabakane Beacon (45 km). The fence was later considered to be substandard by KNP authorities and it was reported that it would ultimately have to be replaced (National Parks Board of Trustees, 1974, c.f. Joubert, 2007).

In 1974 political instability in Mozambique led to the South African Government deciding to fence the eastern boundary in its entirety. The requirements were that the fence should be game-proof and elephant-proof. By March 1976 the eastern boundary fence was completed and work commenced on the new northern boundary fence on the southern bank of the Limpopo River. This fence thus included the area between the Luvuvhu and Limpopo Rivers which had been proclaimed as part of the KNP in 1969. In 1977 the stretch on the western boundary of this area was completed, and finally the fence along the Limpopo River was completed in 1978. The KNP was then fenced in its entirety.

In a reverse of the trend sections of the boundary fence were then removed. After negotiations with the Associated Private Nature Reserves (APNRs) the western boundary fence between the Sabie River and Olifants River was removed in 1993. This once again allowed free movement of game between the KNP and the APNRs.

With the establishment of the Limpopo National Park (LNP) in Mozambique and the Great Limpopo Transfrontier Conservation Area (GLTFCA) in 2002, three

sections of the eastern boundary fence between the Limpopo and Olifants Rivers were removed to allow natural recolonisation of game in this new TFCA.

Impacts of fencing on animal populations

With the exception of the elephant (*Loxodonta africana*) (Whyte, 2001), wildebeest (Whyte & Joubert, 1988) and possibly also zebra (*Equus quagga*) (Smuts, 1972) populations, the impacts of the fencing of KNP have probably been minimal. These are the only species which undertook relatively long movements, and fencing is known to have disrupted these patterns.

Pienaar (1983) concluded however that the western boundary fence had ".. caused the demise of the last two herds of roan (*Hippotragus equinus*) antelope in the CD.." Fencing is known to have had serious consequences for individual animals of other species (see Adendorff, 1984 below) as many got entangled in the wire, but this is not known to have adversely affected their species' population trends.

Wildebeest

The migratory habits of wildebeest and zebra in the CD of KNP were fairly well understood (Fig. 4.7.1) prior to the fencing of the western boundary in 1961 (Pienaar, 1960). Later studies of the movements of these species (Braack, 1973; Smuts, 1972; Whyte, 1985) identified three sub-populations in the CD – the Western Boundary, and two eastern sub-populations (North-east and South-east). The Western Boundary and Southeastern sub-populations were both migratory, while the Northeastern was vagrant rather than migrant (Whyte & Joubert, 1988). The Western Boundary sub-population's migratory routes were disrupted by the western boundary fence while the other two were not affected by fencing.

The fence caused chaos for the Western Boundary migrant herds. A description of the situation was given by Adendorff (1984). "..*the game routes of the bygone days were cut off ... by this sudden barrier. I saw wildebeest and zebra massed against the fence, some wanting to come and others wanting to leave. Carnivora were in the pink of condition as they did not have to hunt, simply chasing their prey into the fence. The animals could not comprehend and they congregated at the fence, dying of thirst and hunger and remaining there to rot. The carnivora could not cope with the situation and the stench from the carcasses was terrible. It took the herds a long time to accustom themselves to the fence and I found many giraffe which had died after being trapped between the strands of wire*".

Between 1963 and 1966, 121 wildebeest were marked with colour-coded collars and the turmoil that the fence had caused was reflected in the erratic movements of these collared animals (Pienaar – unpublished data c.f. Whyte, 1985). Many of these animals were recorded to have crossed sub-population boundaries, something which was not recorded in later studies (Braack, 1973; Whyte, 1985).

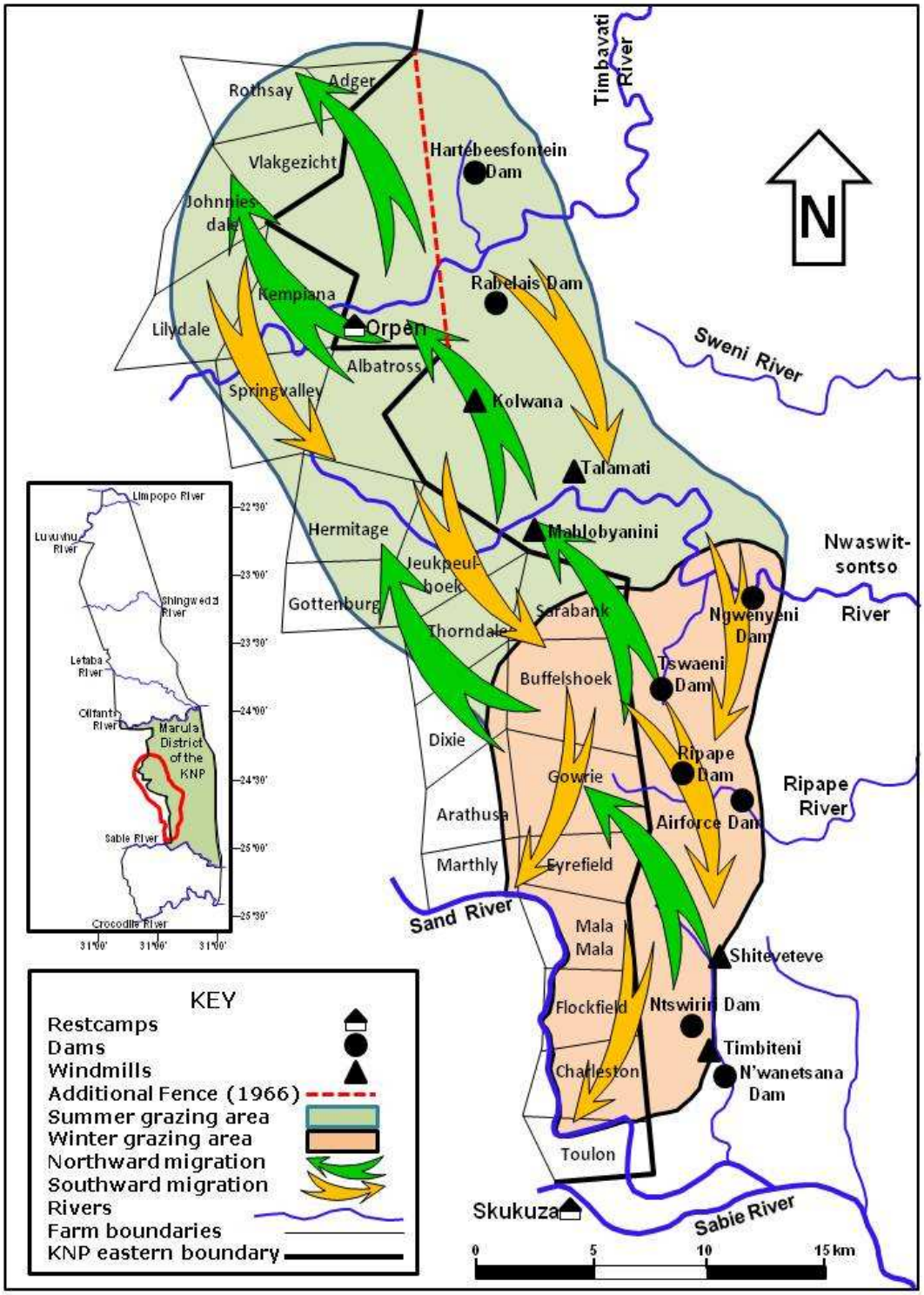


Figure 4.7.1. The migratory range of the Western boundary sub-population of the Central (Marula) Region of the Kruger National Park, showing how the boundary fence split the migratory range, and the water points provided before fencing (after Pienaar, 1960).

In the Orpen area, the compression of the herds up against the fence on the KNP side caused such an impact on the grazing that it was decided to put in a second fence which extended from the corner of the farm Albatross south east of Orpen northward to the corner of the farm Adger (see Fig. 4.7.1). This was

completed in 1966 (c.f. Whyte & Joubert, 1988). This fence effectively excluded the wildebeest from their favoured summer habitats on the gabbro soils to the north of Orpen, and this almost certainly would have accelerated the decline.

The fences were not the only factor inducing declines in the respective sub-populations. The period from 1971 to 1980 was an extremely wet one (Gertenbach, 1980) resulting in widespread long, rank veld conditions. These are generally unfavourable to wildebeest as they prefer short grass and open plains. Rank conditions render wildebeest vulnerable to predation by lions (Whyte, 1985). Whyte & Joubert (1988) showed that all three of these sub-populations underwent declines during this wet period, but the majority of the decline occurred in the Western Boundary sub-population. This was caused by the combination of rank conditions and the impacts of the fence. The two eastern sub-populations both declined by an estimated 36.1% but recovered once drier years were experienced (Table 4.7.1). The Western Boundary sub-population declined by 87.3% but has not recovered, and the old migratory pattern is still defunct. The total contribution of the Western Boundary sub-population to the total decline was estimated at 70%.

These estimates are considered to be very conservative as the decline would have started once the fence was complete in 1961, while the first population estimates were only conducted four years later in 1965. Prior to the erection of the fence in 1961, the numbers are believed to have far exceeded the 5 914 (Table 4.7.1) estimated by Pienaar (1965). Anecdotal accounts (Kloppers, pers. comm.) describe "the hills black with wildebeest", and he subjectively estimated the population at several thousand more than the 1965 census suggested.

Table 4.7.1: The extent of the decline in the wildebeest population and sub-populations of the Central District of the Kruger National Park between 1965 and 1979.

Sub-population	Total in 1965	Total in 1979	Difference	% Decline
South-east	3,134	2,004	1,130	-36.1
North-east	3,149	2,012	1,137	-36.1
Western boundary	5,914	752	5,162	-87.3
TOTAL:	12,197	4,768	7,429	-60.9

The Western Boundary sub-population has probably declined even further than suggested in this table. Unfortunately, more recent census data can not confirm this, as only sample counts have been conducted which yield data that are incomparable with earlier data.

Large herds of wildebeest also occurred in the past in the Pretoriuskop area. This population was also migratory spending the winter months in the well watered areas to the west of the current boundary, and returning to the KNP in the summer months (Stevenson-Hamilton, 1947). This population has also since declined and it is suspected that this was caused by excessive hunting, and as a result of their migrations being disrupted by human developments in

their winter grazing grounds. Such developments are as effective in disrupting migrations as fencing. Pienaar (1983) however concluded that the abolishment of veld burning in the KNP ".. led to the progressive loss of thousands of zebra and wildebeest from the Pretoriuskop area between 1947 and 1953..".

Elephant

During the 1960s there was a fairly large seasonal movement between the KNP and Mozambique and it was realised that fencing along this boundary would be a problem. It was reported (National Parks Board of Trustees, 1967) that "The large-scale movement of elephants between Portuguese East Africa and the Lebombo flats of the Klipkoppies Section was again confirmed during the winter months this year. The movement is of such dimensions and is so regular that a conventional fence in this area would prove useless". This movement consisted of an eastward movement once the summer rains had started and water became available in the pans of the sandveld areas in Mozambique. As the pans dried with the onset of the dry season, the elephants would then return to the west to the more permanent water in the KNP.

In November 1970 an aerial survey was conducted in the area adjacent to the KNP in Mozambique in the triangle between the KNP in the west, the Limpopo River in the east and the Olifants River in the south (Joubert, 1970). A total of 555 elephants were recorded and it was speculated that a connection may exist between the elephant populations of the KNP, the Gonarezhou in Rhodesia (Zimbabwe) and the Save River in Mozambique. Another aerial survey was conducted in Mozambique in April 1972 in a strip 32 km wide from the KNP's eastern boundary and between the Sabie River in the South and the Limpopo River in the north (Joubert, 1972). This time 789 elephants were recorded of which 120 occurred to the south of the Olifants River and the rest (669) to the north. Based on the distribution of elephants and the apparent lack of permanent water in this area, it was concluded that 10 - 15% of the KNP's elephant population moved into Mozambique during the wet summer months and returned as the waterholes dried up.

The eastern boundary was fenced in its entirety by March 1976. This fence is substantial enough to limit the large-scale movement of elephants. Although still occasionally broken by adult bulls, it has stopped movements between Mozambique and the KNP such as those reported earlier (Joubert, 1972a; National Parks Board of Trustees, 1967).

Fencing has also had an effect on the elephant population's rates of increase. Analyses of census data (Whyte, 2001) showed that the rate of growth of the population showed a declining trend between 1965 and 2000. This period can be divided into three periods. The first (Period 1) represents the time between commencement of censusing (1965) until the KNP was entirely enclosed by boundary fences (1976). The second (Period 2) is when the KNP was fenced in its entirety (1976 – 1994), while the third is the period after removal of the western boundary fence (1993) between KNP and the Private Nature Reserves to the west (Period 3). In Period 1, the estimated intrinsic rate of increase ($\bar{r}$) was 0.104. This is well above the estimated maximum $\bar{r}$ of ±0.07 (Calef, 1988), which suggests immigration was occurring from Mozambique during that period. Between 1975 and 1994 (Period 2) the mean $\bar{r}$ declined to 0.066 which is close to that which would have been expected from a confined population (no immigration or emigration). The western boundary fence was removed in 1993 and from then up until 2000 (Period 3), $\bar{r}$ declined to 0.025,

suggesting that emigration was occurring from the KNP population. During this same period, the population of the neighbouring Sabi-Sand Game Reserve (SSGR) increased from 60 to 531 at a mean annual rate of increase of $\bar{r}$ = 0.30. This is well above the normal rate which indicates that after the removal of the fence there was considerable movement across the boundary from KNP to SSGR.

Emigration from KNP also occurred towards the east after removal of sections of the eastern boundary fence. In October 2006 an aerial survey of the Shingwedzi River basin area of the Limpopo National Park was conducted. A total of 630 elephants were recorded at widespread localities in the survey area (Whyte & Swanepoel, 2006). This total represents considerably more than the number that have been translocated to LNP (25). There are now breaks in the fence where stretches of the barrier have been removed, and also at certain river crossings (Shingwedzi and Nshawu Rivers) where wash-aways had occurred. The census result showed that a natural recolonisation process had begun.

Conclusions

- In some species, numerically large populations are sustained through migrations. Resources become depleted and the animals must move to gain access to adequate resources. In some cases these movements become traditional migrations following a fixed pattern. When these migratory routes are disrupted by fencing, massive declines will result.
- This is what happened to the western boundary sub-population. Fencing disrupted the migratory pattern resulting in the complete demise of the migratory herds. Only a few static herds remained on small patches of open habitat in this area (Whyte & Joubert, 1988).
- Fencing of KNP was largely successful in maintaining the goal of separating wild animals from domestic stock, though some outbreaks of FMD did originate from KNP (e.g. Bengis, Kock & Fischer, 2002).
- Fencing was generally successful in containing elephants within KNP. Marauding elephant, hippo, buffalo (*Syncerus caffer*) and lions (*Panther leo)* did continue to breakout in small numbers causing management problems. Larger scale movements of elephants out of the KNP into SSGR and LNP only occurring after sections of fencing had been removed.

With the exception of the elephant, wildebeest and possibly also the zebra populations, the impacts of the fencing of KNP have probably been minimal.

4.8 Linkages, wildlife corridors and shortfalls in the KAZA TFCA

Cumming, D.H.M.
Consultant, 10 Lanark Road, Belgravia, Harare, Zimbabwe
cummingdhm@gmail.com

This section is reproduced with minor edits and the kind permission of the author and Conservation International (Southern Africa) from Chapter 8 in Cumming, D.H.M., 2008. *Large Scale Conservation Planning and Priorities for the Kavango-Zambezi Transfrontier Conservation Area: A report prepared for Conservation International*.

"Most evidence for the use of corridors for movement comes from studies involving relatively few observations of relatively small numbers of individuals of relatively few species" Hobbs (1992)

Introduction

The need to establish wildlife corridors has become an accepted dogma in the development of transfrontier conservation areas in southern Africa. In the case of the KAZA TFCA the wide separation of major protected areas, or clusters of protected areas, has prompted the belief that these need to be connected by wildlife corridors. In this context *wildlife corridors* are features that serve to link isolated habitat patches, or isolated areas, by providing suitable terrain or habitat through which animals can move between patches or areas.[22]

The 'Pre-feasibility Study' (Transfrontier Conservation Consortium, 2006) for the KAZA TFCA made the following recommendation with regard to wildlife corridors:

> *"Identification and consolidation of transfrontier wildlife corridors.* The following potential corridors will receive priority attention in the Feasibility Phase:
>
> - The links between the south of the Kafue National Park and the remainder of the KAZA TFCA, part of which could be one or more wildlife corridors from northern Botswana through East Caprivi, or a link with Sioma Ngwezi National Park or to Zimbabwe.
> - The link between Botswana through West Caprivi to south-eastern Angola. This very important corridor will form a major dispersal route for elephants between Botswana and Angola.
> - The need for a corridor to link the north of Khaudom Game Park to Western Caprivi and south-eastern Angola.

[22] The term '*biodiversity conservation corridor*' or '*conservation corridor'* has recently been coined to refer to a large landscape which is a "*biologically and strategically defined sub-regional space, selected as a unit for large-scale conservation planning and implementation purposes*" (Sanderson, et al., 2003). In this sense the entire KAZA TFCA might be regarded as a conservation corridor. UNEP's Biosphere Reserves were an earlier model for conserving biological diversity over large landscapes and recent work in South Africa has focused on large landscapes and 'mega-conservancy networks' (e.g. Knight, et al., 2006a, 2006b & 2007).

- The link between the protected areas south of Lake Kariba (Hwange) and the remainder of the KAZA TFCA to the west (Chobe)".

These corridors were, understandably, only broadly indicated by arrows on a map and the purpose of one of them was defined in terms of a dispersal route for elephant between Botswana and Angola. Given the lack of evidence of any transboundary migrations of large mammals occurring in the KAZA area (Cumming, 2004a), and the general paucity of evidence that corridors are used by animals (e.g. Beier & Noss, 1998), there is a need to examine more closely what purpose wildlife corridors may serve in the TFCA since this may influence their siting and design.

Corridors for what?

The need for wildlife corridors arises in situations where the intervening habitat has been transformed in such a way that animals are prevented, or at least inhibited, from moving between the isolated areas or patches in question, such as in agriculturally transformed landscapes. These considerations immediately raise questions relating to the extent to which habitat fragmentation has taken place in the KAZA TFCA. To what extent has the landscape been transformed? Are protected areas in the KAZA TFCA isolated by intervening areas of transformed habitat and landscapes? To what extent has such transformation as may have occurred acted as a barrier to animal movement or interrupted past patterns of animal movement? Which species are involved? And so on.

These questions need to be answered in order to decide where, if at all, wildlife corridors may be needed and if so, how they may be created. There is also the need to consider the functions that such corridors may be required to perform and the following may be important in terms of the KAZA TFCA and its sustainability in the face of climate change:

a. Migration corridors that serve to maintain regular seasonal movements of animals between alternative areas or habitats.

b. Dispersal corridors that serve to allow the dispersing component of particular species populations to move to other suitable areas or habitats.

c. Adaptive response corridors that provide for both fauna and flora to shift, or disperse, along ecological gradients in response to changing climatic conditions.

Answers relating to questions about habitat fragmentation, and the functions that wildlife corridors may be required to perform, are spatially and temporally scale dependent and will also be influenced by the body size and natural history of the species concerned. Clearly, corridor requirements for dispersing elephants and corridors for Woosnam's rat to shift its distribution in response to climate change will differ, as will the corridor requirements for predators such as the wild dog.

Habitat fragmentation in the KAZA TFCA

Habitat transformation as a result of agricultural development in the KAZA TFCA is restricted to small pockets and probably covers no more than 5% of its overall area. However its spatial distribution may be such that in some areas it will obstruct the connectivity between the large scale clusters within the TFCA or between specific protected areas. These areas need to be identified and mapped. In other areas habitat transformation may be the result of elephant impacts on woodlands and this is likely to be particularly marked in riparian

fringes in protected areas carrying high densities of elephants. Riparian fringes are in themselves important habitats and corridors for a wide range of species. Fragmentation is, however, not limited to changes in habitat such as occur under cultivation, overgrazing, bush encroachment, and deforestation by people or elephants. Fragmentation can also be caused by the construction of infrastructure such as roads and fences. It can also be established by over-hunting and disturbance resulting in areas that large mammals, at least, will avoid. Areas without surface water, or with deep rivers, can also act as barriers to animal movement and dispersal.

Areas in which habitat fragmentation of various kinds is likely to be an obstacle to animal movements can be identified at a very broad scale (Fig.4.8.1) but these need to be explored in greater detail and at appropriate scales. It is worth noting that the effective development of wildlife-based landuse in many of the intervening areas of the matrix would do away with the need to establish formal corridors.

Migrations

Much of the popular literature on TFCAs has focused on creating corridors to re-establish mythical migration routes. As Cumming (2004b) found, there was no evidence of transboundary migrations of large mammals in the 4-Corners area. Regular migrations of wildebeest and zebra occurred in two areas within Botswana, namely, between the Linyanti and Savuti, and in the Makgadikgadi area. A regular wildebeest migration occurs to the north of the TFCA across the Liuwa Plains.

Wildlife dispersal corridors

Much discussion, and some research, has focused on creating corridors for the dispersal of elephants from areas of high density centered on the Chobe NP. The idea that corridors linking major protected areas will result in effective natural regulation of elephant populations and a reduction of elephant impacts on habitats in protected areas has been espoused by van Aarde (e.g. van Aarde & Jackson, 2007) and his research group at the University of Pretoria. A critical assessment of this approach was offered by Cumming & Jones (2005) who pointed out that should the elephant population continue to grow at about 5% per annum it would double in 12-15 years and there just was not the land available to absorb the increase. Further, most of the land supposedly available to absorb dispersing elephants was communal land, and inhabitants would not accept high densities of elephants without commensurate returns and benefits. In other words consumptive use of elephants would eventually be necessary and the establishment of source-sinks dynamics would be required to regulate elephant populations in the KAZA TFCA region. To some extent this scenario has already developed in the Sebungwe area of Zimbabwe where the elephant population is being stabilised by illegal offtakes (Dunham, 2008) but pressure on habitats within the protected area has not yet been relieved (Cumming, personal observations). There is also the risk that creating dispersal corridors for elephant will merely serve to export the elephant overpopulation problem to new areas.

The potential role of wildlife corridors for the dispersal of other large mammal species has received little if any attention. Cumming (1999, Table 11, page 31) outlined the species likely to benefit from the removal of fences and the establishment of transboundary corridors. Links between the Caprivi, Luiana and Sioma-Ngwezi could potentially benefit nine species, links between Chobe

and Hwange NP 14 species, and between Khaudom and the Caprivi 13 species of large herbivores.

Historically, periodic dispersals of wildebeest occurred from the Makgadikgadi area to Hwange NP along the Nata River and associated drainages (Cumming, 2004a). This route is presently closed by fences and settlement. Little is presently known about the dispersal of predators in the KAZA region but wild dog populations are likely to benefit from appropriately aligned linkages that provide a "safe passage" between the large protected areas within KAZA.

Adaptive response corridors

As climate change results in changes in the distribution of plant species and the structure and composition of dominant habitats the species composition of vertebrate and invertebrate communities will also change. Many species will face local extinctions unless they can shift their distribution or range along appropriate corridors. The current climate change predictions and the distribution of species richness suggest that it will be important to maintain broad scale linkages along a south-east to north gradient, and possibly also along a west-east gradient.

It is this context that the larger conservation planning initiatives, such as envisaged in biodiversity conservation corridors (Sanderson, et al., 2003), biosphere reserves and mega-conservancy networks would be particularly appropriate. Working at these scales could provide opportunities to proactively address biodiversity loss threatened by climate change, provide increased flexibility to consider human development needs and ecosystem services, and provide options to strengthen resilience and adaptability in linked social-ecological systems (K. Lawrence, pers. comm., 2008).

Given that a vast number of species are involved and that their likely responses to climate change are mostly unpredictable the only fail-safe strategy that can be applied under present circumstances is to avoid, as far as possible, foreclosing options on potential linkages along the gradients suggested above.

Maintaining corridors for some specialist species and localized endemics such as plant species confined to Batoka Gorge or to similar widely spaced specific rocky habitats is clearly not possible. Several notable rocky gorges occur in the Sebungwe region of Zimbabwe that could hold some of the Batoka Gorge endemics but targeted plant collections in these areas do not appear to have been made.

Risks associated with corridors

Corridors do not necessarily lead to improved conservation. Greater connectivity between protected areas can facilitate the transfer of invasive species and particularly diseases. Within the KAZA TFCA the movement of tsetse fly from the Sebungwe through to the Hwange-Matetsi would be a particular risk. Tseste fly occurred in the Matetsi area before the rinderpest pandemic of 1896. Similar risks might be incurred in establishing a corridor between the Caprivi and Kafue NP.

Several Palaearctic and Afrotropical bird migrants depend on specific habitats such as wetlands, pans and acacia riparian woodlands. Pans and riparian woodlands are degraded by high densities of elephants which may thus adversely influence populations of migrant species that depend on these habitats.

Other types of corridors such as tourist and trade corridors with their associated infrastructure may exacerbate the transfer of alien invasive species and diseases.

Wildlife corridor options and priorities

There are nine major potential corridor areas (Fig. 4.8.1) each of which has different characteristics and impediments to the establishment of effective linkages (Table 4.8.1). Human settlement and areas of cultivation are common to all of the potential corridor areas but appropriate changes in policies, and laws and incentives, could greatly improve the suitability of these areas for wildlife. Infrastructure development in the form of major highways does present a problem in that it can inhibit free movement of wildlife, result in mortality of both travellers and wildlife and provide a conduit for invasive species and diseases. Disease control fences in Namibia, Botswana and Zimbabwe present a particular problem because of entrenched veterinary control practices and strong vested interests in beef export markets. Recent moves to introduce commodity based trade arrangements and agreements may serve to alleviate these issues in some areas. For example, the introduction of commodity based trade in north-western Ngamiland could allow for export trade in beef alongside wildlife-based land uses where FMD may be endemic. The risk of bovine pleuropneumonia in this area would nevertheless remain and may require more effective control, if not eradication, of the disease in core infective areas within Angola. In some areas, such as between Hwange and Chobe National Parks the distribution of dry season surface water presents a problem for the dispersal or movement of water dependent species.

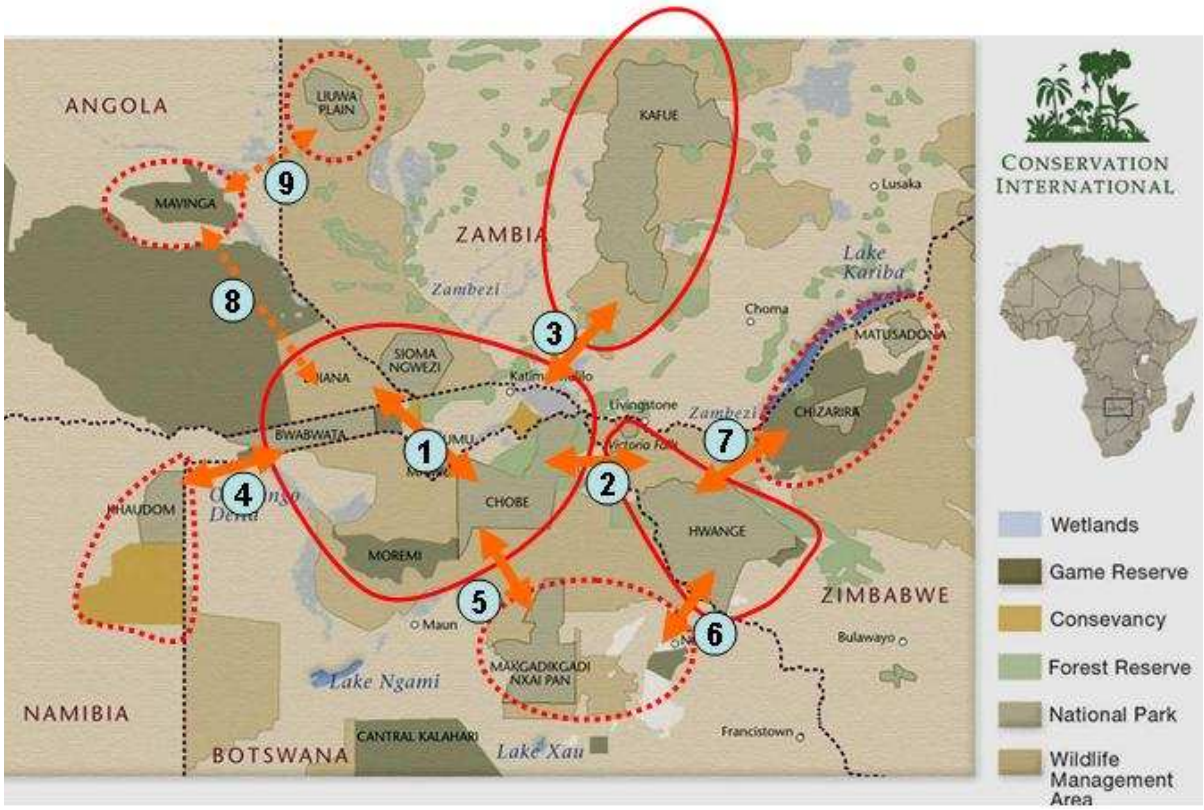


Figure 4.8.1. Potential wildlife corridor areas (1- 9) within the KAZA TFCA. (See Table 4.8.1 for further details. The numbering can be considered as an order of priority).

Not all barriers to dispersal and movement are due to human influences. In some potential corridors, barriers may be the result of natural changes in vegetation types, in habitat structure (e.g. large expanses of grassland separating dense woodland habitats), or large rivers. Clearly, species responses to habitat changes and heterogeneity will differ and a more detailed appraisal of habitat connectivity, and land cover changes and trends in each of the broad corridors areas in relation to dispersal or movement of specific species is needed.

In terms of action on wildlife corridors the three central corridors (i.e. numbers 1, 2, and 3 in Fig. 4.8.1) stand out as clear priorities. The development of community conservancies in the Mudumu complex and along the Kwando River suggest that key components of the corridor linking Chobe NP and Bwabwata, Luiana and Sioma Ngwezi are well advanced. The establishment of a wildlife corridor, or wildlife corridors, between Chobe NP and the Hwange-Matetsi complex appears to have received little attention. Given the short distances involved, and the favourable intervening land uses of forestry and hunting leases, this corridor should be easily established. However, the question of what would prompt species to make use of the corridor needs to be examined.

Table 4.8.1. Major potential wildlife corridor areas in KAZA TFCA and factors likely to impede animal movement or linkages between protected areas. The location of each potential corridor is shown in Fig. 4.8.1. (x indicates level of impedance on a scale of 1-3, and a dash indicates that the factor is probably not significant).

Corridor Area	Impediments to wildlife movement / dispersal					
	Settled	Roads	Fences	Landuse	Disease	Water
1. Chobe / Liuana / Sioma Ngwezi	xx	xx	xx	xx	-	-
2. Chobe / Hwange-Matetsi	xx	x	xx	-	xx	xxx
3. Caprivi / Zambezi / Kafue	xxx	xx	-	xxx	x	-
4. Khaudom / Bwabwata / Ngamiland	xx	x	xxx	xx	xxx	x
5. Chobe / Nxai Pan / Makgadikgadi	xx	xx	xxx	xx	xxx	x
6. Makgadikgadi / Hwange	xxx	xx	xxx	xx	Xxx	xx
7. Hwange-Matetsi / Sebungwe	xxx	xxx	xx	xxx	xxx	-
8. Luiana / Mavinga	x	x	-	-	-	-
9. Mavinga / Liuwa Plain	x	x	-	-	xx?	-

Shortfalls

The central focus of KAZA TFCA is its wetlands and associated wetland species of fauna and flora. Very little attention appears to have been given to maintaining or establishing connectivity between wetlands. A measure of connectivity, particularly upstream connectivity, may be particularly important during the next 30-50 years if increasing aridity is experienced in the region. In this regard the connections between the Zambezi and the Kafue via the

ancient drainage link through Machili to the Kafue Flats could be particularly important. The links from Sioma Ngwezi through the Western GMA to Liuwa Plain have also been neglected and, given the high ranking of the Western GMA and the importance of maintaining upstream connectivity, this linkage deserves closer investigation. It is also important to bear in mind that the relationships between high biological diversity and valued ecosystem services are likely to be complex and that they may not be spatially aligned (e.g. Chan, et al., 2006).

4.9 Climate change and fencing impacts

Seimon, A.
Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, New York 10460.USA
aseimon@wcs.org

In contexts of place-based environmental conservation and socio-economic development, climate is one of several inherited background states, a geographic endowment which, along with factors such as soil types, water availability, and geographic location, exerts a strongly coercive influence on ecological system types and character, and consequentially, human settlement patterns, health characteristics, livelihoods and economies as well. Long-term success in environmental conservation and human development alike therefore cannot be achieved without comprehension and engagement with issues of climatic variability and climate change. Climatic variability is generally well understood and managed, since it draws upon analogs from current and past experience, though occasional extremes such as droughts, floods and other high-magnitude events still register as shocks to human and natural systems due to their relatively infrequent occurrence. In contrast, climatic changes resulting from human-caused changes in Earth's radiative balance from greenhouse gas emissions offer no comparative analogs. Long-range planners are therefore dependent upon climate modelling for inference on future atmospheric and associated environmental conditions, where high degrees of uncertainty are inherent characteristics.

The term "climate change" as used in traditional climatology is the shift from baseline means established in recent multi-decadal experience, as well as changes in climatic variability characteristics; the forcings driving such changes are neither implied nor identified. In conservation and development contexts, the term has come to be universally used in reference to anthropogenically influenced climate change and its perturbation of "natural" climate and climatic variability. Climatic variability and climate change bring stresses that affect that quantity, quality and reliability of ecosystem services which can have deleterious effects on vulnerable populations, and none more so than the global poor (IRI, 2005). For rural populations dependent upon rain-fed cultivation and livestock rearing for their livelihoods and nutrition, climate change has the potential for particularly high degrees of disruption by exacerbating existing vulnerabilities. In a comparable manner, as a consequence of climate change the ecological contexts of conservation into the future will inevitably be characterized by increasing disruption among the myriad complex interactions that are the evolved organizational structures of ecosystems and the species contained therein. Terms such as *range shifts*, *migrations*, *disequilibria* and *asynchronies* are increasingly applicable to characterize the disruption of ecological systems in years to come relative to past experience that has shaped our understanding to date. This means that past experience generally does not offer representative analogs for future outcomes. For example, natural geographic endowments of favourable climate, soils and hydrology that might have described a given landscape as suitable for large populations of a certain species are in a process of alteration that might render them non-viable in that same landscape within several decades.

Sustaining the species in that landscape would therefore require some form of adaptive bio- and/or geo-engineering interventions to enhance the species viability in the face of increasingly adverse conditions.

These factors are all of concern in the conservation and development contexts of the Kavango-Zambezi (KAZA) and Great Limpopo (GL) Transfrontier Conservation Areas (TFCAs) in south-central Africa. Climate change should therefore register strongly in their respective environmental conservation and development planning agendas: this is made even more imperative by the climatic trends projected by a consensus formed by multi-model assemblages of global general circulation climate models (GCMs), which depict starkly warmer and significantly drier climatological means across the region by the close of the 21st century (IPCC, 2007; Nohara, et al., 2006). However, there appears to be significant underrepresentation of climate change into long-term planning for the KAZA and GL regions[23].

Relative to the multifaceted issues associated with fencing and its conservation implications in the KAZA and GL regions, climate change stands as a slow-acting but inexorable long-term challenge that requires rigorous assessment and proper incorporation into planning. Fences are permeable boundaries to numerous species, but by design and engineering are intended to restrict the movement of large herbivores such as elephants (*Loxodonta africana*) and cattle, other taxa, and the pathogens that travel with them. In response to changing climatic conditions, vegetation assemblages shift in both composition and location, causing ruminants and the predators dependent upon them to migrate as an adaptation response. Fencing can therefore present barriers to prevent species from tracking vegetation as it shifts in response to changing climatic conditions.

This is of particular concern for the KAZA landscape. Its domain straddles a strong north-south precipitation gradient that according the IPCC multi-model consensus is likely to intensify during the course of the century. The presence of extensive fencing across the landscape, especially fences with east-west orientation, would represent blockages of potential escape routes of species attempting to track their favoured habitats being displaced by changes climatic conditions. Relocation through migration is both a short-term and long-term adaptation strategy utilized by many species to climatic hazard. High magnitude short-period events such as floods, droughts and widespread fire outbreaks prompt many species to relocate, generally temporarily, until the stress abates. Climate change generally plays out at far longer time scales, over decades, yet the presence of fences will, over time, increasingly hinder the adaptive capacity of species whose movements are curtailed by them, and ultimately may cause the species to become entirely dislocated from favourable habitat, leading to their demise.

In summary, the issues of fencing and climate change are linked by their potential over the long-term to create highly divergent ecological outcomes acting both independently and synergistically. It would therefore be a poor choice to design and implement fencing management strategies in the KAZA and GL landscapes, as elsewhere, without proper consideration of the role that fences may play in mitigating or exacerbating the adverse consequences of

[23] 10th AHEAD (Animal & Human Health for the Environment And Development) Great Limpopo Transfrontier Conservation Area Working Group meeting, Feb 2010

climate change upon species, ecological systems and humanity existent in the regions under consideration.

5. SPECIES SPECIFIC FENCING INTERACTIONS

5.1 Ground pangolins and electric fences

Pietersen, D.
Department of Zoology and Entomology, University of Pretoria, Pretoria 0002, South Africa
dwpietersen@zoology.up.ac.za

Fences are part of our everyday existence in southern Africa. We see them along every road; they enclose many of our nature reserves and national parks, and are seen as effective barriers to keep wanted animals in, and unwanted creatures out. However, these anthropogenic structures can have a broad range of negative impacts on wildlife, including the enigmatic and threatened ground pangolin (*Smutsia temminckii*).

Pangolins (Pholidota: Manidae) are unique among mammals in that their bodies are covered with thick, plate-like scales (Nowak, 1999). When disturbed, pangolins roll into a ball with their heads firmly tucked beneath this armour, affording effective protection from almost all predators (Nowak, 1999). The ground pangolin (hereafter, pangolin) is widespread in southern and East Africa, and varies in length from 800-1,450mm and from 3-18kg in mass, depending on the region (Skinner & Chimimba, 2005; Swart, et al., 1999; Heath & Coulson, 1997; Richer, et al., 1997; Swart, 1997; Jacobsen, et al., 1991; Smithers, 1983; Kingdon, 1971;). They have fairly large home ranges varying from 1-24 km^2, and are capable of moving up to 6 km in a night (Skinner & Chimimba, 2005; Heath & Coulson, 1997; RJ van Aarde, et al., unpubl. data). Relative to their small size, pangolins are extremely strong, often marching forcefully through scrub and over rocks. Pangolins are bipedal, walking on their back legs while the broad, heavy tail is held off the ground and used as a counterbalance (Swart, 1997; Smithers, 1983). Thus when walking, the un-scaled soft under-parts are entirely exposed. Pangolins are currently regarded as *Vulnerable* in South Africa, although most assessment criteria for this species are data deficient (Friedmann & Daly, 2004). Furthermore, pangolin numbers are believed to be decreasing (IUCN, 2009; Friedmann & Daly, 2004). The species is also listed as CITES appendix II (CITES lists as on 22 May 2009, www.cites.org).

Figure 5.1.1. Free-ranging pangolin (Photo credit DW Pietersen)

On account of their unusual body armour, pangolins are held in high regard by many local tribes and are often killed for their scales, which are used extensively for cultural rituals and ornamentation. They are also killed for their meat or out of fear (Friedmann & Daly, 2004; Kyle, 2000; Heath & Coulson, 1997; Swart 1996; Heath, 1992; Kingdon, 1971; Ansell, 1960; RJ van Aarde et al, unpubl. data). However, recent evidence suggests that electrified fences present a threat to pangolins that, in terms of the number of individuals killed, far exceeds that posed by cultural superstitions and the bushmeat trade.

When ground pangolins reach an obstruction, such as a fence, they will often walk along it, periodically trying to push underneath the structure at weak points. Pangolins will also climb over fences, and have been known to climb over fences as high as 2m. Non-electrified fences generally do not pose a significant barrier to pangolins, and individuals may regularly traverse the fences that occur within their home range. In contrast to non-electrified fences, electrified fences pose a significant threat. Numerous pangolins are killed annually by electric fences (EW Pietersen unpubl. data; RJ van Aarde et al., unpubl. data; NC Bennett pers. comm.), and in countries such as South Africa where electric fences are prevalent this may account for the largest proportion of mortalities for this species. Elsewhere in Africa, where electric fences are less prevalent, the magnitude of this threat is presumably less severe. When a pangolin inadvertently walks into an electric fence, it responds in the same way it would to any other threat – by rolling into a ball. This results in the animal rolling around the electric wire, and being repeatedly shocked on its unprotected under-parts by the subsequent electric pulses (which often exceed 7,000V). If not shocked to death, pangolins succumb to resultant exposure and starvation while they are curled around the wire. The threats posed by electric fences are further exacerbated by the fact that most legislation requires an offset trip-wire to be included in the fence array, often set at a height where pangolins are most vulnerable (NCDTEC, 2010).

E.W. Pietersen (unpubl. data) recorded seven pangolins being killed on electric fences in just over two years in the former Transvaal Lowveld. During a 29 month study period in the southern Kalahari, eight pangolins were found killed along 93km of electric fences, with a further four pangolins released after being removed. However, these records are likely to be an underestimate of actual mortality as anecdotal evidence indicates that many more pangolins were found on this stretch of fence during this time period. At least another six pangolins were killed on an additional 24km of electric fence on an adjoining property during the same period. Fence-associated mortalities and encounters were most frequent immediately after the fences were erected, suggesting that pangolins gradually become accustomed to these obstructions. Alternatively, it could also mean that pangolin densities decrease near the fences due to this increased mortality. More recent data indicate that pangolins sometimes do move through electrified fences without getting caught up, but despite this, mortalities and encounters are still recorded regularly, even after fences have been in place for many decades.

There are a number of steps that can be taken to minimise fence-associated mortalities. Daily fence patrols increase the likelihood that animals caught on the fences are found and removed while still alive, greatly reducing mortalities. However, such patrols are often costly and impractical, and more passive mitigation measures are thus required. One such measure is a re-evaluation of fence configurations. Most fence specifications call for the lowest electrified

wire to be a maximum of 200mm above the ground, with or without a single-strand electric wire (trip-wire) offset 500mm horizontally from the base of the fence and set 200mm above the ground (NCDTEC, 2010). Initial evidence suggests that by converting the single-strand offset trip-wire or the bottom-most electrified wire to a two-strand or three-strand configuration, pangolin mortalities could be greatly reduced. Double and triple trip-wires have both a larger span (that is, the distance between the lowest and highest wires) and a greater overall height than standard single-strand trip-wires. The top-most and bottom-most wires are both live, while the middle wire is neutral, with wires spaced 100mm apart and starting 50mm above the ground. If a pangolin tries to breach the lowest wire, it gets shocked and has to withdraw before it can curl up. If it walks into the top-most wire, this wire is positioned to catch it high on the unprotected chest, resulting in the individual withdrawing slightly before rolling up. Both scenarios end with the pangolin safely curled next to the electric wire, rather than "hugging" it. This configuration also provides more adequate deterrence to other burrowing species such as large carnivores, aardvarks (*Orycteropus afer*), porcupines (*Hystrix africaeaustralis*) and warthogs (*Phacochoerus africanus*); all species that greatly increase fence maintenance costs and reduce overall efficiency by continually digging underneath fences.

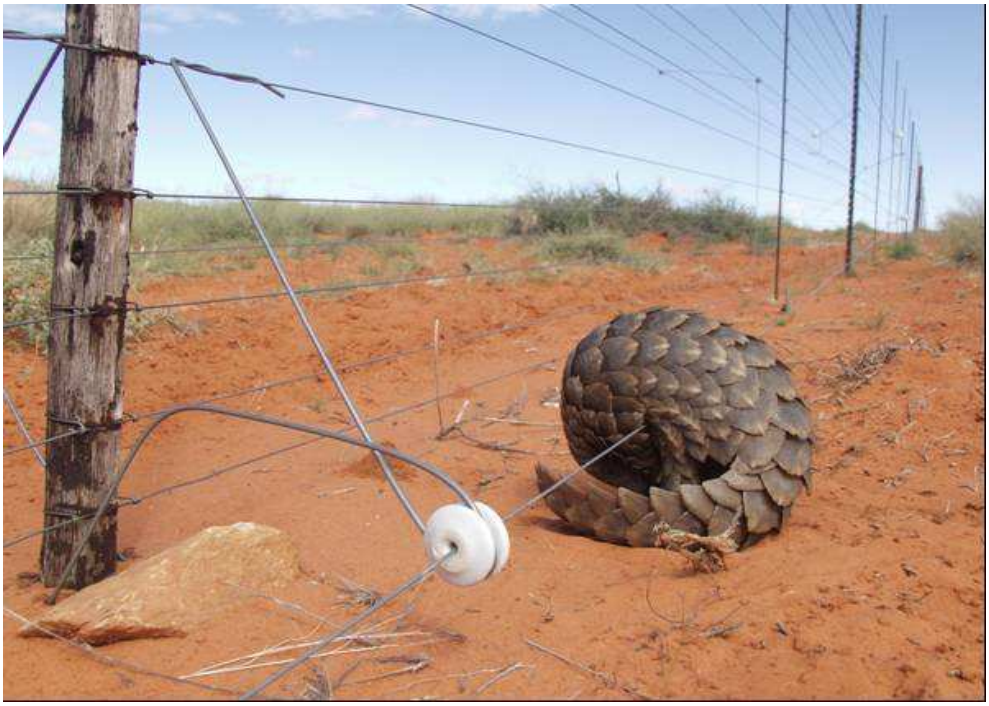


Figure 5.1.2. Pangolin death due to electric fence 'hugging' (Photo credit DW Pietersen)

Trials are currently underway to assess whether the two-strand or three-strand offset trip-wire is most efficient, but this is likely to vary between regions depending on the average size of the pangolins in that area. The span of the wires, and thus the overall height of the trip-wire, may also need to be adjusted, depending on the region. In regions where pangolins are larger trip-wires would need to be positioned at a greater overall height (with a

simultaneous increase in span) to ensure that pangolins are shocked higher on the chest, forcing them to withdraw before rolling into a ball. At present a double or triple trip-wire configuration ranging between 200-400mm in height is proving successful in reducing pangolin mortality at a site in the southern Kalahari. Increasing the height of the lowest live wire would also be a solution, but this has the negative result of decreasing the effectiveness of the fence by allowing animals to burrow underneath it, a particularly undesirable situation where large carnivores are involved.

Thus a simple conversion from a single-strand to a double- or triple-strand electric fence could potentially turn a standard electric fence into a pangolin-friendly fence, while also reducing fence maintenance costs and increasing overall efficiency, thereby creating a win-win situation for all.

Acknowledgements

I am indebted to Errol W. Pietersen and Professor Nigel C. Bennett for sharing their observations with me. Research in the Kalahari is being facilitated by Kalahari Oryx game reserve, and has been approved by the Northern Cape Department of Environment and Nature Conservation, permit no. FAUNA 016/2010.

5.2 Baboons and fencing in the Western Cape

O'Riain, M.J. & Hoffman, T.S.
Baboon Research Unit, Zoology Department, University of Cape Town, Private Bag X3, Rondebosch, 7701, South Africa.
Justin.ORiain@uct.ac.za and HFFTAL001@uct.ac.za

Baboons: successful survivors in the face of anthropogenic change

Of all extant African primates, baboons (genus *Papio*) are the most successful at adapting to large scale anthropogenic habitat transformation such as agriculture and urbanization. Their success is primarily attributable to their generalist diet, behavioural flexibility, diverse modes of locomotion, agility in traversing all manner of human made barriers (e.g. fences) and their ability to persist in areas (e.g. mountains) adjacent to agricultural land that are relatively inaccessible to humans and unsuitable for agriculture, mining and urban development. Thus baboons are not restricted to formally conserved areas and continue to persist and survive throughout sub-Saharan Africa, with some groups even thriving within densely populated urban areas such as the Cape Peninsula, South Africa (van Doorn, et al., 2010; Hoffman & O'Riain, in press).

Baboons and TFCAs – the potential for conflict

Baboons would nevertheless benefit from initiatives such as Transfrontier Conservation Areas (TFCAs) which aim to improve the overall movement of wildlife through space and thus improve population level dynamics. However, the challenge for TFCAs with regard to baboons will almost certainly need to focus on reducing the human-baboon conflict that may result when space between baboons and humans is reduced through, for example, the establishment of connection corridors. Currently baboons are regarded as pests in Uganda (Hill, 2000), Nigeria (Pepeh, 1996), Cameroon (van Oosten, 2000), Kenya (Strum, 1994), Tanzania (Mascarenhas, 1971), Malawi (Morris, 2000) and South Africa (Brown, et al., 2006; Kansky & Gaynor, 2000) and in some agricultural areas cause more crop damage than any other primates (Hill, 2000; Naughton-Treves, 1996; Tweheyoa, et al., 2005) as well as all other wildlife species (Biryahwaho, 2002; Naughton-Treves, 1998). While conservation initiatives such TFCAs are largely concerned with the removal of fences to improve the distributional range of wildlife and allow them to track ephemeral food and water resources in both space and time, the establishment of movement corridors may have the undesirable consequence of bringing certain wildlife species, such as baboons, into closer proximity with humans thereby increasing human-wildlife conflict.

Baboons navigating human modified environments

Mitigating human-baboon conflict that may be a direct or indirect result of TFCAs will necessitate an understanding of the spatial ecology of troops that are exposed to human-modified environments. This area of research has been extensively studied for the chacma baboons (*Papio ursinus*) of the Cape Peninsula which have effectively been forced into close proximity with humans as a result of their systematic displacement from the resource rich, low-lying land. That baboon even exist on the Cape Peninsula and throughout much of

the Western Cape today is largely due to the presence of mountains, which are unsuitable for either intensive agriculture or housing, and provide baboons with safe refuges. Direct competition with humans has resulted in wide-scale persecution of baboons as well as the investment of considerable time and money into determining the most successful and cost-effective methods of reducing spatial overlap between baboons and humans (Lee & Priston, 2005).

Central to the formulation of successful intervention methods is the understanding of how baboons traverse and use the complex mosaic of land types within the Cape Peninsula. In this review we will discuss the efficacy of different fence designs at restricting the passage of baboons into high conflict areas in addition to providing a brief overview of the potential impacts of fences on the spatial ecology of free living chacma baboons. Conventional fencing in both conservation areas (e.g. vertical supports and wire) and urban parks (e.g. palisade/bar fences) is never considered to be anything more than a brief impediment to the movement of baboons. Thus all serious attempts at restricting the movement of baboons using physical barriers, both out of conservation areas and sanctuaries/zoos and into designated exclusion areas such as farmlands, have focused almost exclusively on electric fencing. To date however, we know of no study that has used a scientifically rigorous, before-and-after approach to systematically quantify the success of fences in altering the movement patterns of baboons.

We used long-term GPS data (from both handheld GPS and GPRS collars) to track the movement patterns of baboons in three troops within the Tokai region of the Cape Peninsula. Tokai is an ideal study area for an investigation on the spatial ecology of baboons in relation to different land use practices and fencing as it includes large tracts of agricultural (vineyards and small scale farming practices) and urban (residential) land that is replete with a myriad of fence types including: solid structures (e.g. vibracrete walls), wire mesh fences, barbed wire fences, palisade/bar fences, a variety of electric fences and many combinations of the above (e.g. palisade with electrification).

Are there spatial barriers to the Tokai baboons?

Two years of GPS data collected on three troops revealed that the Tokai baboons have a strong preference for transformed, low lying land (Hoffman & O'Riain, in press) and frequent both the vineyards and residential areas abutting the Table Mountain National Park. As predicted baboons were not at all impeded by any form of conventional fencing (e.g. barbed wire, palisade, vibacrete, wire mesh) and moved effortlessly from natural land into both agricultural and urban areas (see Fig. 5.2.1). Furthermore, the baboons were able to negotiate a variety of electric fences including high tensile smooth wire electric fencing used either as a multi-strand fence from the ground to a height of 1.8m or as a small fence (e.g. 5 wires) placed on top of a solid fence or wall. Multi-strand high tensile smooth wire fences did temporarily impede troop movements into vineyards but in all instances these fences were eventually breached. Breaching was achieved by avoiding all contact with the fence or by successfully climbing the support poles and avoiding direct contact with the wires. The former was achieved by either going under the fence when using burrows excavated by other wildlife, or going over the fence by climbing trees that provided an overhanging branch.

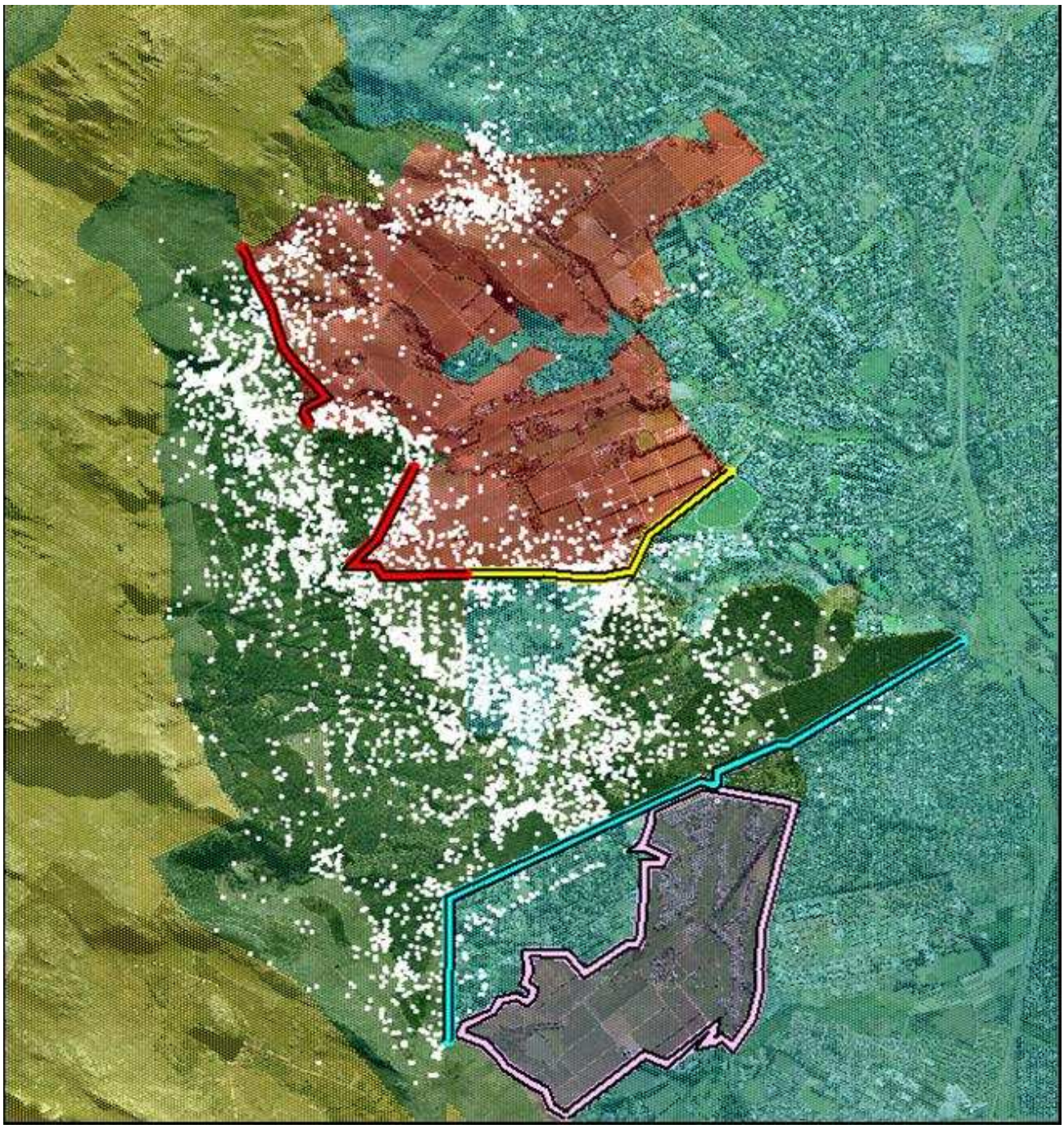


Figure 5.2.1. Baboon locations recorded over two years in relation to different fence types and land use practices within the home range of three Tokai troops. Each white dot represents a GPS data point of a baboon troop. The double lines of different colour represent different fence types (see legend) and the shaded areas represent the different land use types within the study area. The only portion of the low lying land that was not entered was the Mix/urban/vineyards that correspond to Steenberg Estate surrounded by electrified bar fencing.

Indigenous vegetation
Plantation
Vineyards
Urban
Mix Urban/Vineyards
Electrified bar fencing
Mixed residential fencing
Multi-strand electric fencing
Barbed fencing

On occasion baboons were also seen to run through multi-strand high tensile fences and suffer a shock when being chased out of the vineyards by farm workers (B.S. Kaplan, pers. obs.).

Only one fence within the entire Tokai region, Steenberg Estate, was found to be 100% baboon proof over the two year study period. This fence was a combination of 2.1m bar fencing with multi-strand high tensile smooth wires on either side. In addition the fence was secured at the base with a continuous concrete plinth that prevented entry by any burrowing animals and the top of the fence included a 5-strand overhang of high tensile wire that prevented scaling of the fence. The land within this estate represents a combination of both agricultural (vineyards) and urban land use practices both of which offer high quality nutritional rewards. Despite these incentives, no baboons were recorded breaching the fence. A similar fence design (see Fig. 5.2.2) has been used at the C.R.O.W. (Centre for the Rehabilitation of Wildlife) outside Barrydale in the Western Cape. They have successfully contained entire troops of baboons for a number of years whilst simultaneously preventing entry to wild baboons.

Figure 5.2.2. A 100% baboon -proof fence used at the C.R.O.W facility near Barrydale in the Western Cape. The concrete plinths in addition to the 6-strand overhanging high tensile smooth electric wires are essential design parameters for baboon proofing a fence.

The possible impacts of fences on baboons

Chacma baboons are social primates and females typically remain within their natal troops for the duration of their lives. Males by contrast are the dispersing sex and upon attaining adulthood most males will leave their natal troops and transfer to neighbouring troops or move further afield. It is thus probable that males will be more affected by barriers to movement and if these barriers are successful and permanent then it is likely that males will return to their natal troops or transfer into troops that their male relatives have already dispersed into. Both of these options increase the probability of inbreeding and with that pose the threat of increased susceptibility to infectious diseases and parasites. The Cape Peninsula baboons and the Tokai troops more specifically provide an

excellent example of a baboon population that has become geographically isolated from other baboons and consequently have reduced genetic diversity (Bishop, et al., in prep) relative to neighbouring populations without barriers to gene flow. Males frequently attempt to disperse from Tokai upon attaining adulthood and encounter dense urban development which effectively serves as an impenetrable barrier to their movement. These males often return to their natal area and have subsequently been observed to mate with females. Although paternity analyses have not been completed it is highly likely that close inbreeding is already common within the Cape Peninsula as a consequence of permanent barriers to dispersal.

The small home range of baboons relative to many social predators (e.g. wild dog (*Lycaon pictus*) and lion (*Panthera leo*)) translates into fewer instances in which entire troops are likely to move into new areas and encounter park boundaries and fences. However, dramatic ecological changes such as those resulting from large bush fires and changes in predator density within conservation areas may result in dramatic home range shifts and bring entire troops into contact with park fences. Given the magnitude of most existing and proposed TFCAs we would be surprised if it was economically viable to construct baboon proof fences around the entire perimeter. A more prudent approach would be to construct such fences along sections of the park boundary that would bring baboons into close proximity with any human settlements or farms. In addition baboon proof fences should be considered for human habitation within TFCAs to prevent baboons and other wildlife from learning that humans and their structures (e.g. kitchens and waste disposal areas) are a source of rich food resources. By preventing baboons deep within TFCAs from acquiring bad foraging habits (e.g. raiding) there will be less opportunity for dispersing males to transmit such habits to new troops that may live closer to park boundaries and thus be more likely to become chronic crop and our house raiders.

In summary, baboons with their ability to move fast and effectively over all terrains are probably the least likely of all wildlife commonly found within TFCAs to be adversely affected by fencing. Whilst this is good news for gene flow within populations that straddle park boundaries it is also the reason why baboons will continue to be regarded as a pest species by humans that live adjacent to conservation areas. While we have identified fences in the Western Cape that are 100% baboon proof we acknowledge that such fences are not only very costly to install but require considerable resources to maintain. It is for this reason that we would recommend the judicious use of such fences to prevent the learning of raiding within TFCAs (e.g. lodges and camping sites) and in areas where human activities such as crop farming are in close proximity to the home range of troops within a TFCA.

5.3 Mitigating the barrier effect of above-ground pipelines for moose (*Alces alces*) in northern Canada

Quinn, M.S. & Dunne, B.M.
Faculty of Environmental Design, University of Calgary, 2500 University Drive N.W., Calgary, AB, Canada, T2N 1N4,
quinn@ucalgary.ca

Introduction

Anthropogenic linear developments such as fences, roads, pipelines, railways and power lines contribute to habitat fragmentation when smaller, isolated patches of habitat are created as a result of the disturbance (Andren, 1994; Fischer & Lindenmayer, 2007; Reimers, et al., 2007; Benítez-López, et al., 2010; Fu, et al., 2010). Such disturbances reduce or prevent individuals from moving between patches of habitat and result in a barrier effect (Alexander, et al., 2005; Cushman, 2006). Habitat loss, reduced patch size, and more isolated habitat patches are the primary components of fragmentation. All of these result in lower biological diversity and altered ecosystem processes (Andren, 1994; Castelletta, et al., 2005; Hobbs, et al., 2008).

In northern Alberta Canada, deep deposits of bitumen occurring as oil sands are extracted by injecting steam into the heavy oil to increase viscosity. The warmed oil is then pumped to the surface where it is collected and transported for processing via an extensive network of above-ground pipelines. High and variable temperatures result in pipeline expansion and contraction, thus preventing the pipelines from being buried underground. The pipeline clearance (distance between ground and bottom of pipeline) is typically 1m, although this varies with topography. Pipelines generally consist of two or more parallel pipes 30–60cm in diameter separated by 50–200cm. The resultant horizontal barrier is two to several metres wide. Smaller gas lines and other cables may also be associated with the pipeline structure. *In situ* development and associated above-ground pipelines have the potential to cover 138,000km^2 of northern Alberta (Schneider & Dyer, 2006).

Species that display a low resilience to habitat fragmentation include those with life history traits such as late age of first reproduction, low population densities, low reproductive rates, large home-range requirements, and low fecundity (Weaver, et al., 1996; Van Wieren & Worm, 2001; Alexander, et al., 2004). Species that move over great distances to disperse, find food, and mate are also threatened by linear developments (Clevenger, et al., 2001; Ng, et al., 2004). Pipelines pose a significant barrier to moose as the largest mammal in the study area, with large home ranges, low reproductive rates, low population densities, and an extended period of parental care. Mitigating the effects of linear disturbances through the use of crossing structures is thought to have significant promise for lessening barrier effects (Glista, et al., 2009; Corlatti, et al., 2010). The purpose of the study was to evaluate pipeline crossing structures and elevated pipeline clearances as means of mitigating the effects of above-ground pipelines in areas of *in situ* bitumen extraction.

Methods

The study area consisted of a stretch of above-ground pipeline located 55km northeast of Peace River, Alberta (approximately 56° N and 117 ^{O} W). Winter snow tracking and remote cameras were employed for one year to monitor large mammal interactions with a 5.5km stretch of pipeline mitigated with five pipeline crossing structures and a 1.6km control area of unmitigated pipeline. Five earthen structures (mounded over the pipeline) were built 19.8–25.0m long with a height of 2.0–3.0 m. Width at the top of the structures ranged from 3.7 to 4.0m and width at the bottom of the structures was 11.9–14.9m. Elevated pipelines were defined as locations where the natural topography resulted in a pipeline clearance (distance between the ground and the bottom of the pipeline) of at least 180cm. Animal movements were classified as crossings (movement across the pipeline or structure from one side to the other), deflections (movement indicating a definite approach towards the pipeline or structure followed by a change in direction away) or parallel movements (movement parallel to the pipeline or structure). Approaches to the pipeline or structure were considered to be active attempts to cross, and were calculated by summing crossings and deflections for that species or location. More detailed methods are described in Dunne & Quinn (2009).

Results

Of the 86 moose track sequences observed in both study areas combined, 56 crossed the pipeline, 21 deflected away from the pipeline, and 9 moved parallel to the pipeline. Moose also crossed the control area pipeline more frequently and with a higher rate of success (77.1% compared to 65.5%) compared to the pipeline crossing structure area. Fewer moose deflections were observed along the control pipeline (20%) than the pipeline crossing structure area (31%). The mean pipeline clearance for the entire study area was 128.5cm while the mean pipeline clearance at moose crossing locations was 169.7cm (N = 56). The majority of moose crossings (43.5%) occurred at a pipeline clearance of 185–256cm. Although 84.8% of moose crossings occurred at locations with a pipeline clearance greater than 140cm, only 30.4% of the pipeline had a clearance over 140cm. The mean pipeline clearance where moose deflected from the pipeline over the entire study area was 110.7cm (N = 21). Locations where moose deflected from the pipeline occurred at significantly higher snow depths ($F(2,72) = 5.384$, $p < 0.01$) and further from water ($F(2,72) = 4.585$, $p = 0.013$) than moose crossing locations. Moose crossing sites occurred at significantly higher pipeline clearances ($F(2,72) = 16.948$, $p < 0.01$) than deflections or parallel movements.

Camera data indicated moose crossing the pipeline with a mean clearance of 190 cm (N = 47), ranging from 115 to 200cm again showing a clear preference by moose to cross at higher pipeline clearances. Cameras deployed to monitor activity at the crossing structures recorded 157 successful crossings by moose. Crossing success rate for moose at the structures was 88.2% based on total approaches the structures.

Discussion

Moose crossing sites occurred at significantly higher pipeline clearances than at deflection or parallel movement locations. In addition, pipeline clearance was the best predictor of moose pipeline crossing locations in both study areas.

This emphasizes the barrier effect that low pipeline clearances have on moose movement. These findings are consistent with Kansas & Raine (1988) and Golder Associates Limited (2000), where pipeline characteristics have a greater influence on pipeline crossing locations than environmental conditions.

The more frequent observation of moose in the control area, and the higher proportion of moose crossings at elevated pipelines, suggests that moose have become habituated to elevated pipeline locations, as found by Child (1973) and Young, et al. (1989). It is possible that the high number of successful pipeline crossings at elevated sections of the control pipeline (30 of 37) is due to one animal repeatedly using that area. However, the lower proportion of deflections along the control area suggests that moose have habituated to locations where they can easily cross underneath the pipeline. The higher frequency of moose crossings along the control area appears to be a result of proximity to moose habitat and water, along with moose habituating to elevated pipeline locations.

Conclusions

The current project indicates that above-ground pipelines constitute a barrier to moose movement. However, moose movement can be facilitated by constructing pipelines with a clearance of at least 140cm and/or by using pipeline crossing structures when this clearance is not met. Moose readily made use of crossing structures and appeared to use these features preferentially. The majority of pipeline crossings by moose (84.8%) occurred at locations with a clearance of at least 140cm. Small gas pipelines and steel cables are sometimes associated with above-ground pipelines and should be kept at the same clearance as the rest of the pipeline. A pipeline clearance of 140cm may not be sufficient during times of deep snow or flooding and the use of pipeline crossing structures or elevated pipelines should be used in these situations. A pipeline clearance of 140 cm can be achieved at existing pipelines by modifying the ground underneath (Young, 1989). Physically removing the soil beneath a section of pipeline will increase the clearance between the ground and the bottom of the pipeline, allowing wildlife to cross underneath. This is only feasible in dry locations; otherwise the excavated area may flood. The priority here is to create sections of pipeline that facilitate wildlife movement underneath the pipeline.

If pipeline mitigations must be placed near a road, they should be situated so that movement across the structure or under the elevated pipeline moves parallel and not directly perpendicular to the road. In addition, mitigation measures are most effective if placed in known movement corridors and areas of high habitat quality for the focal species.

The results of this project are the first to use longer-term quantitative data to assess the effectiveness of pipeline crossing structures in facilitating wildlife movement. This study found that pipeline crossing structures were utilized more frequently than elevated pipelines. In the 12 months following pipeline construction, these structures facilitated wildlife movement across the pipeline. Wildlife, especially moose, showed habituation to pipeline crossing structures and sections of elevated pipeline. This indicates that such mitigation efforts will likely be used more with time. The inclusion of pipeline crossing structures and elevated pipelines in future developments is essential to lessen the negative

impacts of habitat fragmentation. Our research provides quantitative information on wildlife interactions with above-ground pipelines and associated structures, with special attention paid to moose.

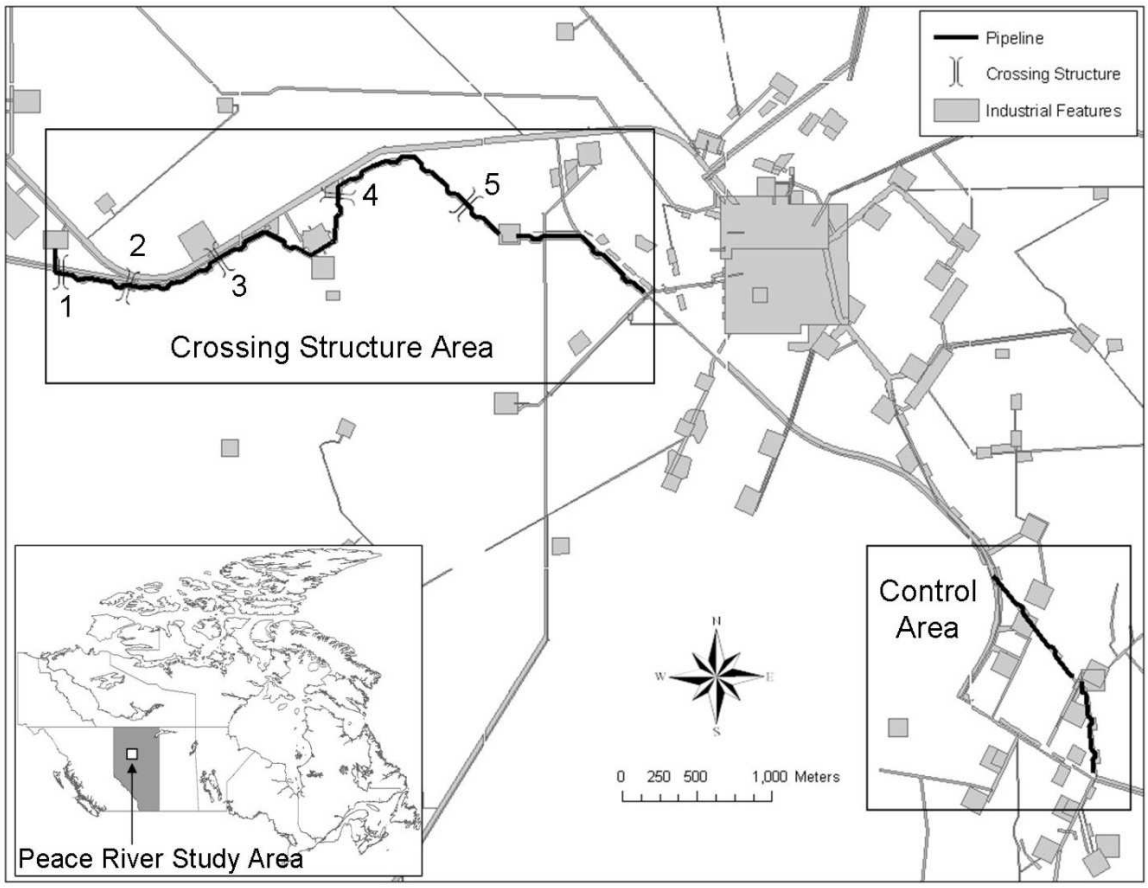


Figure 5.3.1. Study area

Figure 5.3.2. Newly constructed crossing structure (structures were subsequently vegetated)

Figure 5.3.3. Moose crossing under an elevated pipeline

5.4 Conservation fencing strategies in Australia

Hayward, M.W.
Australian Wildlife Conservancy, P.O. Box 432, Nichol's Point, Victoria, Australia; School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, Australia 2052; and Centre for African Conservation Ecology, Nelson Mandela Metropolitan University, P.O. Box 77000, Port Elizabeth 6031, South Africa.
Hayers111@aol.com

Introduction to fencing for conservation

Fences evolved in the Neolithic to separate resources from factors that threaten them (Kotchemidova, 2008) and, in a modern conservation sense, they work to separate biodiversity (resources) from threatening processes, such as habitat alteration, introduced species and persecution (Hayward & Kerley, 2009). Indeed, the IUCN (2009) lists ten key threatening processes in its Red List of Threatened Species, and eight of these can be managed via the use of conservation fencing (Hayward & Kerley, 2009). For example, fencing has been used to stop human disturbance of bat roosting colonies (Tuttle, 1977), to stop human overhunting of reintroduced mountain gazelles *Gazella gazella* (Dunham, 2001) and to stop retributive persecution of marauding megaherbivores and predators (Gusset, et al., 2008; Hayward, 2010; Whitehouse & Hall-Martin, 2000).

Conservation fencing in Australia

Fencing is a fundamental tool in the arsenal of New Zealand conservation managers with dozens of highly threatened species being successfully conserved in fenced reserves that are free of introduced species (Burns, et al., 2010). Fencing is an expensive strategy, however despite this privately funded fenced reserves outnumber government funded fenced reserves in New Zealand (Burns, *et al.,* 2010). The private sector has led the way in innovative conservation strategies in southern Africa (Slotow & Hunter, 2009). It also seems that private/non-government conservation agencies are taking up conservation fencing at a relatively greater rate than public conservation agencies in Australia.

National parks in Australia are frequently fenced to keep livestock out. The primary threat to biodiversity in southern Australia (and probably northern Australia too), however is rarely competition with livestock but rather is predation by introduced red foxes *Vulpes vulpes* and cats *Felis catus* (Burbidge & McKenzie, 1989; Dickman, 1996) and stock fences do nothing to keep these species out. Broad-scale poisoning campaigns have been successful in reducing the density of foxes, thereby allowing a population response of native fauna (de Tores, et al., 2004; Mawson, 2004), until cat numbers increased via mesopredator release and led to declines in species previously considered secure (Orell, 2009).

Public conservation organisations in Australia recognise the value of eradicating introduced predators. Islands, such as Bernier and Dorre (Fig.5.4.1), were the last refuges for species, such as western barred bandicoots *Perameles bouganville*, and numerous native species have been reintroduced to these feral-free areas (Short, et al., 1998; Short & Turner,

1999). Northern quolls *Dasyurus hallucatus* were removed from the Australian mainland before the arrival of invasive cane toads *Bufo marinus* to ensure they were not driven completely extinct (Rankmore, et al., 2008). Islands are considered valuable conservation resources in Australia (Dickman, et al*.,* 1992).

The narrow necks of several peninsulas have been fenced and the area freed of introduced predators in Australia. Heirisson Prong, near Shark Bay, Western Australia (Fig. 1), was fenced and introduced predators were eradicated as part of a CSIRO research program in association with the local community that led to the reintroduction of burrowing bettongs *Bettongia leseuer*, greater stick-nest rats *Leporillus conditor* and western barred bandicoots (Richards & Short, 2003; Short & Turner, 2000). The Venus Bay peninsula has also been relatively successful as a restoration site following fencing and partial feral eradication.

Two non-government organisations have taken to fencing areas and eradicating introduced species in Australia. Arid Recovery is a joint conservation initiative between BHP Billiton, the local Roxby Downs community, the South Australian Department of Environment and Heritage and the University of Adelaide, and involves a 60km^2 fenced area that is free of foxes and cats and where numerous threatened species have been reintroduced (Fig. 5.4.1; Moseby & O'Donnell, 2003; Moseby & Read, 2006).

The second non-government organisation that recognises the value of fenced reserves is the Australian Wildlife Conservancy (AWC), Australia's largest private conservation landowner with 22 wildlife sanctuaries spanning 2.5 million hectares. Three of these sanctuaries have completely feral-free fenced areas (264 ha at Karakamia; 1,100 ha at Yookamurra, and 8,000 ha at Scotia; Fig. 5.4.1) and another (Paruna) forms a corridor between adjacent government conservation areas and is therefore only partially fenced. Bounded by a 2m high floppy-top fence incorporating 3 electric strands with a skirt to dissuade burrowing species from digging out, these sites have had numerous species reintroduced (Table 5.4.1). AWC also own and manage Faure Island (Fig. 5.4.1), where introduced species have been eradicated and boodies, western barred bandicoots, Shark Bay mice *Pseudomys fieldi*, and banded hare-wallaby *Lagostrophus fasciatus* have been successfully reintroduced (Short, 2009).

Conclusions

It is critical to separate fences designed for conservation purposes from those designed for other purposes. Botswana's veterinary fences (Gadd, 2010; Mbaiwa & Mbaiwa, 2006), Australia's 'Dingo' fence (Caughley, et al., 1987) and the US – Mexican border fence are not designed for conservation purposes and, not surprisingly, offer little benefit for conservation and are often conservation problems. Even fences that are designed for conservation but are ineffective through poor construction or maintenance, like the Peron Peninsula, can offer little benefit for conservation because the threatening processes within have not been adequately controlled (De Tores & Marlow, 2010).

Effectively constructed and maintained conservation fences, such as those at Scotia, Karakamia and Arid Recovery are invaluable for conservation however. These sites support some of the few populations of woylies that have not declined in recent years (Hayward, et al., 2010; Orell, 2009). Similarly, they are amongst the last refuges on mainland Australia for bilbies, boodies,

numbats, greater stick-nest rats, bridled nailtail wallabies and mala (Table 5.4.1). This success would not be possible without the use of conservation fencing to exclude red foxes and feral cats from within the reserves.

There remains an aversion within Australian government conservation agencies to fencing conservation areas (De Tores & Marlow, 2010). The current strategy of controlling foxes by broad-scale poisoning campaigns was initially successful until the reduction in fox densities allowed cats to increase via mesopredator release and led to rapid declines in native fauna (De Tores & Marlow, 2010). It is also inevitable that foxes will evolve tolerance or immunity to the poisons used, as rabbits *Oryctolagus cunniculus* already have (Twigg, et al., 2002). The key question for Australia's conservation managers is which will arise first: the evolution of introduced predator avoidance strategies by native fauna or the evolution of tolerance to poisons by foxes and cats. New suggestions of using dingos as mesopredator suppressors of cats and foxes may reduce the latter's densities and thereby delay their extinction, but is still a conservation strategy aiming to achieve a post-1778 conservation benchmark (Hayward, 2009).

In Australia, an ideal conservation scenario would be for a substantial (4,000 ha +) fenced and introduced species-free area in the core of all national parks with animals released outside the fence to areas that are protected by broad-scale poisoning campaigns when they become overabundant within. This would offer the best chance for native fauna to evolve strategies to cope with the onslaught of introduced predators, while ensuring they persist in the environment. In essence, this would be following the lead of conservation managers in New Zealand, where the threat from introduced species is even greater.

Table 5.4.1. Mammal species successfully reintroduced to non-government reserves in Australia

Common name	Scientific name	Arid Recovery	Faure Island	Karakamia	Paruna	Scotia	Yookamurra
Bilby	*Macrotis lagotis*	X				X	X
Boodie	*Bettongia leseuer*	X	X			X	X
Woylie	*Bettongia penicillata*			X	?	X	X
Numbat	*Myrmecobius fasciatus*	[a]		F		X	X
Mala (rufous hare-wallaby)	*Lagorchestes hirsutus*					X	
Bridled nailtail wallaby	*Onychogalea fraenata*					X	
Greater stick-nest rat	*Leporillus conditor*	X				X	F
Black-footed rock-wallaby	*Petrogale lateralis*				X		
Banded hare-wallaby	*Lagostrophus fasciatus*		X				
Shark Bay mouse	*Pseudomys fieldii*		X				
Tammar wallaby	*Macropus eugenii*			X	X		

X – successful reintroduction
F – failed reintroduction
[a] male only reintroduction to determine the presence of suitable habitat (termites).

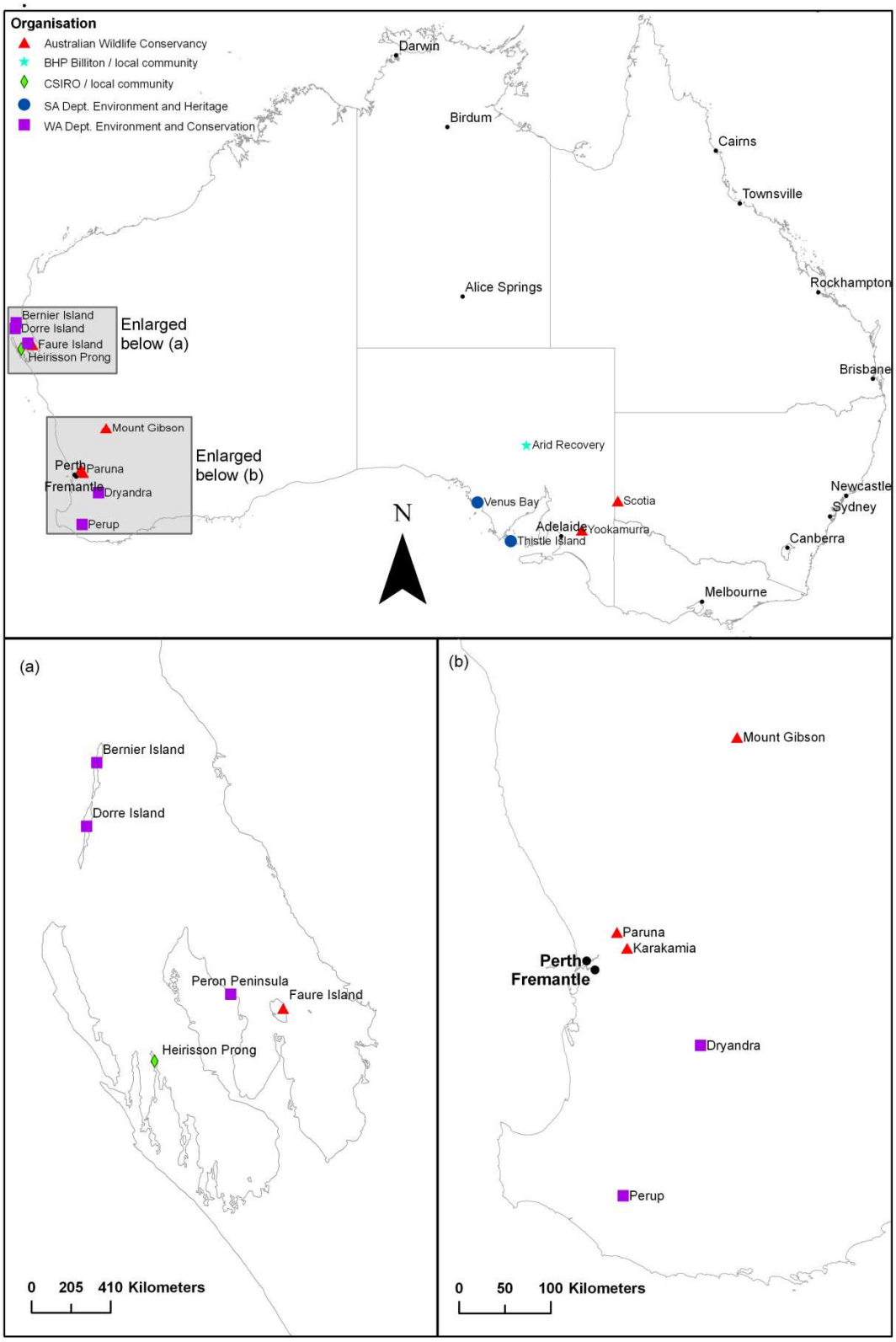


Figure 5.4.1. Location of the fenced reserves mentioned in the text.

5.5 Elephants and fencing conflicts in the GLTFCA and KAZA TFCA

Ferguson, K.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
selousgame@hotmail.com

Chase, M.
Elephants Without Borders and San Diego Zoo's Institute for Conservation Research, P.O. Box 682, Kasane, Botswana
er@info.bw

Introduction

African elephants (*Loxondonta africana*) are a 'keystone' fence species (Ferguson, et al., 2010). Their size and intelligence allows them to circumvent most types of fencing (Grant, et al., 2007), but it is also true to say that they have become a *de facto* flagship species when it comes to determining the potentially beneficial connectivity between various parts of a Transfrontier Conservation Area (TFCA). This section illustrates two very different problems with regards to elephant-fence interactions. The first case from the Kruger National Park's (KNP's) western boundary fence (Ferguson, et al., 2010) is based on the premise that elephants cannot be allowed to destroy this disease control fence that separates wildlife from the high human density settlements and their livestock that are found on the parks border. In the second case, in the Kavango-Zambezi (KAZA) TFCA, Chase and Griffin (2009) and Cushman, et al., (2010) have been determining how large elephant populations in northern Botswana can be allowed to disperse across large swathes of the newly proposed TFCA and how fences are obstructing this proposed meta-population redistribution.

Elephant movement rules

General rules governing the movement and landscape selection by African elephants are slowly being elucidated largely due to the development of more sophisticated telemetry devices. Chase & Griffin (2009), Loarie, et al., (2009), Thomas, et al., (2008) and Cushman, et al., (2010) have presented good evidence that park and veterinary fences in southern Africa (in addition to civil war and other human perturbations) have had a major impact on the traditional movement patterns of African elephant populations. Particular concern is given by these authors, to the excision of this species' wet season ranges as affected by the erection of fence barriers. In East Africa the use of fencing has aided the rapid privatisation of rangeland and has had a major impact on elephant and wildlife distribution (Okello & D'Amour, 2008). But fencing has also proved at this interface to be ineffective at controlling human-wildlife conflict and indeed in some cases even engendering human-human conflict (Okello & D'Amour, 2008).

The coarse scale spatial rules that define elephant movement across landscapes are likely to be primarily predicated on seasonal and rainfall parameters. Surface water availability often presents the best predictor of seasonal range use (Harris, et al., 2008; Smit, et al., 2007a; Cushman, et al., 2010). At a finer spatial scale movement may be linked to landscape

topography, such as avoidance of hills (Wall, et al., 2006 and corridor linkages (Douglas-Hamilton, et al., 2005), direct and indirect conflict with humans (Dublin & Hoare, 2004; Sitati, et al.,2003 Graham, et al., 2009; Knickerbocker & Waithaka, 2005), sexual dimorphism in feeding behaviour (Stokke & du Toit, 2002) and even the ecophysiology of temperature thermoregulation (Kinahan, et al., 2007). Bulls home ranges are larger and more overlapping than mixed herds and the movement rules for adult males may be dictated by water availability, male-male competition and searching for receptive females (Smit, et al.,2007b; Hoare, 1999).

Kruger National Park/ GLTFCA Case Study

Ferguson, et al., (2010) highlighted that elephants represent a unique 'threat' to sustainable fencing along KNP's western boundary fence. The degradation of game fences often is due not only to a consistent lack of maintenance and resources but also due to increasing pressure by elephants. Whilst, in the case of veterinary fences, the species that many of these fences are designed to exclude is primarily buffalo (*Syncerus caffer*) (due to their multiple role in disease transmission), buffalo are almost always of very little importance in terms of causing damage to the fence in comparison with elephants. In the last decade it has been suggested that at least four of KNP's six outbreaks of foot-and-mouth disease (FMD) along the western boundary may be attributed to buffalo crossing fences aided by elephant facilitation via fence breakages (R. Bengis, pers. comm., September 2008). However, another hypothesis is that buffalo are not managing to escape through the fence by using elephant fence breaks as such breaks may be mended too quickly for buffaloes to locate these breaks by chance (F. Jori, pers. comm., March 2010, and it is more likely that they primarily escape from the park by crossing the diffuse and structurally weak fencing that exist along the many watercourses that bisect the fence line.

The impacts of FMD outbreaks are serious in terms of cost and the potential banning of exports. Egypt has only recently lifted its beef import ban on South Africa which dates back to 2000 due to an FMD outbreak in that year (Ghoneim, et al., 2010; SABC3 News, March 2010). The salient fact is often forgotten that it is a relatively simple behaviour, such as elephants physically pushing over fences to reach some resource that triggers off a series of economic and political events. Therefore, elephants can be determined to be a 'keystone' fence breaker. The KNP western boundary fence largely adjoins 'bull enclave' areas (Ferguson, et al., 2010; Smit, et al., 2007a). Habitual fence challengers in this setting are therefore likely to be almost always bull elephants. The 'sub-population' of elephants whose home ranges adjoin the fence is relatively small (data from ear-notch identification files), but this 'cohort' is also likely to be continually replaced after lethal incidents (approximately 10 bull elephant deaths reported during the study period) caused by humans.

The reasons for this study area being a predominantly 'bull area' are not clear. It may be in part due to a sexual dimorphism in elephant physiology, with cow/calf groups being limited by such factors as water or forage or because the area represents an anthropogenic danger to elephants due to lethal control measures. It is also possible that bull home ranges, and movements vary widely due to social pressures induced by hierarchy and musth (Wittmeyer, et al., 2008). The processes which drive elephants to cross the fence (it is debatable that the short-time they seem to spend outside, should be termed part of their 'home range') are therefore multi-factorial and seasonal. Osborn & Parker (2003) contend that in the case of crop raiding, elephant bulls exit

protected areas when the quality of the available forage declines below the level of the quality of the crop species grown outside of the area.

In the case of KNP, it has been long suggested that a seasonal peak in elephant 'excursions' (defined as a repeated series of short-term movements out of the park) is caused by the marula (*Sclerocarya birrea*) fruiting season and this implies that the number of mature female trees that fruit was higher in density outside of the park (R. Bengis, pers. comm., August 2008). This differential may be mainly due to elephant damage of the tree population within the park and perhaps also to differential fire regimes across the boundary preventing seedling recruitment (see Gadd (2002) for more information on tree damage estimates).

Our research has shown, from line transect data inside and outside of the KNP boundary (Fig. 5.5.1), that a tree density differential does exist on either side of the fence and that the February-March peak of elephant movements out of the park is likely to be driven by the availability of this seasonal resource. This result suggests that elephant-induced mortality of marula trees inside the park act as a driver of short-term elephant excursions. Presumably, as the park's elephant population has increased so has the mortality of marula trees within the park.

Ferguson, et al. (2010) found that the ratio of marula trees (of all age classes surveyed) found in compared with directly outside of the fence was approximately 1:4 and that twice the numbers of trees outside of the park fence showed no signs of presumed elephant damage compared with those inside the park (Fig. 5.5.1). The high incidence of fence permeability due to elephant breaks and the evidence from our marula transects accords well with the marula fruiting season. This is further evidence to add to that of Helm, et al. (2009) who state that marula could face local extinction within KNP and its environs. Local extinction is likely to be related to the actions of elephant and fire, but, we suggest a population 'nursery' may exist directly outside of the park boundary. The higher number of marula trees outside relative to inside the park suggests either that fences in the past have worked and they have only recently become highly permeable (due to the park wide floods of the year 2000) or that an increase in elephant numbers has led to a segment of the 'risk-prone' population seeking out the last of these resources on the other side of the fence.

This observation could lead to an interesting management scenario. The rate of elephant induced fence breakages during the peak of the marula season could be reduced by encouraging local people to pre-harvest the fruit and to store and ripen it for later use (F.V. Osborn, pers. comm., December 2009). Another alternative is to deter fence breakages by the selective culling of identifiable 'habitual' elephant fence breakers or to deploy non-lethal mitigation methods, such as direct protection of the fence by chilli pepper or indirect protection by aversion therapy by 'shooting' elephants with 'pepper balls' (Lamarque, et al., 2008).

A second hypothesised 'excursion peak' in winter has yet to be detected by our data but it has been suggested that the primary resource 'capture' in this case seems to be water (R. Bengis, pers. comm., August 2008.). Grant, et al. (2007) showed that in the winter of 2005 up to 35 elephant fence breaks per day occurred along a 12km stretch of the western fence where presumably the elephants were breaking out to drink in one of the few remaining pools in the Klein Letaba River.

The closure of boreholes within the park over the last several decades may have led to recent increases of fence challenges by elephants (and possibly lions) in order to access water sources outside of the KNP (D. Keet, pers. comm., November 2009.). It has also been suggested that a density-dependent effect occurs in terms of increasing annual rates of fence damage and excursions (Grant, et al., 2007). This hypothesis will remain untested until such time that the Kruger fence monitoring system (Ferguson & Jori: 6.1) has accumulated substantial data and that this can be directly related to the results of elephant censuses. However, our marula density results suggest indirect evidence of a density-dependent effect.

Grant, et al., (2007) make the assumption that the marked increase in elephant numbers in KNP since the end of the elephant cull (1995) has led to an increase in the levels of fence damage by this species. How likely is this hypothesised density-dependent causation? Certainly an increase in the number of elephants sighted per kilometre of fence should be a cause for concern, but the available data are inadequate to determine the reasons underlying the increased incidence of fence breaks, especially since 2000. Density independent factors such as the floods of 2000 were largely claimed to be responsible for the disabling of the recently up-graded electric fence and thereafter fence maintenance could not keep pace with the high levels of elephant fence destruction. In addition, theft of fence components was also a factor in the long-term degradation of the fenceline.

We caution, as does Hoare (1999), of suggesting that a greater density of elephants necessarily translates to a higher number of fences breaks. An indirect density dependent effect may be operating however, in that if problem bull fence breakers are responsible for the majority of breaks then a larger population size will contain a greater number of the habit-forming cohort and recruitment into the latter will be greater. Therefore an increase in habitual fence breakage (mainly by bull elephants) could be an indirect result of one or a combination of other factors including (i) more bulls being available and younger being 'taught' to break by older bulls, (ii) younger bulls avoiding an increased number of musth males and/or an increased number of musth males searching more widely, (iii) bulls seeking other essential resources e.g. forage and water, and (iv) dominant herds forcing sub-dominant herds to the periphery of the protected areas boundary (Wittmeyer, et al., 2008).

Increases in elephant density, climatic changes (Ogutu & Owen-Smith, 2003) and floods (D. Keet, pers. comm.) can have impacts on both species movement and fence damage. Further, elephant management control options (lethal and non-lethal) may also alter excursion patterns that could be detected by the monitoring system proposed by Ferguson, et al. (2010). These data, when analysed over-extended periods of time, could be used to adaptively manage fences damage and its causes with optimal effect.

The management of KNP must determine how they wish to try and control their fence breaking elephants. Options are wide and could include the culling of known habitual individual offenders, the targeted culling of the habitual 'cohort' or adopting trial non-lethal measures as part of the overall elephant reduction impact plan or even more desirably a 'boundary management plan' that takes into account the desires of all bordering stakeholders.

Fencing and the redistribution of elephants in the KAZA TFCA

In conservation terms the main aim of the removal of fences in the GLTFCA and KAZA TFCA centres around allowing the previous high build up of elephant

numbers to spread out (facilitated dispersal) to other countries, and thus it is hoped, to avoid the culling due to overabundance impacts (Cushman, et al., 2010; but see Skarpe, et al., 2004). The elephant corridors that have been identified in the Kruger study area may mark the 'gateways' through fences and the interconnectedness between the nation states that form the TFCA. It should be noted that an 'elephant corridor' need not be synonymous with a 'wildebeest corridor' (or any other migratory species), though some species overlap will occur and that gauging the extent and placement of major corridors, through the maze of fences, based on the largest and most mobile species is probably the most parsimonious way forward. Indeed Cushman, et al., (2010) have attempted to create a species-specific landscape resistance model for elephants within key parts of the KAZA TFCA. These authors point out that precise spatial records of elephant movement pathways 'allows direct assessment of the influences of landscape features' on such movement, and therefore on the optimal placing of these corridors. The removal of a 30km section of the Caprivi-Botswana border fence has allowed some elephants to move through this gap from northern Botswana and re-distribute themselves over a wider area including Angola that has fewer elephants than Botswana (Fig. 5.5.2). The large range sizes of these elephants (and the straight line distance that they can cover) mean that key fences do indeed restrict movement and block recolonisation from the source population. The partial or full removal of fences therefore becomes a key strategy in the facilitated dispersal of the northern Botswana elephant population.

Cushman, et al. (2010) analysing the satellite telemetry data gathered by *Elephants Without Borders* found that the autocorrelation of elephant movements is long-term, complex and seasonally related. Movement resistance models (based on elephant movement pathways) can be used to allow the direct assessment of landscape selection of this species and illustrate the impediments (e.g. variables such as roads, rivers fences, towns, villages and subsistence huts) to such movement across the landscape surface (Figs. 5.5.3 & 5.5.4). However, the relationship between elephant movements and these hypothesised impediments may vary with the spatial scale that is considered. The spatial co-variation of the variables (for example the locations of human settlements and water are linked) further, each factorial variable needs to be statistically 'weighted' against the others (and combinations of variables). The conclusion of this work was that the maximum landscape resistance due to settlements was equal to that of fences (examples of a 'virtual' and a physical barrier respectively). Water effects seem to dominate landscape selection at the broadest spatial scales but are 'highly subordinate to settlement and fence effects at fine spatial scales' (Cushman, et al., 2010). In the case of northern Botswana the inter-relationship between defined borders, rivers and veterinary fences protecting the country from transboundary animal diseases are likely to be highly correlated, and that this leads to veterinary fences having a dominant impact on landscape connectivity for elephants in this area.

Acknowledgements

The KAZA TFCA elephant telemetry study was made possible with funding from the Zoological Society of San Diego, the Rockefeller Family Foundation, Mr. and Mrs. Brett Warren, the Malashock Family Foundation, Mutual & Federal Insurance Company Botswana, the Seattle Foundation, Linda & Bob Bradley, the Bester Family and Conservation International. The Governments of Angola, Botswana, Namibia and Zambia are thanked for allowing us permission to

conduct this study. We are grateful for the support and encouragement of J. Hanks, L. Braack, H. Kolberg, B. Beytell, T. Uahengo, C. Taolo, and Kelly Landen. Ken Ferguson's research in the Kruger National Park was supported by generous grants from WWF-SA (Project ZA-1490) and the USFWS (Project Afe-0401). He thanks all those who assisted with his work in the park and especially Drs. Dewald Keet and Roy Bengis and Messrs. Louis Olivier and Albert Machaba.

Figure 5.5.1. Fence incident distribution for elephant in relation to marula tree distribution and density within 24x1km transects in the Kruger NP study area (October 2008– July 2009).

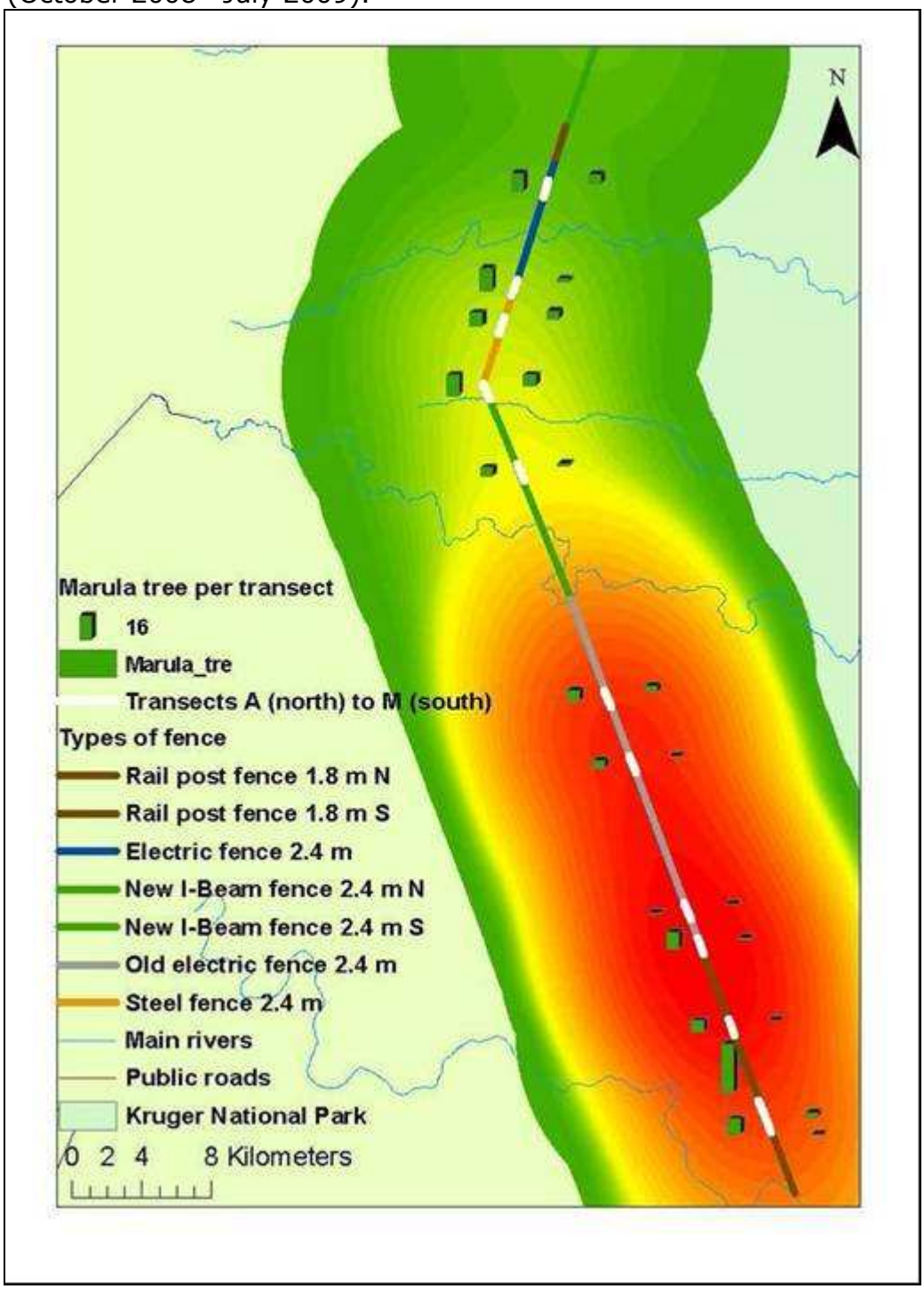


Figure 5.5.2.Human settlements in relation to fencing in part of the KAZA TFCA.

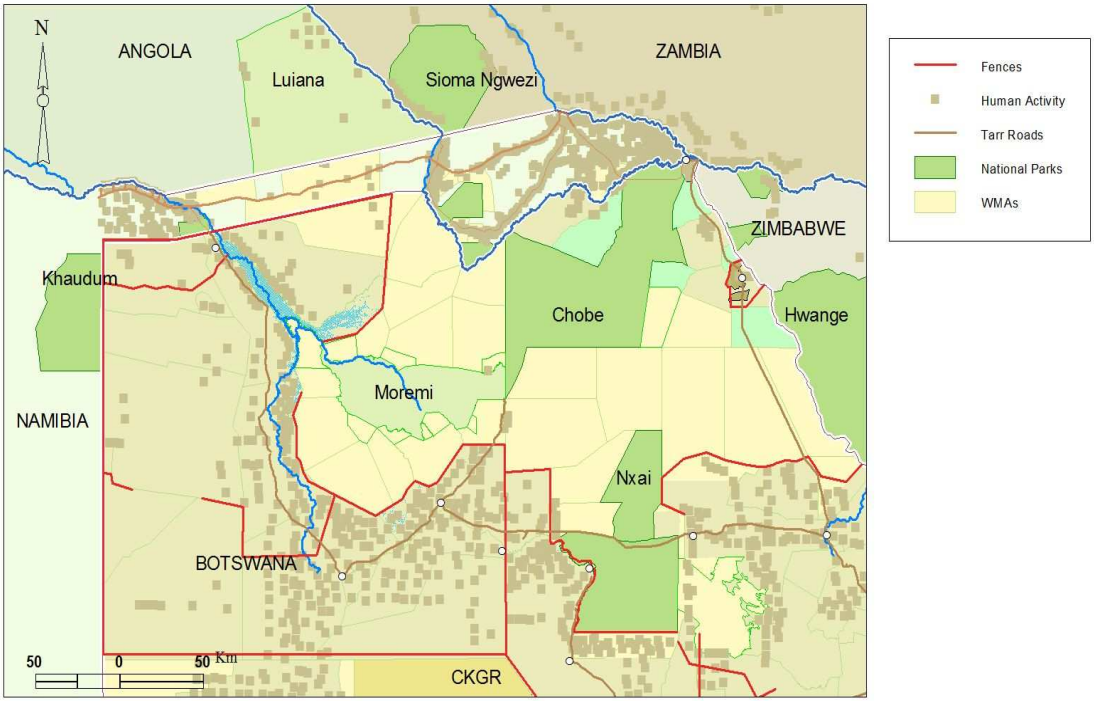


Figure 5.5.3. The movements of nine elephants in relation to fences in part of the KAZA TFCA.

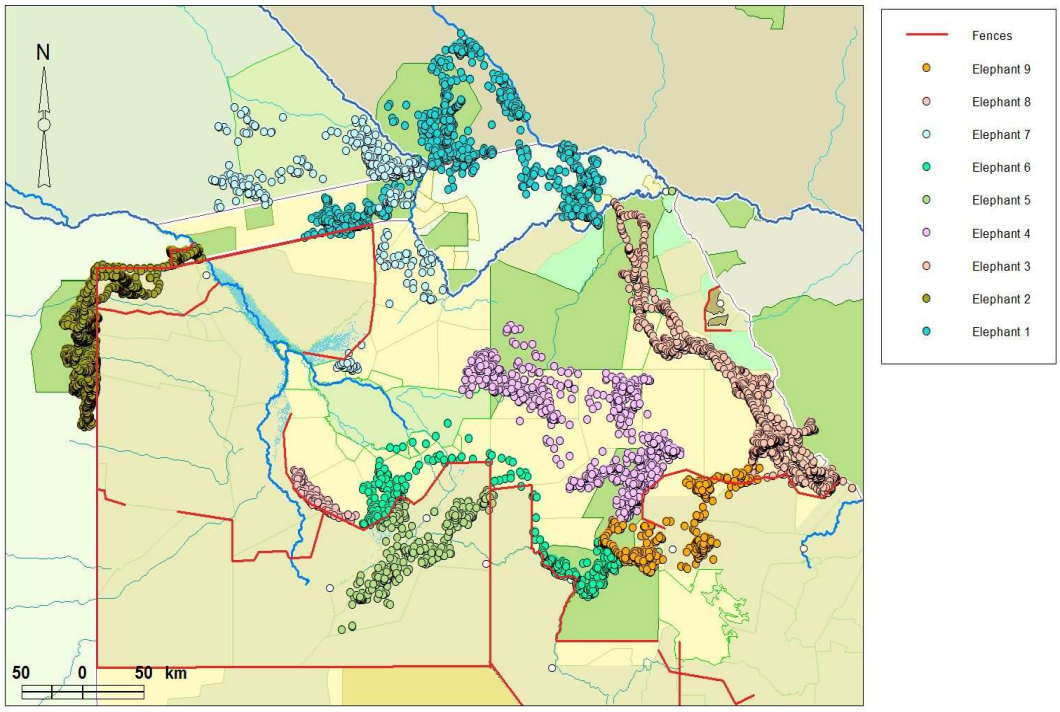
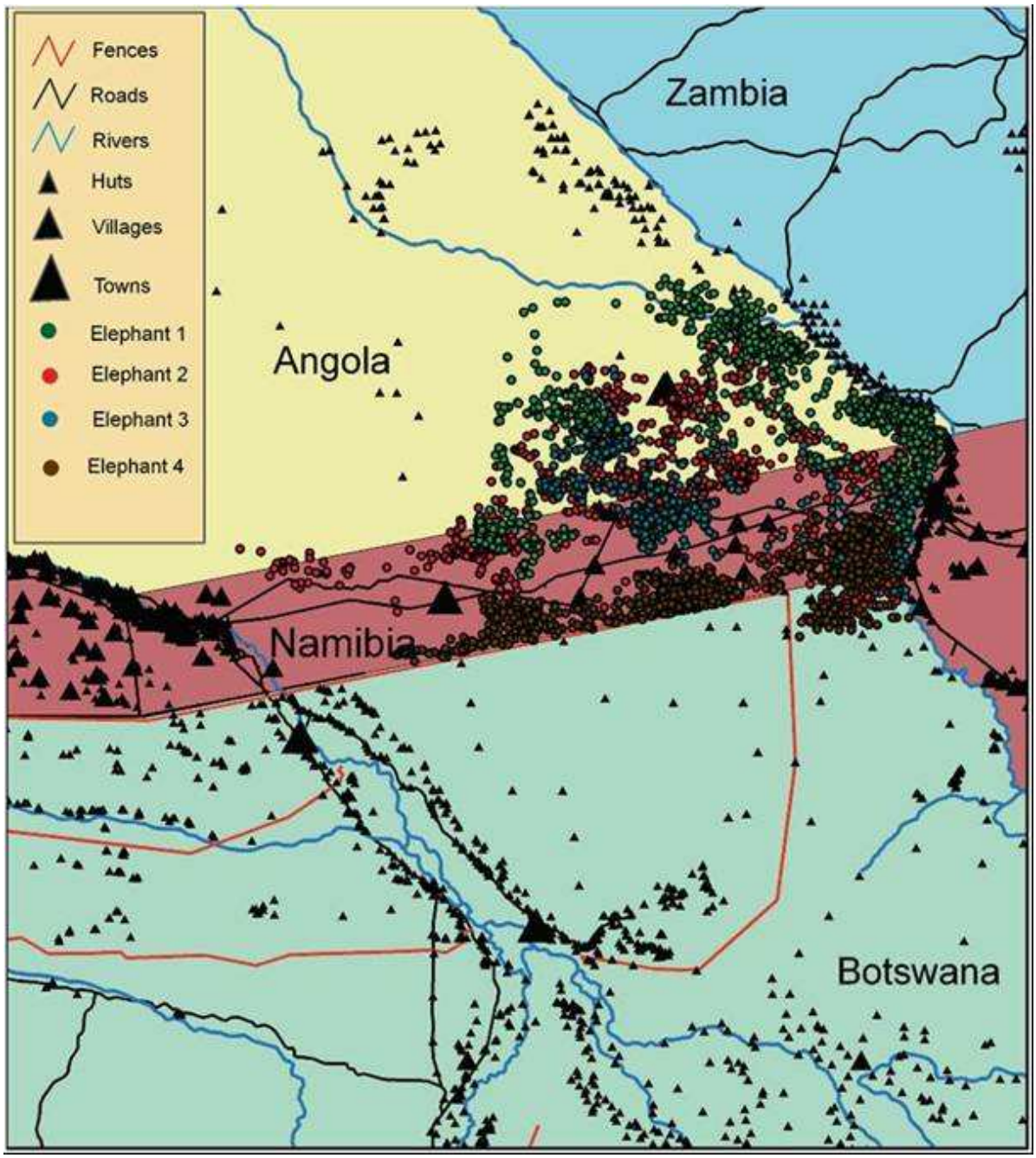


Figure 5.5.4. Map showing the KAZA study area and landscape features used in the resistance hypotheses (fences, roads, rivers and settlements) and the locational data for each of the four elephants included in the analyses of Cushman, et al., (2010; reproduced with permission from page 352, Cushman, et al., 2010)



5.6 Kruger's elephants and fences: possible mitigation strategies

Grant, R.
Systems Ecologist, SANParks Scientific Services, Kruger National Park, P.Bag x40, Skukuza 1350, South Africa.
rinag@sanparks.org

Introduction

In order to decide on the most efficient approach to the management of fences it is essential to have a clear understanding between the stakeholders of the purpose of these fences. Next, the authorities that are responsible for the maintenance of these fences have to be in agreement on this purpose and make sufficient funding and personnel available for their maintenance. Elephants (*Loxodonta africana*) in particular are difficult to restrict with fences as a result of their large size and the ease with which they can break fences. They are capable of going through the most sophisticated barriers, including fences that are highly electrified, although fence breakages are in these cases often associated with a break in the electric current, implying that good fence maintenance is essential to avoid elephant moving out of the protected areas.

To be able to mitigate elephant movements across fences, it is important to understand the reasons for their movement. An increase in elephant density has certainly been listed as a possible cause and there seems to be a spatial and temporal correlation between elephant densities and the number of fence breaks (Gillson & Lindsay, 2003; van Aarde & Jackson, 2007). However, these high densities are in the first place a result of the limitation of elephant movement due to these fences. The elephant population of Kruger has almost doubled between 1995 and 2009 and more fence breakages would therefore be expected. The second important reason for fence breakages is the pursuit of alternative forage and water resources (Buss, 1961). Bulls tend to be more inclined to break fences than females (Sukumar & Gadgil, 1988).

Limiting movement across fences by manipulating water distribution

Water is one of the most important controlling factors of elephant distribution and population numbers (Chamaillé-Jammes, et al., 2007; Redfern, et al., 2003; Smit, et al., 2007; Stokke & Du Toit, 2002). Surface water manipulation has therefore been proposed as a 'non-intrusive and natural' management tool with which to alter elephant distribution patterns (Owen-Smith, 1996; Chaimaillé-Jammes, et al., 2007; Chaimaillé-Jammes, et al., in press). However, considering the mobility of elephants (Viljoen & Bothma, 1990; Verlinden & Gavor, 1998), it is arguable how effective surface water manipulation will be to manipulate elephant distribution in areas like the Kruger National Park (KNP), where water is usually widely available (South African National Parks, 2005; Owen-Smith, et al., 2006; Redfern, et al., 2005; Smit et al., 2007a). In KNP, for example, the landscape-scale dry season distribution of mixed herds and breeding herds is more closely linked to the river system than to the artificial waterhole network, which tend to be more preferred by bull groups (Smit, et al., 2007b). However, there is anecdotal evidence of the elephant moving into the private protected areas to access water in the dry season. If there are suitable water resources outside the

fenced areas, elephant are highly likely to break the fences to access these water-points.

Disturbance as a way to deter elephants

Sensitive habitats, provided they are small enough, could in theory be protected against elephant damage by applying various direct disturbance methods. Such methods usually rely on a combination of loud noise and bright lights to scare away elephants. A wide variety of methods, ranging from traditional practices such as banging drums to 'elephant drives' using vehicles or aircraft, have been experimented with in different parts of Africa (Balfour, et al., 2007) but the effect is limited because they soon become habituated (Hoare, 1995; O'Connell-Rodwell, et al., 2000; Osborn & Rasmussen, 1995), especially if the same animals are regularly involved (Hoare, 1999). As the KNP is a protected area, with no permanent human inhabitants along the fences, disturbance by human interference is not a very feasible option. Alternative approaches such as trip alarms could be considered. O'Connell-Rodwell, et al., (2000) experimented with trip alarms in villages in East Caprivi, Namibia. They found these alarms to be effective over shorter fences in the short-term, but there was no impact on the overall number of conflict incidents as elephants first moved into alternative areas and eventually became habituated.

Massive disturbance (e.g. people, vehicles and/or helicopters) to drive elephants away from a conflict area is also an alternative and may have some immediate, although short-term, success (Hoare, 2001). There is very little evidence to support the hypothesis that shooting an elephant as 'an example to others' is effective at keeping elephants out of an area Osborn (1998).

Changing behaviour as a management tool

(Grant, et al., 2008) discusses the possibility of changing the behaviour of elephant as follows: Elephants are intelligent animals capable of learning, and these attributes may be used to influence their distribution. This is currently a very active area of behaviour and ecosystem management research (Provenza, et al., 2003; Provenza & Villalba, 2006; Davis & Stamps, 2004; Provenza, 2003; Provenza, 2007). This research is based on the fundamental understanding that all animal behaviour is based on the consequences of their experience: positive consequences increase and negative consequences decrease the likelihood of behaviours recurring.

Strategic hunting

Strategic hunting either in the buffer areas adjacent to the fence or a buffer area along the fence in KNP may be a promising solution. Hunting can have significant and lasting impacts on the movement and distribution of game animals (Conner, 2002; Viera, et al., 2003). As an example of this approach: elk (*Cervus canadensis*) were hunted in locations where they were not wanted, such as the former feeding areas, and they were not hunted in areas where they can stay. On a ranch in Utah, USA both bull and cow elk migrated to lower elevations on the eastern portion of the ranch in winter. Since the cow elks were harvested in a single hunt (where 86 animals were hunted) the cow elk have not migrated to lower elevations for the past 20 years (until snow forced them down). Bull elk, which were not hunted in the lower elevations of the ranch, have continued to migrate to lower elevations earlier in the cold season.

Grant, et al. (2008) report that field experience assessed that a minimum of three years typically are required to change the behaviours of long-lived social

animals. The first year is the most difficult, as none of the adults has any experience with the new system. The second year is better because all those involved have a year of experience with the new system and the animals that were unable to adjust to the new system have been weaned. By the third year, all of the adults have two years of experience with the new system and young animals born into the new system are becoming members of the herd. In behaviour-based management, people become agents of change over time in animal cultures. Social organisation of the animal's leads to culture, which includes the knowledge and habits acquired by ancestors and passed from one generation to the next about how to survive in an environment (De Waal, 2001).

Similarly, extended families with matriarchal leadership may provide a means for changing elephant behaviour. Efforts could be focused on individual families, and given the importance of the matriarch in behaviour of the family, specific efforts might be directed at the matriarch of each family. It may be best to test how to train elephants using a variety of techniques with a small number of families. Long-term mother-daughter associations should lead to the learning behaviour being transferred thus limiting the time needed to train the animals to avoid certain areas (Douglas-Hamilton, 1973; Moss & Poole, 1983).

Repellents

Although chilli extracts are an attractive repellent because *Capsicum*-based products are non-toxic and environmentally friendly, these have to be applied regularly or sprays have to be applied to deter approaching elephant. Elephant's advanced olfactory and memory capabilities make them suitable for aversion conditioning (Osborn & Rasmussen, 1995; Osborn, 1997) and have been evaluated particularly in Zimbabwe where the objective was to protect crops belonging to rural populations that adjoin nature reserves or where elephants have caused extensive damage to crops (Osborn & Parker, 2002 & 2003). Research has shown the effectiveness of chilli extracts as a spray, and when administered upwind of elephants, the response by the elephants was more rapid than traditional methods, resulting in prompt withdrawal from the crops without aggression (Osborn, 2002).

Sonic barriers

The use of sonic barriers are an attractive alternative for deterring elephants from entering demarcated areas in KNP as it is non-invasive and relatively easy to maintain once the appliances have been installed. Such high-frequency sound devices have already proved effective in preventing motorists from colliding with wildlife. In Australia vehicles are fitted with devices that provide a safety sound zone of 400m and 50m either side of the vehicle (http://www.shuroo.com/). As humans cannot hear the sound emitted by these sonic barriers and as they are not visible, such techniques may prove to be effective and aesthetically appealing when controlling elephant movements in particular areas.

Conclusion

According to SANParks' policy of adaptive management and learning by doing, these different approaches should be experimented with along the fences, where there is evidence of elephant movement as described by Ferguson & Jori (this volume). From this experience the most appropriate management for each area should be selected. This approach will ensure adaptability and

evaluation, and should avoid a system where one policy is followed even when not effective.

5.7 The use of electrified fences to mitigate human-elephant conflict: experiences from the Laikipia Plateau in northern Kenya

Graham, M. & Ochieng, T.
Laikipia Elephant Project, The Symbiosis Trust, P.O. Box 174 Nanyuki, Kenya, 10400.
lerp@wananchi.com

Introduction

Human-elephant conflict (HEC), in particularly the problem of crop-raiding, is increasingly recognised as a significant problem in rural Africa wherever people and elephants share space (Hoare, 2000). Farmers are rarely, if ever, compensated for their losses and so they often retaliate by injuring or killing elephants (Thouless, 1994; Sitati, et al., 2003; Graham, 2007). The associated political and media interest in the problem, and the spreading culture of intolerance, present a considerable challenge to the conservation of elephants in the wild (Lee & Graham 2006). For these reasons it is critical to identify effective solutions for the management of HEC.

Electrified fences are a major tool used in the management of HEC (Hoare, 1995) and are often perceived by communities and some wildlife managers as the final solution. However in practice the effectiveness of fences in controlling crop-raiding varies widely. Elephants can adapt to new fence features, creating an expensive "arms race" between managers and elephants and while some fences are effective there are many that have failed at preventing elephants from raiding small-scale farms (Thouless & Sakwa, 1995).

This paper describes experiences with the use of electrified fences to mitigate HEC on the 10,000km^2 Laikipia Plateau in north-central Kenya. The Laikipia Plateau represents a natural laboratory for studying electrified fences for the mitigation of HEC as it contains no formally designated protected areas, is home to Kenya's second largest elephant population (>7,000 animals), has some of the highest levels of crop-raiding in East Africa and contains many different types of electrified fences constructed and managed in different ways by different large-scale ranch owners and their development partners (Fig. 5.7.1). This paper assesses the performance of the use of fences to mitigate human-elephant conflict by two different large-scale ranches in Laikipia.

The first of these is the Ol Pejeta Conservancy, covering 370km^2 in southern Laikipia and surrounded to the south, east and west by small-scale farming and large-scale ranches to the north. Ol Pejeta Ranch combined commercial cattle ranching with wildlife-based tourism for over twenty years though did not generate sufficient revenue to adequately address the severe problem of human-elephant conflict on the surrounding small-scale farmland. In 2004 this changed when the property was bought by an international conservation NGO and converted into a conservancy with significant resources made available for managing the problem of crop-raiding by elephants on the surrounding small-scale farms. The second fence assessed in this paper is along the boundary of Mutara Ranch which covers 263km^2 and neighbours Ol Pejeta to the north-west.

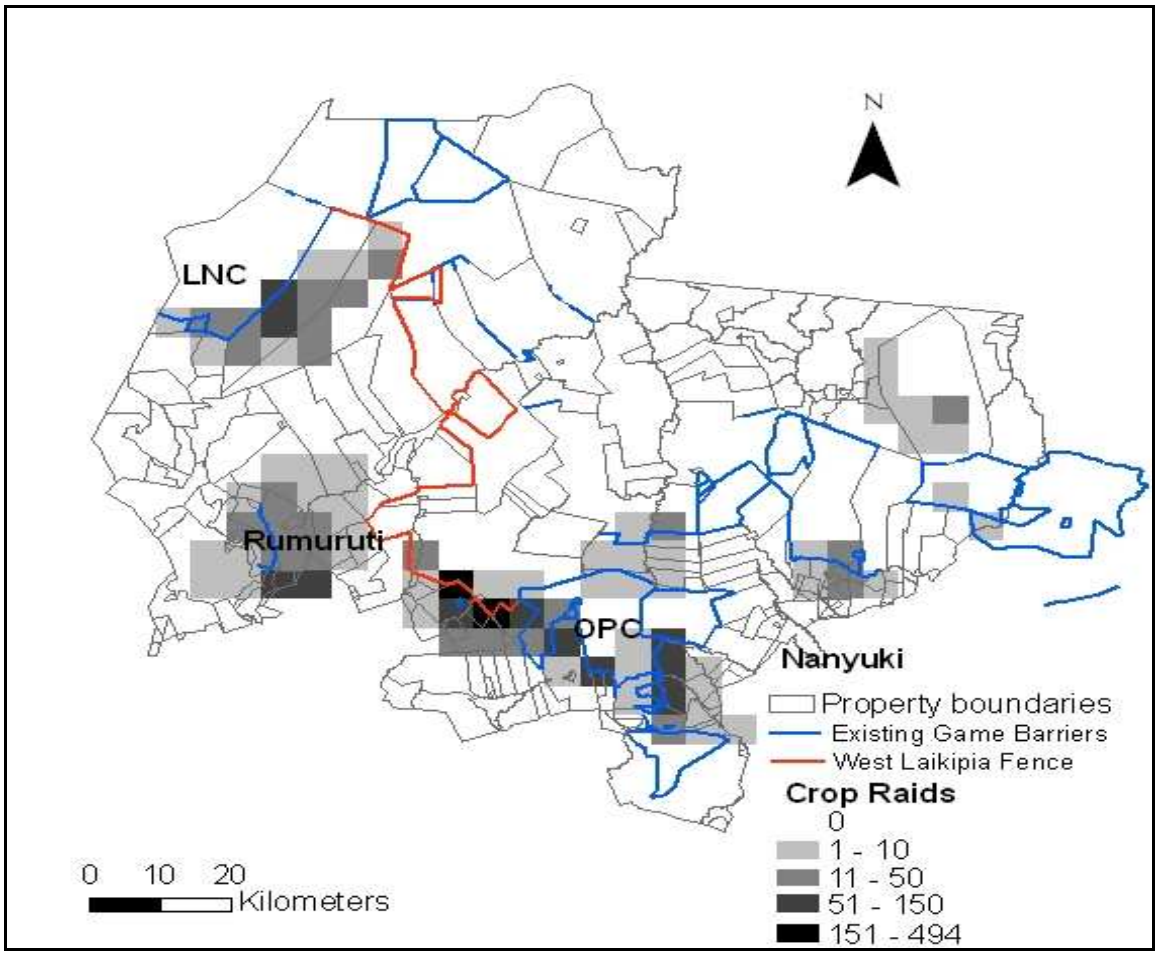


Figure 5.7.1 Crop-raiding in Laikipia between 2003 and 2004, existing game barriers and the proposed West Laikipia Fence.

Mutara Ranch is owned by the Agricultural Development Corporation (ADC), a Kenya Government Parastatal which operates agricultural schemes across the country. ADC's principal aim with owning and operating Mutara Ranch is with the management and maintenance of indigenous breeds of cattle. Like Ol Pejeta crop-raiding by elephants on cultivated smallholder land south of Mutara Ranch has been a major problem for more than twenty years. In 2008 the Laikipia Wildlife Forum (a local conservation NGO) and the Kenya Wildlife Service (the government wildlife authority) supported ADC to construct an electrified fence along the southern boundary of Mutara Ranch. The fence along Mutara Ranch is just part of a longer 163km fence that is being constructed across West Laikipia, along the contiguous boundaries of several large-scale ranches, to address the problem of human-elephant conflict (Fig. 5.7.1).

The Performance of the Ol Pejeta Fence

In 2009 a detailed assessment was undertaken of the impact of the Ol Pejeta Conservancy's management interventions on human-elephant conflict (Graham, et al., 2009a). This assessment is summarised here. Prior to 2006 Ol Pejeta Ranch was surrounded by a simple five foot stock fence with the top wire electrified. The exception was the eastern and southern boundaries of the ranch where a more elaborate ten foot fence was constructed with either five or six live wires. These fences were primarily constructed to prevent elephants from leaving the ranch onto small-scale farms. However there were 107

incidents of fence breaking recorded in the 12 month period between March 2005 and February 2006 with pressure highest along parts of the eastern and western boundaries. As a consequence crop-raiding by elephants among the surrounding small-scale farms was intense, with 692 crop-raiding incidents recorded by trained enumerators within 1.6km of the perimeter boundary of Ol Pejeta Ranch over this period.

In 2006 the new owners of Ol Pejeta Ranch invested over US one million dollars to upgrade the 129km perimeter fence which was completed at the end of February 2006. There were two principal strategies adopted in the design of the new perimeter fence. Firstly concerted efforts were made to ensure fence voltage was maintained above 7kv. This was achieved by ensuring an energiser did not service more than 7km of fence line and that the perimeter fence was systematically patrolled and monitored, with a single fencer assigned to each 7km fence section. Secondly, where pressure from elephants was greatest, outriggers were added to fences. Outriggers are one metre lengths of high tensile wire attached to one of the electrified wires of the fence, approximately one metre above the ground so that they project outwards at a forty-five degree angle perpendicular to the fence and facing into the direction of elephant pressure. These are placed along the area of pressure at one metre intervals. Along one section of Ol Pejeta's eastern boundary, where elephant pressure was particularly high, an additional single short fence with outriggers was constructed in front of a ten strand electrified fence, effectively creating a double fence.

Over and above the fence upgrade, the newly established Ol Pejeta Conservancy also put in place a rigorous system of fence "enforcement". This system was comprised of two components. The first of these was a rapid response team that patrolled the fence line and aggressively drove away any elephants approaching the fence using a vehicle and spot lights. This team also immediately repaired the fence if it was broken. The second component of this system was the identification and monitoring of persistent fence breaking elephants by a specially trained researcher, with information entered into a 'problem elephant database'. Fence breaking incidents could then be assigned to a known individual elephant. The elephants involved in fence breaking were invariably bulls. Seven persistent fence breaking elephants identified were subsequently euthanized by the Kenya Wildlife Service.

The impact of the fence upgrade and subsequent enforcement of Ol Pejeta's perimeter fences was dramatic, with the total number of fence breakages reduced to just 27 incidents and crop-raiding on the surrounding small-scale farms reduced to 392 incidents, over the 12 months between March 2006 and February 2007. While the latter may seem high, crop-raiding east of Ol Pejeta became negligible and most of the crop-raids recorded in fact occurred to the west of Ol Pejeta and were mainly attributed to elephants moving off the neighbouring Mutara Ranch which was not fenced at the time, rather than breaking out of Ol Pejeta Conservancy (Fig. 5.7.2).

The success of the change in approach to elephant management taken by the newly established Ol Pejeta Conservancy was illustrated by the change in movement patterns of resident fence breaking elephant, Kimani, fitted with a GPS collar recording hourly positions.

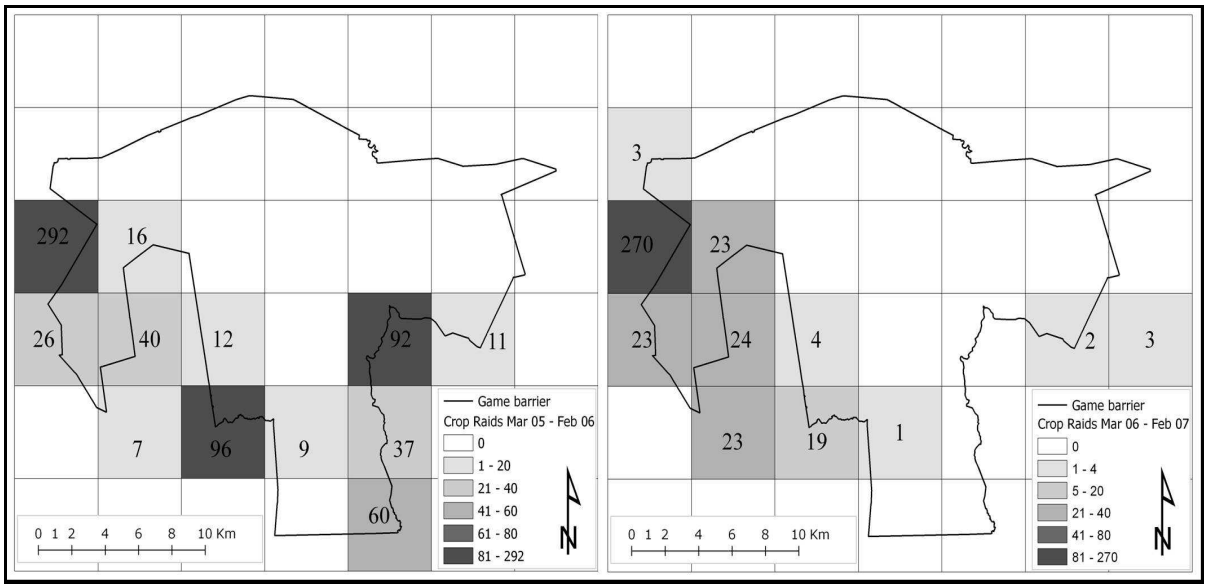


Figure 5.7.2. Crop-raiding on small-scale farms around Ol Pejeta a year before and a year after a major fence upgrade and associated enforcement system were put in place.

Prior to the upgrade of Ol Pejeta' perimeter fences and the associated system of fence enforcement that was put in place, Kimani spent 12% of his time outside of Ol Pejeta, predominantly on small-scale farms to the east and south. After the fence upgrade and enforcement measures were put in place, Kimani spent just 1.36% of his time outside of Ol Pejeta (Graham, et al., 2009a).

The Performance of the Mutara Ranch Fence

In May 2008 a seven foot fence, with five electrified wires, was constructed along the southern 31.6km boundary of Mutara Ranch which neighbours the Ol Pejeta Conservancy, to the north-west. This was part of a much larger 163km fence constructed in West Laikipia by the Laikipia Wildlife Forum to help alleviate human-elephant conflict in the area. Prior to construction, ADC committed in writing to maintaining and managing the Mutara Ranch section of the West Laikipia Fence project

As soon as the fence was constructed along Mutara's southern boundary elephants began to break it. There were a total of 498 breakages by elephants recorded by trained enumerators over the 12 month period after the fence was constructed. Crop-raiding on the neighbouring small-scale farms also remained high, with 1809 incidents recorded on these farms the year before fence construction and 990 incidents, the year after.

There were a number of factors that probably contributed to the poor performance of the Mutara section of the West Laikipia Fence compared with the Ol Pejeta Conservancy fence. Firstly fence voltage was relatively low, often below 5kv. Secondly it was very dry over the first year that the fence was constructed and there were many pastoralists who moved into this area in search of pasture for their livestock. These pastoralists vandalised the Mutara Ranch perimeter fence so as to gain access to grass for their livestock. Vandalised sections were often not repaired quickly and this compromised fence voltage making it easier for elephants to break the fence. Thirdly, there was a lack of commitment among the employees of Mutara Ranch to actively patrol and maintain the electrified fence so when it was broken it was

sometimes left in a state of disrepair for a day or more. Fourthly because there have been a range of different designs of fences on Ol Pejeta over the last twenty years or more, there exist a large number of bull elephants in the area that have become habituated to electric fences and are therefore willing to challenge them. With no enforcement of the Mutara Ranch fence there was no risk to elephants that challenged it. Elephants used their tusks and feet to break fence posts (Fig. 5.7.3).

Figure 5.7.3. Fence breaking elephant using his trunk and foot to push over a fence post; Laikipia Elephant Project, 2009.

Lessons learned

Electrified fences, in their own right, do not represent a solution to HEC. At best they represent the thin edge of a wedge of a particular type of adaptive and flexible management approach that can mitigate HEC to tolerable levels if properly implemented. This management approach must be based on an understanding that a critical factor shaping elephant movement outside of protected area, among the mosaic of the land-use types that comprise elephant ranges across Africa and Asia, is risk (Graham, et al., 2009b). Therefore for fences to be effective as a barrier to elephant movement they must represent a real or perceived risk of injury or mortality to elephants. Clearly the level of risk that needs to be created in association with a fence will vary depending on the rewards to elephants associated with fence breaking (such as access to crops). Here we suggest that once the level of risk associated with a fence goes above a certain threshold, only the occasional bull elephant will be involved in fence breaking. This is because in elephant society bull elephants are high risk-takers, explained by the male behaviour hypothesis among large polygamous mammals (Sukumar, 1991; Hoare, 2001). The case of the Ol Pejeta Conservancy and Mutara Ranch electrified fences illustrate the consequences, in terms of the number of fence breaking incidents, associated with different levels of risk represented by fences. By creating and maintaining a fence with voltage up at around 7KV or above and

by adding elephant 'proofing' components such as outriggers, the number of elephants that continued to persistently challenge the Ol Pejeta perimeter fence was confined to a small number of males that could easily be identified and monitored. Once these animals were eliminated then levels of crop-raiding dropped to very low levels. The results presented here reinforce the conclusions drawn from an assessment of game barriers in Laikipia by Thouless & Sakwa (1995) that the management of fence breaking elephants to demarcate fences as 'no-go zones' may be as important if not more important than fence design in making fences effective.

With the Mutara Ranch fence, poor design and maintenance, the damage caused by local pastoralists and little or no fence enforcement activities resulted in there being little risk to elephants that challenged the fence. As a consequence elephants became habituated to and learned to break the ADC Mutara Ranch fence, much in the same way that elephants are known to become habituated to farm-based deterrents where there is little real risk of injury or mortality to the elephants involved (Osborn & Parker, 2003).

While the cases studies discussed here may illustrate the factors that are important for making electrified fences effective it is also important to note that this isn't easy to achieve. The Ol Pejeta Conservancy spent over US$ 1 million to upgrade its perimeter fence (almost $8,000 per km) and a further $147,000 per annum on fence maintenance and enforcement. Furthermore the Ol Pejeta Conservancy is one of the best resourced conservation estates in Africa with considerable management capacity so it is able to experiment with new fence configurations and deploy mobile rapid response teams in a multi-pronged management approach on an ongoing basis. Clearly these sorts of resources are not available to managers and local communities in many if not most human-elephant conflict situations. However highly sophisticated fences are not necessarily a requirement for creating an effective elephant barrier. The same simple five strand electrified fence constructed along Mutara Ranch's boundary was also constructed along the southern boundary of the neighbouring Kifuko Ranch to the west of Mutara. However the managers of the Kifuko Ranch added several energisers so that the voltage of the fence was maintained at above 8kv. They also rigorously enforced the fence by driving away and harassing any elephants that approached the perimeter of the ranch. As a consequence the Kifuko Ranch section of the West Laikipia Fence has been broken by elephants just 17 times in 21 months (since June 2008), further illustrating that voltage, systematic monitoring, maintenance and enforcement are as important as fence configuration in determining fence performance.

In conclusion, on the basis of our experiences in Laikipia we strongly recommend that wildlife managers, landowners, small-scale farming communities, government departments and their donors ensure that the following issues are considered before committing to fencing as an option for the mitigation of HEC:

1) *Ownership.* The fence must be effectively owned with clear and unequivocal responsibility for fence maintenance and management accepted by a specific stakeholder or stakeholder group.
2) *Support.* The fence must be strongly supported by the neighbouring communities for whom it is being built and this support must be secured prior to fence construction. These communities must be partners in fencing projects as they represent future custodians of the fences that are to be

constructed. Such support should be demonstrated through commitments of in kind labour for ongoing fence maintenance and management if not direct financial support.

3) *Resources.* It must be clear what is required for ongoing fence maintenance and management and the associated costs prior to fences being constructed. If those who are taking responsibility for a fence are unable to secure these resources on an annual basis fencing should not be considered as an option.
4) *Design.* Fences should be constructed to achieve a voltage above 7kv. If elephants learn to break fences with such high voltage then elephant proofing of vulnerable components, in particular posts, should be attempted at particular pressure points. Outriggers have helped in the case of the Ol Pejeta Conservancy fence and electrified loops around exposed parts of fence posts may also be worthwhile adding to a fence to make it more 'elephant proof'.
5) *Enforcement.* Elephants must associate breaking fences with risk beyond just an electric shock. This can be achieved by patrolling fence lines in the early evenings and scaring away any elephants that appear to want to challenge the fence. If fence breaking continues to be a problem then the identification and management of persistent fence breaking elephants must be available as an option for the purpose of fence enforcement. We believe that the case of the Ol Pejeta Conservancy demonstrates that lethal control of persistent fence breaking elephants can greatly enhance the overall performance of an electrified fence. However our experiences in Laikipia suggest that other persistent fence breaking elephants will replace those that are removed and so it is likely that elephants will need to be identified and euthanized on an ongoing basis. This is unlikely to involve more than a few elephants on an annual basis (Thouless & Sakwa, 1995). For example since the initial elimination of seven fence breaking elephants on Ol Pejeta Conservancy in 2005, just three more fence breaking elephants have been destroyed (less than one a year). While this may be ecologically sustainable, clearly there are ethical implications with this fence enforcement option that may arouse controversy among some donors and development partners making implementation problematic. Furthermore the skills required to humanely euthanize an identified problem elephant are not always available given the decline in hunting skills within the wildlife sector in many African countries. Non-lethal tools for fence enforcement, such as de-tusking and the use of smart GPS 'early warning' collars are being trialled in northern Kenya and may represent alternatives in future. Translocation of problem elephants has also been used in the past (Omondi, et al., 2002). However it has yet to be demonstrated conclusively that these non-lethal options are effective alternatives to lethal control for the enforcement of electrified fences. Furthermore the resources required to use these tools may be beyond the reach and therefore unviable for most fencing projects. Therefore for the sake of protecting the livelihoods of small-scale farmers, lethal management of identified fence breaking elephants will need to be an option for fence managers working to alleviate human-elephant conflict until such a time that viable non-lethal options are identified. The latter should be the focus of further research.

Acknowledgements

This study was funded by the UK Darwin Initiative for the Survival of Species (grant no 15/040) and the Laikipia Wildlife Forum. Bill Adams of Cambridge University made this study possible. We are grateful to Batian Craig of the Ol Pejeta Conservancy and Moses Litoroh of the Kenya Wildlife Service for ongoing technical advice and institutional support. We are also grateful to Anthony King of the Laikipia Wildlife Forum for his continual support and commitment. Njenga Kahiro, David Wanjau, Joseph Wahome and Nelson Mbuguro all helped to collect data on fence breaking and crop-raiding.

5.8 A discussion of possible non-lethal methods to deter elephant damage to veterinary and game fences

Osborn, F.V.
Elephant Pepper Development Trust, Hout Bay, Cape Town, South Africa
Loki_osborn@gmail.com

This contribution is a discussion piece on possible areas of research for non-lethal methods to reduce fence-breaking by elephants (Fig. 5.8.1). While fences remain an important management tool in Africa and address a range of issues from veterinary cordons to restricting the movement of large mammals into areas of human settlement, the trend is to pull them down and create 'mega-parks'. Finding alternatives to the 'hard edges' fences create should be the aim of practitioners but until that is achieved, methods for reducing conflicts around fences need to be sought. Elephants are responsible for most fence breakages in southern Africa and the main method to address this has been to shoot the individuals responsible. Thousands and thousands of elephants have been shot as 'fence breakers' (e.g. Graham, 1973; Bell, 1984). As attitudes have changed toward killing elephants, there is increasing public pressure to find effective, non-lethal ways to reduce this problem.

Fences can be long boundary fences along the edges of protected areas or encircling fences around settlement and be electrified or not. Some are erected to restrict the movement of all large mammals into areas of human settlement. However, the chronic problem of breakages and maintenance are similar in all cases. High-tech solutions such as electric fencing tend to produce good results initially, but rely heavily upon international agencies for the set up capital (Hoare, 1995).

Regardless of how well they are designed and built, fences need to be constantly maintained. There are always weak places, such as river crossings, that elephants will try to find a way through. Damage to different types of fencing by wildlife is a major source of their lack of effectiveness (Hoare, 1992). Once a fence is broken it can decline rapidly, in structural terms, and while one species may cause the initial damage, other species will take advantage of this. For example, a major concern for the beef industry in Africa occurs when an elephant breaks through a boundary fence and then buffalo can move into surrounding lands used for livestock grazing. Elephant fences are usually high-voltage and may incorporate a number of design features, such as extra pole wires, to protect them from elephant attacks. Elephants are notorious at seeking out the weak points of fences. Thouless & Sakwa (1995) concluded that elephants could overcome most modifications in time, meaning that a fence's effectiveness could not be ensured by design, construction and voltage alone.

The negative impacts of erecting these fences have been enormous and they have had complex and long reaching effects for both wildlife and people. In many cases they are barriers, often not following any feature in the landscape, severing migration routes and dispersal areas for many species (Laws, et al., 1975). Importantly, people settle along them due to the roads that are built at the same time. They have even become a resource from which poor inhabitants of an area may make their living from stealing the wire for snares

or building material (Naughton-Treves, 1998). There is an interplay between the damage elephants cause to fences, the time it takes to repair that damage and access to wire by local people.

The reasons elephants break through fences are often related to access to resources, such as food and water, dispersal into new areas and the closing off of historical migration routes. Fence breaking is almost always undertaken by bulls at night and breaking through fences may be a learned behaviour and taught by example by older bulls to younger ones (Blair & Noor, 1979; Barnes, 1996; Bell, 1984). Fences also have created hard edges where high densities of animals on one side of the fence have eliminated many of the 'preferred species' of browse. On the other side of the fence, often in lands settled by humans, many of these species of vegetation remain and act to draw elephants to break through weak sections to get at this forage (Osborn, 2002). So a variety of factors draw elephants out of protected areas and all need to be addressed when fence deterrence regimes are developed.

Over the years wildlife managers have considered various non-lethal ways to deter elephants from destroying fences. However there are few published reports on such activities as they have been seen as management interventions. There have been a number of innovative fence designs to try to avoid the habituation that elephants seem to develop (Thouless & Sakwa, 1995). The effectiveness of a deterrent is therefore reduced once elephants are exposed to it multiple times. This problem also applies to high-tech methods: elephants appear to be able to overcome the most elaborate defences given time.

There are few methods available to managers to stop fence breaking and the most obvious is the 'chase them away' method where people with guns and noisemakers position themselves at a section of fence where elephants have broken through the previous night. When the animals approach the fence they are surprised by the noise and sound and retreat. The problem with this method is that fence lines are often hundred of kilometres long and the cost of keeping mobile teams patrolling fences is high. There is no one solution to any complex problem and to address chronic fence breaking, a target must be decided upon and worked toward appreciating that there is no one solution. Combining a good maintenance regime with a range of low and high-tech methods is the most likely approach to take to reduce breakages non-lethally.

Low-tech methods which have been suggested, but not tested, include:

- Clearing the grass or forest on either side of the section of fence that is regularly broken some meters away from the fence line.
- Burning fires around breakage points.
- Placing stones along a section of fence where elephants get too close so they cannot easily reach the fence.
- Coating the fence with the remains of an elephant shot previously.
- Creation of a buffer zone around protected areas where human influence is graduated, thus relieving the pressure on both the protected area and the surrounding human population. (Thouless, 1994).

High-tech methods include:

- Coating a problematic section of fence with various olfactory irritants such as oleo-resin or other chemical repellents (*Hate 4c*™; tobacco dust, etc.)
- Alarms and sirens which are activated when the animal contacts the fence (O'Conell-Rodwell, et al., 1995).

- If the fence is not electrified, a section of temporary, portable electric fence can augment the existing fence line (Hoare, 1995).

Experimental methods include:

- Erect a 'deflecting fence' some distance away from the problematic section where elephants regularly break through. This fence could be of the type that is used by some farmers consisting of rough poles spaced 20m apart and strung with two sisal strings placed at 1.8 and 2.5 m then coated with a mixture of grease which is infused with chilli (Osborn & Parker, 2002).
- Using GSM technology to alert mangers and farmers when collared elephants are near a fence line (this has been tried in Kenya but no results are currently available).
- Fence-breaking elephants have been 'de tusked' in Kenya (Graham, pers. com.)
- Whyte (1993) suggests that elephants may emit low frequency distress calls when they are being culled. If true, these vocalisations could be very useful for repelling elephants.

Much anecdotal evidence suggests that elephants will overcome even the most sophisticated barriers over time. In addition, permanent barriers may not be popular with farmers as they are seen as a restriction on agricultural expansion. In Africa, rural populations incur the primary costs of living with elephants, but receive few of the benefits (Barnes, 1996) and their attitudes towards elephants are frequently negative as a result. The support of rural communities is critical to the success of elephant conservation schemes (O'Connell-Rodwell, et al., 2000), and negative attitudes cast an ominous shadow over the future of elephant conservation (Naughton-Treves, 1998). In conclusion, a multi-layered approach, allowing elephants to access what they are breaking through the fence for, may be the most effective way to reduce the conflict. By working toward the 'softening' of hard boundaries, a new approach toward the interface between wildlife and humans may be achieved that does away with traditional fencing.

Figure 5.8.1. Elephant stepping over fence (Photo Credit F.V. Osborn)

6. MONITORING AND PLANNING THE ROLE OF FENCING IN TFCAs

6.1 Monitoring fence permeability along the western boundary fence of Kruger National Park, South Africa.

Ferguson, K.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
selousgame@hotmail.com

Jori, F.
CIRAD, UR AGIRs, Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa ferran.jori@cirad.fr

Introduction

In this section we introduce our participatory and adaptive *Fence Incident Surveillance System* (FISS), which has been designed to monitor wild mammal permeability to fencing, and the damage to these structures that a number of species of African large mammals can cause along a ninety kilometre pilot study section of the western boundary fence of Kruger National Park (KNP) (Ferguson, et al., 2010).

The entire 480km western boundary of the KNP is demarcated by a veterinary fence, primarily designed to contain the foot-and-mouth disease (FMD) virus within the park or areas where buffalo are allowed to be present (Bengis, et al., 2003). The western fence varies in structural types and different sections can be exposed to different degrees and causes of damage (Ferguson, 2009a & b; Jori, et al., 2009). The resultant large mammal fence permeability patterns represent a vital prerequisite to an understanding of the underlying processes and the potential mitigation of the impacts of such cross boundary animal movement.

Containing wildlife by means of fencing can only serve four purposes (or a combination thereof); first, to reduce human-wildlife conflict by reducing contact between the two, second, to reduce the disease transmission risk between wild and domestic animals; thirdly to increase the security of a protected area and fourthly, on occasion, to demarcate an international boundary (Newmark, 2008).

Types of fence

Our research fence line spans approximately 90km in length (inset box in Fig. 6.1.1) from the Luvuvhu River in the north of KNP to the Olifants River further south along the northern-western KNP boundary fence. The topography along the fence line is generally flat and the dominant vegetation type is mopane (*Colophospermum mopane*) shrub and bushveld. Habitat 'inlets' of a diverse array of other vegetation types (various sandveld habitats) occasionally intrude along the fence.

Along this perimeter we encountered five types of fence which have been erected at various times (refer to Table 6.1.1 for fence incidents statistics per species and per type of fence and Fig. 6.1.2 for temporal permeability data collected over the duration of the field study for three key species).

i) New 'I' Beam: Specifications - 2.4m high; wooden droppers; 4 x 13mm steel cable; barbed wire strands; steel uprights implanted at 50m intervals.

This is the preferred Department of Agriculture, Forestry and Fisheries (DAFF) fencing structure and it is now considered by them to be the universal standard for sealing off elephant (*Loxodonta africana*) populations from livestock dominated landscapes. This fence type composes 42% of the total fence length in the study area. The fence is designed to withstand sustained assault by elephants such that this species cannot facilitate buffalo excursions (and the resultant spread of disease). It is still unclear if elephants have the capacity to successfully challenge this fence (two isolated cases seem to suggest that they can (K. Ferguson, pers. obs., June 2009; D. Keet, pers. comm., March 2010). The 'I' Beam fence is being erected in priority areas prior to the planned complete coverage along the western boundary. It is being constructed at a rate of 25km per annum (D. Keet, pers. comm., October 2008). The 'I' Beam should be relatively maintenance free. The 'I' beam is not carnivore proof and was never intended to be so.

ii) 2.4m Steel Fence: Specifications - as for (i), except with metal droppers and hollow steel uprights.

In some sections many of the metal droppers have not been bent out of shape (either by animals or by fence workers during repairs) which tends to suggest a low incidence of fence challenges. The reason for this remains unknown but it may be due to the inherent strength of the fence, lower densities of bull elephants in this area or landscape differences (e.g. the presence of a large barren sodic pan adjacent to much of this fence section).

iii) 1.8m Rail/Cable Fence: Specifications - as for (i), except for height.

Parts of this fence show severe signs of sustained elephant damage and it is currently being heightened to 2.4m by means of added cables and girders. This represents one of the highest impact zones for elephants and carnivores which epicentres at the joining of this fence and the 'old inactive' electric fence.

iv) 2.4m 'Old inactive' Electric Fence: Specifications - steel posts embedded in concrete, metal droppers, barbed wire strands and conductor strands only.

This was the KNP's major electric fence upgrade of the 1990s. After the floods of 2000 and the continuous theft of electric components (solar panels, batteries, wire) it fell into disrepair. Along most of its length it has suffered sustained damage by elephants and it is no longer an effective barrier to the movement of most species. 90% of recorded excursions occur in these sections.

*v) 2.4m Electric Fence: S*pecifications - *as for (iv) but electric current is active.*

One small section is maintained as an electric fence by the use of solar panels and batteries but since 2001 thirty-six solar panels have been stolen in the study area (D. Keet, pers. comm., March 2010). This fence records very few excursions and usually only when the electric current fails (usually over a week-end when a limited fence maintenance staff remains in the KNP). It is remarkable how quickly (within hours; pers. obs.) elephants can determine a decrease in voltage of the electric fence.

The fence requires constant maintenance and is costly in terms of guarding the solar panels. It is an effective anti-predator fence, except across small drainage lines. We agree with Thouless and Sakwa (1995), Bonnington, et al., (2009) and Graham, et al., (2009) that electric fencing is the most effective anti-elephant barrier, if it is properly maintained and appropriately sited.

The development of the Fence Incident Surveillance System (FISS)

Our adaptive monitoring strategy is intended to provide accurate data via our novel, cost-effective and simple fence permeability monitoring/profiling system. Currently we have trained over forty DAFF fence workers in the methodology of the FISS.

Fence workers are requested to attach strips of plastic tape to the fence inscribed with one (or more) of five symbols that denote lion (*Panthera leo*), elephant *(Loxodonta africana*), buffalo (*Syncercus caffer),* spotted hyaena (*Crocuta crocuta*), and human theft fence incidents (respectively: X = lion; ● = Elephant; ▲ = buffalo; √ = hyena; and ╬ = fence theft) and each symbol is indicative of whether the recorded species has crossed and/or damaged the fence. A sixth symbol, a question mark (?), allows the fence worker to indicate that he is unsure of which species has challenged the fence. Additional symbols (↑= out of park and ↓ = into park) denote whether the fence worker deems that an individual of a particular species has exited or entered the park. Fence workers largely use spoor, scrape marks at the base of the fence, hair on the fence and the general state of the damaged fence to determine which species is considered to have been responsible for the fence damage and/or a species 'excursion' event.

Pocket PC (personal computer) trained fence workers then geo-reference their own data on to a pre-programmed format (using Cyber-Tracker™ Software) for later downloading on to the laptop spreadsheet of a mobile senior fence worker. The latter then downloads this spreadsheet on to the PC of the State Veterinarian with GIS responsibilities in Skukuza (KNP HQ). Permeability maps for each type of fence and its species interactions and a dedicated database are created at this point. The FISS therefore facilitates an unbroken chain of electronic fence data. In the event of a Pocket PC malfunctioning, the fence workers can leave the barrier tape hanging from the fence, for later geo-referencing (the 'lifespan' legibility of black ink on the tape can be up to several months; pers.obs.). Training protocols have been produced in the local language - XiTsonga (explaining instructions for operating the tape/symbol system and the use of the Pocket PC and Cyber-Tracker™ software).

ARCView™ GIS was used to record and map species-specific fence incident permeability and to attempt to discern the potential correlation between species with regard to patterns of fence related movement (for an example see Fig. 6.1.3). Our profile maps accumulate data over time allowing the managers of the fence to detect recurrent patterns of fence damage and to rectify their fencing deterrent strategies as necessary.

Results: Fence Incidence per species per type of fence

A full discussion of our results is given in Ferguson et al., (2010). Within our study area, incidents statistics per type of fence are presented in Table 6.1.1 and temporal FISS data collected over the duration of the field study are illustrated in Fig. 6.1.2. We concluded that none of the fence types are 100%

effective (Table 6.1.1). The highest numbers of fence incidents were recorded in the older fences where electric power was very irregular or nonexistent or the structure of the fence was weak (2.4 m old fence and 1.8 m rail post fence), ranging between 9 and 17 incidents per km. Incidents were much lower in those sections of the fence were electricity was maintained and also in the I-Beam fence (dropping to 3.3 and 2.8 incidents per km). Overall in terms of the percentage of fence incidents that each category produced over the entire study period it was found that elephants were by far the species most often recorded causing damage and/or crossing through the fence with a rate of 64.1%. They were followed by carnivores with 16.8 and 10.6% incidents for hyaena and lion respectively. Buffalo caused the lowest number of animal incidents with only 2.3% of the recorded incidents during the study period.

There was a clear increase in the number of fence incidents caused by elephants in the months of February and March. The other species monitored did not show a specific temporal trend of fence incidents (Fig. 6.1.2).

Limitations and biases of the FISS Method

Spatial permeability to fences by this guild of large mammals is determined by multiple factors, the most important of which are species abundance and distribution. Species-specific behavioural mechanisms for circumventing these barriers will be predicated by the type of fence (and its state of maintenance), the landscape that the fence is embedded in (including access to water points) and the biology of the species in the surrounding matrix (e.g. density, social structure). Temporal permeability will be affected by the above factors but also by the abundance and location of the resources that 'drive' each species to cross this hostile barrier. Our analysis of these multiple factors and the processes which underpin these animal 'excursions' is currently focussing on readily observable patterns of fence damage as this is the easiest and most sustainable way of building up a database of events. Further research, including telemetry of key species will be needed to unravel the complex sequence of events that have emerged in terms of fence excursion rates and timing.

The discernment of FISS patterns for each species is however, not without its limitations. Human observer bias is likely and whilst the fence workers can estimate the spatial and temporal frequency of species excursions from spoor, they cannot accurately estimate the number of animals involved in each incident (unlike other studies that use spoor density indices (Houser, et al., 2009). However, broad agreement between FISS patterns and a second, questionnaire-based fence permeability method (Jori, et al., unpublished data), suggests that that interpretations of spoor reading may not be a significant source of bias. The majority of fence workers experienced few problems related to the use of the Pocket PC and these were overcome with time and extra training. The FISS methodology that we have tested highlights the need for the long-term continuation of fence permeability monitoring (this is not likely to be static over time) and we suggest that sustainable systems for participatory monitoring and the communal management of fences should be encouraged (Ferguson, 2009a & b; Lindenmayer & Likens, 2009).

It is not possible to ignore the role that fence play in the agricultural sector, large mammal ecology in general and animal disease management. Therefore, we hope that this standardised method of collecting permeability data can be validated and tested across the sub-region and perhaps help to inform a Southern African regional position that will seek to lay down guidelines

(encompassing a database of fence related ecological and epidemiological data) for the judicious and responsible erection and/or the removal of these unnatural barriers.

Acknowledgments

This work was conducted by the Fence Interface Research and Monitoring (FIRM) group under the auspices of the Mammal Research Institute. We thank Professor Elissa Cameron and our assistant Miss Laura Adam for their inputs. We also extend our thanks to our major donors WWF-SA (project ZA 1490) and the United States Fish and Wildlife Service (Afe-0401).

Figure 6.1.1: Kruger north-western boundary fence by fence type

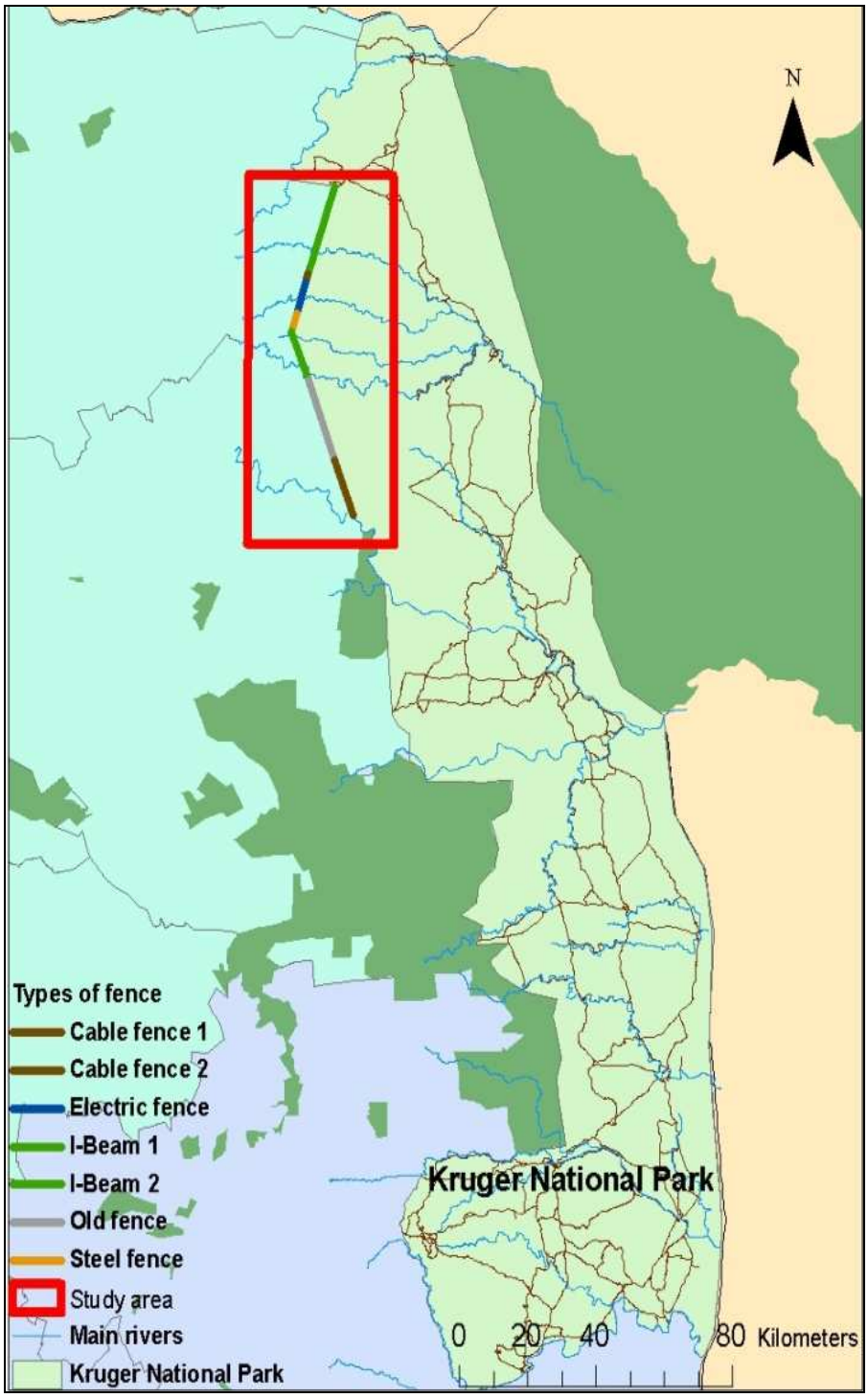


Table 6.1.1. FISS per species and per type of fence between November 2008 and July 2009 (727 incidents recorded).

Type of fence	Proportion of total	Incidents / km	Fence incidents / km by species					
			? *Lion*	*Buffalo*	*Elephant*	*Human*	*Hyaena*	
New 'I' Beam fence	41.8	3.3	0.2	0.1	0.5	0.4	1.7	0.4
2.4 m Steel fence	5.5	2.8	0	0	0.4	0.4	0.8	1.2
1.8 m Rail fence	19.8	8.9	0.1	0.2	6.7	0.1	1.2	0.7
2.4 Old fence	24.2	17	0.1	0.2	13.2	0.5	0.8	1.2
Active electric fence	8.8	3.3	0	0.6	1.3	0.8	0	0.4

Figure 6.1.2. FISS per species (elephant, hyena and lion only) per month between November 2008 and July 2009.

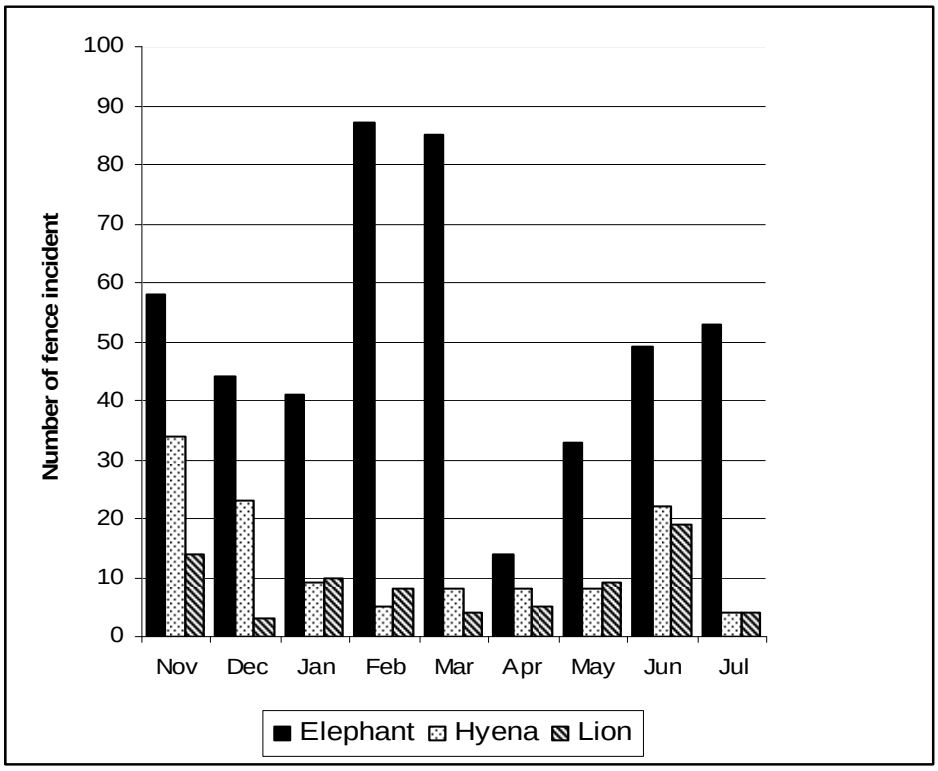
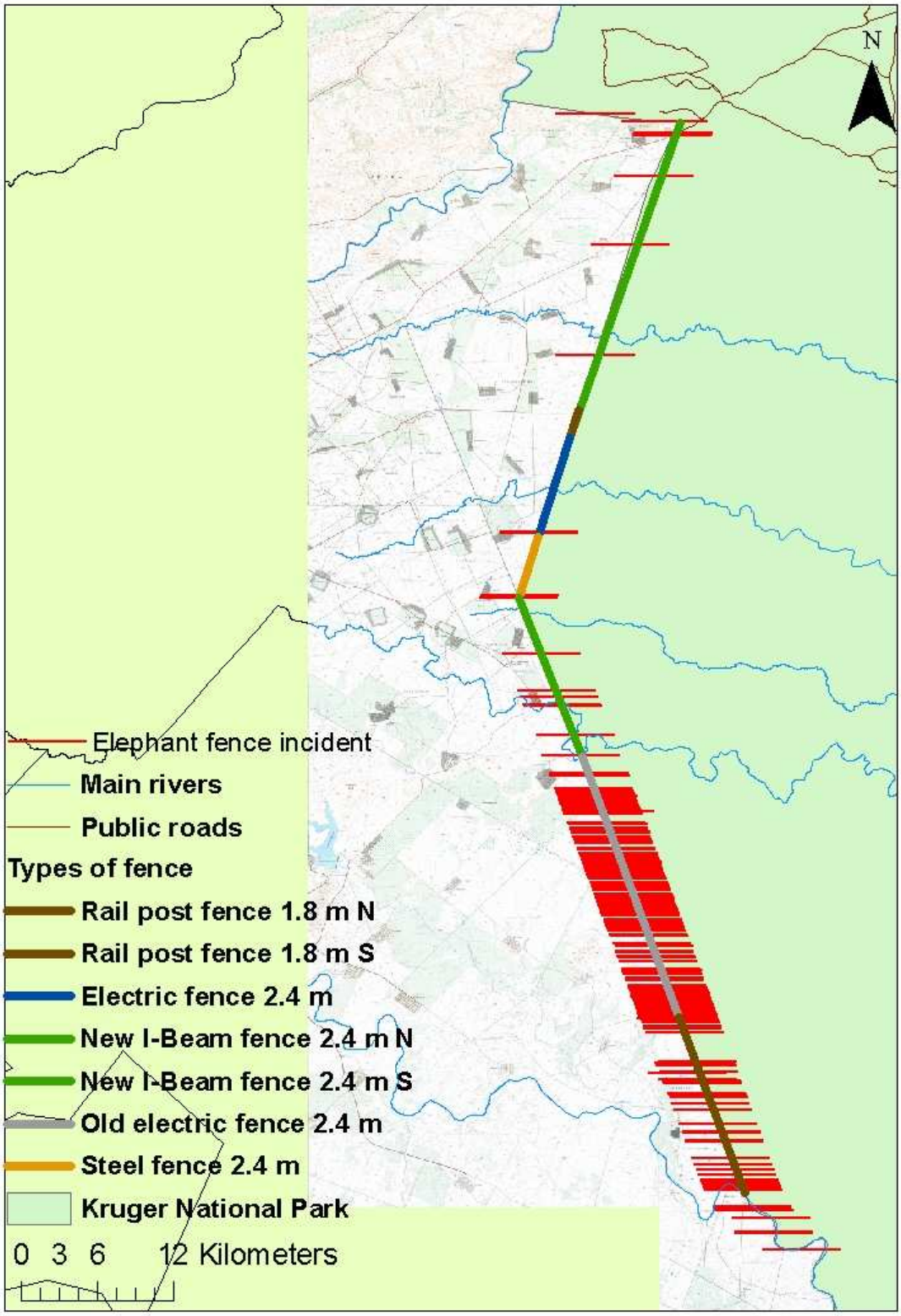


Figure 6.1.3. Total fence incident distribution for elephant permeability in the study area. Each horizontal line represents one or more 'excursion' (October 2008– July 2009: Map created by L. Adam).



6.2 A spoor method for measuring fence crossing rates

Bonnington, C.
Frontier/ Society of Environmental Exploration, Department of Animal and Plant Sciences, University of Sheffield, UK.
c.bonnington@sheffield.ac.uk

Rationale for study

The Kilombero Valley (8°34'S. 8°36'E) in southern Tanzania is an important migratory route for large mammal species (e.g. elephant *Loxodonta africana* and buffalo *Syncerus caffer*) between the Kilombero River floodplain and adjacent protected areas (such as the Selous Game Reserve to the east; Starkey, et al., 2002; Marshall, et al., 2007).

The Kilombero Valley Teak Company (KVTC) established in Tanzania in 1992, has leased 28,159ha of land in the Kilombero Valley. This land is situated in miombo woodland that grows along the edge of the floodplain of the valley. KVTC established a land management plan whereby teak (*Tectona grandis*) plantation plots are arranged in a mosaic among miombo woodland and other natural and semi-natural vegetation plots.

Between 2001 and 2002 elephants destroyed areas of teak plots, resulting in an estimated US$4.2 million loss in timber sales. In an attempt to prevent such losses in the future KVTC encircled these plots with an electrified (5kV) 8-wire 2m high game fence with the lowest strand 50 cm high from the ground level (Fig.6.2.1). Strips of natural habitat were left unfenced around the teak plots to allow animal movements, particularly that of elephant, through this area of the valley.

Concerns arose that these 'full' fences prevented the movements not only of the target species elephant, but also non-problem species. As such, in 2004 KVTC began removing the lower strands of the fence leaving a single electrified strand (5kV) 1.5 m high above the ground (termed 'half' fence in this chapter; Fig. 6.2.2). We were tasked by KVTC to determine whether these two fence types (full and half) affected large mammal movements and it is this study that is outlined here.

Spoor transect methodology

Line transects using indirect survey signs of animals are used extensively in tropical habitats, as a consequence of poor direct detection of many species in these areas (Plumptre, 2000). Transect counts are also considered the most efficient rapid method for detecting large mammals (Silviera, et al., 2003), and have been used extensively in determining large mammal use of teak plantation habitats (Jenkins, et al., 2003; Bonnington, et al., 2009). We used spoor transects along the two fence types to determine crossing rates of large mammals. Large mammal spoor (species above 1.5kg to increase the likelihood of an imprint left in the soil) was studied by six trackers using a 100m transect running parallel to the fence. In total, 16 half fence sites and six full fence sites were selected in a stratified fashion within a 5km radius of each other. We surveyed 6.2km transects (1.2km in April and May 2005, and 5km in January and February 2006) along the half fence and 1.2km along the full fence (April and May 2005; no surveys were undertaken in January and February 2006 as all full fences had been converted to half fences by this

time). A maximum of 600m transects were surveyed at any one fence. We assessed individual fence stretches once and we pooled the results for each fence type. Spoor was recorded up to 2.5m on either side of the fence, in an area cleared of vegetation to allow access during fence repair (Fig.6.2.1/2). Spoor was identified to the lowest possible taxon; the similarity of spoor between some species, i.e. small antelopes, made finer-grain distinctions unreliable and therefore some species were combined when recorded (e.g. forest duikers *Cephalophus* spp. and bush duiker *Sylvicapra grimmia*).

We categorised spoor according to the movement of the mammal in relation to the fence. If the spoor indicated that the fence stopped the animal from crossing, it was tallied as 'restrictive'. There were two distinctive behaviours in this category; spoor approaching the fence and then stopping at the fence line and moving away, and spoor moving along the fence line without crossing it (see Fig. 6.2.3). On the other hand if spoor indicated the fence was crossed, it was categorised as 'accessible'. This was simply confirmed by spoor moving through the fence line from one side to the other side showing that the species had stepped under the fence strands to access or egress the teak plantation (Fig.6.2. 4). Note, that it is not sufficient to include species spoor inside the fence line without definite evidence of a pass through the fence. This is because the presence of an individual inside the teak plantation could be an indication of a breach in the fence or access through the plantation gate which was often of a suitable proportion to allow access to many large mammals (up to 2.5m in size).

Each taxon could score 1 for restrictive behaviour and 1 for accessible behaviour per 50m of transect to limit the probability of the same individual being recorded multiple times. The scores regard the behaviour that each taxon is likely to adopt in relation to the fences and not necessarily the behaviour of different individuals. We appreciate that our behavioural scores only regard those animals within 2.5m of the fence and therefore will underestimate, for example, animals walking along the fence greater than 2.5m from it.

Size-classes were defined based on shoulder height (SH): (i) <0.5m, (ii) 0.5–1.5m, (iii) 1.5–2.5 and (iv) >2.5m, and behaviour recorded for size categories was compared between fence types. The behaviour recorded for all taxa was pooled within each size-class. The proportion of accessible behaviour and restrictive behaviour was calculated as a percentage of the total behaviour. Binary logistic regression analysis was used to confirm differences between the permeability of full and half fences for mammals of four size-classes. By using binary variables (i.e. 'Yes the spoor did cross the fence line' or 'No the spoor did not cross the fence line') binary logistic regression allowed the difference in the occurrence of accessible and restrictive behaviour towards the full and half fences to be statistically measured. Size was treated as a continuous variable, using mean SH for each species recorded. Goodness-of-fit was assessed by the Hosmer-Lemeshow test.

Permeability of the two fence types

Our binary logistic regression analysis of the spoor dataset found that there was a significant difference in the occurrence of accessible and restrictive behaviour towards the full fence compared to the half fence across all size-classes (see Bonnington, et al., 2010 for details). Species with a SH of up to 1.5m (e.g. bush pig *Potamochoerus larvatus* and baboon *Papio* spp.) were able to access the full fence. All species with a SH of greater than 1.5m did not

access the full fence on any occasion. In comparison, species with a SH of up to 2.5m (e.g. buffalo and waterbuck *Kobus ellipsiprymnus*) were able to access the half fence. In addition, a greater proportion of smaller sized species (SH<1.5m) were able to access the half fence compared to the full fence. The main purpose of both fence types was to prevent elephant access and our spoor transects revealed that the fences achieved this goal. The half fence allows connectivity between habitats for all other surveyed (non-problem) species thus acting as an effective targeted species-specific barrier. However, the full fence restricts the movements of many non-problem species and its permeability is non species-specific. In light of these findings, the half fence is now the preferred option for KVTC.

Additional considerations with the spoor method

One caveat that should be considered is the fact that evidence of some 'restrictive' behaviour may also encompass inherent animal movements along the fence, rather than a direct response to the fence. For example, territorial species may use the cleared area around the fence line as a convenient boundary marker and the cleared area may also provide a suitable foraging strip for digging and rooting species. As such species may be able to access the teak plantation but may simply find it functional to walk down the fence line. Nevertheless, territorial and digging/ rooting species that can access the fence line are likely to pass through the fence during the survey period on some occasions, confirming that these species do find the fence accessible.

It may be appropriate in some instances to also consider the spoor data on a species-by-species (perhaps sometimes even case-by-case) basis. This will enable unanticipated high rates of restrictive behaviour along a fence line to be investigated. This may also help to explain further unexpected results, for example larger species gaining access through a full fence. In our study, we recorded instances of bush pig and baboon (0.5-1.5m SH) accessing the full fence (lower strand 50cm from ground level) where the gap between the lower strand and the ground level had been increased because of soil erosion, and also where these species had dug into the soil to gain access. We also observed distress dung of bush pig at some points where this species had crossed the full fence, which shows that although this species can access this fence, there are consequences for doing so (i.e. electric shock). These are important case-by-case events which warrant consideration.

Weather condition is another issue that needs to be considered with regards to the spoor methodology. As stated by Silveira, et al., (2003) "too wet or too dry ground can determine the detectability and identification of tracks, and thus validate or invalidate a survey". This point is especially directed to identification of spoor for the purpose of species richness and abundance estimates, where it is important that all spoor are recorded. In terms of the spoor methodology for determining crossing rates of fences, as a general rule of thumb, extreme weather conditions (e.g. very wet or very dry) should be avoided to maximise spoor detection.

As the nature of the methodology uses spoor to determine the species in question, it is obvious that skills and experience in spoor identification are required to successfully undertake this methodology. In our study, we had experienced trackers to assist with spoor identification.

Benefits of using the spoor method

The spoor methodology allows us to determine large mammal crossing rates at fences which enable statistical comparisons to be made between fences, or at one fence comparing rates of accessible and restrictive behaviour.

In conjunction with these spoor transects we trialled the use of camera-traps as a potential method for determining crossing rates at both fence types. Due to cost, only two camera-traps were set up along the surveyed fence lines (one on each fence type). During 1,440 hours of camera trapping 77 photographs were taken and of these only 8 contained animals. Interpretation of the photographs revealed that waterbuck (2 photographs) and bushbuck *Tragelaphus scriptus* (1 photograph) accessed the half fence, while bushbuck (1 photograph) and baboon (4 photographs) were restricted by the full fence. Our camera trapping trial provided a low dataset (too low for analysis). It is apparent that in order to attempt to obtain a sufficient enough dataset using this method a far greater number of trapping units would need to be used. These would be costly which may not be feasible for many fence monitoring projects of the type described. The issue of camera-trap security is also a major consideration in many areas. Our spoor methodology offers a cheap and more effective alternative to camera-trapping for measuring large mammal crossing rates at fences.

Young, et al., (1998) document comparing dung piles in various enclosed study plots to determine accessibility of different fences. This method is not appropriate for our study as dung (or spoor) within the teak plantation would not prove that that particular species accessed the plantation through the fence. As described previous it may simply illustrate a breach of the fence or access through the plantation gate.

In summary, our spoor method provides an effective, quick, easy and cheap assessment of permeability of fence lines by large mammals. It also enables us to obtain a considerable dataset in a relatively short time period.

Acknowledgements

This study was funded by KVTC, and was produced as part of the Frontier-Tanzania Savanna Research Programme, which is collaboration between the University of Dar es Salaam and the Society for Environmental Exploration. Special thanks go to Matthew Grainger (University of Pretoria) for initiating this study and preliminarily developing the spoor methodology. A final thank you also to the other two co-authors of the study (Suzannah Dangerfield and Eibleis Fanning).

Figure 6.2.1. The full fence with the cleared area either side evident. In the centre of the photograph is a bushbuck walking along the fence line.

Figure 6.2.2. The 'half fence' with the cleared area either side evident.

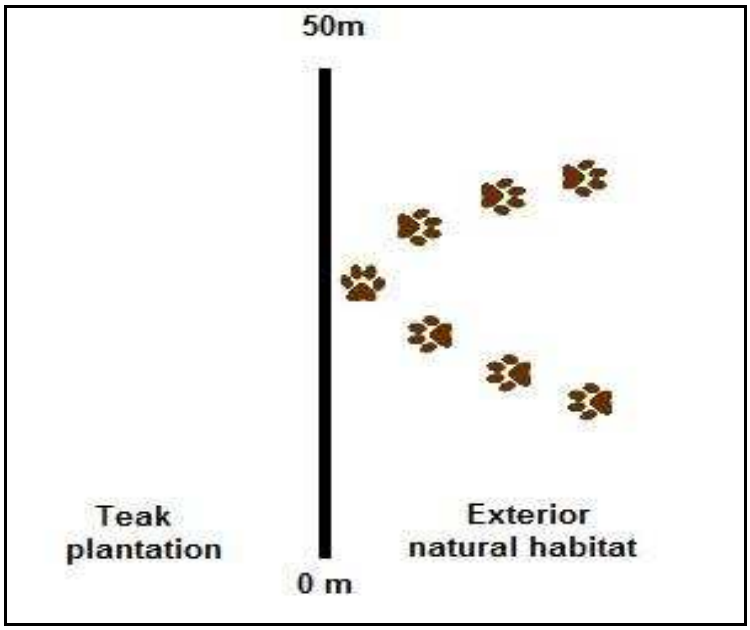


Figure 6.2.3. An example of restrictive behaviour with the spoor approaching the fence line (represented as the straight vertical black line) from the exterior natural habitat, stopping at the fence and then moving away.

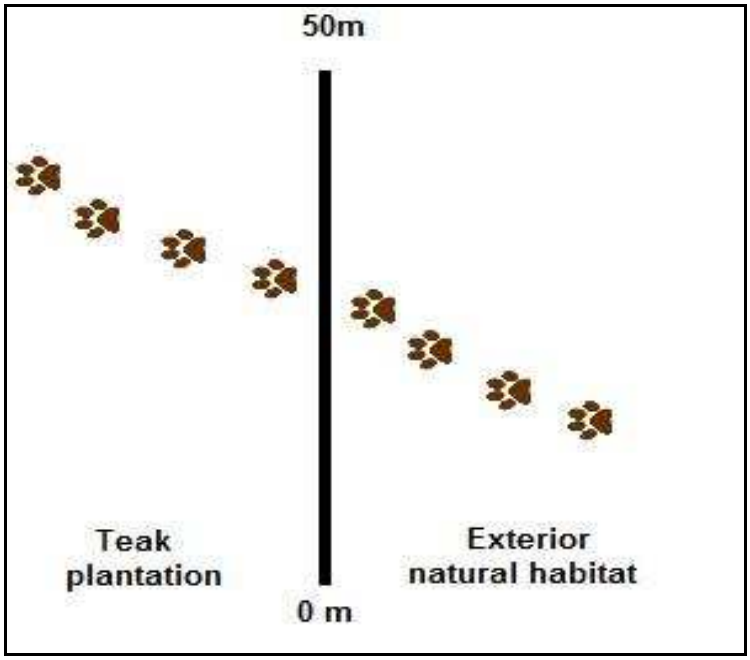


Figure 6.2.4. An example of accessible behaviour with the spoor moving through the fence line from the exterior natural habitat into the teak plantation.

6.3 TFCA integrated development planning processes and fences: 'babble, babble, toil and trouble'

Bewsher, P.
Peace Parks Foundation, Planning and Process Co-ordinator, 1036 Haarhoff Street East, Villieria, Pretoria 0186, South Africa
ecotoura@iafrica.com

"Fences are anathema to migrating wildlife. The higher and stronger the fence, the greater the effect it has on wild animals. Most veterinarians and domestic stock farmers like fences because they curb animal movement, thereby decreasing the risk of disease spreading. Most conservationists, on the other hand, have a love-hate relationship with fences." Hu Berry, 2010

Introduction

Within the development of Transfrontier Conservation Areas (TFCAs) this love-hate relationship continues, with the issue of fences being debated amongst stakeholders at length. Often the debates relate to the removal of fences that constrain the free movement of wildlife within ecosystems, yet across international boundaries. Often the debates relate to the erection of fences to achieve an ecological, economic or social objective. The jury is still out on a definitive stance regarding fencing.

Fences are merely management tools, and like any other tool are expected to work well where applied correctly for the task at hand. Where fences are inappropriately applied they can be as effective as bringing a Swiss army knife to a fire fight. Situations vary, environments vary, objectives vary, and the requests, needs and expectations of stakeholders vary, making the selection of an appropriate tool very site specific.

The TFCA Vision

As a facilitator supporting Governments within the Southern African Development Community regarding the development of TFCAs, Peace Parks Foundation (PPF) envisages *the establishment of a network of protected areas linking ecosystems across international borders.* To attain this vision, PPF accepts its mission as being *to facilitate the establishment of transfrontier conservation areas and developing human resources, thereby supporting sustainable economic development, the conservation of biodiversity and regional peace and stability.*
The broad objectives of PPF are:

- *To promote the establishment of TFCAs and associated conservation of biodiversity and ecosystem functioning as a viable land use option;*
- *To provide support to organisations responsible for conservation and ecosystem management through training, capacity and empowerment programmes;*
- *To unlock the economic potential of TFCAs through compatible land use options; and,*
- *To promote regional peace and stability.*

To attain these objectives PPF recognises the importance of participatory and consultative planning, and thus provides support to the lead agencies within the TFCA partner countries regarding workshops and planning processes aimed

at establishing the TFCAs as functional conservation entities benefiting the region and its people.

Fences and the Integrated Development Planning Process

As part of its support to the partner countries within TFCAs, PPF has assisted the TFCA structures with participatory and consultative planning processes including the preparation of Feasibility Reports, Motivation Documents, Integrated Development Plans (IDP), Joint Operational Strategies and specific protected area management plans. Throughout these participatory planning processes the issue of fences as management tools, as well as the removal of inappropriate and ineffective fences has been raised by stakeholders necessitating clarity by the specific authorities within the countries.

Participatory planning serves as a critical and fundamental component of TFCAs enabling stakeholders an opportunity to actively influence the direction that conservation takes within the TFCA. The process entails workshops, meetings, plenary and sector group discussions, document preparation and review, before final submission to and endorsement by the relevant Ministries. The IDPs are undertaken through a participatory planning process involving stakeholders from various sectors including resource managers, conservation NGOs, private sector operators, traditional community structures, government agencies and departments, spread over several months and numerous meetings aimed at ensuring synergy and understanding amongst all these sectors.

Besides the broad and sector specific objectives, contained within the IDPs, stakeholders are specifically requested to discuss the concept development of the TFCA by addressing the access, use, development and infrastructure requirements of the TFCA, and to align these decisions with the environmental sensitivities – habitat, landscape, visual and cultural – as well as the agricultural suitability of the area. Once the broad use zones and the development cores have been identified, stakeholders deliberate the infrastructural requirements necessary to attain the specific objective. Within this paper, only the fencing infrastructure within each of the TFCAs will be discussed, as well as the objective aimed at being attained through the use of the fence, or the removal of the fence where required.

To guide decisions regarding fences within TFCAs the various uses and types of fences are discussed by the various stakeholders as management interventions covering four main areas:

- Social development tool;
- Wildlife management tool;
- Conservation tool; and,
- Tourism tool.

As a *social development tool*, fences have an important role to play in reducing human-wildlife conflict (HWC) when used as a mitigation measure by reducing contact along the human wildlife interface. Additionally, various types of fences – elephant restraining lines; stockades; game fences etc. – can be utilised around both small areas such as villages, creating safe enclaves, or large areas which serve as agricultural support nodes within TFCAs.

As a *wildlife management tool*, fences can be utilised to create sanctuaries for wildlife recovery programmes or serve as delineation markers for corridors of

significance, albeit for elephant, lions or less charismatic wildlife such as flight paths for birds, or breeding areas for fish.

Fences can also be utilised as *conservation tools* for specific ecological or biodiversity objectives, and normally take on the role of securing specific habitats from unsustainable levels of utilisation, enabling recovery. Alternatively, these conservation areas can serve as refugia for species which would otherwise disappear as a result of habitat change.

As a *tourism tool*, fences are a handy tool to stimulate regional economies by controlling access and ensuring the quality of tourism experiences.

Fences within TFCAs Kavango-Zambezi TFCA – Zambia and Zimbabwe

Within the Kavango-Zambezi TFCA (KAZA TFCA) IDPs have been prepared for Zambia and Zimbabwe, with planning processes being undertaken for the Angolan, Botswana and Namibian components of the KAZA TFCA. Within the IDP process stakeholders deliberated the use of fences as strategic management tools, covering a wide range of objectives, including:

- Social development tool;
- Wildlife management tool; and,
- Tourism tool.

As a *social development tool* both countries identified the use of fences as an important tool to reduce HWC by creating:

- *Enclave villages* – through the construction and maintenance of elephant restraining lines (ERL) and game fences, depending on the animals causing HWC, with a few villages formally requesting support from the Zambia Wildlife Authority (ZAWA) for the establishment of these enclave villages inclusive of Kaale, Kalobolelwa, Lusu, Kapau, Kabula etc. (Fig. 6.3.1 and 6.3.4);
- *Secured communal facilities* – by erecting stockades for livestock as well as stockades around water points and boreholes, such as Kapau Village within the Siloana Complex, consisting of the Sioma Ngwezi National Park and surrounding ecological system within the West Zambezi GMA; and,
- *Agricultural support nodes* – using combinations of ERLs and full game fences, such as the Silolo community close to Katima Mulilo where the community requested a full game fence, and the area surrounding Sioma where an ERL was requested (Fig. 6.3.5).

The alignment of these fences, especially the enclave villages, accommodates identified wildlife corridors, and allows for free movement of wildlife between the fields and the river (Fig. 6.3.4).

Within the Zimbabwe Component of the KAZA TFCA the thrust was for the erection of ERLs and game fences rather than enclave villages (Fig. 6.3.2). Regarding its use as a *wildlife management tool*, fences were requested for both the Simalaha Conservancy and the Mukuni Game Reserve, both community conservation initiatives based on wildlife recovery and ecotourism development.

The Simalaha Conservancy is a conservation initiative of the Sisheke and Chundu Communities, where a Wildlife Recovery Area is established and only

the contact zones between communal areas of high population density and areas with high wildlife potential are fenced. These wing fences reduce the risks of HWC as a result of crop destruction, the transfer of diseases, and loss of domestic livestock, yet allow for the relative free movement of wildlife through the landscape.

The Mukuni Game Reserve is located close to the town of Livingstone, a highly populated area within Zambia, which also has high tourism value. To ensure that the conservation initiative has the potential of developing value as a Big 5 attraction, yet not pose a threat to the other land use practices in the region, the Mukuni Traditional Authority and the Mukuni Community Development Trust deemed it necessary to plan for a fence stretching from the Batoka Gorge to the Kaloma Gorge. This message was captured on a hand drawn map from the Trust which initiated the entire detailed land use planning process. The idea of the Trust is that this will allow for the establishment of a high value wildlife area, attractive to investors, while reducing the possibility for HWC as a result of an increase in wildlife in this area (Fig. 6.3.3 and Figs. 6.3.6 & 7).

As a *tourism tool* several fences have been utilised within the KAZA TFCA, especially as a management tool at the two major waterfalls on the Zambezi – Victoria Falls and Ngonye Falls. At the Victoria Falls, palisade fencing encloses the Zimbabwe side of the core area of the World Heritage Site, while diamond mesh fencing secures the Zambian side. On a micro scale, sickle bush fencing guides tourists along and through the rain forest to the various viewpoints. This fence was designed in 1969 and has proven to be a successful and aesthetically pleasing fence since then.

The main purpose of these fences is to enable the control of tourists to the Falls, allow for entrance fees to be collected at the gates, as well as enhance the visitor experience through ensuring safety and controlling numbers.

At the Ngonye Falls National Park, Zambia's newest and one of the country's first Community Partnership Parks, a full game fence was requested by the management committee consisting of ZAWA and the Barotse Royal Establishment, represented by the affected community, to control access and development, allow for entrance fees to be collected, and to enhance the visitor experience by reducing the impact of domestic livestock on the site (Fig. 6.3.8).

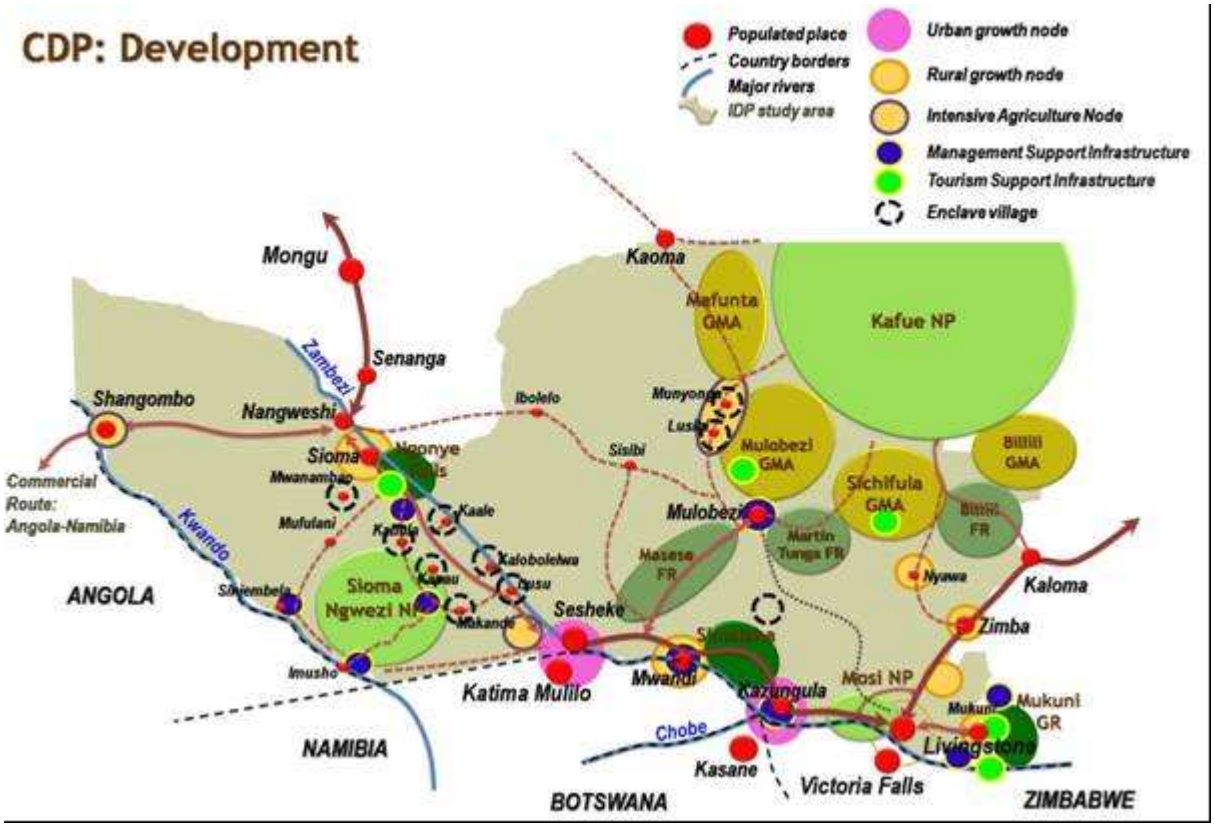


Figure 6.3.1. Enclave villages.

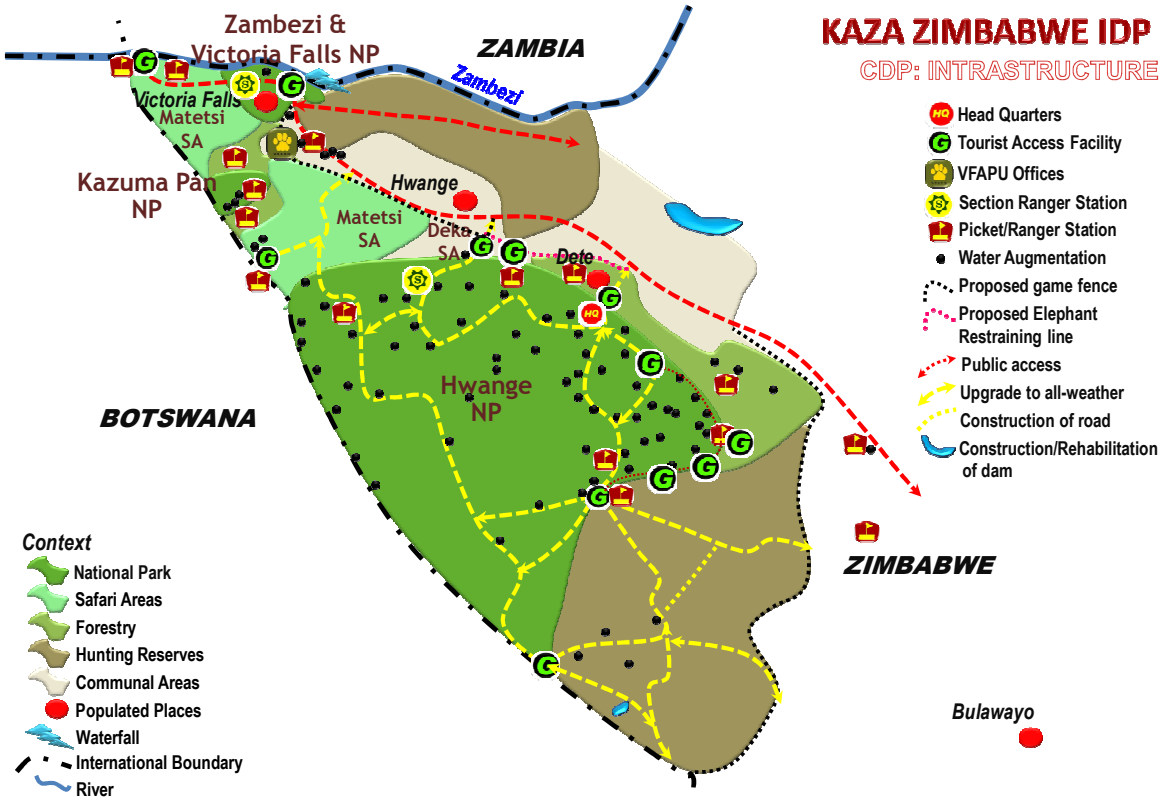


Figure 6.3.2. Elephant restraining lines and proposed game fences.

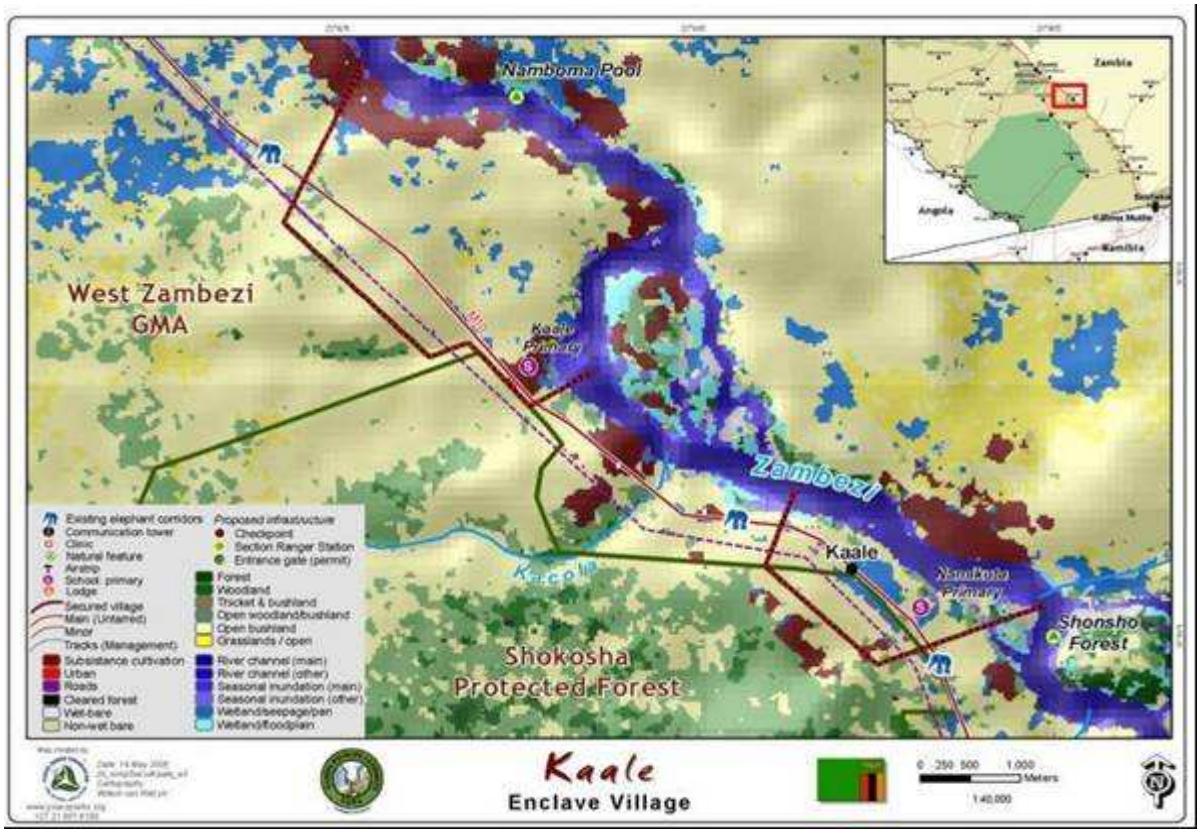


Figure 6.3.4. Kaale enclave village.

Figure 6.3.5. Silolo intensive agricultural support node.

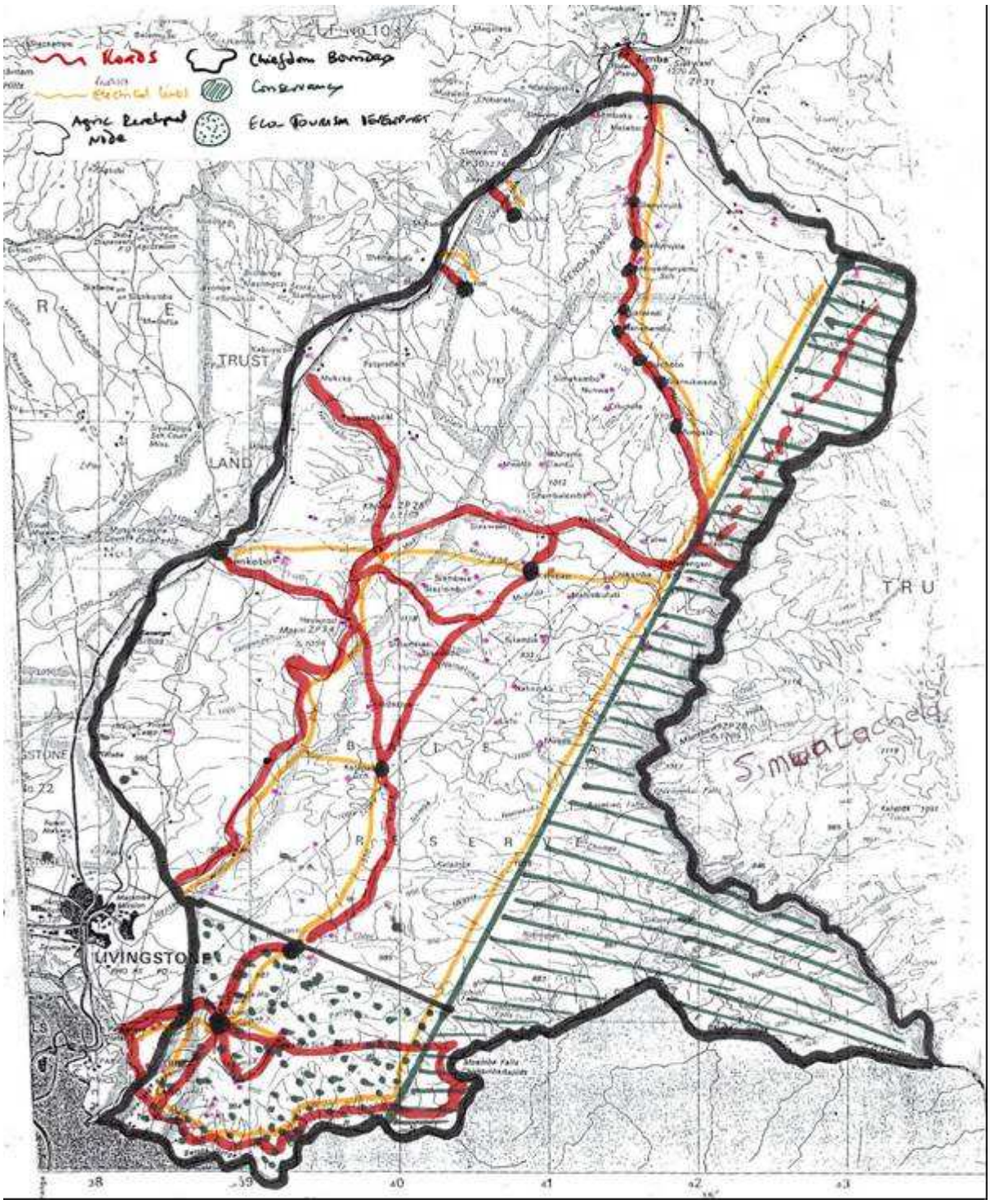


Figure 6.3.3. Mukuni Chiefdom land use plan (community inputs).

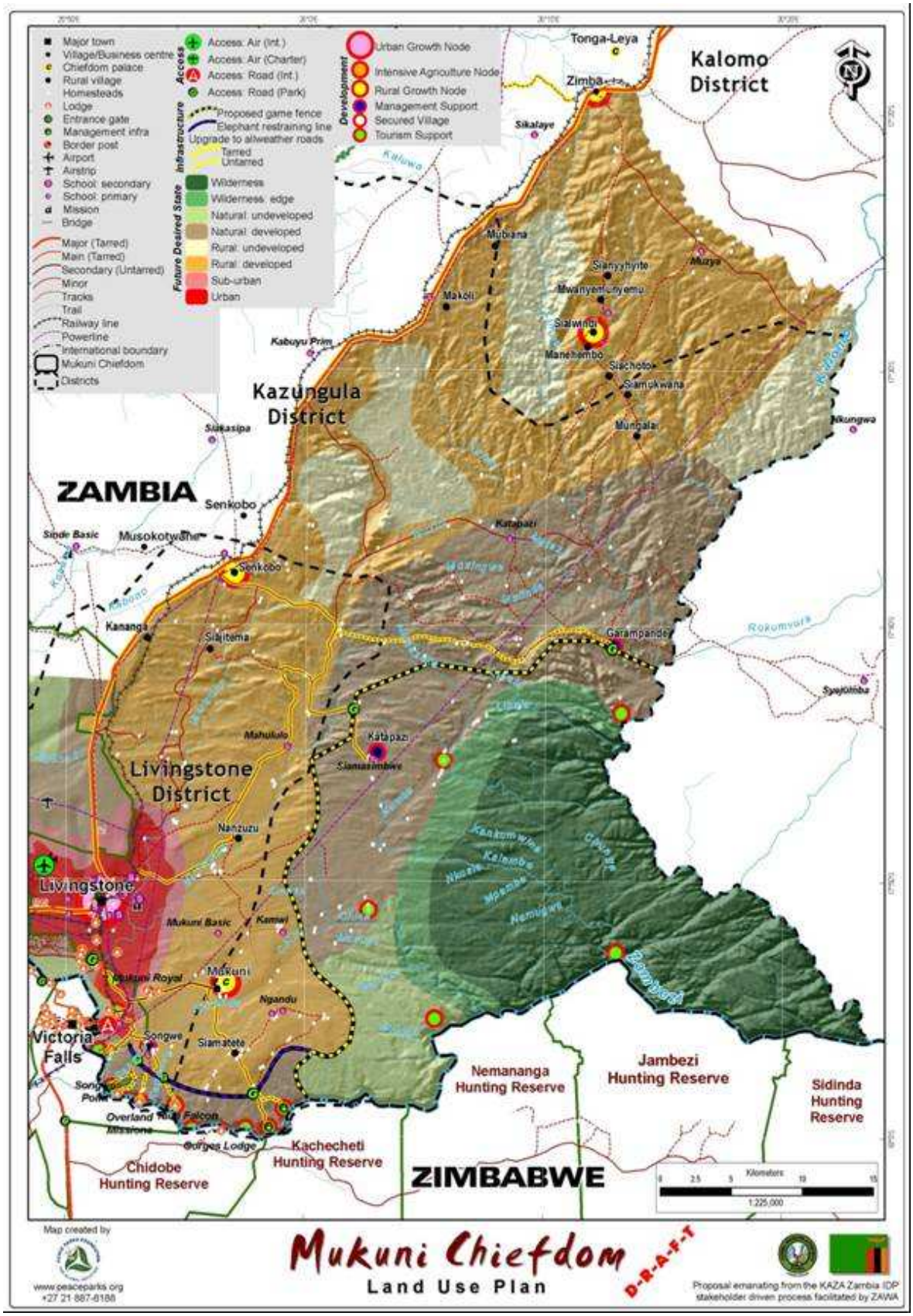


Figure 6.3.6. Mukuni Chiefdom land use plan.

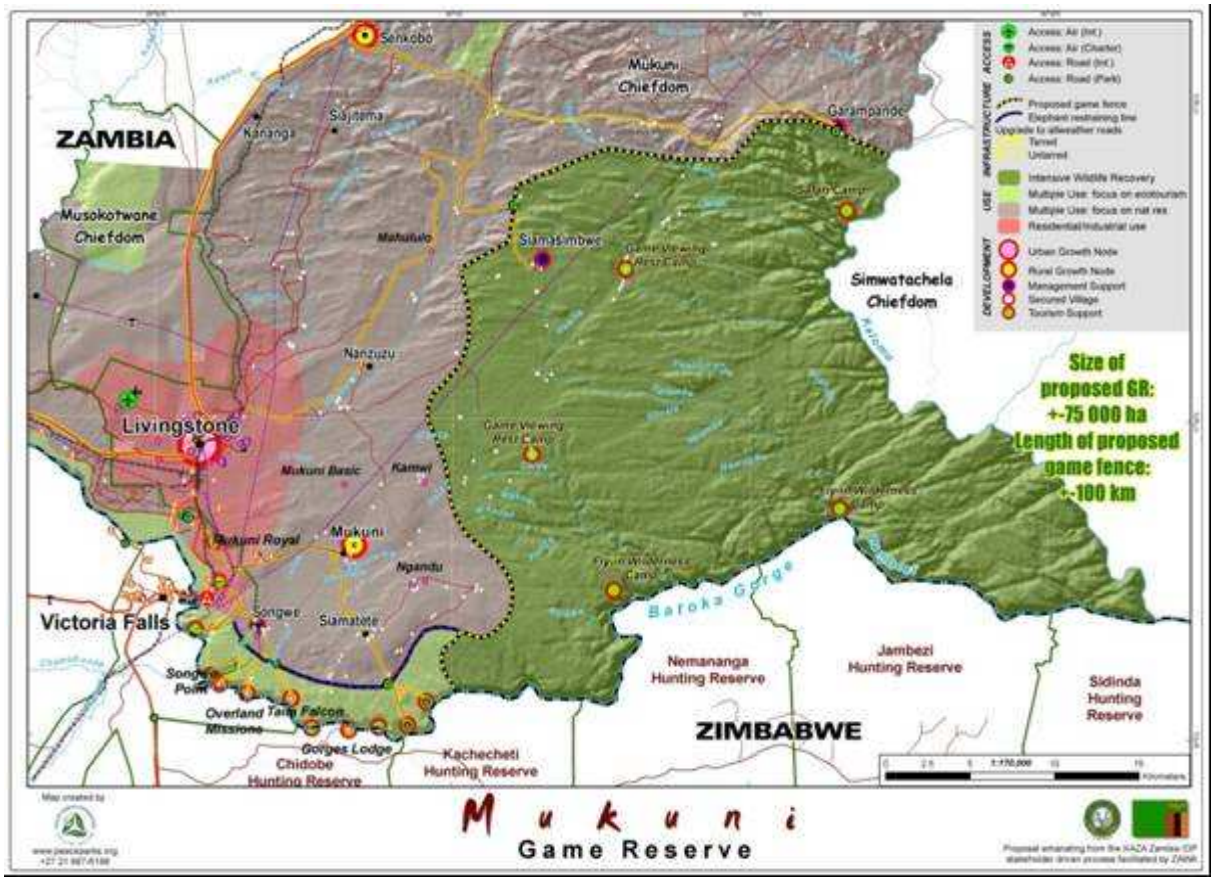


Figure 6.3.7. Mukuni Game Reserve.

Figure 6.3.8. Ngonye Falls National Park.

Great Limpopo Transfrontier Park

Fences have been utilised within the Great Limpopo Transfrontier Park (GLTP) and the surrounding TFCA to attain two of the broad areas, namely, social development and wildlife management. *Social development* fences have been proposed and are being erected from Massingir to Combomune and from the southern portion of Massingir dam to the Sabie River in an attempt to reduce HWC along these human wildlife interfaces. Elephant are a problem compounded by the presence of predators, and the Government of Mozambique, in consultation with the affected communities and private sector concessionaires, have requested the erection of full game fences along these lines. As a *wildlife management tool* fences have been utilised to establish a temporary sanctuary within the Limpopo National Park, a sanctuary that enabled the establishment of founder populations of wildlife within the Park. This fence has subsequently been removed.

A similar sanctuary has been established in the Malawi Zambia TFCA, within the Nyika Component. The Bambanda-Zaro Sanctuary has resulted in dramatic increases in wildlife numbers especially eland, and has proven to be a successful management tool. As the wildlife numbers and the management capacity increases within the Limpopo National Park, the fence between the Limpopo National Park and the Kruger National Park is being removed, and similarly as the private game reserve association is established along the Kruger National Park boundary, and the relationship of this association with the Mozambique Government is formalised, the remainder of the fence along the border will be removed enabling free movement of wildlife throughout the larger conservation area.

Greater Mapungubwe TFCA

The Greater Mapungubwe TFCA (GM TFCA) has numerous fences serving different purposes ranging from social development, conservation, wildlife management and tourism. From a *social development* perspective the stakeholders from the three countries deliberated the use of a fence within Zimbabwe to serve as a developmental tool enclosing the core of the TFCA, and thereby reducing both HWC and veterinary concerns. Both the South Africa and Botswana components have game fences along the perimeter of the core area, while Zimbabwe only has a small portion fenced, with the majority being open. Due to the relatively high numbers of settlements within the Beit Bridge and Gwanda districts HWC has become a problem, negating any benefit accruing to the affected communities from the CAMPFIRE programme (i.e. the Communal Areas Management Programme for Indigenous Resources).

As part of the IDP stakeholders requested the completion of the game fence of the core area stretching around the entire perimeter. Besides the reduction of HWC, this would also reduce the potential impact of wildlife diseases on the domestic livestock industry in the area. To enable the successful establishment of an alternative livelihood project in the area based on irrigation, a fence was erected around the Shashe Irrigation Scheme, where it is believed that intensive agriculture could eventually replace the need for extensive farming which is easily impacted on by wildlife.

Since the impact of both elephant and agriculture has severely impacted on the riparian vegetation, especially the gallery and palm forests along the Limpopo, fences are being utilised as a *conservation tool* to exclude elephant, and in some cases all animals, in an attempt to re-establish the integrity of

these threatened habitats. These fences mostly consist of ERLs, yet the total exclosures use a full game fence.

From a *wildlife management perspective*, the Greater Mapungubwe TFCA aims to consolidate the core area as a Transfrontier Park, while managing the surrounding buffer area as a TFCA. This approach requires the fencing of the core area and the removal of internal fences enabling the reintroduction of a wider range of animals and the free movement of wildlife between the various components.

Besides the social, conservation and wildlife management benefits, the fence also serves as a *tourism tool* by delineating the core area allowing for a wider diversity of game species, and the better management thereof. This should assist in unlocking the economic potential of the Transfrontier Park (Fig. 6.3.9).

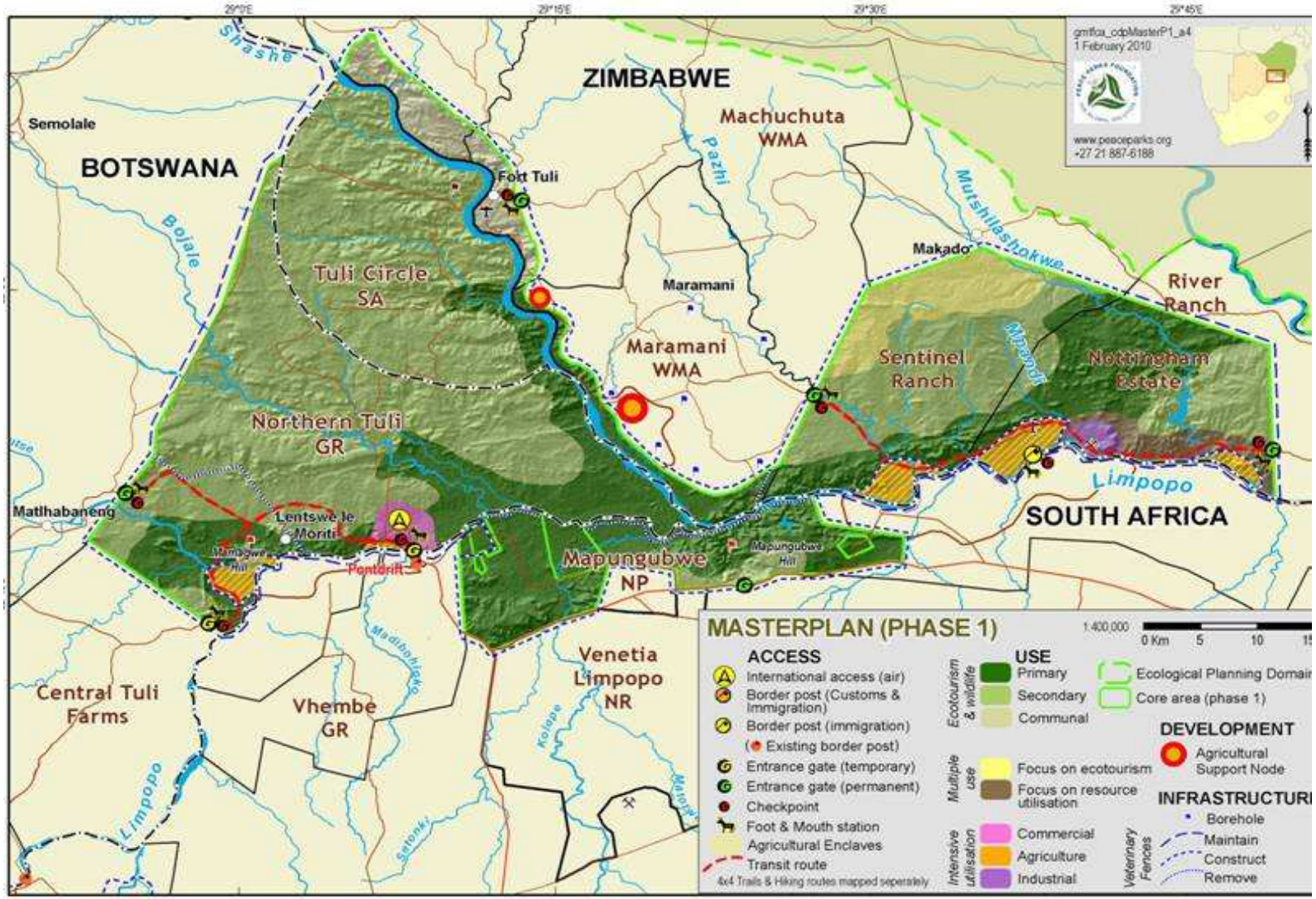


Figure 6.3.9. Greater Mapungubwe TFCA fencing.

Lubombo TFCA – Maputaland Component

Within the Maputaland Component of the Lubombo TFCA, specifically the Usuthu-Tembe-Futi Area – fences have been utilised, or have been proposed for utilisation to achieve social, wildlife management, conservation and tourism objectives.

Historically the areas surrounding the Tembe Elephant Park (TEP) in South Africa and the Maputo Special Reserve (MSR) in Mozambique have been seen as the source for HWC. Since the TEP has subsequently been fully fenced, the problem of negative connotation has largely shifted to the MSR. During the participatory planning process regarding the MSR Management Plan, the use of fences was discussed as a *social development tool*, specifically a HWC mitigation tool. This has resulted in the erection of ERLs along most of the protected area boundary, with the north western portion being a full game fence.

These interventions are all aimed at reducing HWC and increasing the acceptance of wildlife as one of the economic drivers in the region.

Within the Community Action Plan for the MSR several enclave villages have been identified as possibilities to accommodate resident communities and therefore negating the need to move and resettle these communities. These enclave villages can initially be protected by ERLs, yet as the game numbers increase, the use of full game fences could be contemplated.

To enable better *wildlife management* and the restocking of a wider number of species stakeholders within the MSR management planning process identified the need to fully enclose the MSR, similar to TEP, thereby enabling free wildlife movement between these two contiguous protected areas. Initially the first phase would entail the construction of a full game fence around a sanctuary directly adjacent to the TEP, serving initially as a pilot project proving that dangerous game be managed close to areas with high population densities, as well as the fencing of the core area of the MSR, enabling the establishment of founder wildlife populations.

The second phase would entail the fencing of the corridor, either along the minimum ecological boundary or along a wider area incorporating co-managed areas involving the proclaimed corridor and community and private concessions.

The third phase would entail the removal of all internal fences allowing for the free movement of wildlife throughout the entire Transfrontier Park, without negatively impacting on the other land uses in the area.

A buffalo breeding programme has been proposed as an alternative livelihood project which can be undertaken as a partnership between the MSR and affected communities, necessitating the erection of a fenced area within the MSR within which the breeding programme can take place. From this area, surplus animals can be used to restock the MSR and Futi Corridor

Similar to the exclosures within the Mapungubwe National Park, fences will be utilised within the Maputaland Component of the Lubombo TFCA, and serve as a *conservation tool*. These exclosures will be utilised to exclude primarily elephant and secondarily other browsers from sand forest areas. This approach addresses the conservation objectives of the region, TFCA and the specific protected areas.

The efficacy of the fencing intervention on protecting the biodiversity associated with sand forest has been tested within the Phinda Private Game Reserve, a reserve that provides protection to the largest expanse of sand forest on private land in South Africa.

As a *tourism tool* the fences proposed for the MSR and the Futi Corridor will also enable the development of wildlife products such as lodges, which require a diverse and good wildlife product and which would be difficult to attain with the absence of the fences given the population densities in the area directly adjacent to the protected area. This will be critical in broadening the understanding of wildlife as a viable alternative livelihood.

Conclusion

Fences within TFCAs are merely management tools, and can be useful in attaining short, medium and long term objectives. It is; however, critical that the type of fence, the purpose of the fence and the maintenance of the fence be discussed with the primary beneficiaries of the fences. It might seem a laborious task to involve stakeholders from various sectors, yet without this any conservation intervention will be doomed to failure.

If used correctly, fences, of various types, and appropriate for the area where it is being used, can be a critical tool in providing significant benefits to a region, through the provision of social, conservation, wildlife management and tourism advantages.

If this is not done, then the management of the fence will be become a never ending saga of "*babble, babble, tool and trouble*" with a lot of meaningless talk regarding an intervention that causes endless trouble – ecologically, socially and economically.

6.4 Delineating and decommissioning of park and veterinary fences

Alexander, A.
Project Manager LNP
antony.alexander01@gmail.com

Ferguson, K.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
kenferguson.firm@gmail.com

Delineating fences

Park fences can be erected for a variety of reasons, and can be seen to be a flexible management tool. Fences, for example in and around the Kruger National Park (KNP) can be used to exclude large herbivores from areas of sensitive biodiversity (as with the restraining fence for elephant (*Loxodonta africana*) in the southern sector to protect experimental vegetation plots), isolate disease-free breeding herds of buffalo (*Syncercus caffer*), secure tourist rest camps and staff quarters and ultimately to secure the boundaries of the park and prevent the flow of animals and humans to and from the external matrix (Joubert, 2007). The western boundary fence is however also and primarily a 'red-line' foot-and-mouth disease (FMD) control fence. The eastern boundary fence of KNP which borders Limpopo National Park (LNP) in Mozambique was erected for an entirely separate reason, as a security border fence (Joubert, 2007), and is being partially removed to make way for the free-flow of animals and tourists (see below). An emergency fence that was to straddle the middle of the KNP (from east to west) in an attempt to stop the northward movement of Bovine Tuberculosis was briefly considered but it was reasoned that the disease had already spread too widely for a *cordon sanitaire* to be of use (Keet, D. pers. comm., April 2010).

In KAZA TFCA, again we see a multiple pattern emerge in terms of the reasons for fence delineation and construction. None of the major parks in the KAZA TFCA are completely fenced in order to delineate park boundaries, in contrast to the Etosha National Park, which lies outside of the TFCA, and which is entirely fenced (MET, 2007). In the case of the KAZA TFCA the prevalent fences are veterinary fences, erected to stop animal-related disease transmission and can be grouped into either FMD long-term structures that can only be moved if areas north of the red-line can be declared free of the disease or as medium to short-term 'emergency' fences that can be erected relatively quickly to contain a fast spreading disease like Contagious Bovine Pleuroneumonia (CBPP). Added to this, are fences that have been primarily constructed to serve as border fences (e.g. Caprivi border fence between Botswana and Namibia) or to have a mixed purpose (the controversial Zimbabwe/Botswana border fence) to prevent disease, livestock and human transmigrants from crossing a border.

McGahey (2008, Chapter 7) gives a clear account of the complex details involved in the positioning and erection of veterinary fences in Botswana. For example, the northern buffalo fence (NBF) is the only fence in the country to have undergone prior consultation with local people. It was initially aligned on the basis of aerial surveys conducted in the 1980s that recorded densities of

livestock and human settlements. However, the alignment of this fence was also subject to change and according to McGahey (2008) *'Much of the southern sections of the NBF eventually followed the boundary between communal land and land gazetted as a wildlife management area (WMA) during a land-use planning exercise conducted in the mid-1980s . However, the decision to opt for this route was politically motivated and came after the communities had been consulted at least three times to discuss alternative alignments, the last of which agreement was made on a different course for the fence'*

Within the SADC Regional Biodiversity Strategy, fencing impacts are considered to be a regional issue. The development of TFCAs could act to harmonise fencing policies across political boundaries (SADC, 2006).

Decommissioning fences

The process of removing unwanted or derelict fencing can be a complicated process and requires certain criteria to be met. The reasons for the decommissioning of game/veterinary fencing can be due to:

- Formation of a private game conservancy whereby all the owners in an area agree to drop internal fences that previously demarcated individual ownership e.g. Save Valley Conservancy in Zimbabwe (Wels, 2000).
- Removal of veterinary fencing that was erected as a temporary measure to stem a disease outbreak of a highly virulent nature (e.g. the erection of CBPP fences in Botswana in the mid-1990s (see below).
- Removal of veterinary fencing due to the 'shifting of the red line', in effect pushing disease and strict disease control mechanisms farther away from the central livestock production areas and allowing more land to participate in livestock export markets.
- Removal of protected area fencing to allow the inclusion of private or communal lands, an example of the latter being the Makuleke land concession of the 1990s in South Africa (Ramutsindela, 2002)
- Clearing of fencing materials from long abandoned fence lines, either in a planned manner by the state or unplanned by the 'illegal' removal of fences by local people.

The above reasons highlight the fact that in southern Africa decommissioning and the actual removal of the fence in question are not necessarily synonymous. We give two examples below from the GLTP and one from KAZA TFCA that set out the parameters that need to be considered when removing fencing.

Veterinary fencing in Zimbabwe

Fences can be removed for different reasons and in an unplanned or planned way. Degradation of fences by means of lack of maintenance, theft of components and by some species particularly elephants can lead to a *de facto* decommissioning of the fences. This mode of fence degradation seems to be mainly prominent in countries that are deemed to some extent to be failing states and that have little or no livestock export market to protect. An example is the removal of fencing during the land issues in Zimbabwe, where the prohibitive costs of replacing these fences will mean that a realistic programme to rehabilitate fences for animal movement and disease control purposes will be some way off.

No study has in detail documented the decline in Zimbabwe's game fencing infrastructure, nor the costs in terms of the local and export trade economies,

nor on the presumed increase in poaching and human-wildlife conflict that is likely to have increased with the downfall of these structures.

In Zimbabwe the decline of fencing capacity in terms of disease control is also affected by the diminution of capacity of the veterinary services. Transboundary animal diseases can therefore expand their range more freely – in some cases the threat comes from neighbouring states that are participants in a TFCA venture. In 2009 the first cases of BTB were noted in Gonarezhou NP with the disease almost certainly being carried by buffalo that crossed the Limpopo River (from KNP) into Zimbabwe. A fence that blocks this movement across the Limpopo was mooted some years ago but never opertionalised (Foggin, C. pers. comm., March 2009).

Decommissioning the GLTP fence

Both the LNP and KNP lie within the GLTP. The formation of the GLTP required the removal of all barriers and fencing between the parks so as to enable free migration of wildlife. The removal of the KNP eastern boundary fence which adjoins LNP is of the greatest significance in terms of the development of cross border cooperation between two states that were at one time in conflict with each other and in terms of the development of transfrontier conservation. This fence, completed in 1976, in combination with the western boundary fence, sealed off the KNP from its surrounding environs (Joubert, 2007). The fence itself was completed at the behest of the South African Defence Force. It is unknown what impact the fence had on wildlife movements, but the cable and rail-post fence combined with unsuitable conditions for elephant in the Coutada 16 hunting area (now the LNP) probably dissuaded much game movement from occurring. Since the fences removal over 650 elephants from KNP regularly cross over the fence and have established home ranges (demonstrating a quick range expansion potential by this species post-fence removal (D. Pienaar, pers. comm., March 2009). Sections of the fence were first removed in December 2002 in the presence of the ministers of the environment of the TFCA partners and later accompanied by a presidential signing and photo-session at the newly created Giryondo border post. The JMB of the GLTP did not request (as far as we can discern) an environmental or disease risk assessment prior to this event, and the search for disease transmission from KNP to LNP continues (M. Hofmeyr, pers. comm., March 2009).

The sequence of the dropping of the fencing between KNP and LNP is determined by budgetary and resource constraints of South Africa who will perform the fence removal, and the resettlement programme of the LNP. To minimise the possibility of conflict between wildlife and communities to be resettled from the core zone of the LNP, the fence should be removed following resettlement of communities from regions sited alongside the fence-line. The proposed fence dropping sequence is based on the current LNP resettlement programme and sequencing. It should be noted that a consultative process with communities needs to be completed and should this resettlement programme change in future years then the fence dropping sequence may require adjustment. It will be undertaken in consultation with the GLTP Safety and Security Committee to ensure applicable Safety and Security measures are in place, and in close collaboration with the LNP, GLTP and State Veterinary services to ensure baseline and disease monitoring measures are in place. Organisations such as the Peace Parks Foundation are currently supporting:

- disease surveys spanning across border (e.g. Bovine Tuberculosis);
- administrative support to key stakeholders;
- human resources capacity building for veterinary services in all parts of the TFCA.

The proposed Fence dropping sequence is described below in Table 6.4.1 and also detailed in the Fig. 1). From approximately 300km of fence, about 47km have already been removed, 40km running southwards from 10km south of Pafuri, and a further 7km midway between Giriyondo gate and the Shingwedzi entrance into LNP. However, the removal of this boundary fence does not mean that fencing *per se* does not have conservation value in LNP.

Table 6.4.1. Proposed fence-line removal sequence

Sequence	Date	Distance	Location	Trigger
1	2010/ 2011	20km	Running southwards from the southern end of the 40km section of fence already removed.	Nil
2	Mid-2011	30km	Running southwards of the first fence removal with the Shingwedzi running through the middle of the fence-line to be removed.	Resettlement of Makandazulo A&B
3a	Mid-2012	10km	Running southwards of the second fence removal up to the northern edge of the fence already removed between Giriyondo and Shingwedzi.	Resettlement of Chimangue and Machamba villages
3b		20km	Running southwards of the southern edge of the fence already removed between Giriyondo and Shingwedzi.	
4	Early 2013	30km	Running southward of the 3b fence removal down to the Olifants river.	Resettlement of Massingir Velho village
5	Early 2013	10km	Running southwards from Crooks Corner past Pafuri	Consultation with KNP and the Pafuri community

An Environmental Impact Assessment (EIA) is currently being conducted in order examine an alignment and design of a fence-line to run from Massingir gate in a NE direction to the Limpopo River. The fence will be about 65km long and will create a buffer zone in the south-east of the park with the fence (north-west); Limpopo River (east) and Elefantes River (south) forming the boundaries. Communities within this area will be able to live, rear livestock, and grow crops and be protected from the rest of the park's wildlife by this fence. The study should be completed by around mid 2011. There are no other

proposed fences in the LNP, but consideration will be given on a needs basis (subject to funding availability) for certain communities or agricultural fields (including irrigated fields) to be fenced in along the Limpopo River.

The CBPP fences in Botswana

The planned removal of fences should be ecologically more preferable than the simple gradual decline of a fences capacity to contain animals and should follow standard SEA and IEA and/or disease risk assessment procedures. Botswana has been one of the few countries in Africa to remove veterinary fences that it deems unnecessary. The Scott-Wilson report (2000) played a seminal role in targeting the removal of certain fences in Ngamiland. However, the pressure from civil and international environmental bodies has also played a large role in fomenting these fence removals (Albertson, 1998). Essentially therefore fences were erected without proper environmental considerations but arguably their removal is based on a more balanced approach between livestock and conservation concerns.

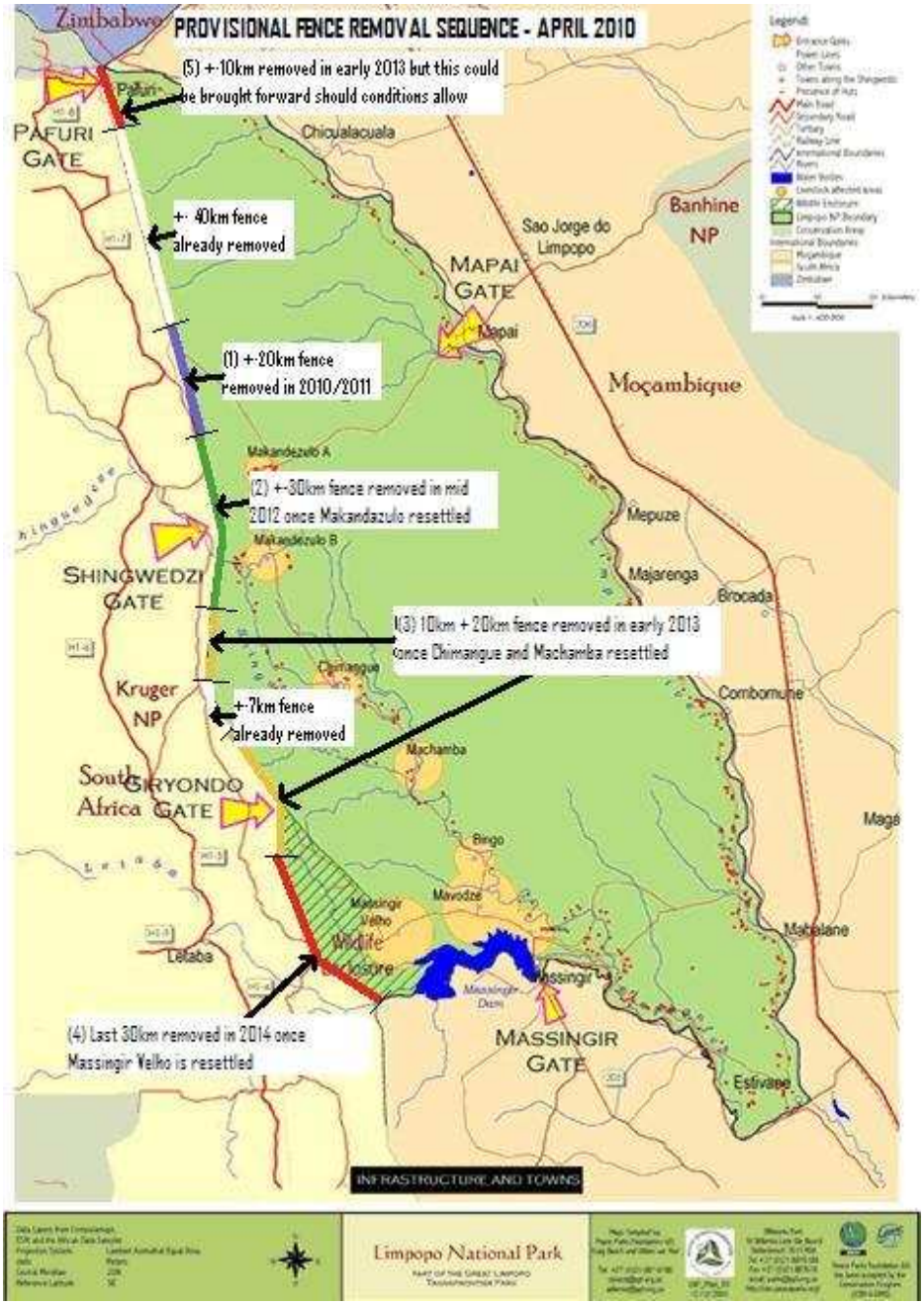
Two fences in the last decade have been removed in the 'sensitive' landscapes (in terms of land use options) in the north of Botswana (Ngamiland). The Government of Botswana identified these fences as being of critical impact on wildlife but no longer necessary for disease control purposes (Albertson, 2005). In late 2003 the Setata fence (210km), originally erected in 1995 as a response to the devastating outbreak of CBPP (which ceased to be maintained from 1998 onwards) was removed during an operation that took three months and in July 2005 the Nxai Pan (66km) fence was removed. The approximate cost of fence removal (excluding transport) was between Pula2,000-4,000 / km (in today's prices US$130-160 / km) and with recycling of wire and droppers for use in maintaining other fences (Albertson, 2005). The removal of the Setata fence in 2003-4 was only the first incident in a long campaign to have the fence re-instated (by the livestock production lobby) and then again attempts to have it removed a few years later (by the conservation lobby). This illustrates in part the extreme economic, psychological and political impact that the 'trauma' of the CBPP outbreak of 1995 still holds on those involved.

Albertson (2005) stated that the removal of these key fences 'has highly positive implications for the long-term viability of Northern Botswana's wildlife populations' and that 'seasonal migrants such as elephant, zebra and wildebeest have resumed their normal movement patterns' (although this assessment was not based on a quantitative analysis).

Conclusion

In summary we would suggest that the planned removal of fencing should be seen to be as important as the erection of these structures. In South Africa if a fence is to be upgraded on state land there is no need for a full EIA but only a screening assessment and it is unclear if such a full EIA is mandatory in the case of the entire removal of a fence. Wherever possible a full EIA with a disease risk assessment component should be conducted before fencing is removed. Lastly, fencing that has become degraded to the 'human-eye' may still pose a considerable risk to wildlife and should be fully removed. The concept of a transfrontier fence management plan may be an opportunity to harmonise conservation and animal health responses to fence issues that are collectively shared.

Figure 6.4.1. Map of GLTP Boundary fence and removal sequence



6.5 Preliminary results on the permeability of veterinary fences to buffalo (*Syncerus caffer*) and cattle in Gonarezhou National Park, Zimbabwe.

Dube, T.,*† Murwira, A.,† Caron, A. & de Garine-Wichatitsky, M.‡
†Department of Geography and Environmental Science, University of Zimbabwe, PO Box,MP167, Mount Pleasant, Harare, Zimbabwe and ‡CIRAD UR AGIRs, 37 Acturus Road, Highlands, Harare, Zimbabwe
Corresponding author: timothydube3@gmail.com; murwira@arts.uz.ac.zw; alexandre.caron@cirad.fr and Michel.de_garine-wichatitsky@cirad.fr

Introduction

Veterinary fences have been erected around conservation areas in southern Africa as a mechanism to prevent the transmission of diseases such as foot-and-mouth disease (FMD) from buffalo (*Syncerus caffer*) to cattle (Machange, 1997; Bengis, et al., 2002). In Zimbabwe however, the use of fences has been criticised (Taylor & Martin, 1987) and they appear to have not produced all of the intended results as FMD diseases outbreaks in livestock have been reported in the areas surrounding conservation areas (Sutmöller, et al., 1999), particularly in the South-East Lowveld during recent years. Although even well designed and maintained fences do not prevent all FMD outbreaks related to wildlife (Hargreaves, et al., 2004), evidence suggests that the economic crisis of 2000 to 2008 in Zimbabwe has resulted in extensive fence failures around Gonarezhou National Park (GNP), partly as a result of the lack of resources for fence management by the veterinary services. To date, little has been documented on the permeability of veterinary fences to buffalo and cattle movement as a result of fence failure, although the spatially explicit understanding of fence condition is an important pre-requisite to enhancing a healthy wildlife and livestock production system in most African savannas, especially in the case where diseases are threatening livestock production (Foggin, 1981).

This paper presents some preliminary results of a study carried out in 2009 and 2010 to map the condition of the veterinary fence around the South-Western boundary of GNP and estimate the magnitude of buffalo and cattle movements between the park and the neighbouring communal areas.

Materials and methods

We conducted our study in the south-eastern Lowveld of Zimbabwe along the fence that separates communal lands from the Mabalauta sub-region of GNP and Malipati Safari area which was officially created in 1963 and 1975 (Saunders, 2006). The veterinary fence, erected in 1975 to control interspecies contact across the interface and prevent disease transmission, was theoretically different from the park's boundary, but eventually turned out to coincide in practise. Its structure includes a three steel strand, separated by steel poles (Fig. 6.5.1), with the aim of restraining the movements of buffaloes. However, other wild animals such as carnivores and small antelopes are able to move across the fence.

Ground coordinates (UTM format) were collected following curves of the veterinary fence using a hand-held Global Positioning System (GPS) receiver while in a vehicle. After computing the total length of the fence, the total

stretch was stratified into four different fence conditions, i.e. undamaged, damaged, removed fence, and fence across river (Fig. 6.5.1).

Field data collection of buffalo and cattle movements consisted in spoor surveys. We conducted fieldwork from the 15 to 30 April 2009 and 15 to 30 April 2010 for the wet season, as well as from 29 Oct to 11 Nov 2009 and 10 to 24 July 2009 for the dry season. Spoors were spotted from a 4x4 vehicle driving slowly (5-10 km/hr), and each spoor group was identified with the aid of experienced rangers from Zimbabwe National Parks and Wildlife Management Authority (ZNPWMA) The evening before each fresh spoor survey, the spoors where cleaned along the 79.4km stretch of the veterinary fence before sunset (16h30 and 18h30), using a tree branch tied at the back of a 4x4. Spoor surveys were conducted from sunrise to mid-morning i.e. from 06h00 to 11h00, and then in the afternoon from 15h30 to 18h30.

Results

Fig. 6.5.1 illustrates the four fence conditions recorded along the park boundary fence. Of the total 79.4km stretch of fence under study, 27.3km was undamaged (34.4%), 30.2km was damaged (38.0%), 21.6km was removed (27.2%) and finally 0.3 km crossed rivers (0.4%). The sections of the fences located near the villages of Pahlela, Malipati and Chilohlela, were the most extensively removed or damaged.

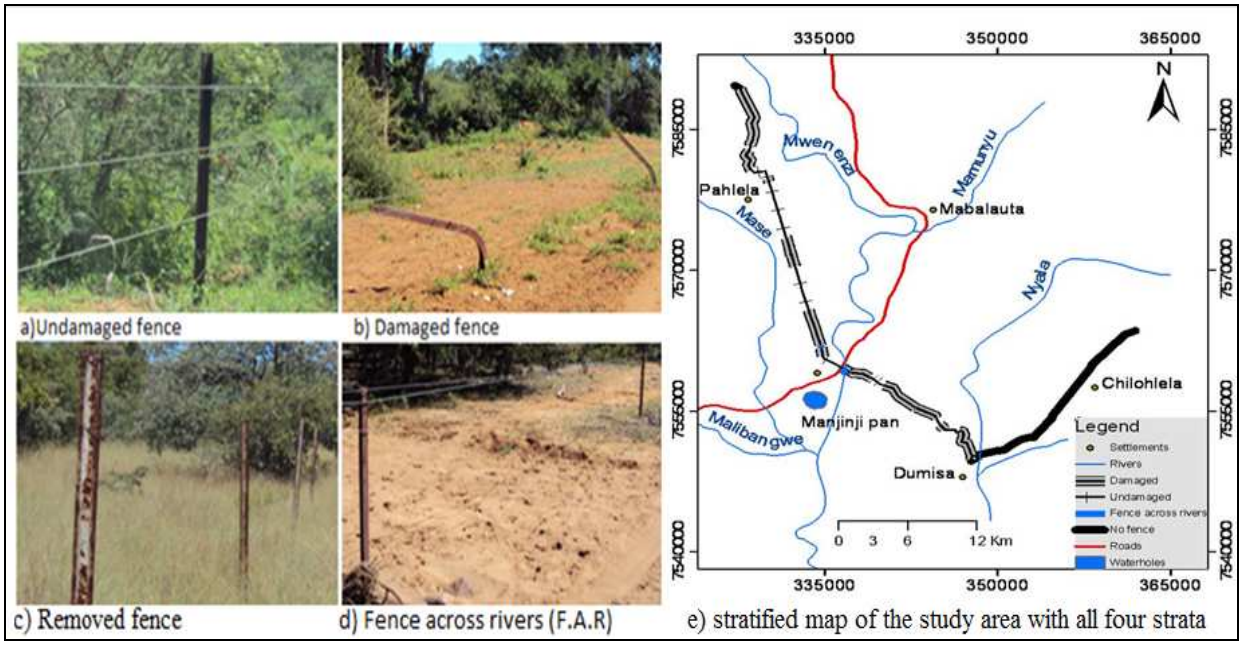


Figure 6.5.1. Assessment of the veterinary fence condition around Mabalauta area, GNP (79.4km inspected in 2009/2010).

Table 6.5.1 illustrates the number of buffalo and cattle movements across the veterinary fence according to season. These results suggest that similar numbers of individual cattle move into the park during the wet and dry seasons, whereas a greater numbers of buffalo move out of the park during the wet season.

Table 6.5.1: Total number of buffalo and cattle (number of individuals recorded using spoor counts) crossing the boundary of the GNP during the wet (April 2009 and 2010) and dry seasons (July, October-November 2009).

Animals species	Wet season	Dry season
Buffalo	47	31
Cattle	803	810
Total	850	842

Fig. 6.5.2 illustrates the areas where most animal movements across the veterinary fence have been recorded. It can be noticed that most cattle movements into the park were observed in areas located close to villages (Pahlela, Malipati, Chilohlela) whereas buffalo movements outside the park were only recorded across the south-eastern section of the study area, where there is currently no fence.

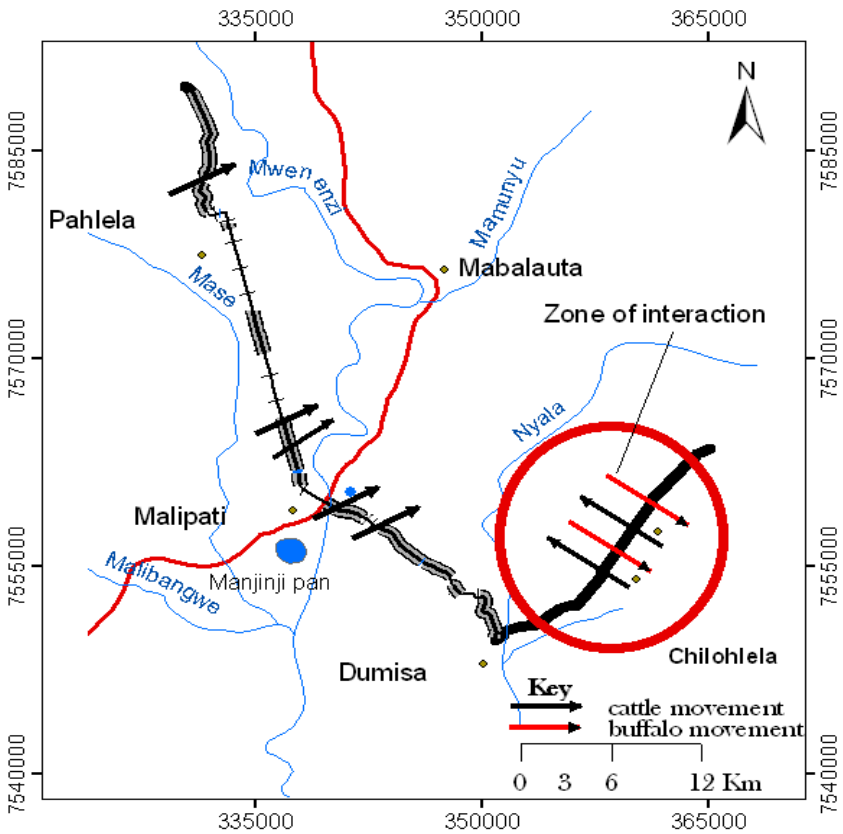


Figure 6.5.2. Areas of buffalo and cattle movements (2009/2010) across the veterinary fence around Mabalauta area, GNP (see Fig. 6.5.1 for legend of fence condition). 79.4km inspected in 2009/2010

Discussion and conclusion

The preliminary results of this study have empirically demonstrated that the damages along the veterinary fence allow cattle movements into several areas of GNP, whereas buffalo movements out of the park seem to be restricted to

the southeastern boundary of the park. Cattle movements occur during both the dry and the wet seasons, and across sections of fence that have been either removed or damaged, as well as where the fence crosses rivers. In contrast, buffalo movements out of GNP seem to occur mostly during the rainy season and across sections of the fence that have been totally removed. Further work needs to be carried out to elucidate the determinants of cattle and buffalo movements in the SEL of Zimbabwe. The seasonal patterns observed seem to suggest that these movements are partly resource oriented (i.e. access to grazing resources and permanent water resources inside GNP during the dry season), as demonstrated for buffalos by several studies in Southern, Eastern and Central Africa (Maddock, 1979; Johnson, et al., 1992; Taylor, 1985). However, cattle movements are also determined by herders and owners decisions, and it is likely that anthropogenic factors have a strong influence on the movements observed across the veterinary fence, such as the necessity to drive the cattle away from the fields during the cropping season.

We conclude that the veterinary fence around Mabalauta area of GNP is currently extensively damaged, with less than 1/3 of the total section examined considered intact. Preliminary data also suggest that cattle do enter the park in several areas and all year round, whereas buffalo seem to mainly move out of the park during the wet season and in specific areas. The management implications are manifold, as the prevention of disease transmission (including FMD) between buffalo and cattle should aim at controlling buffalo movements out of the park and cattle movements into the park. Given our preliminary data, the first aim (controlling movements of buffalo out of GNP) could possibly be achieved in a cost-efficient way by rehabilitating specific sections of the veterinary fence (e.g. approx 25km southeastern side of Mabalauta). However, the rehabilitation of a "buffalo fence" around GNP would be of limited efficiency to prevent cattle movements into the park, unless it is accepted by local stakeholders, which would require specific information, discussions and negotiations. The current state of the veterinary fence around GNP, and the need to re-establish an efficient control of animal diseases, could also be seen as an opportunity for rethinking disease control strategies at the wildlife-livestock interface in this area, exploring the possibility of innovative controlled and negotiated grazing by livestock (e.g. specific areas, specific periods, associated with specific treatments or vaccinations). We also recommend that regular monitoring of the fence condition and animal movements, using track surveys carried out by trained staff of the veterinary services, NPWMA and members of the local communities should be adopted as a routine surveillance system around GNP.

Acknowledgments

This project was conducted within the framework of the Research Platform "Production and Conservation in Partnership" RP-PCP. We thank the Ministère Français des Affaires Etrangères for supporting T. Dube through the French Embassy in Zimbabwe (RP-PCP grant AHE#4). This work was part of a modified poster that was delivered to the AHEAD meeting 22-23/02/2010 (Hazyview, South Africa).

7. LAND USE OPTIONS AND FENCING STRATEGIES

7.1 The impact of fences within the Kruger to Canyons Biosphere Reserve

Peel, M.J.S.
Agricultural Research Council, Animal Production Institute, P.O. Box 7063, Nelspruit, 1200, South Africa
mikep@arc.agric.za

Introduction

Humans have been associated with Africa for more than two million years as hunters, pastoralists and cultivators, an association that has had a profound effect on the structure and extent of the various biomes (Harris, 1980). The Kruger to Canyons Biosphere Reserve (K2C) is located within the Mpumalanga and Limpopo Provinces of South Africa and contains three biomes, the Grasslands, Afro-montane forests of the escarpment and the Savanna of the Lowveld (Fig.7.1.1). The K2C encompasses the Blyde River Canyon Nature Reserve and to the east the largest area of privately owned conservation land in the world, about half of the Kruger National Park (KNP) and part of the recently formed Great Limpopo TFCA (Anon., 2001). The area contains widely diverse landscapes and exceptional biodiversity (some 149 mammal species, 510 birds, 57 fish and over 2,700 plants, many of which are endemic; Anon., 2001). Other land uses that contribute to the economy include gold, phosphate and copper mining, afforestation, the cultivation of subtropical fruits and vegetables and subsistence and commercial stock farming. From the above, it is clear that the K2C exists within a complex interaction of socio-economic, political and ecological factors. When one considers the interconnectedness of the different land uses, we begin to recognise the potential influence that fencing may have on the natural resources of the K2C. This is particularly relevant when seen in the light of rivers and water distribution and the importance of linking the water catchments of the escarpment with the Lowveld's water scarce areas.

A history of land use in the K2C Biosphere Reserve

In examining the current status of natural rangeland in the eastern Lowveld it is useful to investigate the factors that have shaped these savannas over the past two centuries. The following is modified from Peel et al., (2004). Until the beginning of the nineteenth century, life appears to have been relatively harmonious in the eastern Lowveld but this changed with the coming to power of the Zulu King Shaka as people fled his dictatorship (Eloff, 1990). When he died, his sons fought and every winter until the early 1860s the eastern Lowveld as far as the Olifants River was ravaged by fire. Large-scale anthropogenic fires have thus occurred in the K2C area for at least 130 years.

As early as 1884, President Kruger expressed concern at the levels of game hunting in the eastern Lowveld and advised the setting aside of some land to ensure the continued survival of wild animals in the area (Stevenson-Hamilton, 1937) and the notice proclaiming the Sabi Game Reserve was gazetted in 1898. In the 1890s, W.H. Gillfillan, surveyed the area adjacent to the Sabi

Game Reserve between the escarpment and the Lebombo mountains and between the Sabie and Olifants Rivers into 4,000 morgen (3,428 ha) lots (Stevenson-Hamilton, 1929; Porter, 1970; Bornman, 1995). These were sold, first to ranchers and then to mining companies who thought the area might be rich in minerals. Fig. 7.1.1 illustrates the situation as it developed and illustrates the impact of such land divisions and subsequent fencing. In 1923 the Secretary of Lands announced that the Sabi Game Reserve would be cut up into farms and large land companies began cattle ranching in these protected areas (Porter, 1970). This continued until an area on the western border was given to the Land Estates Companies in exchange for the portion of land between the Olifants and Letaba Rivers (Porter, 1970). From 1922 the Transvaal Consolidated Land and Exploration Company (TCL) ran large-scale cattle operations in much of what is now the Sabi Sand Wildtuin (SSW) (Kloppers, 1970). In 1926 the National Parks Bill was passed, which paved the way for the proclamation of the Kruger National Park (Stevenson-Hamilton, 1929). In the winter of 1928 two rangers were appointed to combat poaching in the western and northern parts of what is now the SSW (Kloppers, 1970). This was the beginning of organised game conservation by private initiative, a relatively revolutionary development for the 1920s. From 1930 onwards individuals bought up land in the area and in 1948 the name of SSW was proposed and the reserve was proclaimed in 1965. The idea of forming a nature reserve in the Timbavati area was mooted in around 1937. The proposal of a game reserve was discussed in 1954 and the Timbavati Private Nature Reserve (TPNR) was proclaimed in 1956 (Porter, 1970). A similar pattern is evident for the Klaserie area where by 1936, in addition to cattle ranching, the land was used for hunting. Cattle farmers were finally bought out in the mid-late 1960s and the Klaserie Private Nature Reserve (KPNR) was proclaimed in 1969.

In the early 1960s the SSW, Manyeleti Game Reserve (MGR), TPNR, Umbabat Private Nature Reserve (UPNR) and KPNR (which were separated from each other by fences in the 1970s) were separated from the KNP with the erection of a veterinary fence designed to combat foot-and-mouth disease (FMD). The ecological effects of this fence became apparent in 1962 when a drought resulted in the death of large numbers of blue wildebeest (*Connochaetes taurinus*) and plains zebra (*Equus quagga)* that were prevented from migrating westward.

Cattle farming, often enclosed by fences for restricting game movement as well for recreation and hunting, continued to dominate in the Hoedspruit area to the west of the KNP and large private nature reserves until the late-1970s. There followed a large-scale switch of land-use, with cattle being replaced by game throughout most of the region between the Orpen road and the Olifants River and Selati Rivers. At about this time, the first of the small-scale (200–5,000 ha) operations became involved in the ecotourism industry. In 1992/93, a new era was heralded with the removal of the fence between the KNP and the large private nature reserves. The latter includes the SSW (≈ 63,000ha) in the south which links to the MGR (≈ 23,000ha) which in turn links to the so-called Association of Private Nature Reserves (APNR) which is some 172,747ha in extent and consists of the TPNR (≈ 53,392ha), UPNR (≈ 24,000ha), KPNR (≈ 57,918ha) and the Balule Private Nature Reserve (≈ 37, 437ha) (Fig. 7.1.1). The BNR is an excellent example of a process of fence removal and land consolidation, having previously consisted of properties as small as 1,000ha). The SSW, MGR and APNR fall into what is termed the FMD 'Infected Zone' which means that there can be no movement out livestock or potentially

infected mammals out of the zone and all cattle need to be vaccinated (Fig. 7.1.3). There has also been fence removal and ongoing consolidation of properties adjacent to the APNR including protected areas such as Kapama (≈ 10,900ha), Thornybush (≈ 11,350ha), and Umhlametsi Conservancy (≈ 4,700ha). The latter protected areas occur in the 'Buffer Zone' up to the R40 national road where animal movement is only permitted after quarantining and testing (Fig. 7.1.3). Further to the west further encouraging consolidation including the Blue Canyon Game Conservancy (≈ 14,400ha), Lissataba Phuza Moya Shareblock (≈ 4,200ha), Makalali Game Reserve (≈ 20,500ha) and Selati Game Reserve (≈ 28,547ha). These areas fall in the FMD 'Inspection Area of the Free Zone' where increased surveillance is practiced but where there are no animal movement restrictions. We have thus moved from an initial unfenced through significantly fenced to a reduced fence situation.

Ecological consequences of fencing in the K2C

The following is based largely on Peel, et al., (2004) and Peel (2005). Historically, herbivores such as blue wildebeest and zebra migrated from the eastern Lowveld west towards the Drakensberg Mountains in response to declining winter grazing. In summer, as grazing conditions improved, they migrated back again resulting in a natural resting of large areas of the Lowveld at certain times of the year. Under these conditions, fire was probably important in maintaining the structure of the savanna ecosystem. The erection of the KNP boundary fence and the sub-division and fencing off of land for commercial cattle ranching, and later game ranching, halted these migrations. Vegetation that was naturally rested for part of the year became heavily grazed by the now sedentary, and often unchecked, herbivore populations on units much reduced in size. Species such as zebra, elephant (*Loxodonta africana*), white rhino (*Ceratotherium simum*) and buffalo (*Syncerus caffer*) are capable of bringing about drastic changes to less utilised vegetation (Collinson & Goodman, 1982) which in turn adversely affects poorer competitors such as sable (*Hippotragus niger*) and roan (*H. equinus*) antelope and tsessebe (*Damaliscus lunatus*) that were previously relatively abundant in the K2C area (White, 1951). With fencing it became necessary to provide water artificially year round in areas where water was only seasonally available in the past. As a result the numbers of water-dependent species such as blue wildebeest and impala (*Aepyceros melampus*) increased significantly. These species exploit grass conditions brought about by the impact of elephant, buffalo and zebra, and further alter the composition and structure of the grass layer to a point that accelerates the decline of species such as roan and sable antelope. The above illustrates a reduction in herbivore diversity as a result of fencing and concomitant system changes.

Another impact of fencing involves the interaction of grazing, browsing, fire and woody densification. The latter is promoted by heavy grazing which opens up space where tree seedlings can germinate in the absence of grass competition, particularly during drought. This sets up altered tree:grass interactions that include an increase in competition for soil water, often with an increase in woody density, woody species having access to water deeper down in the soil profile due to their extensive root systems (Smit, 1992). The major implication of such interactions in the Lowveld savanna is that woody species are, from a grazing point of view, generally a poor replacement for grasses. The result is a situation of a weakened grass layer, reduced root growth, decreased grass production, exposure of the soil and reduced litter input. This in turn results in increased exposure to the impact of rainfall, increased soil temperatures, reduced rainfall infiltration, increased run-off and increased soil

erosion. Hot fires, which have a significant effect on the susceptible woody sapling phase become less frequent due to the weakened grass layer and the woody component is again advantaged (Scholes, 1987). Wildlife-based tourist operations in the region are adversely affected by such bush encroachment because the dense woody layer reduces game visibility. Consequently, bush control, which has important implications for the economic viability of wildlife operations, is practiced on many of the protected areas within the K2C (Peel, 2002a).

Thirdly, overgrazing particularly in fenced areas, often occurs because of an excess of artificially supplied surface water resulting high densities of water dependent species as discussed above. Further, the fact that natural migrations are interrupted results in varying levels of mortality in dry years due, in this instance, to a lack of grazing. These population declines vary from minimal to steep as was experienced in the 1982/83 drought in KPNR where 70-90% of the buffalo, waterbuck, warthog, wildebeest, zebra, sable and impala populations perished (Walker, et al., 1987). In subsequent droughts the same pattern has been observed on numerous smaller fenced properties where for example, in one instance, 93%, 25%, 82% and 84% of the blue wildebeest, waterbuck, impala and warthog died respectively (Peel, et al., in prep). Similarly, although not significantly fenced, drought related mortalities are commonplace in the densely populated communal rangelands through reduction of available grazing lands.

A model based on the capacity of the forage species to satisfy the energy requirements of grazers within an area has been developed (Peel, 2005; Peel, et al., in prep.). We can thus begin to predict population trends and implement timeous management action. Adjusting game numbers is critical on these small fenced units and decisions in this regard can be taken twice during the year, at the end of the growth season when the grass standing crop is at its highest and secondly at the end of winter following the annual game count. It must be said that artificial feeding during drought conditions in some protected areas exacerbates the situation as high animal numbers are maintained on already overgrazed areas.

It is important to touch briefly on the complexity of ecological systems. For example experiments simulating the effects of increases in CO_2 found large increases in tree density driven by CO_2 fertilisation. This suggests that in addition to management regimes, bush encroachment in savanna areas may in part be driven by increasing CO_2 levels in the atmosphere (Bond, et al., 2003). As discussed above the ecological and economic consequences of such woody densification is in this instance not positive.

Discussion

There has been large scale removal of fences within the protected areas of the K2C, and those that remain are there to avoid conflict with other land uses to the south (communal rangelands) and west (including forestry, agriculture, mining and nature based tourism). Despite these areas not containing the diversity of big game that is common in the protected areas, all of these activities are reliant to a lesser or greater degree on the natural environment, and contribute to the local and national economy of the region and country.

It is clear that fencing that resulted in the cutting off of the aquatic lifelines that flow through the K2C Biosphere Reserve has had a significant effect on the structure and functioning of this ecosystem. The encouraging consolidation of protected areas is in some way mitigating the previous impacts of fencing as

is the adoption of a Biosphere approach to land management where political processes are enhanced and frameworks created to deal with sustainable utilisation and development through a philosophy of public participation. The result accommodates and benefits both the natural environment and the communities living in and around the K2C.

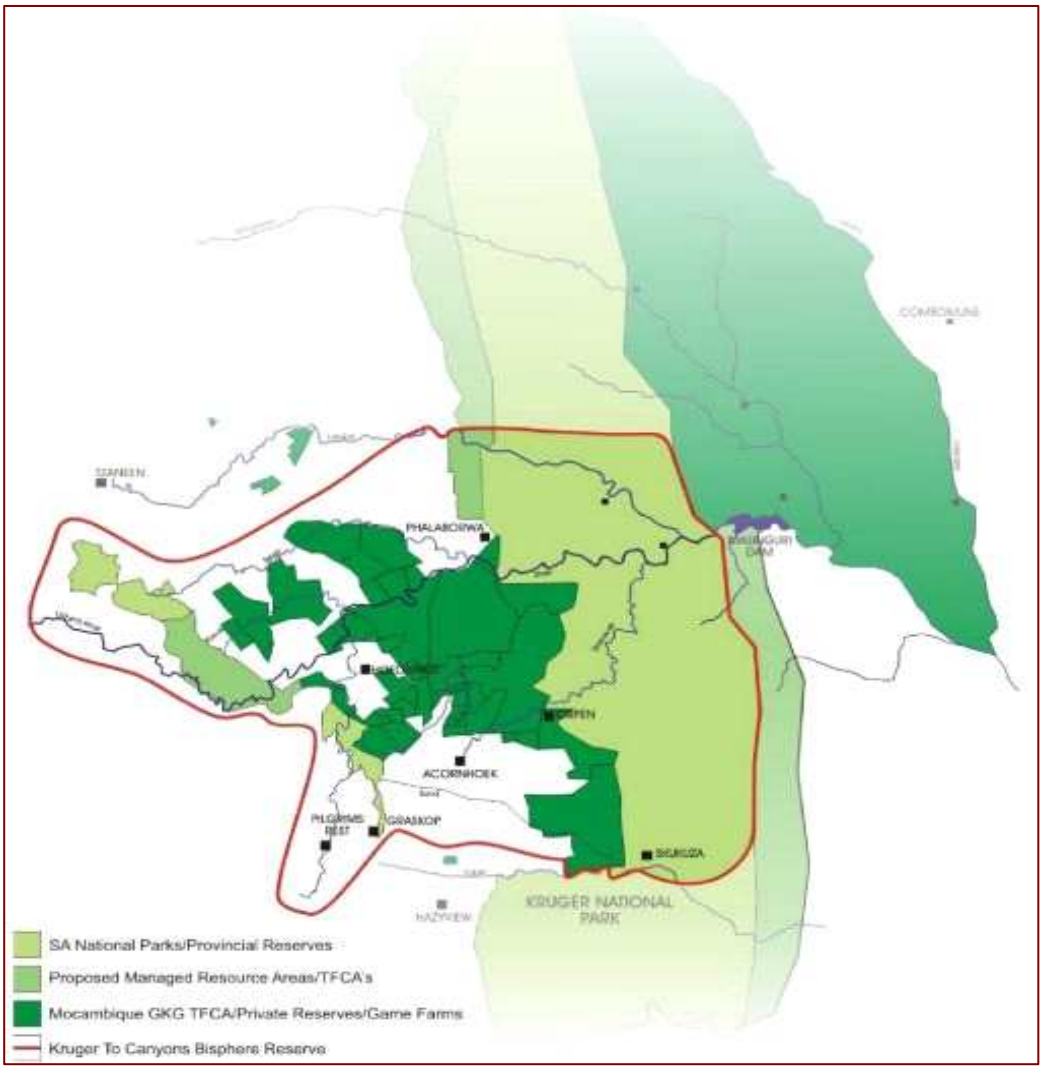


Figure 7.1.3. Boundary demarcation of the K2C.

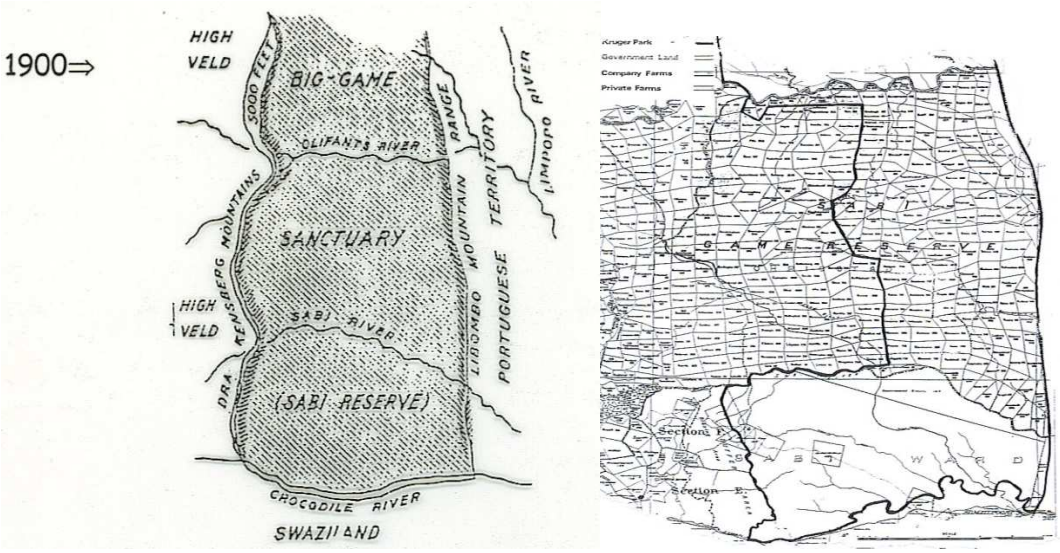


Figure 7.1.2. Illustrating the situation up to ≈1900 and post surveying in the early 1900s showing the impact of land division and the potential for subsequent fencing of large areas.

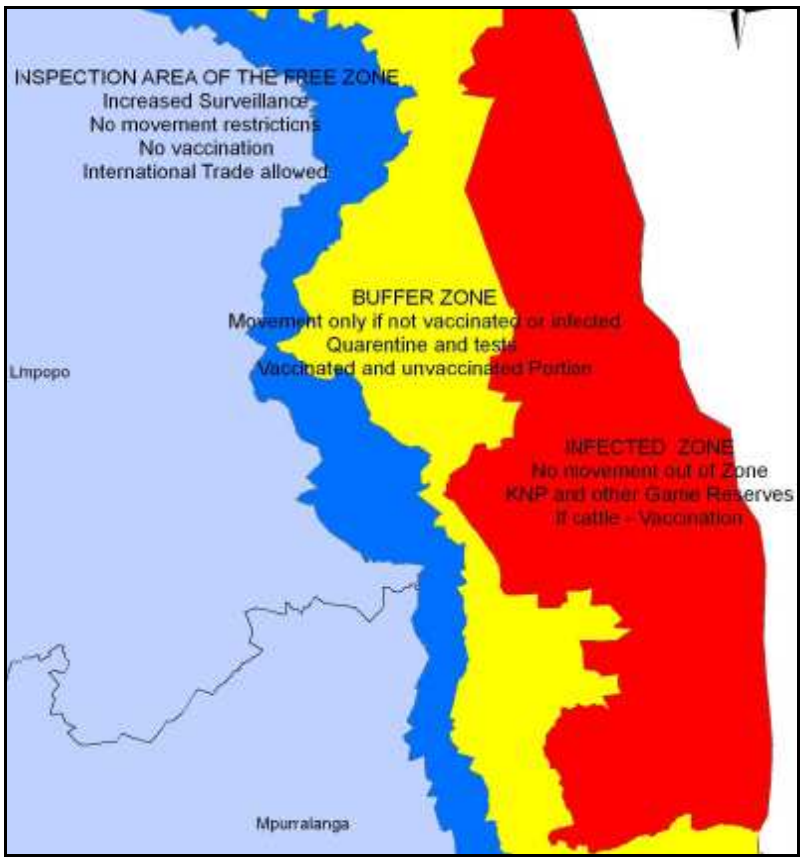


Figure 7.1.3. Foot-and-mouth disease zones in the area of the K2C. (www.agis.agric.za).

7.2 The influence of fencing in the development and limitation of wildlife-based land uses in southern Africa

Lindsey, P.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa. palindsey@gmail.com

Introduction

Fencing has played a key role in the development of wildlife-based land uses outside of protected areas in southern Africa. However, fences have also had the effect of stifling the development of wildlife-based land uses on private land, both by limiting land use options and through the use of fencing as a tool to control diseases for the preferential protection of the livestock industry. In this brief paper, I start out by discussing the positive contributions that fencing has made to wildlife-based land uses on private land in southern Africa, before moving on to cover some of the problems caused. Finally, I suggest interventions that could be made to reduce negative impacts of fencing and disease control strategies on private land. The information below is primarily extracted from Lindsey, et al., (in press) and Lindsey, et al., (2009) and is restricted primarily to issues relating to fencing and land use. A more comprehensive review of ecological, social and financial issues relating to fencing on private land is provided in Lindsey, et al., (in press).

Fencing and the development of wildlife-based land uses on private land

Fencing and the ownership of / user rights over wildlife

During the 1960-70s, legislative changes occurred in several southern African countries granting varying degrees of user rights over wildlife to landowners. These changes (occurring in Namibia in 1967, Zimbabwe in 1960 and 1975, and South Africa at varying times depending on the province) enabled landowners to utilize wildlife occurring on their land for hunting and live capture and trade (Bond et al., 2004). Wildlife was transformed from a burden to an asset for landowners and there was a rapid shift from livestock to game ranching across large areas of southern Africa (Lindsey, et al., 2009).

Wildlife has the status of being *res nullius* in most southern African countries, or without ownership until it has been captured, killed or enclosed. This status effectively means that wildlife belongs to the person whose land it is on, but if it leaves the property, ownership is lost. In South Africa, the Game Theft Act (1991) was promulgated to prevent the theft of wildlife: if a property is adequately fenced, and if the wildlife is positively identifiable (e.g. with micro-chips, brands, ear notches or ear tags), wildlife remains the property of the owner even if it escapes or is lured or otherwise removed from his/her property, or is killed by a poacher (M. Boshoff, Department of Environmental Affairs and Tourism, pers. comm.). Legislation requires that fences are present for landowners to effectively own wildlife in South Africa and Botswana, and in the case of Namibia, the presence of fencing facilitates the process for obtaining permits to utilize wildlife (Bond, et al., 2004; Barnett & Patterson, 2006). Consequently, fencing was an important component in the decision to allocate user rights to wildlife, a decision which resulted in the development of the wildlife ranching industry across large areas by enabling landowners to

benefit financially from wildlife. In South Africa, for example, wildlife ranches comprise as much as 205,000 km^2 (National Agricultural Marketing Council, 2006) and in Namibia, wildlife-based land uses are practised over an area of ~288,000 km^2, of which ~32,000 km^2 is used exclusively for wildlife production (Lindsey, 2010).

Fencing and the utilization of small habitat fragments

Fencing can permit the utilization of habitat fragments that may otherwise be too small by reducing edge-effects through the limitation of the movement of wildlife out of, and people into private ranches. The presence of fencing permits landowners to reintroduce and retain wildlife, including large species and predators, even in areas bordered by incompatible land uses such as agriculture, livestock farming or human settlement.

Fencing as a wildlife management intervention

By enabling manipulation of the movement of wildlife, fencing is an important tool in the management of endangered species and of habitat on private land. For example, fencing can be used to separate black rhinoceros (*Diceros bicornis*) bulls, which may otherwise suffer high mortality rates due to fighting (Hrabar & Du Toit, 2005). Fencing is sometimes used to create enclosures to protect locally rare ungulates such as Lichtenstein's hartebeest (*Alcephalus lichtensteinii*) in Savé Valley Conservancy (C. Stockil, pers. comm.). Fencing is used as an important tool for wildlife reintroductions, by creating release paddocks (or 'bomas') which allow for an acclimatization and familiarization period for wildlife prior to reintroduction. Bomas are of particular importance for reintroductions involving wide-ranging species such as wild dogs (*Lycaon pictus*) by reducing post-release dispersal (Hofmeyr, 2001).

Fencing in disease control

Fencing is widely employed in southern Africa as a tool for limiting the spread of diseases between livestock and wildlife (Thomson, et al., 2004), and have been constructed in several locations in Botswana, Namibia, around Kruger National Park in South Africa, and widely in Zimbabwe, including in the South, Zambezi Valley and escarpment areas (Albertson, 1998; Du Toit, 2005; Martin, 2005). Fences are most commonly used to prevent the transfer of foot-and-mouth (FMD) disease from buffalo and other wildlife species to cattle, to retain access to European Union export-markets for beef and meat from wildlife (Thomson, et al., 2004). Fences are also / have been used to control transfer of other diseases, including corridor disease, rinderpest, African swine fever, contagious bovine pleuropneumonia, malignant catarrhal fever and trypanosomiasis (Taylor & Martin, 1987; Grant, et al., 2007). The assumed ability of fencing to limit disease transfer was significant in the development of the wildlife ranching industry, which may otherwise have been subject to greater resistance.

Problems associated with fences on private land

There are a number of problems associated with fencing on private land which have affected the development of and the conservation value of wildlife-based land uses.

Fences inhibit a variety of ecological processes

Fencing can inhibit or prevent natural ecological processes such as immigration, emigration, and migration. By limiting movement, fenced reserves are vulnerable to problems associated with small populations and

islands, and render populations more susceptible to environmental, demographic and genetic stochasticity (Macarthur & Wilson, 1967; Caughley, 1994). Fencing interrupts gene flow between populations, introducing a risk of inbreeding and enhancing the prevalence and impacts of founder effects and genetic drift (Caughley, 1994; Hayward, et al., 2007). Managing fenced populations as components of a meta-population can help to avoid many of these problems (Hayward, et al., 2008).

Fencing also limits the extent to which wildlife populations can move to utilize patches of primary productivity, and can reduce the ecological capacity of land as a result (Ben-Shahar, 1993; Du Toit, 1998; Boone & Hobbs, 2004). The veterinary fences of Botswana for example, reduced access of plains zebra (*Equus quagga*), blue wildebeest (*Connochaetes taurinus)* and other wildlife to water and dry-season grazing and caused massive die-offs as a result (Williamson & Mbano, 1988; Albertson, 1998; Mbwaia & Mbwaia, 2006). In Kenya, the construction of fencing is exacerbating the impacts of habitat fragmentation associated with the sub-division of communal rangelands into private smallholdings (Western & Nightingale, 2005).Similarly, in South Africa, wildlife ranchers are increasingly constructing predator-proof fencing to protect valuable antelopes, thus reducing habitat availability for free-ranging populations of threatened species such as wild dogs and cheetahs (*Acinonyx jubatus*) (Lindsey, et al., 2009). Fences may exacerbate the impacts of global warming on wildlife conservation by constraining adaptive responses of wildlife to climate change through adjustments in their spatial distribution (Cumming. 2004).

The confinement of wildlife populations with fencing appears to affect density dependent population regulation, and fenced areas are susceptible to unnaturally high densities of some wildlife, resulting in environmental degradation and the risk of population crashes (Boone & Hobbs, 2004; Hayward & Kerley, 2008). For some wildlife, such as the white rhinoceros (*Ceratotherium simum*), unusually high densities may increase the frequency of aggressive social interactions, resulting in elevated incidence of infanticide and reduced reproductive rates (Masterson, unpublished data). As a result of these phenomena, small fenced reserves require frequent management intervention to prevent over-population or local extinction, which can impose additional financial costs on the land manager. Predators reintroduced into small reserves in South Africa, for example, commonly reach unusually high densities, and management intervention is sometimes required to prevent precipitous prey population declines (Hayward & Kerley, 2008; Davies-Mostert, et al., 2009). Furthermore, fencing can modify the behaviour of predators and impose additional financial impacts in small reserves. Wild dogs learn to chase animals against fences during hunting, enabling them to kill large species such as waterbuck (*Kobus ellipsiprymnus*) and kudu (*Tragelaphus strepsiceros*) more frequently than is typical in the absence of fencing (Van Dyk & Slotow, 2003).

Fencing and disease control objectives

Efforts to control FMD on private land through the erection of fences and creation of FMD-free zones seriously limit the profitability of game ranching. In FMD-free zones, buffalo are excluded and their reintroduction is prohibited. In Namibia, even certified FMD-free buffalo may not be reintroduced on private land (DVS, 2007). The reintroduction of FMD-free buffalo is permitted in some circumstances on private land in South Africa, but their high live-sale price has

limited the extent of reintroductions. Buffalo are of key economic importance to both tourism and safari hunting revenues, by virtue of their membership of the so-called 'big five'. Buffalo attract high trophy fees, can be used to sell hunt packages, and can generally be hunted in fairly large numbers and can generate up to 60% of all hunting revenues (Lindsey, unpublished data). As a result of veterinary restrictions, hunting safaris on private land in Namibia and South Africa target almost entirely low-value 'plains game' hunts (Humavindu & Barnes, 2003; Lindsey, et al., 2007) reducing income significantly relative to what could be achieved if buffalo reintroductions were permitted.

In addition to preferential veterinary control policies, the livestock industry in parts of southern Africa benefits from external subsidies which provide unfair advantages over wildlife-based land uses and promote continued erection and maintenance of veterinary fences (Mbwaia & Mbwaia, 2006). Such protection and subsidies are despite a growing body of evidence to suggest that wildlife-based land uses are ecologically, socially, financially and economically preferable to livestock in semi-arid rangelands (especially if allowed to develop without veterinary restrictions) (Barnes, 2001; Mbwaia & Mbwaia, 2006; Lindsey, 2010). The proportion of income derived from wildlife-based land uses is positively correlated with employment levels, whereas the correlation between the proportion of income from livestock and employment is negative (Lindsey, 2010). The relative profitability of wildlife-based land uses is validated by the fact that private land owners have removed livestock from large areas, despite the veterinary restrictions. For example, by 2001 more than half of ranchers in the Limpopo Valley, Central Lowveld and Zululand areas of South Africa were farming only with wildlife, and cattle had been completely removed from several large blocks of former cattle ranching country in the South East Lowveld, Gwayi River valley and Matetsi areas of Zimbabwe (Lindsey, unpublished data). In Namibia, despite restrictive disease control strategies, the value of wildlife-based land uses on freehold land is rapidly approaching that of livestock farming (Lindsey, 2010). Increasing tourist arrivals, the increased prevalence of wildlife-based land uses among younger farmers, and projected declines in income from livestock following the impacts of global warming indicate that earnings from wildlife-ranching in Namibia will become significantly greater than those from domestic stock in the near to medium term (Barnes, et al. in prep; Lindsey, 2010).

The profitability of wildlife-based land uses (and the productivity of land in general) in large areas of semi-arid land in southern Africa would be increased significantly if veterinary restrictions were removed and land owners permitted to reintroduce FMD infected buffaloes. Continued preference of livestock over wildlife-based land uses is due in part to a misconception among some politicians that the latter represents a threat to food security (du Toit, 2004). Research is required to demonstrate the food security benefits created by wildlife-based land uses on semi-arid lands through their relative profitability, the generation of foreign currency, the creation of elevated employment opportunities, and the large quantities of healthy protein produced.

Fencing and wildlife-based land use options

The fragmentation of ranching areas with perimeter fencing along individual properties limits land use options which has implications for conservation. Ranches in South Africa are generally small (8.2–49.2 km^2 depending on the province (Bothma, 2002)). Large charismatic species cannot be reintroduced to small properties with perimeter wildlife fencing, which precludes high-end

ecotourism, and limits land use to high off-take, low income meat and trophy hunting of antelopes (Lindsey, et al., 2009). Under such conditions, predators are perceived to impose direct financial costs by removing animals that could otherwise have been hunted, and are widely persecuted (Marker, et al., 2003; Lindsey, et al., 2005). In addition, the fencing and isolation of game ranches appears to promote environmentally damaging management decisions such as the reintroduction of exotic or extra-limital species and in some cases, the genetic manipulation of species to improve hunting trophies (Hamman, et al., 2003).

Enhancing the role of fencing as a conservation tool on private land

1. *Using the minimum possible amount of fencing:* The key ecological problems associated with fencing stem from the isolation of small populations and inhibition of the processes of immigration, emigration, and movement to exploit patchy primary productivity. Most of these problems can be resolved by increasing the size of an area encompassed by a fence and thus reducing the length of fence per unit area. A practical means of achieving this is through the amalgamation of adjacent properties and the creation of collaboratively-managed conservancies. Conservancies are created when adjacent landowners remove internal fencing to create a larger area, usually encompassed by a single perimeter fence. Conservancies can support larger populations of wildlife than isolated ranches, and contain larger areas which are more resilient to stochastic events. Consequently, they are less susceptible to localized variation in rainfall (Du Toit, 1998; Lindsey, et al., 2009). Furthermore, the larger areas encompassed by conservancies permit the re-establishment of the full complement of mammal fauna and encourage land uses such as ecotourism and high-value safari hunting which are more profitable, provide more employment opportunities and are more closely aligned with conservation objectives than the high off-take meat hunting typical of small, fenced ranches (Lindsey, et al., 2009). In addition, management tends to be guided by professional management plans, which in combination with group-accountability reduce the prevalence of arbitrary and environmentally damaging management decisions by individuals (Lindsey, et al., 2009; C. Brown, Namibia Nature Foundation, pers. comm.). Conservancies have potential to bring together a critical mass of funding, capacity, ideas and motivation which provide for more effective and profitable wildlife management (C. Brown, pers. comm.). Finally, conservancies can provide effective vehicles for land reform by providing an institutional scale more appropriate for dealing with governments and communities (du Toit, 2004; Lindsey, et al., 2009). In addition, the centralized management and economies of scale associated with conservancies remove some of the barriers to the entry of farmers from previously disadvantaged groups into wildlife-ranching (e.g. lack of funds for developing infrastructure, or lack of experience/expertise in wildlife management) (Lindsey, et al., 2009). Consequently, conservancies are preferable over fenced game ranches on ecological, financial/economic and social grounds and so governments should consider introducing incentives such as tax breaks to promote their development (Lindsey, et al., 2009).

A key barrier to the formation of conservancies is fear among ranchers of the loss of wildlife to neighbouring land owners. However, effective models for collaborative management of wildlife exist which enable neighbouring ranchers to share the mobile resource equitably, and which address differential prior investments in wildlife. The development of such agreements can effectively remove the need for physical barriers between adjacent wildlife ranches. A

review of the relative efficacy of various conservancy constitutions and co-management agreements across southern Africa is urgently required.

2. *Re-thinking fences for veterinary purposes:* A re-think of the strategy of fencing for veterinary purposes is required. Several alternative options for veterinary control exist. For example, much larger FMD-endemic zones could be created to promote wildlife-based land uses by moving veterinary fences and 'lines'. In Zimbabwe, for example, several authors have suggested that the FMD fence in the south east of the country could be realigned to create a larger FMD zone without adversely affecting potential for beef exports (Taylor & Martin, 1987; Du Toit, 2005). In South Africa, a FMD-endemic zone could be created in key wildlife production zones, where wildlife-ranching is already practiced in preference over livestock (e.g. Limpopo Valley, Central Lowveld, and northern Zululand). Alternatively, FMD-endemic islands could be created within FMD-free zones, using fences and possibly narrow wildlife-free buffers to contain the disease. Conversely, FMD-free islands could be created within a larger FMD-endemic landscape to provide for preferential conditions for wildlife production, while retaining the option to export livestock from areas particularly suited to that land use (Kock, 2005). Perhaps the most promising potential strategy is through lobbying for acceptance of commodity based trading of processed meat products (Thomson, et al., 2004). Under commodity based trading, meat processed in a manner proven to provide minimal risk of transmitting FMD-virus (for example through removal of bones and lymph nodes) could be considered acceptable for export (Thomson, et al., 2004). The most pressing issue for gaining acceptance of commodity-based trade is obtaining support of the concept from the World Organisation for Animal Health (AHEAD, 2008). Research is urgently required to demonstrate the financial and economic pros and cons of potential alternative strategies for the control of wildlife-borne diseases.

Conclusions

In conclusion, fencing was crucial in the development of wildlife-based land uses in southern Africa and has greatly enhanced ability to manage wildlife effectively. However, inappropriate legislation and policies designed to promote livestock production have resulted in fencing stifling the development of wildlife-based land uses and a reduction in the conservation-value of game ranching. A re-think of policies is required to promote more judicious use of fencing, to encourage the development of large, co-managed landscapes, and to adjust veterinary control strategies to provide greater scope for the reintroduction of buffalo on private land.

7.3 Conservation on private land in South Africa: management without boundaries?

Child, M.F.
Department of Zoology, Conservation Science Group, University of Cambridge, U.K.
mattychild@gmail.com

Fences and the flux paradigm

Fences are used primarily to delimit resource use in rural systems, which can cause extensive habitat fragmentation (Hobbs, et al., 2008). Spatial delimitation, however, also engenders certain social constructs. For example, fenced-off national parks are, in the minds of its many patrons, pristine areas where human interference is minimised, whereas in reality these areas are most often managed to appear natural (King & Stewart, 1996). Communities living in poverty outside the Kruger National Park (KNP) probably did not foresee the functional significance of the veterinary fence that was erected in the early 1960s more than it marked yet another boundary to another restricted area. Spatial segregation, along with the naming of the park after President Kruger, may have been used to establish KNP as a cultural space where Afrikaners could express their nationalistic ideals by harking back to the wilderness days of the Great Trek (sensu Carruthers, 1994), which highlights how controlled spaces can create cultural divisions (Spierenburg & Wels, 2006). Following the first democratic elections in 1994, however, conservation in South Africa embraced the concepts of the 'flux of nature' paradigm and began initiating transfrontier endeavours (Venter, et al., 2008).

In KNP, boundary fences have been dropped to form vast joint-spaces with Mozambique, Zimbabwe and the private conservancies abutting its western edges. Concomitant with the significance for biodiversity is the symbolic value of social inclusion and integration. The conservancy sector also contributes to this trend: private landowners are increasingly willing to drop fences and form large-scale reserves for ecotourism (Bond, et al., 2004). As an indication, around 90% of the internal fencing constituting the conservancy areas west of KNP have been dropped since the 1980s (M. Child, unpublished data, for example, Fig.7.3.1). Thus fence management has the power to act upon the ideology behind management actions. Analyses of fence use will shed light on the social-political systems that govern conservation.

The rise of conservancies

Private landowners, having been almost inconspicuous in the conservation literature for many decades, now promise to recreate the conservation landscape in the 21st century (Langholz & Lassoie, 2001). One of the most important aspects of private land-use is the tendency to form conservancies, in most cases dropping internal fences between properties and jointly managing the land through agreed-upon ecological goals and constitutions (Peel, et al., 1999; Lindsey, et al., 2009). The steady amalgamation of ex-livestock farms and other properties into conservancies potentially generates greater landscape heterogeneity and connectivity. Thus, conservancy formation can be seen as a counter movement to urban sprawl, industrial development and agricultural monocultures. In the lowveld, conservancy formation to the west of KNP has hugely helped to reduce landscape fragmentation. Consequently,

the average mammal species richness in these reserves has increased steadily through time (10 ± 2 species, n = 6, Fig. 7.3.2, M. Peel, unpublished data). For thorough reviews of the benefits of dropping fences on private lands, see Hobbs, et al., (2008), Lindsey, et al., (2009), and Hayward & Kerley (2009). However, unlike statutory protected areas where the mandate is clearly the conservation of biodiversity (Biggs & Rogers, 2003), private landowners are under no obligation to formally contribute to national biodiversity targets, although they are constrained to operate under existing environmental legislation (Lindsey, et al., 2009). Instead, many conservancy landowners manage for profit derived from high-end ecotourism.

Deeds and cadastral (property boundaries) data show that, due to the conservancies, average property sizes used for wildlife in both the Eastern Cape and the lowveld have become larger (T. Palmer & M.F. Child, unpublished data), despite the fragmentation caused by the requisite fencing of small game ranches (Bothma, 2002). This trend is correlated with increasing corporatisation of reserves (T. Palmer & M.F. Child, unpublished data). Conservancy expansion appears to be spatially autocorrelated, accelerating at the edges of existing conservancies and reserves. However, less established reserves at the fringe of core conservancies tend to become buffer zones that absorb poaching pressure and other edge effects and so tend to remain fenced out (R. Kettels, pers. comm.). Thus, fences maintain their social-political dimensions in private conservation and are used to create intricate social (and consequently ecological) landscapes.

Compromises

Fences are functional as well as ideological tools. Observations of the conservancies in the lowveld suggest there are subtle but salient ideological clashes playing out. Fig. 7.3.1 demonstrates how conservancy expansion may lead to fence retention as well as fence removal during property consolidation. At a regional scale, the incorporation of specialist game-ranching farms into conservancies might be balanced by the splintering off of farms who disagree with management regulations, perhaps analogous to an island-biogeography model of balanced speciation-extinction rates (Diamond, 1975). The reasons behind local 'extinctions', however, go beyond the usual tragedy of the commons conundrum of unwillingness to share a pooled resource or disagreement over conservancy regulations (such as hunting quotas). Interviews with dissenting landowners have revealed deep dissatisfaction with how commercial conservancies are managed for 'Big 5' tourism at the expense of the more historically accurate 'plains' restoration of the land (before it was transformed by agriculture and overgrazing). Some landowners forgo money received from traversing right fees and are prepared to incur the increased costs of managing small parcels of land (including fence maintenance, rotation of water-points and culling) in order to preserve their own conservation ideal. Smaller fenced farms may stimulate local economies because many require supplemented forage and other subsidiary services to maintain predetermined herbivore biomass or community composition. Stimulation of local producer-consumer relationships is a key to healthy communities (Tasch, 2008). Thus, it is possible that there is an optimal level of conservancy to fenced farm ratio that could reinvigorate rural socio-economic as well as socio-ecological systems.

The ideological reservations of many landowners, although still to be formally evaluated, appear to be justified: many conservancy habitats are no longer optimal for obligate grazers like sable (*Hippotragus niger*), roan (*Hippotragus*

equinus), tsessebe (*Damaliscus lunatus*) and eland (*Taurotragus oryx*) and these species occur in very low densities in the region (M. Peel, unpublished data). Instead, these species have been bred intensively and extensively on predator-free specialist farms. However, these specialist farms are in danger of being amalgamated into conservancies, in which case conservancy expansion could subsume the refugia where rare antelope can exist in sizeable populations, thereby decreasing regional biodiversity as well as decreasing capacity and competition in the bourgeoning trade of live animals (sensu Damm, 2005). This in turn may increase the price of these animals and further hinder the feasibility of future reintroduction attempts (Fig. 2). Reintroductions onto commercial conservancies are also dogged by high concentrations of predators for which the reintroduced animals are too few in number to survive predation pressure. The expense of continued reintroduction may make this management option undesirable in periods of financial duress. Rarer species may thus fall prey to increasing commercialisation of nature where the emphasis is squarely placed on the 'Big 5' and charismatic carnivores. Ironically, then, it is possible that fencing may still be necessary to ensure the regional presence of species vulnerable to management practices that focus on optimising ecotourism revenue.

Private management practice may also become an obstacle in itself to fence removal. Disease probability is heightened when large numbers of animals congregate at waterholes (Young (1970), cited in Gaylard, et al., 2003). Given the hyper-distribution of artificial water-points in conservancies (for example, Conservancy B has an average distance between water-points of 0.7 ± 0.3 km) pathogen source pools (in both the still water and the high concentration of dung surrounding these areas) are likely to increase dramatically. Diseases that are likely to be transmitted at waterholes include mange, blackleg, anthrax, and foot and mouth disease. The subsequent likelihood of wildlife-livestock disease transmission will only reinforce the need for more veterinary fences, especially when clean buffalo breeding farms become incorporated into the conservancies themselves.

Interviews with conservancy managers and reserve wardens reveal that fences are sometimes used to forge market niches. Preliminary data suggest that the Conservancy A, which is fenced off from the Greater Kruger Park[24], has fewer species of mammals than nearby Conservancies B and C (Fig. 3). Thus, market differentiation in competitive ecotourism may impact on biodiversity conservation. Social and ecological networks are not independent of one another but are structured by similar constraints and opportunities (Cumming, et al., 2010). Thus, the social dynamics of a system, in generating its own social network, probably feeds back into the ecological organisation of the landscape. A cursory analysis reveals that even while Conservancy A exhibits lower overall mammalian diversity, certain species exist in far higher abundances than surrounding conservancies (for example, nyala (*Tragelaphus angasii*): 88 ± 23 compared to 36 ± 26, $F_{2, 25} = 15.6$, $n = 28$, $p < 0.01$, M. Peel, unpublished data), which portends that market differentiation may come to alter ecosystem structure. Of course, several factors must be considered to counterbalance these concerns: 1) the foreign revenue that this conservancy brings to the country is considerable; 2) the land will benefit biodiversity conservation far more than any type of agricultural or urban-related transformation; and 3) tourists probably still cultivate a conservation ethic from experiences in such 'farmed wildernesses', although this is debatable: for

[24] The "Greater Kruger Park" refers to the KNP and the adjoining private game reserves.

example, West & Carrier (2004). The crux of this debate is in deciding whether or not the commercialisation of conservation is a slippery slope and whether conservation agencies should act now to alter future models of conservancy development. If the goal of conservation is to sustain heterogeneous landscapes in flux and allow all elements of biodiversity to function freely, how much should the movement be willing to trade-off on its ideals (Child, 2009)?

Conclusions

Conservancies are a potent force for conservation. The trend is for landowners to remove internal fences and shift commercial activity to high-end ecotourism, which generally benefits biodiversity but may lead to the local loss of certain species (Fig. 4). Fences are used by dissenting landowners to state ideological arguments over ecosystem restoration, management ethics, and hunting restrictions; and are also used at the conservancy scale to create a marketing niche. Thus, fences fulfil an equivocal role in private conservation. Much more research is necessary to determine the genuine impact and potential of fencing in these new contexts. Such research is crucial to elucidate the best policy recommendation for a land use that has the potential to stem biodiversity loss worldwide.

Acknowledgements

I thank the Oppenheimer Memorial Trust and the Cambridge Commonwealth Trust for financial support during this project. I thank Dr. Mike Peel for his crucial ongoing help and advice. All opinions expressed are the author's alone.

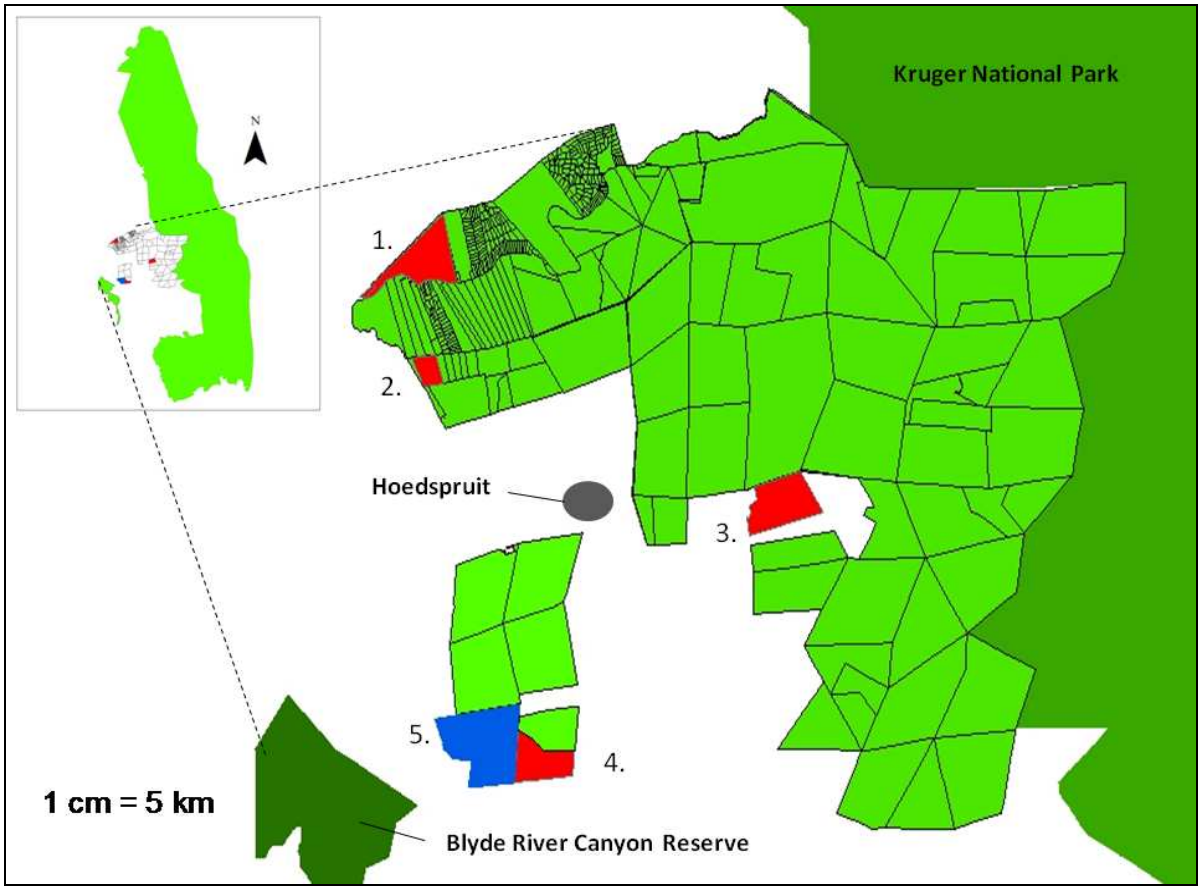


Figure 7.3.1. Map of the Associated Private Nature Reserves and a recently formed conservancy near the Blyde River Canyon Reserve. The properties in red (1-4) have fenced out of the conservancies for ideological, hunting, and conflicting land-use issues. The property in blue (5), formerly a specialist sable and roan antelope breeding farm, is being amalgamated into a conservancy. All boundary fences, besides properties 1-4, have been dropped.

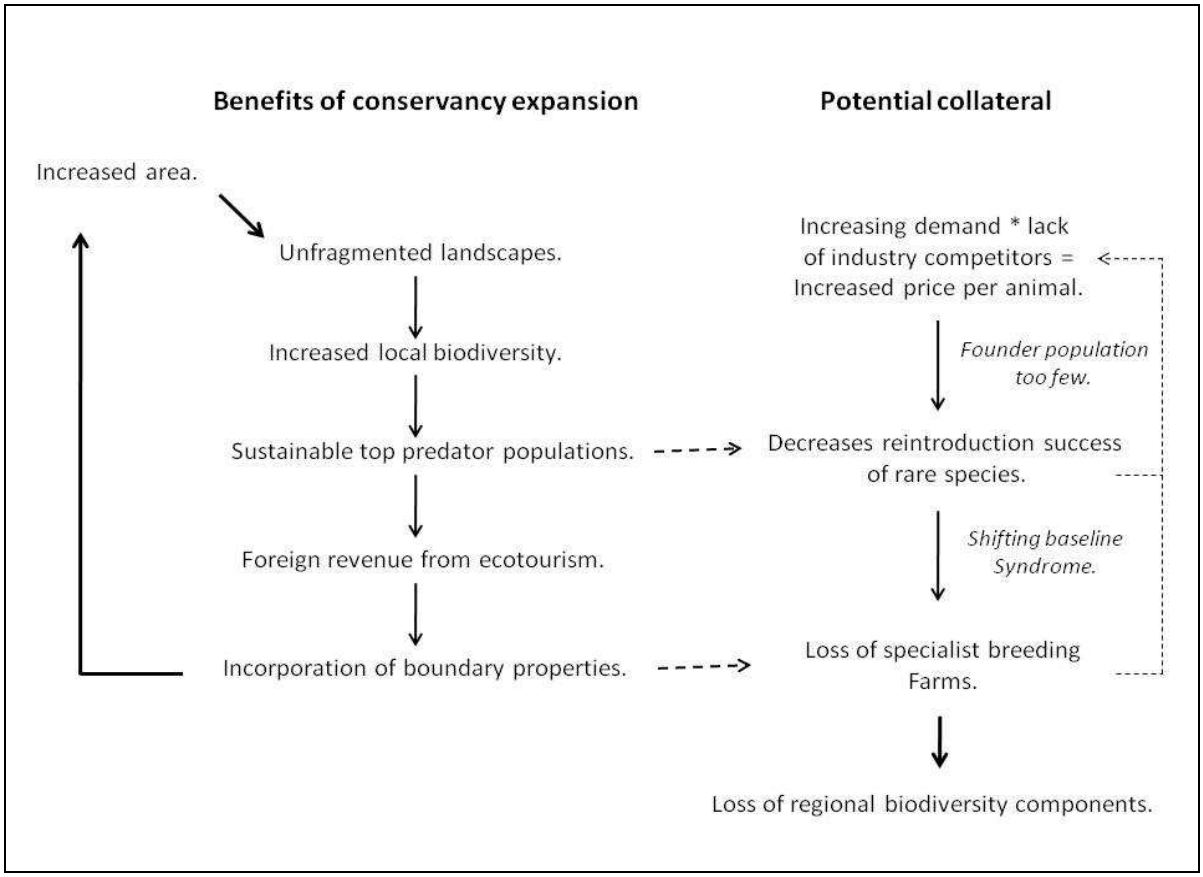


Figure 7.3.2. A schematic outline of possible, cross-scale consequences for biodiversity arising from continued conservancy expansion.

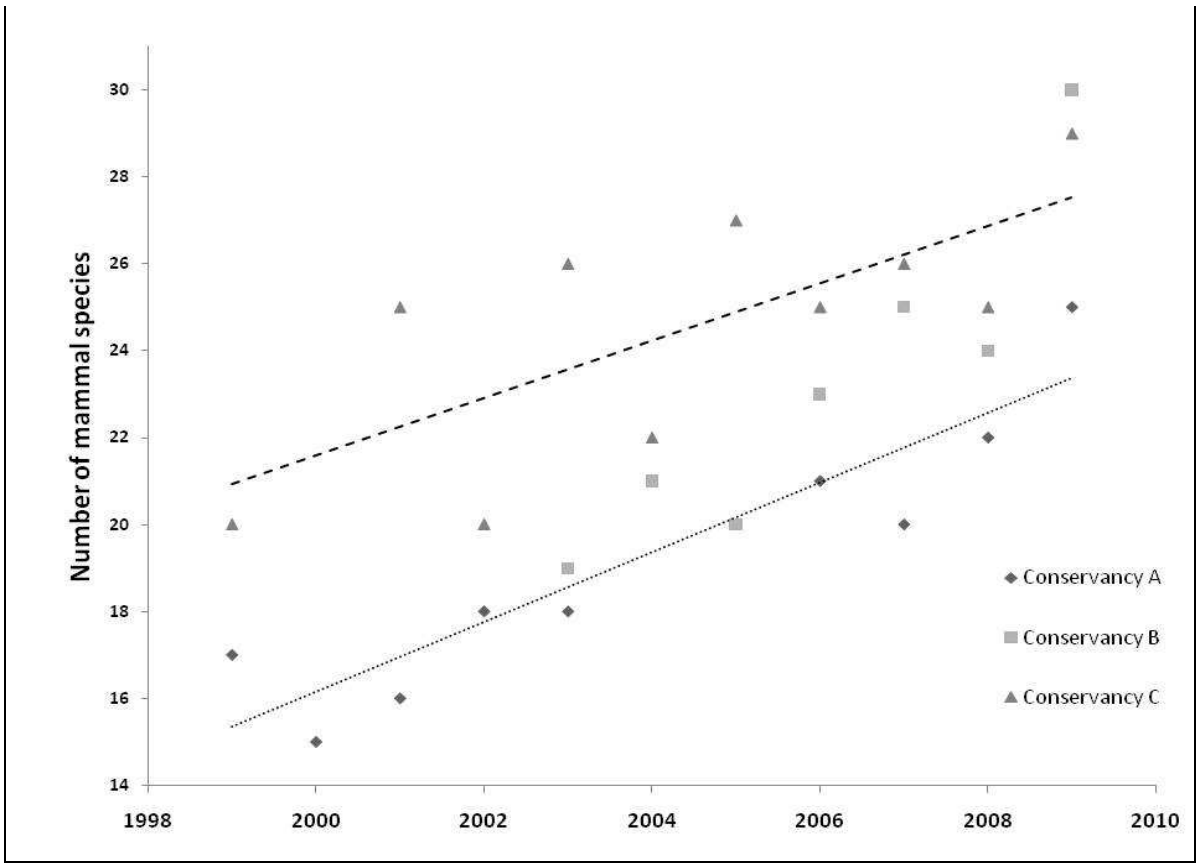


Figure 7.3.3. Conservancy A (lower trend line), which is fenced off from the rest of the APNR, displays consistently lower numbers of mammal species than either Conservancy B or C (19 ± 3 compared to 23 ± 4 and 25 ± 3 respectively, $F_{2, 25} = 7.50$, n = 28, $p < 0.01$, M Peel, unpublished data).

7.4 The economic impacts of game and veterinary fencing

Ferguson, K.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
selousgame@hotmail.com

Introduction

The delineation of rangeland into 'biodiversity friendly' versus 'human and livestock' dominated landscapes is as much an economic distinction as it is anything else. Game and veterinary cordon fencing represent not only a physical barrier but a fiscal one as well, in the sense that they are expensive to build and maintain and they may have unintended and ultimately costly environmental impacts. Ulitmately, the spatial distribution and spatial choices made by large mammal species (wild or domestic/and their owners) that utilise rangeland provides the basis for all economic incentives and is directly linked to environmental resource gradients created by soil fertility and rainfall. It is primarily along these gradients that fencing serves to reinforce the social, economic and political hegemony of agricultural practices. Environmental gradients, especially, that of rainfall, therefore delimit the most economically viable rangeland areas by virtue of the creation of spatio-temporal heterogeneity (maintained by large herbivores) in key landscape resources. As human population density and intensification of the efficiency of natural resource extraction increases in higher rainfall areas (e.g. conversion to arable crops), so, 'less' efficient and more traditional forms of range land use are 'pushed' into the lower rainfall and nutrient margins – and at this physical juncture the conflict between wildlife and social development (and in some cases, traditional pastoralism) is likely to become more intense (Olff and Hopcraft 2008; Ogutu et al., 2010).

Fences can act to disrupt large mammal movement. We can divide the role and impacts of fencing by making the primary distinction between fencing for veterinary requirements and for fencing for other uses – such as protecting a protected area or preventing human-wildlife conflict (HWC) around rural settlements. Fences can be multi-purpose (e.g. Kruger National Park's western boundary fence is both a 'red-line' veterinary fence and a park boundary) or serve a single purpose. Therefore, the economic, ecological and epidemiological factors related to fencing are dependent on the purpose of the fence, its efficiency and critically its political backing and motivations.

The second major fencing distinction to be made is between the use of fencing by the State and by private entities. The development or wildlife commercialism in South Africa is partly due to the use of fencing to control 'externalities' (such as laws requiring fencing, control of disease in a private area etc.) and promote viability and strong user rights within mixed-agricultural settings. In Zimbabwe such externalities *'avoided the financial and ecological disadvantages of fences with a rather elegant common property solution'* (B.Child 2009; referring to game conservancies and community-based conservation). However, the downside to private fencing is the potential to fragment land in to smaller parcels whereby over-stocking and rangeland degradation may occur (see also sections 7.2 and 7.3).

Game fencing is an expensive item to purchase and maintain by either individuals or the state. Private sector fencing is concerned with protecting

investments such as introduced game or rare species (or protecting staff and guests from crime). In the case of state owned veterinary control fences, the costs of the fencing are directly linked to the financial returns from the livestock to be safeguarded from disease(s).

How does one measure the impacts that fencing can have on the environment and society (and the interplay between the two)? In the USA the impacts that the extensive roads network has on wildlife mortality and landscape fragmentation is being intensively researched (Forman, et al., 2003). Blake, et al., (2008) found that road development in central Africa 'represent a formidable barrier to movement' of elephants (*Loxodonta africana*). Developing a similar understanding of the role that fencing in Africa may play in terms of the impacts on the environment and development is critical to the formation of a coherent itemization of the costs and benefits of such barriers. It is possible, in a general way, to scale the economic impacts of fencing from the macroeconomic (e.g. external beef subsidies received by Botswana) to the microeconomic (e.g. health effects of a serious disease outbreak on livestock and their owners from rural families, due to the failure of fencing).

Macroeconomic impacts of fencing

At the top of the macroeconomic scale, climate change in relation to the livestock industry in semi or arid rangelands takes pre-eminence. For example, the eastward movement of the Kalahari desert, due to increasing regional temperatures and El Nino effects may 'cut across' fence lines and alter the dynamics of water, grazing availability and stocking densities (Africa Geographic, 2007). Presumably, the restriction of movement of wildlife and livestock will be acted upon to an even greater extent than before and therefore the restrictive role of fences will be magnified.

Such changes may then interact with the need for equity and justice for natural-resource-dependent societies (Thomas & Twyman, 2005) and a re-thinking of the strategic role of fences within the context shrinking resources may become a part of the climate change adaption required in the dry lands of southern Africa. Kock, et al., (2010) note that the socially mediated changes (increasing privatization and fragmentation) in southern Africa rangelands over the past century have led to new disease transmission pathways and we can surmise that climate change will further concentrate populations of humans, livestock and wildlife and therefore this effect will be set to introduce new disease transmission pathways. On the benefit side, livestock produces livelihoods for 1.3 billion people worldwide and makes productive use of some 33% of the world's arable land. In Kenya 88% of Kenya's landmass is populated by 4.5 million people with approximately 9 million head of livestock. Most of Kenya's protected areas fall within this 'catchment' area and some 70% or more of the wild large mammals live seasonally outside of the parks (Norton-Griffiths & Said, 2010). At this huge interface between state controlled conservation and a rapidly changing tribal or private system, conflict comes in many guises, all of which emphasize the nature of the competition for resources between people (and inter-group competition) and the remaining traditional wildlife and pastoral areas. In 21st Century Kenya, fences are providing a way of privatizing and fragmenting the landscape (Kioko, et al., 2008) which historically parallels the role of fencing in the way that the 'American Wild West' was 'tamed' (Fleischner, 2010). Indeed Victurine and Curtin (2010) note that the 'wild west' is still being 'tamed' and fragmented by

a new wave of fencing, erected due the sale of cattle ranches to urbanites, who wish to parcel them up still further in to 'ranchettes'.

The costs of the reorganization of land tenure-ship in Africa, through the sub-division of land, in terms of reduced ecosystem goods and services is exemplified by the fact that at least 50% of large mammal populations in these arid and semi-arid Kenyan rangelands which lie outside protected areas have declined in the last few decades (Norton-Griffiths & Said, 2010).

The economic role of veterinary fencing in southern Africa is distorted by another type of barrier – trade. Africa produces a mere 2% of global livestock exports (G. Thomson, pers. comm.) due to the combined effects of under capacity, trade protectionism and the fear of diseases spreading to the exporting nations. The 'failure' of South African foot-and-mouth disease (FMD) fences in the year 2000 led to a ban on beef imports from Egypt that lasted 10 years (long after the outbreak was brought under control and months after an unrelated outbreak in Egypt; SABC News, 19 March 2010) and Europe is still fearful of a repeat of its 2001 FMD outbreak. Therefore the primary rationale for veterinary fencing has always been an economic one.

Various agreements are in place to give Africa preferential livestock trading status, but these apply only if the rules governing the safe export of these products are adhered to. It must be remembered that the financial loss incurred by an FMD outbreak in the source country is dwarfed by the potential loss to an uncontrolled outbreak, in for example, Europe (e.g. during the United Kingdom 2001 FMD outbreak losses amounted to approximately £900 million pounds in direct losses and £ 5 billion pounds loss of tourism revenue; Farmers Weekly, Undated). Fencing therefore has been heavily subsidized by the European Union and new disease control fences have recently been proposed, such as a 1,000km fence between Angola and Zambia (AHEAD, 2003). More research is needed on the macroeconomic connections between fencing, foreign investment and sustainable livestock development in general.

A recent article in an influential South African financial magazine has suggested that 'South Africa must allow more of its marginal agricultural land to switch to tourism and game farming' (FINWEEK, 2010) and that it is policy failures that drive down the value of indigenous species (and by extension game farming features less intensive management practices which may include less fencing and habitat fragmentation). This should be seen in the light of increased agricultural debt in South Africa and of gross income from total agricultural output rather than red meat production alone (27.7% compared to 9.8% respectively). However, such bold claims must be seen in the context of the total gross value of South African agricultural production valued at Rand 112 billion in 2007-2008 (of which livestock production account for 49% of this output; South Africa Yearbook 2008/09).

Farther north and buoyed by the foreign subsidies already alluded to, the commercial ranching systems that demands 'red-line' (areas free of disease and therefore export zones) zonation in Ngamiland has become a key focus area for the 'weighting' of different land use options and the impacts of fencing (Barnes, et al., 2003;Scott Wilson, 2000).

Barnes, et al., (2001; 2003) have examined in detail the relationship between continued expansion of the livestock sector (and fencing infrastructure) and its competition for land and resources with wildlife. In Botswana traditional livestock keeping occupies 60% of the land surface and commercial ranches 6%. Yet, the export figures are shared equally between the two systems with

government seeking to bolster the export earnings of the communal farmers. This expansion into largely undeveloped communal lands of Ngamiland by commercial livestock was preceded by massive fencing investment and without any prior knowledge of the impacts that various land use options would have on biodiversity. However, Barnes, et al., (2003) concluded that in northern Botswana 'capital-intensive commercial livestock ranching is economically inefficient' and that wildlife production systems or low (capital) input systems would provide for better sustained wealth accretion.

Child (2009) unambiguously states that *'it is financially and ecologically hazardous to ranch cattle where annual rainfall is less than 750mm per annum, as it cannot meet the twin objectives of being profitable and sustainable'* and further that *'Botswana missed an opportunity to support a substantial industry with the abundant wildlife it has only 60 years ago.'* Part of this missed opportunity relates to the role of fencing in de-populating wildlife areas.

On this issue of wider economic returns for livestock and wildlife land use policies, the role of fences in a comparative economic assessment cannot be easily disentangled from the profitability of the entire land use option. However, when the external 'beef' subsidies are removed from the calculation we find that economic returns can be negative. In the absence of subsidies and for a similar profit to accrue Barnes, et al., (2001) found that in Ngamiland calving rates would have to increase by 90%, beef prices by 60% or capital costs would need to be reduced by 60%.

In Ngamiland, investing in new large scale commercial ranches is beset by prohibitively high capital costs of which fencing is but one of these costs (Barnes, et al., 2001). Positioning of commercial farms near wildlife areas or veterinary fences obviously increases the risk of herd contamination (and predation (Hemson, et al., 2009) and will effect land prices and again could deter the expansion of ranches. Barnes, et al., (2003) take a 'common-sense' approach to the sub-division of land-use practices, ' wildlife-based tourism in high quality wildlife areas…should get priority where these conditions exist', and 'where the economic values (of wildlife) exceed those of livestock' and that a spectrum of land-use planning should be envisaged. In this sense one could argue that the fencing network in Botswana could be reconfigured to take into account some basic cost-benefit sums i.e. ecological economics must become part of the cost-benefit analysis of fencing. Spinage (1992) relates the decline of the wildebeest in the central Kalahari to the impacts of fencing, which begs the question of how to place a monetary figures on the numbers of animals lost and even how is it possible to calculate the loss of migrations associated with this species – which may affect tourists 'willingness to pay' for the experience of visiting such areas.

A biodiverse economy

Tourism in Botswana is forecast to grow on average by 7.3% per annum, from the year 2007, over the next decade far outcompeting most African countries. Currently travel and tourism account for 16% of non-mining GDP. The ethos for the tourist plan for Botswana is 'high-yield and minimal impact' (WTCC, 2007). For this market to grow as predicted it is a fair comment to make that the natural capital assets must be protected whether it relates to the issue of fencing and fragmentation or as another example water user rights for its main transboundary rivers.

A study by Wallgren, et al., (2009) showed that protected areas were important not just to aid the protection of endangered species, but, that the

abundance, diversity and species richness of mammals in the Kalahari is to a greater or lesser extent impacted upon by human land use and that large-bodied wild species did not overlap and compete with large-bodied livestock species. Again the reasons for population declines in large-bodied wild ungulates in these dry systems is likely to be partly related to fencing but also nested within an overall complex climate induced framework, such as drought periods (Spinage, 1992).

The compromise solution would be to integrate wildlife and livestock production so that each form of use can bolster the other in times of meagre income from any one source (e.g. a drop in tourism due to terrorism can be compensated for by an increased but not irreversible increase in livestock production). Kreuter & Workman (1997) examined a mixed ranching scheme in Zimbabwe and concluded that with regards to fencing, that less investment was required in wildlife than cattle enterprises (11% to 20% respectively of the cost of asset structures) a saving due to the removal of internal conservancy fencing. They also concluded that the combination of cattle and wildlife production could spread the risks that were associated with each separately (e.g. tourism instability could be compensated for by an increase in livestock production). However, such mixed ranching schemes have rarely been successful largely due to the epidemiological problems of a merged interface and the cultural biases in favour of livestock production (Kock, et al., 2010).

Microeconomic impacts of fencing

The development of 'coarse' and 'fine' scale economic indicators of fence efficiency needs to be developed. For example a fine scale indicator would be to measure the rate of permeability per km of fencing by different species (Ferguson, et al., 2010; Table 6.1.1 in section 6.1) and relate this to the economic or environmental importance of the disease concerned or the impact of carrier species on the fence (e.g. in terms of FMD whereby buffalo (*Syncerus caffer*) are a high disease risk species, elephants are not such a risk but they do break fences more often). Such a scale of disease risk would be more suited to risk probability modelling exercises. The number of disease outbreaks per unit time would give a coarse level of efficiency of the fence as a barrier, therefore, five outbreaks in 10 years would give a 50% level of fence security and this figure would have to be compared with the total amount of months of clean up costs versus the cost of the fence in terms of construction and maintenance. Ultimately, such a holistic economic approach should have the double benefit of discerning whether a fence upgrade is required or whether the fence itself is a financial burden with little efficiency. This fencing cost to benefit ratio should form part of the overall economic and financial estimation of using rangeland for livestock production as opposed to other land uses such as wildlife production.

In African countries where pastoralism is still a major source of livestock production, the role of fencing may be even more acute. For example, around Nairobi National Park (partially fenced) wildlife dispersal areas are being blocked by the relatively new phenomenon of Maasai peoples subdividing the land into parcels 'protected' by fencing. Reid et al., (2008; and see section 7.6) surmise that fencing in this context will differentially parcel off water points and good grazing areas from the general matrix thereby not only reducing the land area available to wildlife but also the diversity of patch types available. Within the enclosed patches wildlife may be deliberately eradicated or excluded and the size of the area may be less than the average home range size

required for some wild large mammal species. Curtailment of the dispersal corridors used by migratory species, by means of fencing, may be additively fragmented by drought, increasing urbanisation and the selling of land for infrastructure development. All of these fragmentary factors will depress the resilience of the ecosystem and may, in the case of wildlife, lead to a threshold to be crossed that culminates in 'mega-faunal' collapse.

Estimating the direct cost of fencing materials, construction and maintenance (including salaries) over time is again difficult to sustain in any meaningful way, largely due to inflationary pressures. Electric fencing in Zimbabwe estimated over the period 1990-1998 was approximately USD $1,900 per kilometre, but today, this figure would be considerably higher (Price Waterhouse Coopers, 1998). A more reliable method for estimating fence 'capital costs' would be to calculate the benefits accrued in terms of square kilometres protected (state or private land), households protected, or disease outbreaks averted. Fencing designs and purposes have to be carefully matched and related to long-term financial management. This requires skills in terms of sourcing materials, competent contractors, and fence planning in general, especially in the case of community based fencing projects whereby early successes with electric fencing lead to most projects 'being stuck in a partially functioning state' (Price Waterhouse Coopers, 1998).

The Karoo National Park has recently upgraded its 'stock' fence to a fully operational 2.4m electrified fence (as specified by provincial legislation). Due to the fact that a fence was already in place an EIA was not conducted but a Screening Assessment was (J. de Klerk; SANParks pers. comm.). The primary rationale behind this expensive construction was the re-introduction of species such as cheetah (*Acinonyx jubatus*) and buffalo. The new fence will have a length of 175 km and costs R85,000 per km (total of R14.9 million). It is assumed that benefits of the expected tourist increases (due to more 'desirable' viewing species) and the natural regulation of prey by introduced predators outweighs the cost to the public purse.

De Boer, et al., (2007) introduced a fencing element directly into a cost-benefit analysis of conservation efforts in southern Africa. A projection of tourist numbers and elephant density (both perceived benefits) in terms of profit were compared with costs as exemplified by poaching losses, costs of crop raiding by elephants and electric fencing construction to contain these animals in the Maputo Elephant Reserve Mozambique. They concluded from their model that 'costs generated' through elephant poaching and elephant crop raid costs were higher than fence construction costs at a population size >100 for this species. In other words the fence capital outlay became profitable only after either a natural increase or assisted by a higher translocation rate of elephants exceeded this number. This model also factored in the maintenance costs of the fence as 10% of the initial investment; however they did not estimate the potential for theft and damage of fence components affecting this figure.

Perry, et al., (2001) suggested that the discipline of veterinary epidemiology should be directly integrated into economics in terms of how they interrelate, which may have an important bearing on setting the priorities of disease control implementation and which selected interventions to use. Fencing should thus also be considered as part of the economic assessment of the entire control strategy deployed and would have to be balanced against the potential for developing effective vaccines or the attempted eradication of a particular disease. An example of how disease, politics, economy and barriers can

intermesh is given in Nasereddin & Jaffe (2004). They note that the disease visceral lieshmaniasis which is caused by the parasite *Leishmania infantum* is debilitating and can be fatal to humans is associated with several species of canid which act as primary hosts. The spatial dynamics of this disease suggests that the epidemiological pathway is linked to the presence of a new Israeli security fence. The Israeli security fence is approximately 645km long and 5-8m high and is being built to separate Israel from the Palestinian territories. The authors note that the fence will act as a direct barrier to the movement of jackals (*Canis aureus*) and dogs (*Canis familiaris*) but that ultimately the spread of this disease will depend instead upon the newly re-created (by the fence) home ranges and dispersal distances. Further, the long-distance transportation of dogs by their owners (when entering or leaving the territories through policed checkpoints) may also result in the inter-city spread of the disease (possibly to currently disease free areas).

Measuring the livelihood and health impacts on livestock owners and their dependents of serious zoonotic outbreaks is not often attempted. We can make the assumption that to livestock owners and their dependents (whose livelihoods are predicated in part on the successful containment of disease) may, in certain circumstances, view fences as a means of securing their income. The 1995 CBPP outbreak in Namibia caused the mass deaths (by 'stamping-out campaigns') of some 320,000 cattle (Amanfu, et al., 1998). Many families will have been left destitute and 15 years later it has been reported in the newly proclaimed Bwabwata National Park, that donkeys and goats have replaced the cattle lost and that this has resulted in a lower annual income for these rural people (M. Atkinson, pers. comm., April 2010.). Quantifying this in terms of human psychological impact, let alone general health and financial loss, is a mammoth task. In 2001, an FMD outbreak in the United Kingdom lead to a spate of farming related suicides and surprisingly an upsurge in 'grounded poetry' based on the experiences of the farming communities (Nerlich & Doring, 2005). In the Netherlands an outbreak of FMD disease, in the same year as the one in the UK, led to an increase in levels of stress, feelings of marginalization and clinical depression amongst the dairy farming families (Van Haaften, et al., 2004).

The importance of fencing for the future protection of national herds from disease (and from human-wildlife conflict in general) has to be offset against the impacts on conservation. In this sense there is a real clash between the two when it comes to prioritising the Millennium Development Goals. All of the 8 goals are required to be met by 2015, but, unsurprisingly the sustainable environment goal (Goal 7) is the one that is most unlikely to reach this target – and it is the goal which has 'fencing issue' nested as a minor subset within it. It is therefore tempting to speculate that this issue could be ignored in favour of the more achievable targets. However, very recently it has been suggested that some of the longer-standing veterinary fences in Botswana could be removed in the not too distant future (Anon pers. comm. March 2010). Thus the role of fencing in the wider sense is seemingly in a state of flux.

In summary with respect to rangeland sustainability, I can conclude that the role (especially veterinary) fences play in landscape sculpturing are a part of what du Toit (2010) has termed the 'mismatches of scale' as far as the sustainability of rangelands, in all their broad facets, are concerned. Thus fencing structures are embedded locally and, yet, they have ultimately far reaching regional and global environmental and economic impacts, far beyond the physical situation of the fence itself.

7.5 Land use management on the border of Kruger National Park, the case of the Nghunghunyani buffer zone project

Van Ierland, J.
Mpfuneko Community Support (Pty) Ltd, P.O. Box 1475, Giyani, 0826.
jotte@mpfuneko.co.za

Introduction

The objective of a so-called buffer zone project is to fence-in part of communal land into the Kruger National Park (KNP) so that local communities get access to land within the park, which they can use to develop tourist activities while at the same time the conservation area is enlarged. At first sight establishment of such a buffer zone project may seem to be a win-win situation for both people and the environment. However, re-location of the KNP fence has negative side-effects outside the project area that should be taken into consideration before implementing a buffer zone project. An integrated development package could help to off-set some of the negative side-effects and make re-location of the fence more attractive for all members of local communities.

Nghunghunyani buffer zone project

In 1993 the Limpopo Province Government initiated a project, which was called the 'Mariyeta Buffer Zone Reserve', to establish a buffer zone between KNP and neighbouring communities. The aim of the project was to resolve several conflicts that originate from the establishment of the park and its management during the apartheid era. One of the most debated conflicts is compensation for loss of cattle caused by predators from the park. When the Mariyeta project failed to realise its objective of establishing a reserve, several communities withdrew from the project. Three of those communities (Hlomela, Muyexe, and Ndindani) formed their own organisation, Nghunghunyani Community Trust, which has drafted a proposal for a smaller buffer zone project that comprises land of Gawula, Hlomela, Mahlati, Muyexe, and Ndindani. The idea is that both KNP and the communities that are part of the Nghunghunyani project will allocate approximately 10,000 hectares of land to the project (Fig. 7.5.1). The part of the buffer zone that is currently part of KNP will be managed by Nghunghunyani and used for non-consumptive tourist activities such as photo safaris and bird watching only. The land of the communities will be fenced into KNP and will, once it is part of the park, be used for both consumptive and non-consumptive tourist activities, like accommodation and trophy hunting (Groothoff, 2004, pp.1-2).

Land use management in Gawula Village

Implementation of a buffer zone project like Nghunghunyani requires land that is currently being used for some kind of economic activity. Some people may not consider a piece of bush land as being in use, but villagers extract valuable resources (called environmental goods and services) from bush land and therefore changing the use of the land will affect the villagers in an economic way. Gawula Village is one of the communities that are included in the proposal for the Nghunghunyani buffer zone project. Its chieftainship is well aware of the economic value of their bush land and therefore reluctant to join Nghunghunyani (S.E. Ngobeni, Secretary of the Royal Council, pers. com. June 2008). The village is divided into two parts by an un-tarred main road that

connects Giyani and Phalaborwa. Most of the agricultural farms are located at the Western side of the road, while the Eastern side is designated as grazing land for cattle. By separating agricultural farms and grazing land Gawula Village tries to avoid cattle destroying crops on the farms. By designating the land bordering KNP as grazing land, the village leaders implicitly choose to increase the risk of predators attacking their cattle by letting the cattle graze close to the KNP fence and thereby reducing the chance that elephants destroy crops, which is more likely to occur should the crop farms have been located near the park.

How Nghunghunyani may affect the villagers

It is envisaged, by the participating communities, that establishment of a buffer zone like Nghunghunyani would have a positive impact as it would bring tourists who spend their money in and maybe around the buffer zone. Local people would be employed by the project and the income of employees would be spent in the villages, which would generate a secondary stream of income for, for example, owners of small village shops. Establishment of a buffer zone is, however, not without negative side-effects. One side-effect is that the amount of grazing land for cattle will be reduced. This will increase the pressure of grazing cattle on the ranging land. A second side-effect is that the area where villagers can collect fuel wood will be reduced, which will result in higher rates of fuel wood harvesting on the ranging land. Both effects will increase the rate of two ongoing processes that are already considered to be severe environmental problems in the area, namely overgrazing and deforestation. Such a development requires careful consideration because what is called a buffer zone project (suggesting some kind of gradual transition between the park and the bordering communities) could, in an extreme case, result in a desert next to a world icon of nature conservation.

The side-effects may not only be limited to communities that are included in the buffer zone project. Moving the fence away from what currently is known as KNP will probably also lead to re-location of the redline. This could result in villages that are currently outside the redline zone becoming part of that zone. This will result, among other things, in lower selling prices for their cattle. It is not clear how these communities are going to benefit from buffer zone projects as they do not have land that could be fenced into the park and therefore are unlikely to be included in the revenues from the project.

How introduction of biogas could off-set the negative side-effects

What the example of Nghunghunyani project shows is that before implementing a project that at first sight seems to make everyone a winner, one should carefully consider the side-effects on ranging land and communities. If sustainable development and protection of the natural environment are primary objectives of the proposed buffer zone project, relocation of the fence should be part of an integrated development package rather than a stand-alone development with its side-effects. Blignaut, et al., (in press) show how the lack of an integrated approach was one of the main reasons for the failure of an environmental restoration project in the Nghunghunyani project area and Blignaut (2009) highlights the importance of an integrated approach.

Production of biogas, as a renewable energy source to replace fuel wood for cooking purposes, could be part of such an integrated development plan. Biogas is produced from cow dung (or other organic matter) and water in an underground brick structure, called a biogas digester. A by-product of biogas

production is the digested cow dung, which is a good fertiliser. By using biogas instead of fuel wood for cooking purposes, deforestation can be reduced or, if one is planning a buffer zone project, the increased pressure of harvesting fuel wood on the ranging land can be reduced or off-set. By using the fertiliser, crop growth can be increased. Increased agricultural produce could be used for human consumption or as fodder for cattle. In the latter case, cattle needs to graze less on communal land and the increased grazing pressure on the ranging land could be reduced or off-set.

Biogas as part of an integrated development plan

In addition to off-setting some of the negative impacts of establishing a buffer zone project, biogas may also contribute to solutions for other primary concerns of cattle owners. For biogas production from cow dung in rural villages, it currently only pays to collect the cow dung that is left behind in the kraal by the cattle overnight. This source of cow dung is insufficient to supply all households with biogas (Van Ierland, 2007). By keeping the cattle in the kraal for a longer period of time, the amount of cow dung available in the kraal could be increased so that all households could be supplied with biogas. In an extreme case one could consider a zero-grazing policy, which would reduce chances of cattle being stolen or attacked by predators to nearly zero. This would off course require supplying fodder to the cattle, which could be produced on what is currently grazing land.

How realistic is an integrated development plan for rural communities?

A South African Section 21 Company has installed a number of biogas digesters in the villages that participate in the Nghunghunyani project since July 2008 (see www.idsfoundation.org). The households that are using the biogas in May 2010 are all enthusiastic, but these households did not have to pay for the biogas digesters which were installed as pilot digesters. The group of households that agreed to pay ZAR125.00 per month for a biogas contract that entitles them to sufficient biogas for all their cooking and water-heating needs, are not yet using the biogas and therefore it is difficult to say how they will respond. It is envisaged that, under favourable conditions, the biogas project could be fully financed through commercial loans, which will be paid-back with the revenue from the household contributions for using the gas, carbon credits, and selling digested cow dung as fertiliser, in future. Therefore, based on the first preliminary results of a pilot project, it seems that introduction of biogas is a realistic component of such a development scenario.

The ideas to improve cattle and agricultural farming practices are not well developed yet, which makes it more difficult to assess their feasibility. There is little doubt that such a development is technically feasible as zero-grazing is practiced in many other areas in South Africa. Socio-cultural objections against this form of grazing are likely to be overcome if it appears that that it is more profitable than the traditional way of farming. The remoteness of the area could make zero-grazing cattle farming less profitable than in other parts of the country as transportation costs for, for example, fodder are likely to be higher. However, low profitability of zero-grazing cattle farming does not need to be a problem, if introduction of this form of grazing policy is necessary to make a buffer zone project possible and if that buffer zone project is highly profitable. For the assessment of the financial desirability we should look at the overall profitability of the integrated development package and compare this with not only the current situation, but also alternative development packages.

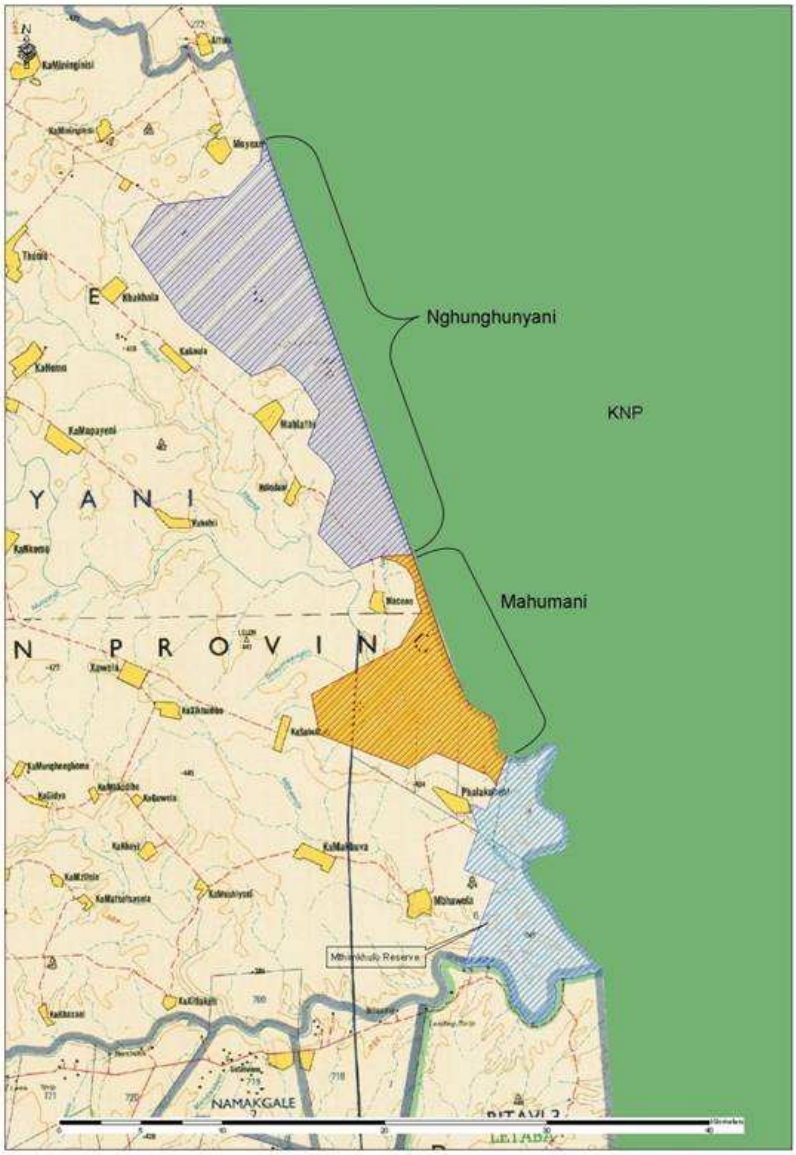
The buffer zone seems to be highly desired by the primary stakeholders, SANParks and the communities. However, their objectives and ideas of a buffer

zone project might differ significantly (Groothoff, 2004). The community's primary objectives are profit and job-creation, while SANParks primary objective is nature conservation. As a result of these different objectives, the communities included revenues from trophy hunting in the budget for the Nghunghunyani project to increase profit, while it is not clear that SANParks will allow trophy hunting in the proposed buffer zone.

Conclusion

To assess the desirability of establishing buffer zone projects, both the revenue from the project itself and the (in-kind) revenue that currently comes from the land must be considered. The way in which the establishment of the buffer zone affects revenue that accrues from ranging land, and a consideration of alternative land-uses that may generate even higher revenue are also important. Land that is currently in use could be made available for a buffer zone project by improving farming practices on ranging land. Biogas production may be a catalyst for such development as it is linked to both more intensive crop and animal farming.

Figure 7.5.1. Map of the proposed buffer zone, north western KNP



7.6 Nairobi National Park Wildlife Conservation Lease Project and the fencing problem

Ole Nkedianye, D. K.
International Livestock Research Institute, P.O. Box 30709, 00100, Nairobi, and African Wildlife Foundation, P.O. Box 48177, 00100, Nairobi, Kenya.
nkedav@yahoo.com

Introduction

The Nairobi National Park (NNP) is about 10km from the city centre. Its dispersal area, mainly in the Kaputiei Plains ranges from about 40km to 100km from the city centre. The Park is unique, yet also under great pressure from surrounding interests which manifest mainly as incompatible land uses. Although there are complex issues facing conservation in the whole of East Africa (Galvin, 2008; Homewood, et al., 2009; Western, 2009; Reid, et al., 2009), the NNP faces a peculiar set of problems mainly due to its proximity to a major city.

The Wildlife Conservation Lease Project for the NNP was initiated by the Friends of Nairobi National Park (FoNNaP) in 2000. The idea emanated from The Wildlife Foundation (TWF) with support from the Wildlife Trust (USA). In partnership with TWF, FoNNaP started the implementation of a hitherto untested idea: paying pastoralists for accommodating wildlife on their land. The project started in a small way as many local landowners were afraid of joining for fear of having their lands 'taken away'. The fear was fuelled by the novelty of the idea to the local pastoralists in the Kitengela area, coupled with historically-entrenched suspicions on land-related issues as the government had earlier shown an interest in acquiring the Kitengela dispersal area, which was a critical part of the greater ecosystem for the NNP (Gichohi, 1996; Gichohi, 2000; Kristjanson, et al., 2002; Reid, et al.; 2008; Nkedianye, et al., 2009). In spite of the initial problems, the program started with two participating landowners with a total of 214 acres. The first cheque-issuing ceremony was held at the Kitengela Primary school on 29 April, 2000. By early 2010, the program had over three hundred families and over 30,000 acres leased under the program.

Challenges facing the Nairobi National Park dispersal area

Prioritization

From the beginning, there was the problem of land prioritization. As more landowners became interested, the question of whose land was leased first became an issue. TWF worked closely with several organizations that helped to develop criteria for land prioritization. Key among these NGOs were FoNNaP, the International Livestock Research Institute (ILRI), and later, the African Wildlife Foundation (AWF). These organizations helped to come up with prioritization criteria that included among others: the proximity to the NNP, crossing points, potential threat for conversion to other land uses especially for those lands near the tarmac road, connectedness to the other leased lands, and biological significance such as the wildebeest calving areas. Later on the issue of 'open and available' areas became important as fences became a more

pronounced problem. In most cases, the priority areas are also the ones under higher threat of conversion to other uses (see Fig. 7.6.1 below).

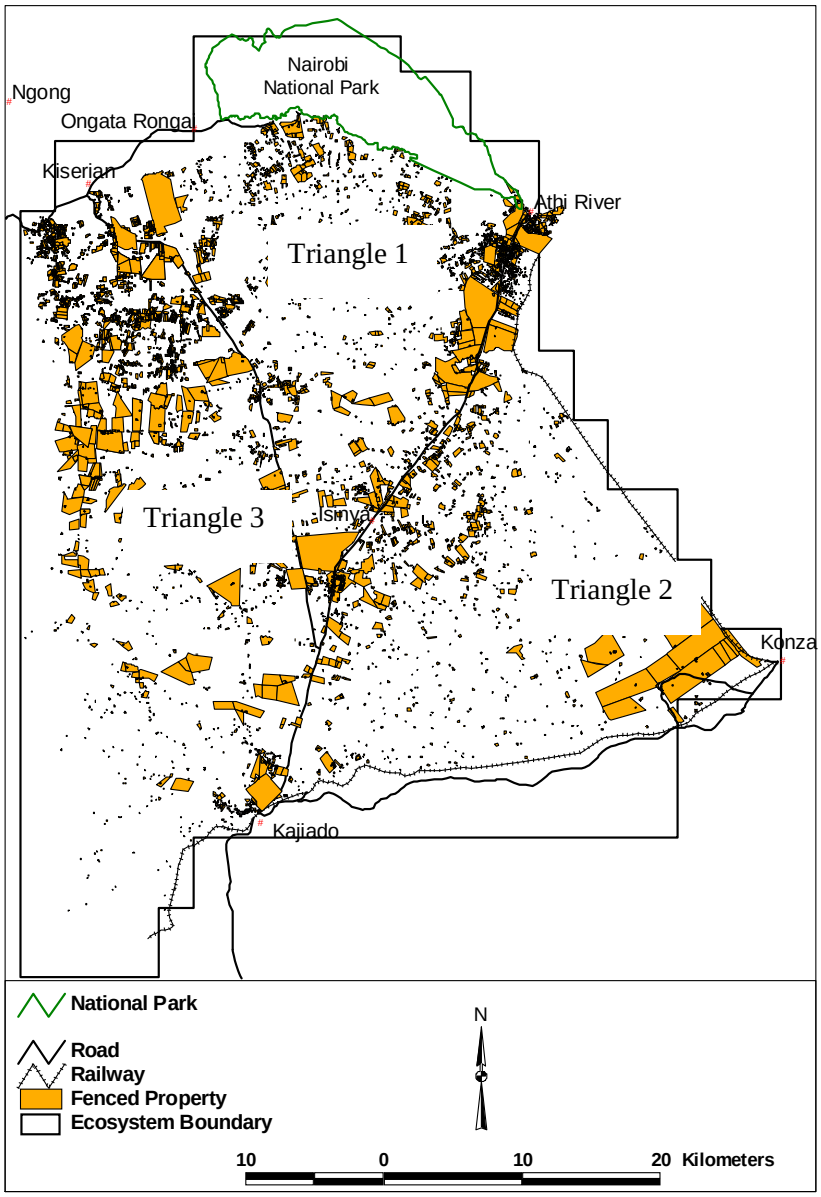


Figure 7.6.1. The Nairobi National Park and the Kaputiei Dispersal Area to the south and mapped fences (brown polygons). Information for the fences is based on mapping conducted in 2004 (for triangles 1; Kitengela Game Controlled Area) & 2; Kaputiei Dispersal Area) and in 2009 (for triangle 3; Rift Valley Escarpment). The leased lands are in the less fenced places. (Map courtesy of Reto-o-Reto, and USAID-funded AWF-ILRI work). An update of the fence map is ongoing (for triangles 1 & 2).

Lack of a land use plan/regulating framework

The NNP dispersal area is faced with myriad problems regarding conflicting land uses. The traditional land use of the area has been livestock keeping by the Maasai pastoralists with the open space also being used by large numbers of wildlife. The shrinking space has brought about an urgent need for regulation of land use. The main threat to free movement of both livestock and wildlife has grown tremendously due to the fences being erected by land buyers and incompatible land uses (Kimani & Pickard, 1998). Fragmentation has resulted from competing land uses which include fences, flower farms,

poultry farms, settlements and other emerging uses. The unregulated land uses have been a key hindrance to mobility for wildlife and livestock.

Opportunity cost

Due to the scarcity of land in the peri-urban areas of Nairobi, the rise in land prices has been phenomenal. In order to join and remain in the lease program, landowners have to be prepared to forego the opportunity of getting significantly more money through the sale of that land (although for most of them the benefits from such sales are short-lived). The pressure for land ownership is also part of the Kenyan culture, where a majority of people view land as one of the most secure investments. Besides that there is the cultural attachment to land that pushes many Kenyans towards land ownership.

Other challenges include the legality of the lease agreement, which started as a straightforward and simple agreement. With time, there may be need for a legally-binding agreement to ensure legally-enforceable compliance. However, monitoring non-compliance still remains a challenge. The greatest risk of failure lies in areas of highest land values such as those next to the tarmac road, near urban areas, and next to the NNP. Other factors include the size of landholding (the smaller the land the smaller the amount received and the higher the chance for default). Large families (such as polygamous ones with grown up sons) tend to be prone to disagreements on whether to join the program, and also in sharing the money.

Sustainability and scale issues

The size of the area under lease has been expanding but is mainly dependent on availability of funds. There continues to be a long waiting list of those willing to join but cannot do so due to lack of funds. After the release of the World Bank (through GEF) funds in 2009, many of those on the waiting list joined, but there still remains a long list of others. An issue of concern has been that of sustainability funding for the program. The growing fragmentation of the landscape is also a major source of concern. Funding may require a large-enough endowment fund but that has yet to be established. In addition more landowners could sub-divide their land to share among wives and sons. If these sub-divisions result in extra fences, the program is likely to be jeopardized. That aside, there are conflict issues that need to be resolved to complement the program. These include the consolation program (where landowners are paid a certain amount of money if livestock are killed by predators). Fundraising and accountability issues have been and may continue to be a problem.

Successes

A unique characteristic of the lease program is that the payments are direct. Cheques are written in the name of the landowner. Many other payments have hitherto been aimed at community projects, yet their impact may be unclear (Emerton, 2001; Bulte, et al., 2006). In the Kaputiei area the success of the program has been seen through its popularity among landowners hence its potential for expansion and replication elsewhere. With more people willing to join, there is likelihood that more pastoral landowners will be supportive of wildlife conservation on their land and in general as attitudes towards wildlife improve (Nkedianye, 2004).

The future

One of the greatest challenges for the lease program is the sustainability of its funding. However, if an endowment fund can be established the area can be enlarged substantially. The next problem would then be matching landowners'

growing financial expectations with what the lease program can provide. The delay in funding (the GEF funds were applied for in 2002 and came through in 2009) has shown that in a fast-changing environment, time can be the critical issue. Due to the delay in funding, a lot of fragmentation happened between 2002 and 2009 (see Fig. 7.6.1 above). Another challenge will continue to be the pressure from the expanding Nairobi city. The government must therefore fully enforce the locally-developed Master Plan and related land use in Kajiado and other neighbouring Districts. If properly implemented, the approved Master Plan for the area is likely to control development but the lesson is that planning and funding should not delay if proper results are to be realized. Another challenge will be to keep the landowners from pulling off from the program so they can sub-divide their land for various other uses including sale to land-hungry outsiders and especially speculators. Yet it is still possible to save large tracts of land if resources were immediately available. Government goodwill in implementation of the land use plan will be critical to the success of the whole process.

Acknowledgements

The map (Fig. 7.6.1) was prepared by Shem Kifugo and his ILRI-AWF team with support from the Belgian-funded Reto-o-Reto, and USAID-funded Kitengela projects. This work was partially supported with funds from my fellowship at the Center for Collaborative Conservation at the Warner College of Natural Resources, Colorado State University.

8. RECOMMENDATIONS FOR THE MANAGEMENT OF FENCES IN TFCAs

8.1 Developing guidelines for the management and monitoring of fences

Ferguson, K.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
selousgame@hotmail.com

The benefits of transfrontier integration of fence monitoring and management

Great benefits can potentially accrue from transfrontier conservation (Hanks, 2000) by means of integrating environmentally sustainable land use options. In certain circumstances it may be beneficial for fences between countries to be removed. However, the potential spread of transboundary animal diseases between the Transfrontier Conservation Area (TFCA) countries may be concomitant with a lack of capacity to integrate fencing policy that could in turn impact on wildlife movement corridors and also on human livelihoods.

Fences are a prevalent barrier where a 'high-risk' of animal disease transfer or human-wildlife conflict occur and act as an interface where two systems meet ('natural' ecosystems and socio-ecological systems). Understanding the effects (and mitigation) of these impacts requires that the country partners should consider implementing standard adaptive fence monitoring and managing methods which will allow for data comparisons between fences and the 'evolution' of an eventual transfrontier fence policy. Research into the impacts of fencing is beginning to illustrate just how complex the effects a simple 'barrier-effect' can be on species, ecosystems and people. As research on the impacts of fences progresses there will be a continuous need to update the ways of monitoring and managing these barriers.

The impacts of fencing can only be gauged by access to good quality data which are produced as a result of integrated research projects. The emphasis on the need to take an adaptive management approach to fencing issues means that such an approach must be flexible enough to take into account the major concerns of all stakeholders. None of these stakeholders are well served by the 'conflict' that often seems to accompany the variety of fencing problems that arise from either a livestock production or conservation perspective.

Resolving conflicting issues that involve fences may be assisted by the development of TFCAs. The importance of transboundary animal disease transmission is closely allied to the redistribution of wild species populations which in turn may aid the persistence and survival of these populations. Clarity of purpose in the monitoring and management of fences is predicated on transparency, good governance, and data of good quality and the participation of stakeholders.

Harmonizing the way that fences are discussed and standardizing the means by which we gather information on fencing are essential prerequisites in developing robust fence management plans that are integrated and reflect the

goal of the co-survival of people and wildlife within increasingly arid and transformed rangelands.

Furthermore, a clear understanding of the purpose(s) of the fence, an economic analysis of fence impacts and the return on investment of the fence type and positioning in relation to cost (or upgrade), efficacy and frequency/scale of fence breaches is vital to fence management.

Critical to the success of the development of fence management plans are the following:

- Development and implementation of robust fence monitoring systems that measures epidemiological information such as permeability of the fence to buffalo (*Syncerus caffer*) and foot-and-mouth disease (F. Jori, pers. comm., April 2009), mortality of wild species caused directly by the fence, indirect effects of landscape fragmentation on ecosystem health and the decline of endangered species, particularly wild dog (*Lycaon pictus*).
- Recognition that the management of fencing should be seen as a key issue in the development of TFCAs and that the adaptive management paradigm is the appropriate tool to mitigate negative impacts of fencing. Fencing systems should be seen to be more labile that they currently are viewed, and alternatives should be tested (see section 8.2).
- Commitment to the participation of all major stakeholders in decisions on the introduction or removal of new fences within the TFCAs.

To this end, the Fence Interface Research and Monitoring (FIRM) project, based at the Mammal Research Institute, University of Pretoria, has prepared a generic set of 'guidelines' termed the Fence Management Plan (FMP) for the management of fences which may be applicable to the Great Limpopo Transfrontier Conservation Area or the Great Limpopo Transfrontier Park (GLTFCA/GLTP) or, in this case, we specifically address in the FIRM document, the Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA) (Ferguson, 2009c). The purpose of the FMP is to establish an agenda for implementing standardized decision making, monitoring, and EIA protocols for the existing, 'decommissioned' and proposed fences within a TFCA.

Each FMP must become an integral part of the parent TFCA initiative and objectives. The proposed Terms of Reference for each FMP may be as follows:

a) To review the existing information and the legislative, policy and institutional environment in relation to the fence network within the proposed TFCA and its structures.

b) To test the adaptive fence monitoring and mitigation systems that have been developed by fence interface researchers.

c) To propose an integrated and institutional framework for participative planning, development and implementation of the TFCA FMP process within the remit of the guidelines for implementing such work within the TFCA.

d) To propose an action plan embracing key activities and time scales for planning, development and implementation of the TFCA FMP (including, but not limited to, legislation, policies, strategies, research required, wildlife management, fence planning, infrastructure development, community participation and public relations).

e) To identify the resources required for the planning, development and implementation of the TFCA FMP and to define the plan for their mobilization.

f) To determine the correlation between fence locations and other forms of barriers (or 'virtual' barriers) e.g. minefields, roads, human settlements and natural barriers (e.g. scarcity of water in arid areas).

g) To link up past and current research on the issue of fencing impacts, by means of a general review and workshop.

Interpretation of the FMP brief and recommended processes to be followed

The integration of fencing policy between the TFCA partner countries will be a complex and time consuming process that will need to involve a variety of stakeholders representing divergent interests. For example, in the case of the KAZA TFCA as noted in the 2006 Pre-feasibility Study:

> *'The TCC (2006) accordingly placed a major emphasis on the design of a participatory planning process which involved undertaking five individual country surveys and associated consultations'.* (TCC 2006)

In line with the TCC (2006) recommendation for KAZA TFCA we propose that:

- The initial focus on how best to facilitate the implementation of the KAZA TFCA FMP should be an iterative process to identify the existing country structures, the regional structures and international obligations. Specific attention should be given to*' identifying the practical steps that the partner countries need to take to realize this initiative'* (TCC, 2006).

- At the same time the benefits and risks associated with the establishment of the TFCA FMP should be canvassed.

- Recognizing the sovereignty of each country, the FMP should explore means of improving collaboration between the partner countries, with regard to fences with emphasis on the following components:

  - The spatial extent (network connectivity) of fences within the TFCA needs to be accurately mapped at coarse and where necessary fine scales, as for example at the potential junction of fencing and wildlife corridors. Initial consultations should lead to the following operational procedures: (i) a Geographical Information Systems mediated database of the spatial extent and condition of fences within the TFCA; (ii) location of priority conservation corridor areas bisected by fences; and (iii) monitoring of key fences and sub-sections of fences which are frequently challenged by wildlife species and the seasonality of such damage.

  - Development of a common vision for the TFCA FMP amongst diverse stakeholders, exploring the nature and extent of the TFCA FMP and requirements (infrastructural and managerial) to realise the vision.

  - Identification of key interventions necessary to realise the TFCA FMP and making recommendations on how to optimise TFCA FMP investment returns.

  - Determination of resources required to establish a TFCA FMP.

Developing a fence research strategy

One of the aims of this section is to illustrate how it is possible to collect data with regards to fence damage and animal interactions along the fence that can then be compared with the efficiency and the underlying rationale of the fence. Scientific habitat fragmentation research and disease risk modelling studies of fence permeability and the impacts that such permeability can have on disease control and animal welfare/species persistence are still in their infancies (but see Lindenmayer & Fischer 2006; Ferguson, et al., 2010; Somers & Hayward, in press). Devising new fence monitoring systems is a prerequisite to reaching an understanding of, and, the possible mitigation of fencing impacts.

To aid in this endeavour, primary sources of information on fences can be gleaned from fence contractors, their workers, and manufacturers. It is imperative to note that the best fencing solution for any given situation (biosecurity or disease related) is not necessarily the most expensive and robust fence. Bode and Whittle (2009) make the explicit statement that 'the best fencing solution depends on both costs and benefits', such that the cost of breaches in the fence must be weighed against the expense of up-grades and a more secure design. It is the 'return on investment' that often dictates fence types and levels of fence maintenance and not necessarily biological considerations.

Calculations of fence breaching rates are dependent on many factors such as the purpose type and location of the fence and the species mix (and pathogens) that is to be prevented from crossing the fence. Therefore, for example, an FMD control fence that is embedded within an elephant range may be more likely to be permeable to the virus because of a non-host species (elephant) rather than the actual primary host (buffaloes), and indeed breaches of the fence in terms of rates of potential 'virus' crossings can be linked to numerous secondary host strategies for circumventing the fence (e.g. warthog digging; impala jumping). Recording the scale of permeability of the fence in terms of multiple human and animal factors is thus a major future challenge for fence research and has a direct bearing on the potential to upgrade, re-align or remove fences. This 'return on investment' calculation can equally be applied to the biosecurity role of park fences, whereby blocking the movement of key human-wildlife-conflict species may or may not be linked to the ecology of secondary species that weaken the integrity of the fence but do not pose a direct threat to external human livelihoods.

A broader research aim would be the development of a fence-related research programme for key 'fence' host species (e.g. African buffalo; cattle Fig.8.1.1) that seeks to measure epidemiological parameters in relation to exogenous ecological factors that may be linked to seasonality ('seasonal forcing'; Bolzoni et al., 2008) such as host birth-rate, social aggregation and resource availability as these parameters interact with the animal's seasonal mobility, intra and inter species transmission and contact rates and the permeability/efficiency of the fence. Similarly, we urgently require knowledge of the impacts of fencing and habitat fragmentation on the population dynamics of fence sensitive species, especially, blue wildebeest. Regular reports on the decline of this species are often masked by the huge numbers in the Serengeti Region of East Africa, but, even in this region fragmentation is partially causing precipitous declines in numbers (the most recent being the portion of the cross-border area around Kilimanjaro; KWS, 2010).

Auditing fence structures

Investigations of fence efficiencies involving assistance from government and non-government institutions requires the cooperation of these agencies and the private owners who are in charge of some fences. It is in the interest of the fence 'owner' to cooperate in fence permeability research, as these studies could identify how to optimise fence efficiency or identify other potential methods of containment. Identifying zones of 'high impact' pressure on fences by wildlife, especially elephant, and the relation of this impact to the maintenance teams schedules and efficiency is vital in fences that are deemed necessary. Hoare (2003) emphasises that 'maintenance is the number one problem with any type of wildlife fencing'. A fence is only as good as its maintenance'.

The following is a list of auditable factors should be included in a strategic or environmental impact assessment of fencing in TFCAs (in addition to the ecological impact information that should be gathered).

- Fence length and location, Global Positioning System Referenced (and preferably mapped at a relatively fine scale using Geographical Information Systems).
- Considered by the government/owner to be a high or low maintenance fence line and to function as a partial or total containment barrier – indicate target species and habitats.
- Type of fence and materials used.
- Single or double fence line, height, number of cables, electrified/not, presence or not of stainless steel wire strands, width of vegetation exclusion area (left and right side and/or in the middle for double fences) and the percentage vegetation clearance per annum by maintenance crews.
- Gross cost per kilometre of fencing, itemized costs of materials, inflationary items identified, costs of transport and actual construction
- Full inspection of fence construction e.g. energiser placement/distance between, electromotive force measurements, straining forces on wires and cables, doubles offset brackets and posts.

Fence Maintenance

The acquisition of secondary information requires a degree of cooperation that may be limited. Albertson (1998) noted that fence maintenance workers were sometimes not forthcoming about fence observations. Observations by fence workers may therefore be biased. The information required for a fence audit should also include the following:

- From the Maintenance Contractor: Work schedules, time (person days) spent by crews per km of fence line (identify High Impact Zones), location of fence breaks, cost of repair per metre.
- From the maintenance crews: Simple questionnaire denoting location of fence breaks (white paint placed on poles at breaks for researcher to find), carcasses, skulls found (to be left on fence track), and wildlife seen near to fence (simple observations).
- For electrified fences, information on location of solar panel transformers/energizers and current distribution. The most serious problem for electric fences is the power supply, if this is disrupted even

for a short period, the adverse conditioning associated by elephant is quickly lost and the fence becomes 'porous' (Hoare, 2003; Thouless & Sakwa, 1995).

- Explore the potential for the development and implementation of a participatory and sustainable fence monitoring system

In conclusion, the systematic auditing of existing fences, in terms of repair status, upgrading or removal potential, must be considered at a holistic level and be conducted along transparent and participatory lines.

Figure 8.1.1. Cattle grazing along the boundary fence of KNP.

8.2 Fencing and the 'Barrier-Effect': Research needs, innovations and knowledge gaps

Ferguson, K.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
selousgame@hotmail.com

Cameron, E.Z.
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
ezcameron@zoology.up.ac.za

Hanks, J.
Consultant, P.O. Box 254, Greyton 7233, South Africa.
hanksppt@iafrica.com

Introduction

The 'barrier-effect' is a term that may be used to denote the physical (or psychological) blocking of an animal's movement by an object or series of objects. Barrier formation can be natural (such as mountains and rivers) and these can be critical, for example, for allopatric speciation to occur (Mayr, 2001). The presence of these barriers can also lead to environmental changes due to the geographic separation of species. Natural barriers can also be responsible for mass mortalities, for example in the recent deaths of an estimated 10,000 migrating blue wildebeest (*Connochaetes taurinus)* at one Mara River (Kenya) crossing in 2007 (de Pastino, 2007). The Serengeti ecosystem itself is now under severe threat from human-induced fragmentation due to a proposed road that will bisect the northern sector of the park and may even lead to fencing to protect commuters. The risk of a 'mega-faunal' collapse of the famed migration must be very real (Bigurube, et al., 2010).

Therefore, increasingly such barriers are anthropogenically induced, including roads, fences, railways (see Fig.8.2.1) and hedges in agricultural land (Forman, et al., 2003). Such Anthropologically Created (or constructed) Barriers (ACBs) are responsible for the curtailment of animal movement (in differing degrees) that may lead to a concomitant detrimental impact on the population persistence of, particularly, migratory large mammalian herbivore species (Harris, et al., 2009). Indeed, the importance of ACBs is demonstrated by the worldwide decline in large mammalian herbivore migrations (Harris, et al., 2009). ACBs are widely and directly implicated in the immediacy of the 'barrier-effect' threat to these migratory species.

ACBs have had a long-standing impact, since they were first used when *Homo sapiens* started to organise into societies and needed to keep nature at bay (Hayward & Kerley, 2009). However, there has subsequently been a role reversal of this aim in many parts of the world, with 'nature' being fenced *in* by the use of ACBs (or other forms of human-induced fragmentation) rather than the ACBs acting to 'fence' *out* wildlife from human dominated enclaves.

ACBs are causally nested within the biodiversity threatening process of 'habitat fragmentation' (Lindenmayer & Fischer, 2006). Fences are primary agents of habitat fragmentation, particularly with regards to the creation of edge effects defined *as 'diverse physical and biotic alterations associated with the artificial boundaries of fragments – are dominant drivers of change in many fragmented landscapes'* (Laurance et al., 2007). The 'depth' to which edge effects can cause corollary impacts by 'penetrating' into a protected area can be highly variable and may not be fully picked up by short-term studies, which aim, for example, to design protected area buffer zones. In vernacular terms, fences could harden an edge in ecological and social terms by distributing animal densities along resource and human settlement gradients (Ogutu et al., 2010) which may lead to more distant (in relation to the fence) changes in the ecology of an area. Western et al., (2009) have suggested that human settlement and the subdivision of land associated with the sedentarization of pastoralists and their herds in Kenya is *'likely to reduce wildlife numbers both by direct displacement and by suppressing grassland productivit*y'.

Within this landscape ecology based approach, the ecological matrix is being seen to be increasingly 'carved up' by human activities such that patches of high biodiversity are increasingly isolated, and any corridors connecting these isolates are fewer and more hazardous for animals (or plants) to negotiate safely. Metapopulations isolated by these barriers become more vulnerable to multiple extinction processes (Akçakaya, et al., 2006). ACBs assist this fragmentation process and yet each type of ACB produces its own impact 'signature' which varies with the ecological conditions within which the ACB is set and the species that interact with the structure (e.g. Berger, 2002; Fu, et al., 2010).

How do these structures directly or indirectly affect these populations and individuals as they attempt to move across landscapes, and how does a large mammal migration collapse when its seasonal movements are disrupted by barriers? Is this collapse primarily due to direct mortality factors, such as mass deaths at a fence, or are other indirect and more subtle factors involved (Perkins, (4.3); Gibson, (4.4)). Do demographic and behavioural variables change in the impacted populations over an extended period of time after the erection of the barrier (such as the lengthening of the inter-calving interval once key resources areas have been excised)? Do these barriers have differential impacts on different sex and age classes (M. Murray, pers. comm., March 2010)? Furthermore, predation may increase as more animals became sedentary or trapped by fencing (van Dyk & Slotow, 2003), or new disease pathways decimate the remaining 'enforced' sedentary population (Kock, et al., 2010). There could be a variety of additional indirect effects, such as increase in physiological stress, all impacting on species demographics and population growth. Much more research is required on the impacts of ACB construction on large mammal behavioural and population ecology, including studies that span pre- to post-ACB time periods (Brooks & Bradley, (4.5)).

In terms of the defensive nature of ACBs we can see that certain types serve as a front-line defence against the infection of domestic livestock herds via contact with potentially infectious host wildlife animals. The consequences of such contact have forced some rural families in Namibia, since a devastating outbreak of contagious bovine pleuropneumonia (CBPP) in the mid-1990s to rely on animals with lower financial yield such as donkeys and goats as replacing the cattle, which were slaughtered to halt the spread of the disease

(M. Atkinson pers. comm. Feb 2010; Amanfu, et al., 1998). Did this diminution in income lead to premature child deaths, or, perhaps loss of schooling days because the fees could not be afforded, was there an 'outbreak' of depression or suicides amongst the people as a result of this epidemic? These questions illustrate the importance of the human dimension when discussing barriers such as veterinary fencing.

Diluting the barrier-effect

In order to reduce ACB impacts, Jaeger and Fahrig (2004) created a simple model of the impact that a road may have on a population of large mammals that attempt to cross a highway in North America (Fig.8.2.2). They attempted to 'balance' the impact of the road with the impact of fencing. Fences are usually erected in North America to decrease road deaths; both of humans and wildlife, but fences can also cause habitat fragmentation and increase extinction probabilities. Therefore, they suggest that fences should only be used when the risk of animal or human mortality during wildlife road-crossing is very high. Otherwise, the construction of fences should be avoided when the population requires resources from both sides of the road, and alternative measures should be used to avoid road-kill, such underpasses.

In southern Africa the ACBs may be quite different structurally, but, the effects are likely to be similar and lead to population declines in barrier-sensitive species. For example, long-straight veterinary fences cut across landscapes and habitats without regard to habitat heterogeneity or the species that are dependent on such variability. Therefore, the impacts of ACBs in southern Africa need to be understood, and solutions need to be appropriate to the economic, social and ecological variables of the local area.

Removing unnecessary ACBs is an obvious first response to the ACB threat (see Alexander & Ferguson (6.4)). Furthermore, justification for future ACBs should be rigorously judged against the potential impacts. Therefore, whenever major new ACBs are proposed, the threat to biodiversity should be acknowledged and the threats researched when compiling the requisite environmental impact assessments. Environmental impact assessments should be a legal requirement in all Transfrontier Conservation Areas (TFCA) participating countries when a major ACB is erected, removed, replaced or realigned. TFCAs in particular should draft integrated fence management plans to highlight where ACBs could be detrimental to conservation (for example at the junction of fences and critical wildlife corridors).

Of central importance to reducing negative impacts of ACBs is that, where fencing is essential, appropriate specifications should be adhered to and that the type of fencing should be appropriate for reducing the impact on non-target species and populations. For example, elephant restraining fences can be constructed so that the cable is suspended high enough to stop elephants (*Loxodonta africana*) (and giraffes; *Giraffa camelopardalis*) but allows smaller species to pass underneath. Unfortunately, designing a fence that constrains disease carrying buffalo whilst allowing the movement of the relatively disease-free elephant is logistically difficult. However, it has been previously attempted. Recently the Kruger National Park authorities suggested that the existing far north-western disease control fence in the Madimbo Corridor (adjacent to the Limpopo River) could be reduced in height (from 2.4m to 1.2m) to allow elephants to cross out of the park where they could be of value to tourism and hunting ventures in the corridor. A 1.2m high fence should

prevent buffalo from escaping, but in the Save Valley Conservancy (Zimbabwe), where a similar experiment was attempted, the adult elephants destroyed the fence rather than stepping over it, largely because very young elephants could not negotiate the height of the fence (D. Joubert, pers., comm., November 2009). Therefore, it is not clear that this strategy will be successful.

Park fences can lead to a decline in human-wildlife conflict (HWC), if properly maintained (Hoare, 2003). However, wherever elephants are present an 'arms-race' seems to develop between elephant ingenuity and fence designs (Graham 5.5). ACBs can benefit a protected area by demarcating the boundary of the reserve and thereby clarifying that certain human activities will not be tolerated (e.g. encroachment of cultivation). In addition, fences can be used to protect people and their livestock from wild mammals either via the actual park boundary fencing or by 'ring-fencing' in human settlements and crop fields (Hayward & Kerley, 2009; Bewsher 6.3).

Veterinary fence alignment and construction is largely predicated on the major type of animal disease that the fence is meant to constrain, and by the abundance of the species' which the fence is attempting to keep separate. Some diseases (and their hosts) are less amenable to being blocked by physical structures (CBPP for example) and vaccination strategies may be more likely to provide a long-term solution. A simple scale of the risks and benefits of fence types in relation to the disease epidemiology of various key vectors and their hosts would be useful, and allow modelling of different population impacts.

Conservationists may have to come to accept that some key fences are necessary for the preservation of livestock export markets, or to protect parks and game reserves from human encroachment. It is likely that many of these key fences are in areas where wildlife is or was formally abundant. Consequently, the question arises as to whether there any other ACB mitigatory strategies that can be deployed to partially or completely replace the role of traditional fencing? This will require the identification of gaps in our knowledge and testing ways to mitigate the worst excesses of fencing.

Smart Fencing – Landscape considerations

In order for expensive fencing materials to create a cost-effective barrier, fences are often constructed in sections of straight lines. However, it is possible that if ecological impacts are incorporated into economic estimates that more sinuous or wavy forms of fences may be more cost-effective and environmentally acceptable without compromising the purpose of the barrier (Lindenmayer & Fischer, 2006). Such fencing alterations (or novelties) can be summarised under the acronym of 'Smart' (**S**pecific, **m**easured, **a**ppropriate, **r**esearched, **t**echnologies) fencing. We define this as fencing that is sensitive to ecological landscapes and in tune with ecological processes (such as migration). For example, if the opportunity arises and cost allows it may makes sense to place fences in relation to iso-height contours or water points rather than ignoring these variables through the construction of a perfectly straight fences. Fences should be devised and planned that can mimic curvilinear 'natural' boundaries (Forman, 2009), yet still effectively constrain the movement of animals and their pathogens. Fences will continue to play a major role in protected area and disease management, consequently in some

circumstances fence modification rather than complete removal is a more realistic goal.

One version of 'Smart' fencing would be to fence in compartments of livestock rangeland (in effect creating 'super-kraals' e.g. as has been proposed for sections of NG13 in Ngamiland) and allow wildlife to utilise the extensive matrix outside (Albertson, 4.1). Where this is not possible (e.g. along border areas or areas that are already highly fragmented) it may be possible (if land tenure allows) to re-align the fence in relatively minor ways. For example, as suggested above by including a waterhole that is just outside a fence could prevent dry season elephant damage and possible disease release via buffalo while allowing animals' access to this important resource. The key to seeking a landscape-scale stakeholder consensus on alignment routes of fences, that takes into account both conservation and livestock production, is to increase our knowledge of the landscape features, species movements and human utilisation at this interface. For example, participatory GIS mapping could be a critical resource that will aid this goal.

Smart Fencing – The use of technology

'Smart' fencing is an attempt to move away from the indiscriminate 'blunt' instrument that fencing can represent and instead target those species or contexts that require to be separated from human endeavours.

Much of our information on wildlife corridors and animal movement is currently derived from the advances in satellite and cell phone technology (analysed by GIS technology) over the last decade. This technology will enable future researchers to better record and understand the patterns and processes that act to drive animals to cross an ACB. Relatively recently scientists and Information Technicians have developed various types of 'virtual fences', whereby an animal collared with a transmitter (VHF, Satellite or GPSM) will activate a download sequence when it enters within range of a receiver, thereby triggering a short message service (sms) alert to the researcher. This technology has been used to alert rural farmers in Kenya to the imminent arrival of a marauding elephant and it is currently being developed to protect expensive game animals in the Waterberg Area of South Africa (M. Gregor, pers. comm., April 2010). Other researchers working in Gonarezhou National Park, in Zimbabwe, have used VHF technology to record the contact rates of potentially diseased buffalo with cattle that are wearing a receiver (A. Caron, pers. comm., March 2009; see section 6.5).

Smart 'virtual' fencing therefore could be used to locate threatened species before they leave a protected area, or to keep them under surveillance where illegal hunting is a threat. However, the technology is still too expensive and diffuse to be of any real significance in the African context with regards to the more pressing problems associated with fencing (such as disease control), but it still holds great promise for the future in certain respects.

'Biofences' are a type of ACB that uses a biologically-derived agent to block the movement of a specific type of animal. 'Biofences' using urine to create a 'virtual' barrier are a concept that has been tested as a means to keep wild dogs (*Lycaon pictus*) from moving out of protected areas and into hostile landscapes (Borrell, 2009). This has proved to be an effective means of movement control for this species in the Limpopo area of South Africa, but, it is labour intensive and obviously also highly species-specific (C. Jackson, pers. comm., March 2009). The deterrent value of pheromones in the context of interface disease management may in the future be of greater use once the

socio-biology of contact behaviour in key species (both inter and intra-specific) is better understood (Böhm et al., 2009).

'Live' fences are structures made up of living and preferably indigenous plant species that can be used to separate different land-use activities but allow the maintenance of some biodiversity (Leon & Harvey, 2006). The first fence to be erected by European settlers (to South Africa) used a hedge-row ('Van Riebeeck's fence') that can still be seen today in Kirstenbosch Gardens in Cape Town (pers.obs.). However, due largely to aridity and the vectors that attack living fences these structures are not common outside urban and peri-urban settings in southern Africa. In the 1970s an attempt was made by the South African Defence Force to build a living fence made out of sisal with the fence having the dual purpose of preventing the movement of armed fighters and acting as an infiltration surveillance system (due to damage inflicted on the plant by people cutting their way through). The idea was abandoned after it was found that elephants eat the fence (Joubert, 2007; M. Gregor, pers. comm.). However, the planting of 'buffer crops' (such as chilli pepper) as a form of living fence around the edges of highly prized fields could deter species like elephants and serve a dual purpose of protecting crops and providing a cash crop (Osborn & Parker, 2002).

The fence redundancy hypothesis: creating fencing disincentives

East and Southern Africa have traditionally taken differing views about the role of fencing to protect parks and livestock. In East Africa the large size of protected areas makes perimeter fencing, in most cases, unfeasible. Veterinary fencing is rudimentary due to the low level of livestock exports from East Africa, in part due to the existing multiple disease pathways and the lack of infrastructure and capacity to deal with these pathways. However, the main reason why these rangelands were never historically fenced is due to the strong communal pastoralist tradition. In the very latter part of the 20th Century a rangeland paradigm shift emerged in much of East Africa (Norton-Griffiths & Said, 2010). Privatisation of rangeland and fencing in East Africa has become more prominent amongst pastoralist societies, as human populations expand and the pressure upon natural resources increases. Consequently, the need to fence protected land has also increased, and an increasing number of protected areas in this sub-region secured their boundaries and animals with fences. A prime example of this is the relatively recent fencing of the Aberdare National Park in Kenya where the 'Rhino Ark Fence' runs for 388km and aims to protect the park from encroachment and poaching (Stanley, 2007).

Do any conservation schemes exist that could lead to fencing becoming a redundant issue, and can the powerful lobbies that support the use of fencing be persuaded that alternatives do exist? Where and when the veterinary fencing issue is of primary concern, 'Commodity-based trading', could offer a radical alternative. This novel concept is outlined in more detail by G. Thomson (3.2). On the more general issue of preventing habitat fragmentation and preventing HWC, progress will most likely be made only by integrating the needs and interests of people and conservation.

Wildlife damage compensation payment schemes in Africa have been a part of conservation since the modern inception of a conservation ethos (Maclellan, et al., 2009). In the past the process of directly recompensing local people for losses incurred, frequently encountered difficulties due to the unsympathetic nature of conservationists and the tendency of rural people to exaggerate claims. Fencing began to take over from the role of compensation claims as a means of reducing contact between adjacent communities and the parks' and

this helped to usher in the era of 'fines and fencing'. Historically, therefore, fencing became one of the primary means of lessening HWC and reducing the scale of compensation claims and disease transmission (and from keeping valuable wild animals from straying out of the park).

In South Africa, animals that leave a protected area through a permeable fence are considered by law (but, dependent on legal precedents) to be *res nullius* (literally 'not owned by anybody'). This means that a lion (*Panthera leo*) that has left a park and killed a cow is not necessarily the responsibility of the park authority and no compensation is legally required to be made, even if the fence is found to be in disrepair. Clearly, this is unreasonable and could increase conflict between people and park. New ideas concerning compensation schemes are now being debated, and often these innovations are now being based on private enterprise initiatives. Three types of participatory compensation schemes that relate to fencing can be recognised:

1. *Payments for Environmental Services (PES)* are essentially compensation schemes (State or privately run) designed to alter poor environmental behaviour by paying direct incentives to people to change their behaviour. Corporate PES schemes could be a useful way of monitoring the compensation payouts due to be paid to people who have lost, for example, livestock due to lions that have exited via a park fence. This has the double benefit of compensating for the loss (but not involving the state since some state compensation schemes often perform poorly; Nyhus et al., 2005; Haney 2007) and making the fence itself less of a source of conflict. One potential downside would be the temptation for people to deliberately damage the fence and encourage wild animals to leave the park. PES schemes are not dissimilar from the more traditional forms of compensation schemes (or indeed the 'Easement' schemes highlighted below), but they may be more efficient.

2. *Easement schemes* such as that operating on the margins of Tarangire National Park in Tanzania (Nelson, et al., 2009). In this park over the past 40 years the numbers of wildebeest, a species that is highly susceptible to the effects of habitat fragmentation, have dropped from 40,000 to about 5,000 animals (see also; Whyte & Joubert (4.7). In this case, changes in livelihood practices and politics have been the major reasons for the increasing insularization of the park. The Enterprise Linkage to Conservation and Development (ELAND) is a collaborative effort of private sector interests that has attempted to protect the wildebeest calving areas that lie outside the park boundaries. By directly paying villages to conserve the habitat in these key dispersal areas by creating an easement (in this case an agreement for five years between the owners of the land and those who offer financial compensation for income lost) agreement has been established. A similar system operates around Nairobi National Park where local farmers are paid to not fence off the rangeland (see Nkedianye 7.6).

3. *Community-based conservation* involves active participation in the conservation and ownership of land and wildlife by rural people and has become an important item within the available conservation 'tool-box'. In the case of fencing, certain circumstances could allow the removal of protected area fences to allow local communities to directly and indirectly benefit from the 'profit and protein' that wildlife can offer. Animals that move out of a park would therefore do so at their own risk.

The removal of fencing could rehabilitate fragmented habitats (such as riverine catchments) and, if the fence is a disease control fence, livestock may have to be removed from the 'rewilded' area. If a fence was still necessary at the edge of such an extended 'contract park' then community-based fence management schemes could be used to protect human homesteads from HWC due to the closer proximity of wildlife to settlements thus engaging the community in fence permeability issues.

All of these schemes can be used to prevent fragmentation of habitats that adjoin and soften the edges of protected areas while simultaneously investigating alternatives to fencing.

Conclusion

The outbreak of contagious bovine pleuropneumonia in Namibia and Botswana in 1995-1996 had a crippling effect on the livestock industries of these countries with up to 320,000 head of cattle culled in Botswana in an effort to try and stop the epidemic (Amanfu, et al., 1998; Albertson, (4.1); Ross, (2.3)). Emergency fences were erected in Botswana and over time these fences caused wildlife deaths (Albertson, 2005). What is not often recorded is the impact that such a devastating disease has on the health and wealth of poor rural people.

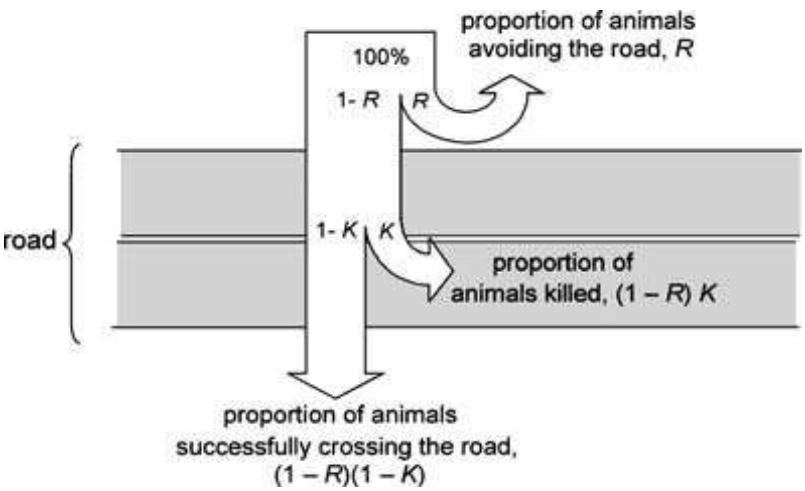
It is therefore imperative that the habitat fragmentation caused by fencing be framed within an holistic 'One-Health' approach, and future research must include an examination of conservation concerns, land-use options, land tenure-ship and sustainable development (Kock, 2005; Mazet, et al., 2009; Walker, 2008). We believe that the best vehicle for achieving natural resource sustainability, in areas where these issues collide, is by bolstering transfrontier conservation efforts, which are 'stakeholder' inclusive by nature (Hanks, 2000).

Indeed, it seems timely to consider the proposal made by Ferguson, et al., (in press) to create a *Pan African Fencing Charter* that seeks to identify a common set of guidelines for the management of ACBs. In the interim, we agree with Roy Bengis (State Veterinarian, KNP) that if fencing at the wildlife/livestock interface is deemed necessary then it should be managed responsibly (R. Bengis, pers. comm., October 2008).

In conclusion, we speculate that the amount of kilometres of fencing that is erected in any given year in southern and eastern Africa will be much greater than the amount removed due to the expansion of transfrontier or game conservancy conservation. Therefore, we urge caution in stating too unequivocally that the new renaissance in fencing research will necessarily imminently change conservation and development goals for the better. Fencing mitigation, regardless of technique, should not be seen in isolation from a holistic view of interface dynamics. For example, ACBs impact and are impacted on by the combined effects of HWC, habitat fragmentation and disease control. It is important that the *conflict* that has ensued around the fencing issue should instead become a matter of attempting to find *consensus*. It seems unlikely that at any time in the near to mid-term future that science is likely to conquer and eradicate these pathogens, diseases and the untold misery that they cause for animal and human alike.

Figure 8.2.1. The Barrier-effect and elephant overabundance in Tsavo National Park in the late 1960s. The straight lines seen to the left of this picture are not fence lines but the railway line (and road?) joining Mombasa with Nairobi. On the right side of these lines is Tsavo National Park which at that time harboured large elephant numbers. To the left of these lines is the area outside of the park and here the vegetation is relatively unscathed due to the reluctance of elephants to cross the railway line. (Picture credit: Norman Myers with permission from Myers 1972).

Figure 8.2.2. Reproduced with permission from Jaeger & Fahrig (2004). '*For an existing road, if it is known that the population size of the species of concern is decreasing and there is evidence that high traffic mortality plays an important role in the population decline, then fences should be a useful measure. Even if the population is not declining, if the animals sometimes try to cross the road but never or almost never succeed due to high traffic mortality, then fences should be beneficial. On the other hand, if population size is stable or increasing, adding fences could be harmful'.*



9. REFERENCES

Abel, N.O.J. Flint, M.E.S. Hunter, N.D. Chandler, D. & Maka, G., 1987. Cattle-keeping, ecological change and communal management in Ngwaketse. Norwich, East Anglia: ILCA/IFPP/ODG.

Aberly, D., 1999. Interpreting bioregionalism: a story from many voices. In: M.V. McGinni, ed. *Bioregionalism*. London: Routledge, pp.13-42.

Adams, J.S. & McShane, T.O., 1996. *The myth of wild Africa. Conservation without illusion.* Berkeley, London: University of California Press.

Adendorff, G., 1984. *Wild Company*. Muizenberg: Books of Africa.

Africa Geographic, 2007. 6 degrees from catastrophe. *Africa Geographic* 15(7), pp.40-41.

AHEAD-GLTFCA, 2008. As the fences come down: emerging concerns in transfrontier conservation areas. Produced by the Animal Health for the Environment and Development – GLTFCA working group. New York: Wildlife Conservation Society/AHEAD Program.

Available at*:* www.wcs-ahead.org/documents/asthefencescomedown.pdf

Aidley, D.J., 1981. *Animal Migration.* Society for Experimental Biology Seminar Series 13. Cambridge: University of Cambridge.

Akçakaya, H.R. Mills, G. & Doncaster, C.P., 2006. The Role of Metapopulations in Conservation. In: D.W. MacDonald, & K. Service, eds. *Key Topics in Conservation Biology*. Mass: Wiley-Blackwell.

Albertson, A., 1997a. *Botswana: death by cattle*. Botswana: The Ntsu Foundation.

Albertson, A., 1997b. *New fences threaten Botswana's wildlife.* Botswana: The Ntsu Foundation.

Albertson, A., 1998a. *Northern Botswana veterinary fences: critical ecological impacts.* Gaborone, Botswana: The Wild Foundation/Kalahari Conservation Society. 59 pp.

Albertson, A., 1998b. *Setata fence: assessment reports on fence-line ecological impacts*. Okavango People's Wildlife Trust.

Albertson, A., 2002. *Setata fence survey, 24-25 August 2002*. Maun, Botswana: Okavango Peoples Wildlife Trust.

Albertson, A., 2005. *Kalahari Conservation Society assessment report: removal of decommissioned veterinary fences in Ngamiland District, Botswana.* Botswana: Kalahari Conservation Society, The Sierra Club & The Wild Foundation.

Albertson, A., 2008. *Survey of new veterinary cordon fence, Ngamiland District, Botswana*. Botswana: Kalahari Conservation Society & Department of Wildlife and National Parks, Botswana.

Arthur Albertson Consulting, 2003. *NG13 assessment and land use management Plan.* (First Draft). Shakawe, Botswana: Tcheku Community Trust, Trust for Okavango Cultural and Development Initiatives & Bernard Van Leer Foundation**.**

Alexander, S.M. Waters, N.M. & Paquet, P.C., 2004. A probability based GIS model for identifying focal species linkage zones across highways in the Canadian Rocky Mountains. In: G. Clarke & J. Stillwell, eds. *Applied GIS and Spatial Analysis*. West Sussex, England: John Wiley and Sons, pp.233–255.

Alexander, S.M. Waters, N.M. & Paquet, P.C., 2005. Traffic volume and highway permeability for a mammalian community in the Canadian Rocky Mountains. *Canadian Geographer,* 49, pp.321–331.

Allafrica Global Media, 2006. *Report on veterinary matters in Namibia.* Available at: http://al lafrica.com/stories/200602240655.html

Amanfu, W. Masupu, K.V. Adom, E.K. Raborokgwe, M.V. Bashiruddin, J.B., 1998. An outbreak of contagious bovine pleuropneumonia in Ngamiland district of north-western Botswana. *Veterinary Record,* 143, pp.46–48.

Anderson, D. & Grove, R., 1987. The scramble for Eden: past, present and future in African conservation. In: D. Anderson & R. Grove, eds. *Conservation in Africa. People, policies and practice*. Cambridge: Cambridge University Press, pp.1-12.

Anderson, J.L., 2003. *Large mammal migrations of the Great Limpopo Transfrontier Park: The implications for planning, development and management*. USAID. PCE –I-00-99-00002-00. Contract to Development Alternatives Inc.

Anderson, J.L. & Pariela, F., 2005. *Strategies to mitigate human-wildlife conflict in Moçambique.* Maputo, Mozambique: DNFFB.

Andren, H., 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos*, 71, pp.355–366.

Anonymous, 1994. *Annual Report. Department of Veterinary Services.* Harare, Zimbabwe.

Anonymous, 2001. K2C Nomination form summary. April 2001.

Ansell, W.F.H., 1960. *Mammals of Northern Rhodesia*. Lusaka, Zambia: The Government Printer. pp.30-31.

Anthony, B., 2006. *A view from the other side of the fence: Tsonga communities and the KNP, South Africa.* Ph.D. Budapest: Central European University.

Anthony, B., 2007. The dual nature of parks: attitudes of neighbouring communities towards Kruger National Park, South Africa. *Environmental Conservation,* 34(3)**,** pp.236-245.

Atkins, A., 1990. *Pandamatenga development study.* (Final report and Environmental Impact Assessment). Gaborone, Botswana.

Aylward, B. & Lutz, E., 2003, eds. *Nature tourism, conservation and development in KwaZulu Natal, South Africa.* Washington DC: World Bank.

Balfour, D. Dublin, H. T. Fennessy, J. Gibson, D. Niskaden, L. & Whyte, I.J., 2007. *Review of options for managing the impacts of locally overabundant African elephants.* 1 edn. Gland, Switzerland: IUCN

Barnes, J., 2001. Economic returns and allocation of resources in the wildlife sector of Botswana. *South African Journal of Wildlife Research*, 31, pp.141-153.

Barnes, J. Boyd, C. & Cannon, J., 2003. Economic incentives for rangeland management in northern Botswana: implications for biodiversity. In: A.R. Palmer, S.J. Milton, K.P. Kirkman, G.I.H. Kerley & C.H.R. Hurt, eds. *Proc. VIIth International Rangelands Congress*; 26 Jul – 1 Aug 2003; Durban, South Africa. pp.203–212.

Barnes, J. Cannon, J. & Morrison, K., 2001. *Economic returns to selected land uses in Ngamiland, Botswana.* Botswana: Conservation International.

Barnes, J. Alberts, M. & MacGregor, J. (In preparation). *An economic valuation of the impact of climate change on agricultural and natural resource land uses in Namibia.* Unpublished Paper. Environmental Economics Programme. London, WC1H 0DD: International Institute of Environment and Development (IIED). http://www.iied.org.

Barnes, R.F.W., 1996. The conflict between humans and elephants in the Central African forests. *Mammal Review,* 26, pp.67-80.

Barnett, R., 1998. *Food for thought: the utilisation of wild meat in eastern and southern Africa.* Nairobi, Kenya: Traffic East/Southern Africa.

Barnett, R. & Patterson, C., 2006. *Sport hunting in the SADC Region: an overview.* Johannesburg, South Africa: TRAFFIC East/Southern Africa.

Bartlam-Brooks, H. Bonyongo, C. & Harris, S., 2010. Will reconnecting ecosystems allow long distance mammal migrations to resume? A case study of a zebra migration in Botswana. *Oryx*. (In press).

Battacharhya, D.K. Brondizio, E. Spierenburg, M. Ghosh, A. Traverse, M. de Castro, F. Morsello, C. & Siqueira, A., 2005. Cultural Services. In: K. Chopra, R. Leemans, P. Kumar & H. Simons, eds. *Ecosystems and human well-being, policy responses. Volume 3 of the findings of the responses working group of the Millennium Ecosystem Assessment.* Washington DC: Island Press, pp.401-422.

Beier, P. & Noss, R.F., 1998. Do habitat corridors provide connectivity? *Conservation Biology*, 12, pp.1241-1252.

Beinart, W., 1987. Introduction. In: D. Anderson & R. Grove, eds. *Conservation in Africa. People, policies and practice*, Cambridge: Cambridge University Press, pp.15-19.

Bell, R.H.V., 1984. The man-animal interface: an assessment of crop damage and wildlife control. In: R.H.V. Bell & T. Mcshane-Caluzi, eds. *Conservation and wildlife management in Africa*: US Peace Corps Seminar, Malawi.

Bendsen, H. & Meyer, T., 2003. *The dynamics of the land use systems in Ngamiland, Botswana: changing livelihood options and strategies*. Maun, Botswana: Paper presented at Environmental Monitoring of Tropical Wetlands.

Bengis, R.G. Kock, R.A. & Fischer, J., 2002. Infectious animal diseases: the wildlife/livestock interface. In: *Infectious diseases of wildlife: detection, diagnosis and management.* O.I.E. Scientific and Technical Review 21. pp.53-65.

Bengis, R.G., Grant, R. & de Vos, V., 2003. Wildlife diseases and veterinary controls: a savanna ecosystem perspective. In: J. T. du Toit, K. H. Rogers & H. C. Biggs, eds. *The Kruger experience: ecology and management of savanna heterogeneity*. Island Press, Washington. pp.349-369.

Bengis, R.G., 2005. Transfrontier conservation area initiatives in sub-Saharan Africa: some animal health challenges. In: S.A. Osofsky, S. Cleaveland, W.B. Karesh, M.D. Kock, P.J. Nyhus, L. Starr & A. Yang, eds. *Conservation and development interventions at the wildlife/livestock interface: implications for wildlife, livestock and human health.* Gland, Switzerland and Cambridge, UK: IUCN. Ch.2, xxxiii and pp.220. Available at: http://www.wcs-ahead.org/wpc_launch.html

Benítez-López, A. Alkemade, R. & Verweij, P.A., 2010. The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. *Biological Conservation,* (In press).

Ben-Shahar, R., 1993. Does fencing reduce the carrying capacity for populations of large herbivores? *Journal of Tropical Ecology,* 9, pp.249-253.

Ben-Shahar, R., 1995. Woodland dynamics under the influence of elephants and fire in northern Botswana. *Vegetatio,* 123, pp.153-163.

Ben-Shahar, R., 1998. Elephant density and impact on Kalahari woodland habitats. *Transactions of the Royal Society of South Africa,* 53, pp.149-155.

Berger, J., 2002. The last mile: how to sustain long-distance migration in mammals. *Conservation Biology*, 18, pp.320-331.

Berry, H., 2010. The fence. *Flamingo*, April 2010, pp.39-41.

Biggs, H. & Rogers, K.H., 2003. An adaptive system to link science, monitoring and management in practice. In: J.du Toit, K.H. Rogers, & H. Biggs, eds. *The Kruger experience: ecology and management of savanna heterogeneity*. Washington DC: Island Press. pp.59-80.

Bigurube, G. Borner, M. & Sinclair. A.R.E., 2010. The Serengeti North Road Project. A Commercial Road through Serengeti National Park jeopardizes the Integrity of a World Heritage Site. Frankfurt Zoological Society. Available at: www.zgf.de/download/1135/SerenegtiRoad2.pdf

Biryahwaho, B., 2002. Community perspectives towards management of crop raiding animals, experiences of Care DTC with communities living adjacent to Bwindi Impenetrable and Mgahinga Gorilla National Parks, south west Uganda. In: C.M. Hill, F.V. Osborne, A.J. Plumptre. eds. *Human-wildlife conflict, identifying the problem and possible solutions*, *Albertine Rift Technical Reports Series*, Volume 1. New York, NY: Wildlife Conservation Society. pp. 46-57.

Blair, J. & Noor, N., 1979*. Incompatible neighbours*. Proceedings of an elephant workshop held at the FELDA institute, Malaysia.

Blake, S. Deem, S.L. Strindberg, S. Maisels, F. & Momont, L., 2008. Roadless wilderness area determines forest elephant movements in the Congo Basin. *PLoS ONE* 3(10): e3546. doi:10.1371/journal.pone.0003546.

Blignaut, J., 2009. Fixing both the symptoms and the causes of degradation: the need for an integrated approach to economic development and restoration. *Journal of Arid Environments*, 73 (6/7), pp.696-698.

Blignaut, J. van Ierland, J. Xivuri, T. van Aarde, R. & Aronson, J. (In press). The Socio-economic impact of ARISE, an ecological restoration project in greater Giyani, South Africa: a critical assessment. In: D. Egan, J. Abrams & E. Van Hjerpe, eds. *Exploring the Social Dimensions of Ecological Restoration*. Island Press, California, USA.

Bode, M. & Whittle, B., 2009. How to build an efficient conservation fence. *Conservation Biology*, 24, pp. 182-188.

Böhm, M. Hutchings, M.R. & White, P.C.L., 2009. Contact networks in a wildlife-livestock host community: identifying high-risk individuals in the transmission of Bovine TB among badgers and cattle. PLoS ONE, 4: e5016. Doi:10.1371/journal.poone.0005016.

Bolzoni, L. Dobson, A.P. Gatto, M. & De Leo, G.A., 2008. Allometric scaling and seasonality in the epidemics of wildlife diseases. *American Naturalist*, 172, pp. 818-828.

Bond, I. Child, B. de la Harpe, D. Jones, B. Barnes, J. & Anderson, H., 2004. Private land contribution to conservation in South Africa. In: B. Child, ed. *Parks in Transition*. London: Earthscan. pp.29-61.

Bond, W.J. Midgley, G.F. & Woodward, F.I., 2003. The importance of low atmospheric CO_2 and fire in promoting the spread of grasslands and savannas. *Global Change Biology*, 9, pp.1-10.

Bonnington, C. Grainger, M. Dangerfield, S. & Fanning. E., 2009. The influence of electric fences on large mammal movements in the Kilombero Valley, Tanzania. *African Journal of Ecology,* 46, pp.138-145.

Bonnington, C. Weaver, D. & Fanning, E., 2009. The use of teak (*Tectona grandis*) plantations by large mammals in the Kilombero Valley, southern Tanzania. *African Journal of Ecology*, 47, pp.138–145.

Bonnington, C. Grainger, M. Dangerfield, S. & Fanning, E., 2010. The influence of electric fences on large mammal movements in the Kilombero Valley, Tanzania. *African Journal of Ecology*, 48, pp.280-284.

Boone, R. B. Burnsilver, S. B. Thornton, P. K. Worden, J. & Galvin, K. A., 2005. Quantifying declines in livestock due to land subdivision. *Rangeland Ecology & Management,* 58, pp.523-532.

Boone, R.B. & Hobbs, N.T., 2004. Lines around fragments: effects of fencing on large herbivores. *African Journal of Range & Forage Science,* 21(3), pp.147-158.

Bornman, H. 1995. *Establishment and development of the Klaserie Private Nature Reserve.* Hoedspruit, South Africa: Klaserie Private Nature Reserve.

Borrell, B., 2009. Don't fence me in: Researchers devise bio-boundary for African wild dogs. Available at:

http://www.scientificamerican.com/article.cfm?id=bio-boundary-for-african-wild-dogs

Borrini–Feyerabend, G., 1997, ed. D. Buchan, co-ed. *Beyond fences. Seeking social sustainability in conservation*. Vol. I: A process companion; Vol. II: A resource book. Gland: IUCN (in co-operation with GTZ).

Bothma, J. du P., 2002. Some economics of game ranching. In: B. Penzhorn, ed. *Proceedings of a symposium on game ranch planning and management*. Onderstepoort, South Africa: Wildlife Group, SA Veterinary Association. pp.23-40.

Bothma, J. Du P., Suich, H. & Spenceley, A., 2009. Extensive wildlife production on private land in South Africa. In: H. Suich, B. Child & A. Spenceley, eds. *Evolution and Innovation in Wildlife Conservation Areas: Parks and game Ranches to Transfrontier Conservation Areas*: London, Earthscan, pp. 147-161.

Bowen-Jones, E. & Pendry, S., 1999. The threat to primates and other mammals from the wild meat trade in Africa, and how this threat could be diminished. *Oryx*, 33, pp.233-246.

Boyt, W.P., 1979. 'Trypanosomiasis in Zimbabwe Rhodesia' *Rhodesian Veterinary Journal*, 10, pp. 54-63.

Braack, H., 1973. *Population dynamics of the blue wildebeest* (Connochaetes taurinus taurinus [Burchell, 1823]) *in the Central District of the Kruger National Park.* (Project report). Salisbury (Harare): University of Rhodesia.

Breytenbach, J., 1997. *Eden's exiles. One soldier's fight for paradise*. Cape Town: Queillerie Publishers.

Breytenbach, J., 2001. *The plunderers*. Johannesburg; London: Covos Day Books.

Brits, J. van Rooyen, M.W. & van Rooyen, N., 2002. Ecological impact of large herbivores on the woody vegetation at selected watering points on the eastern basaltic soils in the Kruger National Park. *African Journal of Ecology*, 40, pp.53-60.

Brockington, D., 2002. *Fortress conservation. The preservation of the Mkomazi Game Reserve, Tanzania*. Oxford: James Currey.

Brooks C.J., 2005. *The foraging behavior of Burchell's zebra* (Equus burchelli antiquorum). D. Phil. Bristol University.

Brynard, A.M. & Pienaar, U. de V., 1961. *Jaarverslag van die Biologiese Afdeling, Nasionale Krugerwildtuin. 1 April 1960 to 31 March 1961*. (Unpublished internal memorandum). Skukuza: South African National Parks.

Bulte, E.H. Boone, R.B. Stringer, R. & Thornton, P.K., 2006. *Wildlife conservation in Amboseli, Kenya: paying for non-use value*., Policy case study final report for the Roles of Agriculture Project. Rome: FAO.

Burbidge, A.A. & McKenzie, N.L., 1989. Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation*, 50, pp.143-198.

Burns, B. Innes, J. & Day, T.D., 2010. The use and potential of pest-proof fencing for ecosystem restoration and fauna reintroduction in New Zealand. In: M.J. Somers & M.W. Hayward, eds. *Fencing for Conservation*. (In press). New York: Springer-US.

Buss, I.O., 1961. Some observations on food habits and behaviour of the African elephant. *Journal of Wildlife Management*, 25, pp.130-149.

Calef, G.W., 1988. Maximum rate of increase in the African elephant. *African Journal of Ecology,* 26, pp.323-327.

Campbell, A.C., 1978. The 1960s drought in Botswana. In: M.T. Hinchley, ed. *Proceedings of a symposium on drought in Botswana.* Gaborone, Botswana: The Botswana Society, pp.98-109.

Campbell, A.C., 1981. A comment on Kalahari wildlife and the Kuke fence. *Botswana Notes and Records*, 13, pp.111-118.

Cape Times, 2010. Agriculture authorities to build a vaccine bank. 20.5.2010. Independent Newspapers, Cape Town, South Africa.

CAR, Geoflux & Ecosurv, 2009. *Environmental and social impact assessment of the Zambezi Agro-Commercial Integrated Development Project, Phase 1*. (Draft Environmental Impact Assessment). TAHAL.

Carruthers, J., 1994. Dissecting the myth: Paul Kruger and the Kruger National Park. *Journal of Southern African Studies,* 20, pp.263-283.

Carruthers, J., 1995. *The Kruger National Park: a social and political history.* Pietermartizburg, South Africa: University of Natal Press.

Carruthers, J., 2001. *Wildlife and warfare.* Pietermaritzburg: University of Natal Press.

Castelletta, M. Thiollay, J. & Sodhi, N.S., 2005. The effects of extreme forest fragmentation on the bird community of Singapore Island. *Biological Conservation*, 121, pp.135–155.

Caughley, G. Shepherd, N. & Short, J., eds., 1987. *Kangaroos: their ecology and management in the sheep rangelands of Australia*. Melbourne, Australia: Cambridge University Press.

Caughley, G. & Sinclair, A.R.E., 1994. *Wildlife Ecology and Management*. Oxford, UK: Blackwell Science, pp.334.

Chamaillé-Jammes, S. Valeix, M. & Fritz H., 2007. Managing heterogeneity in elephant distribution: interactions between elephant population density and surface-water availability. *Journal of Applied Ecology*, 44, pp.625-633.

Chamaillé-Jammes, S. Valeix, M. & Fritz, H. (In press). Elephant management: why can't we throw the babies out with the artificial bathwater? *Diversity and Distributions.*

Chaminuka, P. van der Zijpp, A. McCrindle, C.M.E. Udo, H. Eilers, K. van Ierland, E.C. & Groeneveld, R., 2008. Livestock systems and livelihoods: responding to competing claims for land at the tourism/livestock interface. *10th World Conference on Animal Production*. Cape Town, South Africa, 22-29 November 2008.

Chan, K. M. A. Shaw, M. R. Cameron, D. R. Underwood, E. C. & Daily, G. C., 2006. Conservation planning for ecosystem services. *PLoS Biology*, 4, e379.

Chapin, M., 2004. A challenge to conservationists. (Excerpt). *World Watch Magazine*, November/December 2004. Available at: www.worldwatch.org

Chase, M.J. & Griffin, C.R., 2009. Elephants caught in the middle: impacts of war, fences and people on elephant distribution and abundance in the Caprivi Strip, Namibia. *African Journal of Ecology,* 47, pp.223-233.

Chetkiewicz, C-L. St Clair, B.C.C. & Boyce, M.S., 2006. Corridors for conservation: integrating pattern and process*. Annual Review of Ecology, Evolution and Systematics*, 37, pp.317-342.

Child, B., 2009. Private conservation in southern Africa: practice and emerging principles. In: H. Suich, B. Child & A. Spenceley, eds. *Evolution and Innovation in Wildlife Conservation Areas: Parks and game Ranches to Transfrontier Conservation Areas*: London, Earthscan, pp.103-111.

Child, G, 1972. Observations on a wildebeest die-off in Botswana. *Arnoldia*, 5(31), pp.1-13.

Child, G, 2009. The growth of park conservation in Botswana. In: H. Suich, B. Child & A. Spenceley, eds. *Evolution and Innovation in Wildlife Conservation Areas: Parks and game Ranches to Transfrontier Conservation Areas*: London, Earthscan, pp. 51-66.

Child, K.N., 1973. *The reactions of barren-ground caribou (*Rangifer tarandus granti*) to simulated pipeline and pipeline crossing structures at Prudhoe Bay, Alaska*. Fairbanks: Alaska Cooperative Wildlife Research Unit, University of Alaska.

Child, M.F., 2009. The Thoreau Ideal as a unifying thread in the conservation movement. *Conservation Biology*, 23, pp.241-243.

Clevenger, A.P. Chruszcz, B. Gunson & Kari E., 2001. Highway mitigation fencing reduces wildlife–vehicle collisions. *Wildlife Society Bulletin,* 29, pp.646–653.

Coates Palgrave, K. Drummond, R. B. Moll, E. J. & Coates Palgrave, M., 2002. *Trees of Southern Africa,* 3rd Ed. Cape Town: Struik Publishers.

Condy, J.B., 1979. A history of foot and mouth disease in Rhodesia. *Rhodesian Veterinary Journal*,10, pp.2-10.

Conner, M.M., 2002. *Movements of mule deer and elk in response to human disturbance: a literature review*. Fort Collins, USA: Colorado Division of Wildlife, Mammals Research.

Connor, R.J. & P. Van den Bossche, 2004. African animal trypanosomes. In: J.W. Coetzer & R.C. Tustin, eds. *Infectious Diseases of Livestock Vol 1, 2nd Edition*. Oxford. pp.251-296.

Conover, M.R., 2002. *Resolving human-wildlife conflicts: the science of wildlife damage management*. Boca Raton, FL: Lewis Publishers.

Conservation International, 1989. *Proceedings on the Regional Conference on Fences. CI Okavango Program Series*. Gaborone: CI-Botswana offices.

Conservation International, 2006. *Towards rationalizing transboundary elephant management and human needs in the Kavango/mid-Zambezi region*. (Proceedings of workshop) Gaborone, Botswana 23 - 24 May 2006. Cape Town: Conservation International.

Conservation International & DWNP, 2007. *Aerial census of animals in the western Kgalagadi conservation corridor: dry season 2007.* Gaborone: Conservation International.

Consultec Lda. & sub-contracted Anderson, J.L., 2004. *Infrastructure development in Transfrontier Conservation Areas.* Maputo, Mozambique: DNFFB.

Corlatti, L. Hackländer, K. & Frey-Roos, F., 2009. Ability of wildlife overpasses to provide connectivity and prevent genetic isolation. *Conservation Biology,* 23, pp.548-556.

Cumming, D.H.M., 1999. *Study on the development of transboundary natural resource management areas in southern Africa, environmental context: natural resources, land use and conservation.* Washington, DC: Biodiversity Support Program.

Cumming, D.H.M., 2004a. *Sustaining animal health and ecosystem services in large landscapes - 2nd draft - Concept for a programme to address wildlife, livestock and related human and ecosystem health issues in the Greater Limpopo Transfrontier Conservation Area.* Wildlife Conservation Society. Available at:

http://www.wcs-ahead.org/workinggrps/limpopo.html

Cumming, D.H.M., 2004b. Movements and seasonal migrations of large mammals in the Four Corners Area. In: J.R. Timberlake & S. L. Childes, eds. *Biodiversity of the Four Corners Area: technical reviews, Volume Two*. Bulawayo: Biodiversity Foundation for Africa. Ch.13, pp.444-457.

Cumming, D.H.M., 2008. *Large scale conservation planning and priorities for the Kavango-Zambezi Transfrontier Conservation Area.* A report prepared for Conservation International. Cape Town: Conservation International.

Cumming, D.H.M. & Jones, B., 2005. *Elephants in southern Africa: management issues and options.* WWF-SARPO Occasional Paper Series No. 11. Harare, Zimbabwe: WWF-Southern African Regional Program Office.

Cumming, G.S. Bodin, Ö. Ernstson, H. & Elmqvist, T., 2010. Network analysis in conservation biogeography: challenges and opportunities. *Diversity and Distributions*, 16(3), pp.414-425.

Cushman, S.A., 2006. Effects of habitat loss and fragmentation on amphibians: a review and prospectus. *Biological Conservation,* 128, pp.231–240.

Cushman, S.A. Chase, M. & Griffin, C., 2005. Elephants in space and time*. Oikos,* 109, pp.331–341.

Cushman, S.A. Chase, M. & Griffin, C., 2010. Mapping landscape resistance to identify corridors and barriers for elephant movement in southern Africa. In: S.A. Cushman, & Huettmann, eds. *Spatial complexity, informatics and wildlife conservation.* Japan: Springer.

D'Amico Hales, J. Osofsky, S.A. & Cumming, D.HM., 2004. Wildlife health in Africa: implications for conservation in the decades ahead. In: N. Burgess, J. D'Amico Hales, E. Underwood, E. Dinerstein, D. Olson, I. Itoua, J. Schipper, T. Ricketts & K. Newman, eds. *The terrestria lecoregions of Africa and Madagascar: a conservation assessment.* Washington, D C: Island Press.

Damm, G., 2005. Game sale statistics South Africa. *African Indaba*, 3, pp.15-16.

Davies-Mostert, H.T.M. MacDonald, G.L. & D.W., 2009. South Africa's wild dog *(Lycaon pictus)* meta-population management programme. In: M.W. Hayward & M.J. Somers, eds. *The re-introduction of top-order predators*. Oxford: Blackwell Publishing, pp.10-42.

Davis, J.M. & Stamps, J.A., 2004. The effect of natal experience on habitat preferences. *TREE*, 19, pp.411-416.

Davison, T., 1998 (1967). *Wankie. The story of a great game reserve*. Bulawayo: Thorntree Press.

de Pastino, B., 2007. *National Geographic News*. Available at

http://news.nationalgeographic.com/news/2007/10/071001-wildebeest.html

DNAC, 2010. *Maputo special Reserve – Futi Corridor project implementation plan*, *May 2010*. Maputo: DNAC

Debenham, F., 1952. The Kalahari today. *Geographical Journal*, 118, pp.12-24.

de Boer, F. & Ntumi, C., 2001. Elephant crop damage and electric fence construction in the Maputo Elephant Reserve*,* Mozambique*. Pachyderm,* 30, pp.57-64.

de Boer, W.F. Stigter, J.D. & Ntumi, C.P, 2007. Optimising investments from elephant tourist revenues in the Maputo Special Elephant Reserve. *Journal of Nature Conservation,* 15, pp.225-236.

Defries, R. Hansen, A. Turner, B.L. Reid, R. & Liu, J., 2007. Land use change around protected areas: management to balance human needs and ecological function. *Ecological Applications,* 17, pp.1031-1038.

De Garine-Wichatitsky, M. Caron, A. Gomo, C. Foggin, C. Dutlow, K. Pfukenyi, D. Lane, E. Le Bel, S, Hofmeyr, M. Hlokwe, T. & Michel, A., 2010. Bovine tuberculosis in buffaloes, southern Africa. *Emerging Infectious Diseases*,16, pp.884-885.

De Klerk-Lorist, L., 2006. (In Litt.) *Wildlife diseases in the Kruger National Park*. PowerPoint presentation to the Scientific Networking Meeting. Skukuza: Kruger National Park.

De Leeuw, J. Waweru, M.N. Okello, O.O. Maloba, M. Nguru, P. Said, M.Y. Aligula, H.M. Heikonig, I.M.A. & Reid, R.S., 2001. Distribution and diversity of wildlife in northern Kenya. *Biological Conservation*, 100, pp.297-306.

Deloitte & Touche., 1996. *Financial and economic review of the livestock sector in Botswana*. (Final Report).

Department of Animal Health & Production, Department of Wildlife & National Parks, Okavango Peoples Wildlife Trust & Cgae-cgae Tlhabololo Trust, 1998. *Environmental Impact Assessment report on Setata Fence*. Internal report to Government of Botswana.

De Tores, P.J. Hayward, M.W. & Rosier, S.M., 2004. The western ringtail possum (*Pseudocheirus occidentalis)*, and the quokka (*Setonix brachyurus)*, case studies: Western Shield review - February 2003. *Conservation Science Western Australia*, 5, pp.235-257.

De Tores, P.J. & Marlow, N.J., 2010. A review of the relative merits of predator exclusion fencing and repeated 1080 fox baiting for protection of native fauna: five case studies from Western Australia. In: M.J. Somers & M.W. Hayward, eds. *Fencing for conservation*. (In press). New York: Springer-US.

De Waal, F. 2001. *The ape and the sushi master: cultural reflections of a primatologist*. New York: Basic Books.

DHV, 1980. *Countrywide animal and range assessment project*, 7 vols. Gaborone, Botswana: European Development Fund and Ministry of Commerce and Industry.

Diamond, J.M., 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. *Biological Conservation*, 7, pp.129-146.

Dickman, C.R., 1996. *Overview of the impacts of feral cats on Australian native fauna*. Canberra: Australian Nature Conservation Agency.

Dickman, C.R. Coles, J.N. & Drew, J.M., 1992. Conservation of mammals in the Australasian region: the importance of islands. In: J.N. Coles, & J.M. Drew, eds. *Australia and the global environmental crisis*. Canberra: Academic Press, pp.175-214.

DNPWM, 1998-2002. *Gonarezhou National Park Management Plan.* Harare: Department of National Parks and Wildlife Management.

Douglas-Hamilton, I., 1973. On the ecology and behaviour of the Lake Manyara elephants. *East African Wildlife Journal*, 11, pp.401-403.

Douglas-Hamilton, I. Krink, T. & Vollrath, F., 2005. Movements and corridors of African elephants in relation to protected areas. *Naturwissenschaften,* 92, pp.158–163.

Draper, M., 1998. Zen and the art of garden province maintenance: the soft intimacy of hard men in the wilderness of KwaZulu-Natal, 1952-1997. *Journal of Southern African Studies*, 24(4), pp.801–828.

Dublin, H. & Hoare, R., 2004. Searching for solutions: the evolution of an integrated approach to understanding and mitigating human-elephant conflict in Africa. *Human Dimensions of Wildlife*, 9, pp.271-278.

Ducheyne, E. Mweempwab, C. De Pus, C. Vernieuwe, H. A. De Deken, R. Hendrickx, G & Van den Bossche. P, 2009. The impact of habitat fragmentation on tsetse abundance on the plateau of eastern Zambia. *Preventive Veterinary Medicine,* 91, pp. 11–18.

Duffy, R., 1997. The environmental challenge to the nation state: superparks and national parks policy in Zimbabwe. *Journal of Southern African Studies*, 23, pp.441-451.

Duffy, R., 2000. *Killing for conservation. Wildlife policy in Zimbabwe*. Oxford: James Currey.

Dunham, K.M., 2001. Status of a reintroduced population of mountain gazelles (*Gazella gazella)* in central Arabia: management lessons from an aridland reintroduction. *Oryx*, 35, pp.111-118.

Dunham, K.M. Robertson, E.F. & Swanepoel, C.M., 2003. Population decline of tsessebe antelope (*Damaliscus lunatus lunatus*) on a mixed cattle and wildlife ranch in Zimbabwe. *Biological Conservation*, 113, pp.111-124.

Dunham, K.M., 2008. Detection of anthropogenic mortality in elephant (*Loxodonta africana)* populations: a long-term case study from the Sebungwe region of Zimbabwe. *Oryx*, 42, pp.36-48.

Dunne, B.M. & Quinn, M.S., 2009. Effectiveness of above-ground pipeline mitigation for moose (*Alces alces*) and other large mammals. *Biological Conservation*, 142, pp.332-343.

du Toit, J., 2010. Addressing the mismatches between livestock production and wildlife conservation across spatio-temporal scales and institutional levels. In: J. du Toit, R. Kock & J.C. Deutsch, eds. *Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems*, pp.30-52. Oxford: Wiley-Blackwell Publishers.

du Toit, J.T. Rogers, K.H. & Biggs, H.C., eds., 2003. *The Kruger experience: ecology and management of savanna heterogeneity*. Washington, DC: Island Press.

du Toit, R., 1998. Case study of policies that support sustainable development in Africa: the Savé Valley Conservancy, Zimbabwe. *A workshop on African perspectives of policies which support sustainable development.* Harare: The Scandinavian Seminar College.

du Toit, R., 2004. *Review of wildlife issues associated with the land reform programme in Zimbabwe.* World Wide Fund for Nature – Southern African Regional Programme Office. Working Paper 10.

du Toit, R., 2005. Foot-and-mouth disease management and land-use implications in the Zimbabwean Lowveld: the rationale for creating a biosphere reserve. In: S. Osofsky, ed. *Conservation and development interventions at the wildlife/livestock interface: implications for wildlife, livestock and human health.* Gland, Switzerland: IUCN, pp.109–112.

DVS, 2007. *Veterinary science, transboundary animal diseases and markets: pathways for policy in southern Africa - the Namibian component.* Republic of Namibia, Ministry of Agriculture, Water and Forestry, Directorate of Veterinary Services. (Report), p.59.

DWNP, 1994a. *Aerial census of animals in Botswana: dry season 1994*. Gaborone, Botswana: ULG Consultants Ltd., UK, and Department of Wildlife and National Parks.

DWNP, 1994b. *Aerial census of animals in Botswana: wet season 1994*. Gaborone, Botswana: ULG Consultants Ltd, UK, & Department of Wildlife and National Parks.

DWNP, 2003. *Aerial census of animals in Botswana: dry season 2003*. Gaborone, Botswana: Department of Wildlife and National Parks.

Dzingirai, V., 2003. The new scramble for the African countryside. *Development and Change*, 34(2), pp.243-263.

Dzingirai, V., 2004. *Disenfranchisement at large. Transfrontier zones, conservation and local livelihoods.* Harare: IUCN/ROSA.

Ehes, 2007. *Environmental and Social Impact Assessment (ESIA) of the Pandamatenga Agricultural Infrastructure Development Project*. Ehes (Pty) Ltd and the Department of Crop Production and Forestry, 294pp.

Ellis, S., 1994. Of elephant and men: politics and nature conservation in South Africa. *Journal of Southern African Studies*, 20(1), pp.53-69.

Eloff, J.H., 1990. 'n Nuwe orde. In: *Neem uit die verlede.* Pretoria: National Parks Board of South Africa. Sigma Press.

Els, H., 1995. Value and function of the Kruger National Park - value judgements of rest camp personnel. *South African Journal of Ethnology,* 18(1), pp.12–21.

Els, H., 2002. Rural development and game ranch management. In: J. Bothma, ed. *Game ranch management*. Pretoria, South Africa: van Schaik, pp.677-686.

Emerton, L., 2001. The nature of benefits and the benefits of nature: why wildlife conservation has not economically benefited communities in Africa. In: D. Hulme & M. Murphree, eds. *African Wildlife and Livelihoods - The Promise and Performance of Community Conservation*. Oxford: James Currey, pp.208-226.

Environmental Investigation Agency, 2003. *A line in the sand – the unsustainable expansion of Botswana's beef industry at the expense of local communities and the Okavango Delta.* London: EIA Publication.

Estes, R.D., 1968. *The Kalahari region*. (Unpublished typescript). Peterborough: pp.1-16.

European Commission, 1998. Agreement between the European Community and the United States of America on sanitary measures to protect public and animal health in trade in live animals and animal products. *Official Journal of the European Communities,* (EN, L118/3-63 of 21.4.98).

Fa, J., Garcia Yuste, J.E. & Castelo, R., 2000. Bushmeat markets on Bioko Island as a measure of hunting pressure. *Conservation Biology,* 14, pp.1602-1613.

Farmers Weekly, 2007. Available at: http://www.fwi.co.uk/Articles/2007/10/05/106655/Foot-and-mouth-disease-FMD-2007-Surrey-outbreak-Farmers-Weekly-Interactives-special.htm

Ferguson, K.J., 2009a. *The spatial dynamics of wildlife populations across and along the north-western Kruger National Park boundary fence.* (Final Report). Stellenbosch: WWF-SA (Project 1490).

Ferguson, K.J., 2009b. *Longitudinal archiving and concurrent capture of fence egress data in the Kruger National Park.* (Final Performance Report) (Project: AFE-0401-8-G752): Washington, DC: USFWS.

Ferguson, K., 2009c. *The development of an integrated fences management plan within the proposed Kavango-Zambezi Transfrontier Conservation Area*. Fence Interface Research and Monitoring. University of Pretoria. Manuscript, pp.1-99.

Ferguson, K. Adam, L. Jori, F., 2010. An adaptive monitoring programme for studying impacts along the western boundary fence of Kruger National Park, South Africa. In: M.J. Somers & M.W. Hayward, eds. *Fencing for Conservation*. New York:Springer-US. (In press).

Ferrar A., 1995. *Magkadikgadi Pans management plan: incorporating Makgadikgadi Pans, Nxai Pan National Park and neighbouring community areas and wildlife management areas.* Botswana: MCI/DWNP.

FINWEEK, 2010. *Sticking our necks out for game farms: more maize not the answer*. April Edition, pp.14-19.

Fischer, J. & Lindenmayer, D.B., 2007. Landscape modification and habitat fragmentation: a synthesis. *Global Ecology and Biogeography* 16, pp.265-280.

Fitzgibbon, C. Mogaka, H. & Fanshawe, J., 1995. Subsistence hunting in Arabuko-Sokoke Forest, Kenya, and its effects on mammal populations. *Conservation Biology,* 9, pp.1116-1126.

Fleischner, T.L, 2010. Livestock grazing and wildlife conservation in the American West: historical policy and conservation biology perspectives. In: J. du Toit, R. Kock, & J.C. Deutsch, eds. *Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems*. Oxford: Wiley-Blackwell Publishers, pp.235-265.

Foggin, C.M., 1981. Disease problems associated with wildlife utilization on Zimbabwe farms. *Zimbabwe Science News,* 15, pp.187-189.

Foggin, C.M. & Taylor, R.D., 1996. Management and Utilization of the African buffalo in Zimbabwe. In: B.L. Penzhorn, ed.*The African Buffalo as a Game Ranch Animal.* Onderstepoort, South Africa. pp.144-162.

Forman, R.T.T. Sperling, D. Bissonette J.A. Clevenger, A.P. Cutshall, C.D. Dale, V.H. Fahrig, L. France, R. Goldman, C.R. Heanue, K. Jones, J.A. Swanson, F.J. Turrentine, T. & Winter, T.C, 2003. *Road ecology: science and solutions*. Washington, D.C.: Island Press.

Fox, D., 2009. On the fence. *Conservation,* 3, pp.27–32.

Fraser, C., 2009. *Rewilding the world. Dispatches from the conservation revolution.* New York: Henry Holt.

Fratkin, E. & Mearns, R., 2003. Sustainability and pastoral livelihoods: lessons from east African Maasai and Mongolia. *Human Organisation,* 62(2), pp.112-122.

Friedman, Y. & Daly, B., eds., 2004. *Red Data Book of the mammals of South Africa: A conservation assessment.* CBSG Southern Africa, Conservation Breeding Specialist Group (SSC/IUCN), Endangered Wildlife Trust, South Africa. pp.598-599.

Fritz, H. Said, S. Renaud, P.C. Mutake, S. Coid, C. & Monicat, F., 2003. The effects of agricultural fields and human settlements on the use of rivers by wildlife in the mid-Zambezi valley, Zimbabwe. *Landscape Ecology*, 18, pp.293-302.

Fu, W. Liu, S. Degloria, S.D. Dong, S. & Beazley, R., 2010. Characterizing the 'Fragmentation-barrier' effect of road networks on landscape connectivity: a case study in Xishuangbanna, southwest China. *Landscape and Urban Planning*, 95, pp.122-129.

Gadd, M.E., 2002. The impact of elephants on the marula tree (*Sclerocarya birrea). African Journal of Ecology*, 40, pp.328-336.

Gadd, M.E., 2010. *Barriers, the beef industry and unnatural selection: a review of the impacts of veterinary fencing on mammals in southern Africa.* In: M.J. Somers, M.W. Hayward, eds. Fencing for conservation. (In press*). New York: Springer-US.*

Gaillard, J-M. Coulson, T. & Festa-Bianchet, M., 2010. Demographic processes: lessons from long-term and individual based studies. In: N. Owen-Smith, ed. *Dynamics of Large Herbivore Populations in Changing Environments*, Oxford: Blackwell, pp. 117-140.

Galvin, K.A., 2008. Responses of Pastoralists to Land Fragmentation: Social Capital, Connectivity, and Resilience. In: K.A. Galvin, R.S. Reid, R.H.Jr. Behnke & N.T. Hobbs, eds. *Fragmentation in Semi-Arid and Arid Landscapes: Consequences for Human and Natural Systems*, Fort Collins: Springer, pp.369-389.

Gaylard, A. Owen-Smith, N. & Redfern, J., 2003. Surface water availability: implications for heterogeneity and ecosystem processes. In: J. Du Toit, K.H Rogers, & H. Biggs, eds. *The Kruger experience: ecology and management of savanna heterogeneity.* Washington, DC: Island Press. pp.149-170.

Gertenbach, W.P.D., 1980. Rainfall patterns in the Kruger National Park. *Koedoe,* 23, pp.35-44.

Ghoneim, N.H. Abdel-Karim, A.K.M. El-Shaway, L. & Abdel-Moein, K.A., 2010. Foot and Mouth Disease in animals in Sharkia Goevernate – Egypt. Transboundary and Emerging Diseases, 57, pp. 19-21.

Gibson, C.C, 1999. *Politicians and poachers. The political economy of wildlife in Africa.* Cambridge: Cambridge University Press.

Gichohi, H., 1996. *The Ecology of a truncated Ecosystem: The Athi-Kapiti Plains.* Ph.D., University of Leicester, UK.

Gichohi, H., 2000. Functional relationships between parks and agricultural areas in East Africa: The Case of Nairobi National Park. In: H.H.T. Prins, J. Grotenhuis & T.Thomas, eds. *Wildlife Conservation by Sustainable Use*. Netherlands: Kluwer Academic Publishers, pp.141-168,

Gillson, L. & Lindsay, K., 2003. Ivory and ecology - changing perspectives on elephant management and the international trade in ivory. *Environmental Science & Policy*, 6, pp.411-419.

Glista, D.J. de Vault, T.L. & de Woody, J.A., 2009. A review of mitigation measures for reducing wildlife mortality on roadways. *Landscape and Urban Planning*, 91, pp.1-7.

GMTFCA TTC, 2010. *Greater Mapungubwe Transfrontier Conservation Area Integrated Development Plan, February 2010.* Stellenbosch: PPF.

Golder Associates Limited, 2004. *Review of wildlife crossing structures for above-ground pipelines*. Calgary, Alberta: South Alberta SAGD Operators.

Gordon, R. & Sholto Douglas, S., 2000. *The Bushmen myth. The making of a Namibian underclass.* Boulder, Oxford: Westview Press, 2nd edition.

Government of Botswana, DWNP, 2007. *Anticipated impact of the new agric fencing policy on wildlife conservation in western Ngamiland - a report on wildlife numbers and distribution in NG5.*

Government of Botswana, Ministry of Finance & Development Planning, 2010. *National Development Plan 10*. *Chapter 9: Sustainable Economic Growth.*

Government of Botswana, Ministry of Local Government, 2003. *Ghanzi District Development Plan 6: 2003 – 2009*.

Graetz, R. D. & Tongway, D. J., 1986. Influence of grazing management on vegetation, soil structure and nutrient distribution and the infiltration of applied rainfall in a semi-arid chenopod shrubland. *Australian Journal of Ecology,* 11(4), pp.347-360.

Graham, M.D., 2007. *Coexistence in a land use mosaic? Land use, risk and elephant ecology in Laikipia District, Kenya*. Ph.D., Cambridge, UK: University of Cambridge.

Graham, A.D., 1973. *The gardeners of Eden.* London: George Allen & Unwin Ltd.

Graham, A.D. Dawson, J. & Parker, I.S.C., 1974. *Results of a zebra and wildebeest census in the vicinity of the Makgadikgadi game reserve made in November 1974*. Incomplete reference.

Graham, M.D. Douglas-Hamilton, I. Adams, W.M. & Lee, P.C., 2009a. The movement of African elephants in a human-dominated land-use mosaic. Animal Conservation, 12, pp.445–455**.**

Graham, M.D. Gichohi, N. Kamau, F. Aike, G. Craig, B. Douglas-Hamilton, I. & Adams, W.M., 2009b. *The use of electrified fences to reduce human elephant conflict: a case study of the Ol Pejeta Conservancy, Laikipia District, Kenya.* (Working Paper 1) Nanyuki, Kenya: Laikipia Elephant Project.

Grant, R. Bengis, R. Balfour, D. & Peel, M., 2007. Controlling the distribution of elephants. In: K. Mennell & R. Scholes, eds., 2007. *The 2007 scientific assessment of elephant management in South Africa.* 1st edn. Johannesburg, South Africa: Witwatersrand University Press.

Groothoff, D., 2004. *Animals & Animosities: a Tsonga community wildlife project in the Limpopo Province of South Africa.* M.Sc, The Netherlands: Vrije Universiteit Amsterdam, pp.68.

Gunderson, L.H. & Holling, C.S., eds., 2002. *Panarchy: understanding transformations in human and natural systems*. Washington DC: Island Press.

Gupta C., 2004. *A study of the decision to construct the Makgadikgadi Wildlife Fence and its subsequent impacts on the Makgadikgadi Pans region*. (Research Report). Hanover, NH: Dartmouth College..

Gusset, M. Ryan, S.J. Hofmeyr, M. van Dyk, G. Davies-Mostert, H.T. Graf, J.A. Owen, C. Szykman, M. MacDonald, D.W. Monfort, S.L. Wildt, D.E. Maddock, A. Mills, M.G.L. Slotow, R. & Somers, M.J., 2008. Efforts going to the dogs? Evaluating attempts to re-introduce endangered wild dogs in South Africa. *Journal of Applied Ecology*, 45, pp.100-108.

Hack, M.A. East, R. & Rubenstein, D.I., 2002. Status and action plan for the plains zebra *(Equus burchelli)*. In: P.D. Moehlman, ed. *Equids: zebras, asses and horses. Status survey and conservation action plan*. Gland, Switzerland & Cambridge, U K: IUCN/SSC Equid specialist group, pp.43-60.

Hahn, B. D. Richardson, F. D. Hoffman, M. T. Roberts, R. Todd, S. W. & Carrick, P. J., 2005. A simulation model of long-term climate, livestock and vegetation interactions on communal rangelands in the semi-arid Succulent Karoo, Namaqualand, South Africa. *Ecological Modelling,* 183(2–3), pp.211-230.

Hall-Martin, A. & Modise, S., 2002. *Existing and potential Transfrontier Conservation Areas in the SADC region.* (Status Report). Stellenbosch: PPF, RETOSA & DBSA.

Hamman, K. Vrahimis, S. & Blom, H., 2003. Can current trends in the game industry be reconciled with nature conservation? *African Indaba Yearbook*, 2003.

Haney, J.C., 2007. Wildlife Compensation Schemes from around the World: An annotated bibliography. Defenders of the Wild.

Hanks, J., 1997. The origin, objectives and activities of the Peace Park Foundation. *International conference on Transboundary protected areas as a vehicle for international co-operation*. Cape Town, South Africa, 16-18 September 1997.

Hanks J., 2000. The role of Transfrontier Conservation Areas in southern Africa in the conservation of mammalian biodiversity. In: A. Entwistle and N. Dunstone, eds. *Priorities for the conservation of mammalian diversity: has the panda had its day?* Cambridge, UK: Cambridge University Press.

Hanks, J., 2003. Transfrontier Conservation Areas (TFCAs) in southern Africa: their role in conserving biodiversity, socioeconomic development and promoting a culture of peace. *Journal of Sustainable Forestry,* 17(1-2), pp.127-148.

Hargreaves, S.K. Foggin, C.M. Anderson, E.C. Bastos, A.D.S. Thomson, G.R. Ferris, N.P. & Knowles N.J., 2000. An investigation into the source and spread of foot and mouth disease virus from a wildlife conservancy in Zimbabwe. *Scientific and Technical Review*, 23, pp.783-790.

Harris, D.R., 1980. Commentary: human occupation and exploitation of savanna environments. In: *Human ecology in savanna environments.* D.R. Harris, ed. London: Academic Press. pp.31-39.

Harris, G.M. Russel, G.J. van Aarde, R.J. & Pimm, S.L., 2008. Rules of habitat use by elephants (*Loxodonta africana)* in southern Africa: insights for regional management*. Oryx,* 42, pp.66–75.

Harris. G, Thirgood, S. Hopcraft, J.G.C, Cromsight, J.P.G.M & Berger, J., 2009. Global decline in aggregated migrations of large terrestrial mammals. *Endangered Species Research*, 7, pp.55–76.

Hatton, J. Couto, M. & Oglethorpe, J., 2001. *Biodiversity and war: a case study of Mozambique*. Washington DC: WWF Biodiversity Support Program.

Hayward, M.W., 2009. Conservation management for the past, present and future. *Biodiversity and Conservation*, 18, pp.765-775.

Hayward, M.W., 2010. Perspectives on fencing for conservation based on four case studies: marsupial conservation in Australian forests; bushmeat hunting in South Africa; large predator reintroduction in South Africa; and large mammal conservation in Poland. In: M.J. Somers & M.W. Hayward, eds. *Fencing for conservation*. (In press). New York: Springer-US.

Hayward, M.W. & Kerley, G.I.H., 2009. Fencing for conservation: restriction of evolutionary potential or a riposte to threatening processes? *Biological Conservation*, 142, pp.1-13.

Hayward, M.W. Legge, S. Parsons, B.C. Page, M.J. Herman, K. & Mulder, E., 2010. Woylie *Bettongia penicillata* (Potoroidae: Marsupialia) reintroduction as part of the Australian Wildlife Conservancy's Endangered Species Recovery Programme at Scotia Sanctuary, far western New South Wales, Australia. In: P.S. Soorae, ed. *Reintroduction Case Studies*. p.(In press). Gland, Switzerland: IUCN Species Survival Commission's Reintroduction Specialist Group.

Hayward, M. O' Brien, J. & Kerley, G. I. H., 2007. Carrying capacity of large African predators: predictions and tests. *Biological Conservation*, 139, pp.219-229.

Heath, M.E., 1992. Manis temminckii. *Mammalian Species*, 415, pp.1-5.

Heath, M.E. & Coulson, I.M., 1997. Home range size and distribution in a wild population of Cape pangolins *(Manis temminckii)* in north-west Zimbabwe. *African Journal of Ecology*, 35, pp.94-109.

Heath, M.E. & Coulson, I.M., 1998. Measurements of length and mass in a wild population of Cape pangolins *(Manis temminckii)* in north-west Zimbabwe. *African Journal of Ecology*, 36, pp.267-270.

Hedger, R.S. Condy, J.B.. & Golding, S.M, 1972. 'Infection of some species of African wildlife with foot-and-mouth disease virus' *Journal of Comparative Pathology* , 82, pp. 455-461.

Helm, C.V. Witkowski, E.T.F. Kruger, L. Hofmeyr, M. & Owen-Smith, N., 2009. Mortality and utilisation of *Sclerocarya birrea* subsp. *caffra* between 2001 and 2008 in the Kruger National Park, South Africa. *South African Journal of Botany*, 75, pp.475-484.

Hemson, G., 2004. *The ecology and conservation of lions*. D. Phil. University of Oxford.

Hemson, G. Maclennan, S. Mills, G. Johnson, P. & Macdonald, D., 2009. Community, lions, livestock and money: a spatial and social analysis of attitudes to wildlife and the conservation value of tourism in a human–carnivore conflict in Botswana. *Biological Conservation*, 142, pp.2718–2725.

Hess, G.R. Randolph, S.E. Arnebeg, P. Chemini, C. Furlanello, Harwood, J. Roberts, M.G. & Swinton, J., 2002. Spatial aspects of disease dynamics. In: P. Hudson, A. Rizzoli, B. Grenfell, H. Heesterbeek & A. Dobson eds. *The Ecology of Wildlife Diseases.* Oxford: Oxford University Press, pp. 102-118.

Hill, C.M., 2000. Conflict of interest between people and baboons, crop raiding in Uganda. *International Journal of Primatology,* 21, pp.299-315.

Hipondoka, M. H. T. & Versfeld, W. D., 2006. Root system of *Terminalia sericea* shrubs across rainfall gradient in a semi-arid environment of Etosha National Park, Namibia. *Ecological Indicators,* 6(3), pp.516-524.

Hitchcock, R.K., 1995. Centralisation, resource depletion, and coercive conservation among the Tyua of the northern Kalahari. *Human Ecology,* 23(2), pp.169-196.

Hitchcock, R.K., 2002. Coping with uncertainty: adaptive responses to drought and livestock disease in the northern Kalahari. In: D. Sporton, and D.S.G. Thomas, eds. *Sustainable livelihoods in Kalahari environments: contributions to global debates*. Oxford: Oxford University Press, pp.161-192.

Hoare, B., 2009. *Animal Migration.* London: Natural History Museum.

Hoare, R.E., 1992. Present and future uses of fencing in the management of larger mammals. *Environmental Conservation*, 19, pp.160-164.

Hoare, R.E., 1995. Options for the control of elephants in conflict with people. *Pachyderm*, 19, pp.54-63.

Hoare, R.E., 1999. Determinants of human-elephant conflict in a land-use mosaic. *Journal of Applied Ecology,* 36, pp.689-700.

Hoare, R.E., 2000. African elephants and humans in conflict: the outlook for coexistence. *Oryx,* 34, pp.34-38.

Hoare, R.E., 2001. Management implications of new research on problem elephants. *Pachyderm*, 30, pp.44-48.

Hoare, R.E., 2001. *A decision support system for managing human-elephant conflict situations in Africa.* Nairobi, Kenya: IUCN African Elephant Specialist Group, International Development Research Centre, 2009. (Project Report). Available at:

http://www.idrc.ca/en/ev-83072-201_860250-1-IDRC_ADM_INFO.html

Hoare, R., 2003. Fencing and other barriers against problem elephants. AfESG Website HEC Section. Nairobi, Kenya: Technical Brief Series.

Hobbs, J. C. A., 1981. The environmental impact of veterinary cordon fences. *African Wildlife,* 35(6), pp.16-21.

Hobbs, N.T. Galvin, K.A. Stokes, C.J. Lackett, J.M. Ash, A.J. Boone, R.B. Reid, R.S. & Thornton, P.K., 2008. Fragmentation of rangelands: implications for humans, animals, and landscapes. *Global Environmental Change*, 18, pp.776-785.

Hobbs, N.T. & Gordon, I.J., 2010. How does landscape heterogeneity shape dynamics of large herbivore populations? In: N. Owen-Smith, ed. *Dynamics of Large Herbivore Populations in Changing Environments*, Oxford: Blackwell, pp. 141-164

Hobbs, R.J., 1992. The role of corridors in conservation: solution or bandwagon? *TREE*, 7, pp.389-392.

Hoffman T.S. & O'Riain M.J. The spatial ecology of chacma baboons (*Papio ursinus*) in a human-modified environment. *International Journal of Primatology*. (In press).

Hofmeyr, M., 2001. Introduction of the African wild dog *(Lycaon pictus)* to game reserves. *Proceedings of a Symposium on the re-introduction of larger mammals to game reserves.* (Report). Faculty of Veterinary Sciences, University of Pretoria.

Homann, S. Rischkowsky, B. & Steinbach, J., 2004. Herd mobility leads the way for sustainable pastoral development: the case of the Borana rangelands, southern Ethiopia. *Conference on International Agricultural Research for Development*. Berlin, Germany: Deutscher Tropentag, Berlin.

Homewood, K. Kristjanson, P. & Chevenix Trench, P., 2009. Changing Land Use, Livelihoods and Wildlife Conservation in Maasailand. In: K. Homewood, P. Kristjanson & P. Chevenix Trench, eds. *Staying Maasai? Livelihoods, Conservation and Development in East African Rangelands*. New York: Springer Press. pp.1-42.

Hoon, P.N., 2004. Impersonal markets and personal communities? Wildlife, conservation, and development in Botswana. *Journal of International Wildlife Law and Policy,*7, pp.143-160.

Houser, A.M. Somers, M.J. & Boast, K.L., 2009. Spoor density as a measure of true density of a known population of free-ranging wild cheetah in Botswana*. Journal of Zoology*, 270, pp.108-115.

Hrabar, H. & du Toit, J.G., 2005. Dynamics of a protected black rhino *(Diceros bicornis)* population: Pilanesberg National Park, South Africa. *Animal Conservation*, 8, pp.259-267.

Hughes, D.M., 2002. *When tourists cross boundaries and peasants don't: inequality and regional metaphors in southern African conservation.* (Unpublished paper). Department of Human Ecology, Rutgers State University of New Jersey.

Hulme, D. & Murphree, M., 2001. Community conservation in Africa, an introduction. In: D. Hulme & M. Murphree, eds. *African wildlife & livelihoods. The promise & performance of community conservation.* Oxford: James Currey, pp.1-8.

Humavindu, M.N. & Barnes J.L., 2003. Trophy hunting in the Namibian economy: an assessment. *South African Journal of Wildlife Research*, 33, pp.65–70.

Hutton, J. Adams, W.M. & Murombedzi, J., 2005. Back to the barriers? Changing narratives in biodiversity conservation. *Forum for Development Studies*, 2, pp.341-370.

IFAD, 1997. *Social and ecological status of controlled hunting areas for community use*. IFAD/Ecosurv Report for the Department of Wildlife and National Parks, Botswana Government 235pp., excluding maps.

Impacto, 2005. *Possible voluntary resettlement of communities living along the Shingwedzi River. Preliminary identification of areas with potential for resettlement*. (Unpublished report). Maputo, Mozambique: Impacto.

Impey, A., 2006. Sounding place in the western Maputaland borderlands. *Journal of the Musical Arts in Africa*, 3, pp.55–79.

IPCC, 2007. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor & H.L. Miller, eds. *Climate change 2007. The physical science basis*. Contribution of Working Group I to the 4th assessment report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

IRI, 2005. *Sustainable development in Africa: is the climate right?* (IRI technical report no. IRI-TR/05/1). International Research Institute for Climate and Society.

IUCN, 2009. *IUCN Red List of Threatened Species*. (Version 2009.1). Available at: http://www.iucnredlist.org

Jacobsen, N.H.G. Newbery, R.E. de Wet, M.J. Viljoen, P.C. & Pietersen, E., 1991. A contribution to the ecology of the Steppe Pangolin *(Manis temminckii)* in the Transvaal. *Zeitschrift für Säugetierkunde*, 56(2), pp.94-100.

Jaeger, J.A.G. & Fahrig, L., 2004. Effects of road fencing on population persistence. *Conservation Biology*, 18, pp.1651-1657.

Jenkins, R.K.B., Roettcher, K. & Corti, G., 2003. The influence of stand age on wildlife habitat use in exotic teak tree *(Tectona grandis)* plantations. *Biodiversity and Conservation*, 12, pp.975–990.

Jerve, A.M., 1982. *Cattle and inequality. A study in rural differentiation from southern Kgalagadi in Botswana*. Bergen: Chr. Michelson Institute. DERAP Publications, 143.

Johnson, A.R. Wiens, J.A. Milne, B.T. & Crist, T.O., 1992. Animal movements and population dynamics in heterogeneous landscapes. *Landscape Ecology,* 7, pp.63-75.

Jones, J.L., 2006. *Dynamics of conservation and society*, Ph.D. University of Pretoria.

Jori, F. Vosloo, W. Du Plessis, B. Bengis, R. Brahmbatt, D. Gummow, B. & Thomson, G.R., 2009. A qualitative risk assessment of factors contributing to foot and mouth disease outbreaks on the western boundary of Kruger National Park. *Rev. sci. tech. Off. int. Epiz.*, 2009, 28(3), pp.917-931.

Jori, F., Brahmbatt, D. Fosgate, G. Thompson, P. Budke, C. Ward, M. Ferguson, K. & Gummow, B., *In press.* A questionnaire-based evaluation of the veterinary cordon fence separating wildlife and livestock along the Kruger National Park, South Africa. *Preventive Veterinary Medicine*.

Joubert, C.J. & Joubert, L. 2009. *Aerial survey of the larger herbivores, Save Valley Conservancy, Zimbabwe.* Report on behalf of the Technical Advisory Committee, Save Valley Conservancy. 57 pp.

Joubert, S.C.J., 1970. *Verslag i/s besoek aan Mosambiek, 18 tot 25 November 1970.* (Unpublished internal memorandum). Skukuza: South African National Parks.

Joubert, S.C.J., 1972. *Verslag i/s Lugopname van olifante in Mosambiek langs 'n strook van 32 kilometer vanaf die Sabie tot by die Limpopo Rivier, 10 - 11 April 1972.* (Unpublished internal memorandum). Skukuza: South African National Parks.

Joubert, S.C.J., 2007. *The Kruger National Park – a history.* 3 volumes. Johannesburg, South Africa: High-Branching.

Kalahari Conservation Society, 2005. *Kalahari Conservation Society Assessment Report: Removal of decommissioned veterinary fences in Ngamiland District, Botswana.* Gaborone, Botswana: Kalahari Conservation Society.

Kansas, J.L. & Raine R.M., 1988. *Interactions of moose and deer with linear facility structures and corridors in the Cold Lake Production Project Area*. Calgary, Alberta: Esso Resources Canada Limited.

Kansky, R. & Gaynor, D., 2000. *Baboon management strategy for the Cape Peninsula. Final Report, Table Mountain Fund Project number ZA 568*. Cape Town: Table Mountain Fund.

Keene-Young, R., 1999. A thin line: Botswana's cattle fences. *Africa Environment & Wildlife,* March/April, pp.71-79.

Kgathi, D. K. & Kalikawe, M. C., 1993. Seasonal distribution of zebra and wildebeest in Makgadikgadi Pans Game Reserve, Botswana. *African Journal of Ecology*, 31, pp.210-219.

Khan, L., 2010. Number of human Rift Valley Fever cases now 143. Cape Times 22/4/10. Cape Town: South Africa.

Kimani, K. & Pickard, J., 1998. Recent Trends and implications of group ranch sub-division and fragmentation in Kajiado, Kenya. *The Geographical Journal,* 164, pp,202-13.

Kinahan, A.A. Pimm, S.L. & van Aarde, R.J., 2007. Ambient temperature as a determinant of landscape use in the savanna elephant, (*Loxodonta africana)*. *Journal of Thermal Biology*, 32, pp.47–58.

King, D.A. & Stewart, W.P., 1996. Ecotourism and commodification: protecting people and places. *Biodiversity and Conservation*, 5, pp.293-305.

Kingdon, J., 1971. *East African mammals – an atlas of evolution in Africa Vol. 1. (Primates, Hyraxes, Pangolins, Protoungulates, Sirenians).* London: Academic Press, pp.365-369.

Kinloch, B., 1972. *The shamba raiders. Memories of a game warden*. London: Harvill Press.

Kioko, J. Muruth, P. Omondi, P. & Chiyo, P.I., 2008. The performance of electric fences as elephant barriers in Amboseli, Kenya. *South African Journal of Wildlife Research,* 38, pp.52–58

Kiss, A., 1990, ed. *Living with wildlife: wildlife resource management with local participation in Africa.* Washington DC: World Bank.

Kloppers, H., 1970. *Game Ranger.* Cape Town: Juta & Company Limited.

Kloppers, R.J., 2003. *Natural resource use in the Matutuine District in southern Mozambique: implications for transfrontier conservation*. M.A, University of Pretoria.

Kloppers, R.J., 2005. *Border crossings. Life in the Mozambique-South Africa borderland since 1975*. Ph.D, University of Pretoria.

Kloppers, R.J., 2006. We are only here for the pension, tomorrow we will go back to Mozambique. State welfare and development projects in communities that transcend borders. *Journal of Development Studies*, 36(2), pp.154-166.

Knickerbocker, T.J. & Waithaka. J., 2005. People and elephants in Shimba Hills, Kenya. In: R. Woodrooffe, S. Thirgood & A. Rabinowitz, eds. *People and wildlife: conflict or coexistence?* Cambridge, UK: Cambridge University Press.

Knight, M.H., 1991. Ecology of the gemsbok *(Oryx gazella gazella [Linnaeus])* and blue wildebeest *(Connochaetes taurinus [Burchell])* in the southern Kalahari. Unpublished Ph.D. thesis. University of Pretoria. 242pp.

Koch, E., 1998. Nature has the power to heal old wounds: war, peace and changing patterns of conservation in southern Africa. In: D.I. Simon, ed. *South Africa in southern Africa: reconfiguring the region*. Oxford: James Currey, pp.54-71.

Kock M.D., 2005. The health paradigm and protected areas: linkages between people and their livelihoods, ecosystems and natural communities, and health and disease. In: S.A. Osofsky, S. Cleaveland, W.B. Karesh, M.D. Kock, P.J. Nyhus, L. Starr & A. Yang, eds. *Conservation and development interventions at the wildlife/livestock interface: implications for wildlife, livestock and human health.* Gland, Switzerland and Cambridge, UK: IUCN, p. xxv.

Available at: http://www.wcs-ahead.org/book/AHEADbook6.5MB.

Kock, R., 2005. What is this infamous 'wildlife/livestock interface?' A review of current knowledge. In: S.A. Osofsky, S. Cleaveland, W.B. Karesh, M.D. Kock, P.J. Nyhus, L. Starr & A. Yang, eds. *Conservation and development interventions at the wildlife/livestock interface: implications for wildlife, livestock and human health.* Gland, Switzerland and Cambridge, UK: IUCN. pp.1-13.

Kock, R., Kock, M., Cleaveland, S. & Thomson, G., 2010. Health and disease in wild rangelands. In: J. du Toit, R. Kock & J.C. Deutsch, eds. *Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems*. Oxford: Wiley-Blackwell Publishers. pp.98-128.

Kotchemidova, C., 2008. The culture of the fence: artifacts and meanings. *Counterblast – The Journal of Culture and Communication*, 2, pp.1-4. Available at: http://www.nyu.edu/pubs/counterblast/fence.pdf

Krell, A., 2002. *The devil's rope. A cultural history of barbed wire*. London: Reaktion Books.

Kristjanson, P. Radeny, M. Nkedianye, D. Kruska, R. Reid, R. Gichohi, H. Atieno, F. & Sanford, R., 2002. *Valuing alternative land-use options in the Kitengela wildlife dispersal area of Kenya.* A joint International Livestock Research Institute (ILRI) and African Conservation Centre (ACC) report undertaken for the Kitengela community. ILRI Impact Assessment Series, no. 10. 61p. Nairobi (Kenya): ILRI.

Krug, W., 2001. Private supply of protected land in southern Africa. *Workshop on market creation for biodiversity products and services.* Paris: World Bank/OECD.

Kruger Park Times (23 February 2005).

Krueter, U.P. & Workman,J.P., 1997. Comparative profitability of cattle and wildlife ranches in semi-arid Zimbabwe. *Journal of Arid Environments,* 35, pp.171-187.

Kuiper, S. M. & Meadows, M. E., 2002. Sustainability of livestock farming in the communal lands of southern Namibia. *Land Degradation & Development,* 13(1), pp.1-15.

Kyle, R., 2000. Some notes on the occurrence and conservation status of *Manis temminckii*, the pangolin, in Maputaland, KwaZulu-Natal. *Koedoe*, 43, pp.97-98.

KWS., 2010. *Aerial Total Count: Amboseli-West Kilimanjaro and Magadi-Natron Cross Border Landscape. Wet Season, March 2010.* Kenya Wildlife Service and Tanzania Wildlife Research Institute. Available at: www.kws.org.../kws.../Amboseli_West_kili_Magadi_Natron_2010_census_report.pdf

Lagendijk, G.D. & Gusset, M., 2008. Human–carnivore coexistence on communal land bordering the greater Kruger area, South Africa. *Environmental Management*, 42, pp.971-976.

Lamarque, F. Anderson, J. Chardonnet, P. Fergusson, R. Lagrange, M. Osei-Owusu, Y. Bakker, L. Belemsobgo, U. Beytell, B. Boulet, H. Soto, B. & Tabi Tako-Eta, P., 2008. *Human-wildlife conflict in Africa: an overview of causes, consequences and management strategies.* (Report). Rome: International Foundation for the Conservation of Wildlife and FAO. Available at:

http://www.wildlifeconservation.org/en/content/download/1034/4568/file/HumanWildlifeConflict2008.pdf

Landflow Solutions (Pty) Ltd., 2009. *Review of the national land use map.* (Final Report). Gaborone, Botswana: Department of Lands, Ministry of Lands and Housing.

Lange, R.T., 1969. The piosphere: sheep track and dung patterns. *Journal of Range Management*, 22, pp.396-400.

Langholz, J.A. & Lassoie, J.P., 2001. Perils and promise of privately owned protected areas. *BioScience*, 51, pp.1079-1085.

Laurance, W.F. Nascimento, H.E.M. Laurance, S.G. Andrade, A. Ewers, R.M., Harms, K.E. Regina, L.C.C. & Ribero J.E., 2007. Habitat Fragmentation, Variable Edge Effects, and the Landscape-Divergence Hypothesis. *PLoS ONE* 2(10): e1017. doi:10.1371/journal.pone.0001017.

Laws, R.M. Parker, I.S.C. & Johnstone, R.C.B., 1975. *Elephants and their habitats. The ecology of elephants in North Bunyoro, Uganda*. Oxford: Clarendon Press.

Leakey, R. (together with Morell, V.), 2001. *Wildlife wars. My battle to save Kenya's elephants*. London: Pan Books.

Lee, P.C. & Graham, M.D., 2006. African elephants and human-elephant interactions: implications for conservation. *International Zoo Yearbook,* 40, pp.9-19.

Lee, P.C. & Priston, N.E.C., 2005. Human attitudes to primates: perceptions of pests, conflict and consequences for primate conservation. In: J.D. Patterson & J. Wallace, eds. *Primate-human interaction and conservation*. Alberta: American Society of Primatologist Publications, pp. 1-23.

Leon, M.C. & Harvey, C.A., 2006. Live fences and landscape connectivity in a neotropical agricultural landscape. *Agroforestry Systems,* 68, pp.15-26.

Levin, S., 1999. *Fragile dominion: complexity and the commons.* Cambridge, MA: Helix Books.

Lewis, A. R. & Wilson, V. G., 1977. An evaluation of a fence in the control of wild ungulates under extensive conditions in Africa. *British Veterinary Journal,* 133, pp.379-387.

Lewis, D., 2007. Can wildlife and agriculture co-exist outside protected areas in Africa? A hopeful case-study in Zambia. In: G. Davies, & D. Brown, eds. *Bushmeat and livelihoods*. Oxford: Blackwell, pp.177-196.

Lewis, D. & Phiri, A., 1998. Wildlife snaring – an indicator of community response to a community-based conservation project. *Oryx*, 32, pp.111–121.

Lindemayer, S.B. & Fischer, J., 2006. *Habitat fragmentation and landscape change: an ecological and conservation synthesis*. Washington, DC: Island Press.

Lindenmayer, D.B. & Likens, G.E., 2009. Adaptive monitoring: a new paradigm for long-term research and monitoring. *Trends in Ecology & Evolution*, 24, pp.482-486.

Lindeque, M. & Lindeque, P.M., 1991. Satellite tracking of elephants in northern Namibia. *Afr. J. Ecol.* 27, pp.198–206.

Lindsay, W.K., 1992. *Technical assistance to the project, 'Initial measures for the conservation of the Kalahari ecosystem'*. (Final report). Commission of the European Communities. Bonifica: S.p.A.

Lindsey, P. du Toit, J. & Mills, M., 2005. Attitudes of ranchers towards African wild dogs *(Lycaon pictus)*: conservation implications for wild dogs on private land. *Biological Conservation*, 125, pp.113-121.

Lindsey, P.A. Masterson, C. Beck, A. & Romañach, S., (In press). The ecological, financial and social issues associated with fencing as a conservation tool in southern Africa. Invited submission as a chapter for forthcoming book, *Fencing for Conservation - restriction of evolutionary potential or a riposte to threatening processes?* Springer publishers.

Lindsey, P. Romañach, S. Tambling, C. & Chartier, K., (In press [a]). Ecological and financial impacts of illegal bushmeat trade in Zimbabwe. *Oryx.*

Lindsey, P. Romañach, S. & Matema, S., (In press [b]) Dynamics and underlying causes of illegal bushmeat trade in Zimbabwe. *Oryx.*

Lindsey, P. Roulet, P. & Romañach, S., 2007. Economic and conservation significance of the trophy hunting industry in sub-Saharan Africa. *Biological Conservation*, 134, pp.455-469.

Lindsey, P.A. Romañach, S.S. & Davies-Mostert, H.T., 2009. The importance of conservancies for enhancing the value of game ranch land for large mammal conservation in southern Africa. *Journal of Zoology*, 277, pp.99-105.

Lindsey, P., 2010. *An analysis of game meat production and wildlife-based land uses in Namibia.* (Report). TRAFFIC, pp.90.

Lindsey, P. Beck, A. Masterson, C. & Romañach, S. (In press). The ecological, financial and social issues associated with fencing as a conservation tool in southern Africa. Invited submission as a chapter in a forthcoming book, *Fencing for Conservation - restriction of evolutionary potential or a riposte to threatening processes?* Springer publishers.

Liversedge, T., 1969. *Report on the movement of game animals south to the Molopo River in the Kgalagadi District, August – November, 1969*. Botswana Archives, 3pp.

Loarie, S.R. van Aarde, R.J. & Pimm. S.L., 2009. Fences and artificial water affect African savannah elephant movement patterns. *Biological Conservation*, 142, pp.3086-3098.

Loibooki, M. Hofer, H. Campbell, K. & East, M., 2002. Bushmeat hunting by communities adjacent to the Serengeti National Park, Tanzania: the importance of livestock ownership and alternative sources of protein and income. *Environmental Conservation*, 29, pp.391-398.

Lomba, R., 1991. *Buffalo fences: Botswana's shame. The death trap*. (Unpublished collection of documents concerning the northern buffalo fence). Gaborone, Botswana: Department of Wildlife and National Parks Library.

Mabunda, D., 2004. *An integrated tourism management framework for the Kruger National Park, South Africa, 2003.* Ph.D. South Africa: University of Pretoria.

MacArthur, R.H. & Wilson, E. O., 1967. *The theory of island biogeography.* New Jersey: Princeton University Press.

Machange, J., 1997. Livestock and wildlife interactions. In: D.M. Thompson, ed. *The Experience of the Ngorongoro Conservation Area, Tanzania.* Gland, Switzerland: IUCN, pp.127-141.

Mackenzie, I., 1955. *Proposed fencing of the western boundary of the Kruger National Park.* (Annexure T, Meeting Agenda: National Parks Board of Trustees, November 1955). Skukuza: National Parks Board.

Maddock, L., 1979. The "migration" and grazing succession. In: A.R.E. Sinclair & M. Norton- Griffiths, eds. *Serengeti: the dynamics of an ecosystem*. Chicago: The University of Chicago Press, pp.104-129.

Marker, L. Mills, M. & Macdonald, M., 2003. Factors influencing perceptions of conflict and tolerance toward cheetahs on Namibian farmlands. *Conservation Biology*, 17, pp.1290-1298.

Marshall, A.R. Aloyce, Z. Mariki, S. Jones, T. Burgess, N. Kilahama, F. Massao, J. Nashanda, E. Sawe, C. Rovero, F. & Watkin, J., 2007. Tanzania's second nature reserve: improving the conservation status of the Udzungwa mountains? *Oryx*, 41, pp.429–430.

Martin, R.B., 2005. The influence of veterinary control fences on certain wild large mammal species in the Caprivi, Namibia. In: S.A. Osofsky, S. Cleaveland, W.B. Karesh, M.D. Kock, P.J. Nyhus, L. Starr & A. Yang, eds. *Conservation and development interventions at the wildlife/livestock interface: implications for wildlife, livestock and human health.* Gland, Switzerland and Cambridge, UK: IUCN. pp 27-46.

Mascarenhas, A., 1971. Agricultural vermin in Tanzania. In: S.H. Ominde, ed. *Studies in East African geography and development.* London, UK: Heinemann Educational Books Ltd. pp.259-267.

Masunga, G., 1999. *Mass die-off of wildebeest and zebra along Boteti River during 1998 dry season.* Gaborone: DWNP.

Masunga, G. & M. Kegoeng, 1998. *Impacts of Setata fence on survival and movement of wildlife in western Ngamiland, Botswana*. Gaborone: DWNP.

Matthews, W.S. van Wyk, A.E. Van Rooyen, N. & Botha, G.A., 2001. Vegetation of the Tembe Elephant Park, Maputaland, South Africa. *South African Journal of Botany*, 67, pp.573 – 594.

Maude, G., 2010. *Human-predator conflict report: Makgadikgadi Framework Management Plan*. Gaborone, Botswana: Department of Environmental Affairs & Centre for Applied Research.

Mawson, P.R., 2004. Translocations and fauna reconstruction sites: Western Shield review - February 2003. *Conservation Science Western Australia*, 5, pp.108-121.

Mayr, E., 2001. *What evolution is*. New York: Basic Books.

Mazet, J.A.K. Clifford, D.L. Coppolillo, P.B. Deolalikar, A.B. & Erickson J.D., 2009. A 'One Health' approach to address emerging zoonoses: the HALI Project in Tanzania. *PLoS Med* 6(12): e1000190. doi:10.1371/journal.pmed.1000190.

Mbaiwa, J., 2004. Prospects of basket production in promoting sustainable rural livelihoods in the Okavango Delta, Botswana. *International Journal of Tourism Research,* 6, pp.221-235.

Mbaiwa, J.E. & Mbaiwa, O.I., 2006. The effects of veterinary fences on wildlife populations in Okavango Delta, Botswana. *International Journal of Wilderness*, 12(3), pp.17-41.

Mbaiwa, J. Ngwenya, B.N. and Kgathi, D.L., 2008. Contending with unequal and privileged access to natural resources and land in the Okavango Delta, Botswana. *Singapore Journal of Tropical Geography*, 29, pp.155-172.

McCallum, H.,2008. Landscape structure, disturbance and disease dynamics. In: Ostefeld, R.S. Keesing, F. & V.T. Eviner*. Infectious Disease Ecology: Effects of Ecosystems on Disease and of Disease on Ecosystems.* New Jersey, Princeton University press, pp. 100-124.

McCarthy, J. M. Gumbricht, T. McCarthy, T. Frost, P. Wessels, K. & Seidel, F., 2003. Flooding patterns of the Okavango wetland in Botswana between 1972 and 2000. *Ambio,* 32, pp.453-457.

McCarthy, T. S. and Ellery, W. N., 1998. The Okavango Delta. *Transactions of the Royal Society of South Africa,* 53, pp.157-182.

McGahey, D.J., 2001. *The impact of veterinary cordon fences on semi-arid vegetation systems in northern Botswana*. (Unpublished). B.Sc, University of Sussex.

McGahey, D.J., 2008. *Maintaining opportunism and mobility in drylands: the impact of veterinary cordon fences in Botswana*. (Unpublished). D.Phil, University of Oxford.

McGinnis, M.D., ed., 1999. *Polycentric governance and development: readings from the workshop in political theory and policy analysis*. Ann Arbor, MI: University of Michigan Press.

McGregor, J., 1998. Violence and social change in a border economy: war in the Maputo hinterland, 1984-1994. *Journal of Southern African Studies*, 24(1), pp.37-60.

McNeely, J.A., ed., 1992. *Parks for life. Report of the IVth World Congress on national parks and protected areas*. Gland, Switzerland: IUCN.

MET, 2007. *Etosha Management Plan, April 2007.* Windhoek, Namibia: Ministry of Environment and Tourism.

Michler, I., 2008. A beef with Botswana. *Africa Geographic*. 16, p.22.

Milgroom, J. & Spierenburg, M., 2008. Induced volition: resettlement from the Limpopo National Park, Mozambique. *Journal of Contemporary African Studies*, 26(4), pp.435-448.

Mittermeier, R. A., Mittermeier, C. G., Brooks, T. M. P. J. D., Konstant, W. R., da Fonseca, G. A. B. & Kormos, C., 2003. Wilderness and biodiversity conservation. *Proceedings, National Academy of Sciences*, 100, pp.10309 -10313.

Moleele, N. M. & Perkins, J. S., 1998. Encroaching woody plant species and boreholes: is cattle density the main driving factor in the Olifants Drift communal grazing lands, south-eastern Botswana? *Journal of Arid Environments,* 4(3), pp.245-253.

Momberg, E., 2008. Row brews over plan to erect wildlife fence. *The Sunday Independent,* March 30, South Africa.

Mordi, R., 1989. The future of animal wildlife and its habitat in Botswana. *Environmental Conservation,* 16, pp.147-56.

Morley, R. and van Aarde, R., 2006. Estimating abundance for a savanna elephant population using mark–resight methods: a case study for the Tembe Elephant Park, South Africa. *Journal of Zoology*, 271, pp.418-427.

Morris, B., 2000. Wildlife depredations in Malawi, the historical dimension. In: J. Knight, ed., *Natural enemies, people-wildlife conflicts in anthropological perspective*. London: Routledge. pp.36-49.

Moseby, K.E. & O'Donnell, E., 2003. Reintroduction of the greater bilby, (*Macrotis lagotis* [Reid]) (Marsupialia: Thylacomyidae), to northern South Australia: survival, ecology and notes on reintroduction protocols. *Wildlife Research*, 30, pp.15-27.

Moseby, K.E. & Read, J., 2006. The efficacy of feral cat, fox and rabbit exclusion fence designs for threatened species protection. *Biological Conservation*, 127, pp.427-437.

Moss, C.J. & Poole, J.H., 1983. Relationships and social structure of African elephants. In: R.A. Hinde, ed. *Primate social relationships: an integrated approach*. Sutherland, MA: Sinauer. pp.315-325.

Mouchel Consulting Ltd & Price Waterhouse, 1997. *Ngamiland fences scoping exercise, Botswana*. Report on behalf of Botswana Department of Animal Health and Production. 31pp

Mughogho, D.E.C., 1996. *The State and potential impact of fences on wildlife populations in north west Ngamiland*. (Trip Report). Department of Wildlife & National Parks, Botswana. 6pp.

Mughogho, D., 1998. *Setata fence situation report, 15 July 1998*. Department of Wildlife & National Parks, Botswana.

Mughogho, D., 1998. *Zebra and wildebeest die off in Makgadikgadi.* DWNP Report, Botswana.

Murray, M., 1988. *Management plan for Central Kalahari and Khutse Game Reserves.* Gaborone, Botswana: Kalahari Conservation Society.

Myers, N., 1972. *The long African day*. London: Macmillan.

Nasereddin, A. & Jaffe, C.L., 2004. Effects of the security fence on zoonotic visceral leishmaniasis in Israel and Palestine. *Infectious Diseases,* 4, p.393.

Naughton-Treves, L., 1996. *Uneasy neighbors, wildlife and farmers around Kibale National Park, Uganda*. Ph.D., Gainesville, Florida: University of Florida.

Naughton-Treves, L., 1998. Predicting the patterns of crop damage by wildlife around Kibale N P, Uganda. *Conservation Biology*, 12, pp.156-158.

Naughton-Treves, L. Treves, A. Chapman, C. & Wrangham, R., 1998. Temporal patterns of crop-raiding by primates, linking food availability in croplands and adjacent forest. *Journal of Applied Ecology,* 35, pp.596–606.

National Agricultural Marketing Council, 2006. Report on the investigation to identify problems for sustainable growth and development in South African wildlife ranching. National Agricultural Marketing Council Report, 3. Available at:

http://www.namc.co.za/ASSETS/PDF/Report%20on%20Wildlife%20ranching.pdf

National Parks Board of Trustees, 1926–1994. Meetings (agendas and minutes) for the period 1926 – 1994. Skukuza: National Parks Board.

NCDTEC (Northern Cape Department of Tourism, Environment and Conservation), 2010. *Draft Northern Cape Nature Conservation Regulations.* Northern Cape Province Provincial Gazette 1385.

Nel, T.G., 1951. *Insake seekoeie in die Krokodilrivier – die suidelike grens van die Wildtuin.* (Unpublished internal memorandum). Skukuza: National Parks Board.

Nelson, F. Foley, C. Foley, L.S. Leposo, A. Loure, E. Peterson, D. Peterson, T. Sachedina, H. & Williams, A., 2009. Payments for ecosystem services as a framework for community-based conservation in northern Tanzania. *Conservation Biology*, 24, pp.78-85.

Nerlich, B. & Doring, M., 2005. Poetic justice? Rural policy clashes with rural poetry in the 2001 outbreak of foot and mouth disease in the UK. *Journal of Rural Studies,* 21, pp.165-180.

Netz, R., 2004. *Barbed wire. An ecology of modernity*. Middletown, CT: Wesleyan University Press.

Neuman, R.P., 1998. *Imposing wilderness. Struggles over livelihood and nature preservation in Africa*. London; Los Angeles: University of California Press.

Neumann, R.P., 2000. Primitive ideas: protected area buffer zones and the politics of land in Africa. In: V. Broch-Due, & R. A. Schroeder, eds. *Producing nature and poverty in Africa*. Stockholm: Nordiska Afrikainstitutet, pp.220-242.

Newmark, W.D., 2008. Isolation in African protected areas. *Frontiers in Ecology and Environment*, 6, pp.231-328.

Ng, S.J. Dole, J.W. Sauvajot, R.M. Riley, S.P.D. & Valone, T.J., 2004. Use of highway undercrossings by wildlife in southern California. *Biological Conservation,* 115, pp.499–507.

Niamir-Fuller, M., 1999. *Managing mobility in African rangelands: the legitimization of transhumance*. London: IT Publication.

Nkedianye, D.K., 2004. *Testing the Attitudinal impact of a Conservation Tool outside a Protected Area: The case of the Kitengela Wildlife Conservation Lease Programme for Nairobi National Park.* M.A., University of Nairobi, Kenya.

Nkedianye, D. Radeny, M. Kristjanson, P. & Herrero M., 2009. Assessing Returns to Land and Changing Livelihood Strategies in Kitengela. In: K. Homewood, P. Kristjanson & P. Chevenix Trench, eds. *Staying Maasai? Livelihoods, Conservation and Development in East African Rangelands*. New York: Springer Press. pp 115-149.

Nohara, D. Kitoh, A. Hosaka, M. & Oki, T., 2006. Impact of climate change on river discharge projected by Multimodel Ensemble. *Journal of Hydrometeorology*, 7, pp.1076–1089.

Norton-Griffiths, M. & Said, M.Y., 2010. The future of Kenya's rangelands: An economic perspective. In: J. du Toit, R. Kock, & J.C. Deutsch, eds. *Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems.* Oxford: Wiley-Blackwell Publishers. pp.367-392.

Noss, A., 1998. The impacts of cable snare hunting on wildlife populations of the Central African Republic. *Conservation Biology*, 12, pp.390-398.

Nowak, R.M., 1999. *Walker's mammals of the world, 6th edition*. Baltimore: Johns Hopkins University Press.

NRP, 2001. *Okavango River Panhandle Management Plan*. (Draft Final Report). Maun, Botswana: Tawana Land Board. 3 Vols.

Nyhus, P.J. Osofsky, S.A. Ferraro, P. Madden, F. & Fischer, H., 2005. Bearing the cost of human-wildlife conflict: the challenges of compensation schemes. In: R. Woodroffe, S. Thirgood & A. Rabinowitz, eds. *People and wildlife: conflict or coexistence?* Cambridge, UK: Cambridge University Press. pp.107-121.

O'Connell-Rodwell, C.E. Rodwell, T. Rice, M. & Hart, L.A., 2000. Living with the modern conservation paradigm: can agricultural communities co-exist with elephant? A five-year case study in East Caprivi, Namibia. *Biological Conservation,* 93, pp.381-391.

Odell, M.L., 1980. *Botswana's first livestock development project: an experiment in agricultural transformation*. Gaborone, Botswana: Synergy International, MA, USA; for the Swedish International Development Authority.

Ogutu, J.O. & Owen-Smith, N., 2003. ENSO, rainfall and temperature influences on extreme population declines among African savanna ungulates. *Ecology Letters*, 6, pp.412–419.

Oguto, J.O. Piepho, H-P. Reid, R.S. Rainy, M.E. Kruska, R.L. Worden, J.S. Nyabenge, M. & Hobbs, N.T., 2010. Large herbivore responses to water and settlements in savannas. *Ecological Monographs*, 80, pp. 241-266.

Olff, H. Hopcraft, G.C., 2008. The resource basis of human wildlife interaction. In: A.R.E. Sinclair, C. Packer, S.A.R. Mduma & J.M. Fryxell, eds. *Serengeti III: Human Impacts on Ecosystem Dynamics*. Chicago, Chicago University Press, pp. 95-133.

Omondi, P. Wambua, E. Gayuka, F. Bitok, E. Ndeere, D. Manyibe, T. Ogola, P. & Kanyingi, J., 2002. Recent translocation of elephant family units from Sweetwaters Rhino Sanctuary to Meru National Park, Kenya. *Pachyderm*, 32, pp.39-48.

OIE, 2009a. *Terrestrial Animal Health Code.* Paris: OIE. Available at: http://www.oie.int/eng/normes/mcode/en_sommaire.htm

OIE, Paton, D.J. Sinclair, M. & Rodriguez, R., 2009b. Qualitative assessment of the commodity risk factor for spread of foot-and-mouth disease associated with international trade in deboned beef.

Available at: http://www.oie.int/eng/normes/ENG_DFID_paper_fin.pdf

Okello, M. & Kiringe, J., 2004. Threats to biodiversity and their implications in protected and adjacent dispersal areas of Kenya. *Journal of Sustainable Tourism*, 12, pp.55-69.

Okello, M.M. & D'Amour, D.E., 2008. Agricultural expansion within Kimana: electric fences and implications for natural resource conservation around Amboseli National Park, Kenya. *Journal of Arid Environments*, 72, pp.2179-2192.

Orell, P., 2009. *Current status of the Woylie*. Perth, Western Australia: Department of Environment and Conservation.

Orians, G.H. & Pearson, N.E., 1979. On the theory of central place foraging. In: A.C. Kamil & T.D. Sargent, eds. *Foraging behaviour: ecological, ethological and psychological approaches*. New York: Garland STPM Press, pp.154-177.

Osborn, F.V. & Rasmussen, L.E.L., 1995. Evidence for the effectiveness of an oleo-resin capsicum aerosol as a repellent against wild elephants in Zimbabwe. *Pachyderm*, 20, pp.55-64.

Osborn, F.V., 1998. Ecology of crop-raiding elephants. *Pachyderm*, 25, pp.40.

Osborn, F.V., 2002. Elephant-induced change in woody vegetation and its impact on elephant movements out of a protected area in Zimbabwe, *Pachyderm,* 33, pp. 50-57.

Osborn, F.V. & Parker G.E., 2002a. *Living with elephants II; a manual*. MZEP, 37. Lewisam Ave, Chisipite, Harare, Zimbabwe. 21 pages typescript.

Osborn, F.V. & Parker, G.E., 2002b. A community-based method to reduce crop loss to elephants: experiments in the communal lands of Zimbabwe. *Pachyderm*, 33, pp.32-38.

Osborn, F.V. & Parker, G.E., 2003. Linking two elephant refuges with a corridor in the communal lands of Zimbabwe. *African Journal of Ecology*, 41, pp.68-74.

Osborn, F.V. & Parker, G.E., 2003. An integrated approach for reducing the conflict between elephants and people: a review of current research. *Oryx*, 37, pp.80-84.

Osborn, F.V. & Hill C.M., 2005. Techniques to reduce crop loss: human and technical dimensions in Africa. In: R. Woodroffe, S. Thirgood & A. Rabinowitz, eds. *People and wildlife: conflict or coexistence?* Cambridge, UK: Cambridge University Press. Chapter 5.

Osofsky, S.A., ed., 2005. *Conservation and development interventions at the wildlife/livestock interface: implications for wildlife, livestock and human health.* (Occasional paper Number 30 of the IUCN Species Survival Commission). Gland, Switzerland and Cambridge, UK: IUCN.

Osofsky, S.A. Cumming, D.H.M. & Kock, M.D., 2008. Transboundary management of natural resources and the importance of a 'One Health' approach: perspectives on southern Africa. In: E. Fearn and K.H. Redford, eds. *State of the wild 2008-2009: a global portrait of wildlife, wildlands and oceans*. Washington DC: Island Press, pp.89-98.

Ostrom, E., 2007. A diagnostic approach for going beyond panaceas. *PNAS*, 104(39), pp.15181-15187.

Ottichilo, W.K. de Leeuw, J. & Prins, H.H.T., 2001. Population trends of resident wildebeest *(Connochaetes taurinus hecki [Neumann])* and factors influencing them in the Masai Mara ecosystem, Kenya. *Biological Conservation*, 97, pp.271-282.

Owen-Smith, N., 1996. Ecological guidelines for waterpoints in extensive protected areas. *South African Journal of Wildlife Research*, 26, pp.107-112.

Owen-Smith, N., 2010. Climatic influences: temperate-tropical contrasts. In: N. Owen-Smith, ed. *Dynamics of Large Herbivore Populations in Changing Environments*, Oxford: Blackwell, pp. 63-97.

Owen-Smith, N. Kerley, G. I. Page, B. Slotow, R. & van Aarde, R., 2006. A scientific perspective on the management of elephants in the Kruger National Park and elsewhere. *South African Journal of Science*, 102, pp.389-394.

Owens, M. & Owens, D., 1985. *Cry of the Kalahari*. London: Collins

Parker, I.S.C., 1975. *A census of ostriches* (Struthio camelus [Linn.]) *in the vicinity of the Makgadikgadi Pans of Botswana.* Nairobi, Kenya: Wildlife Services Ltd.

Parry, D.C., 1987a. Wildebeest *(Connochaetes taurinus)* mortalities at Lake Xau, Botswana. *Botswana Notes and Records*, 19, pp.95-101.

Parry, D., 1987b. Zebra die in the Makgadikgadi. *Kalahari Conservation Society Newsletter*, 18, p.4.

Peace Park Foundation, 2004. *Tourism Plan for Limpopo National Park.* Stellenbosch: PPF.

Pearce, F., 1992. Beef for Europe threatens Botswana's wildlife. *New Scientist*, 134(1822), p.10.

Peel, M.J.S., 2002. Ecological monitoring in the Lowveld. (Unpublished Reports). Nelspruit, South Africa: Agricultural Research Council, Range and Forage Institute.

Peel, M.J.S., 2005. *Towards a predictive understanding of savanna vegetation dynamics in the eastern Lowveld of South Africa: with implications for effective management.* Ph.D. University of KwaZulu-Natal.

Peel, M.J.S. Biggs, H. & Zacharias, P., 1999. The evolving use of stocking rate indices currently based on animal number and type in semi-arid heterogeneous and complex land-use systems. *African Journal of Range & Forage Science*, 15, pp.117-127.

Peel, M.J.S. Davies, R. & Hurt R., 2004. The value and costs of wildlife and wildlife-based activities in the eastern Lowveld savanna, South Africa. In: M.J. Lawes, H.A.C. Eeley, C.M. Shackleton & B.G.S. Geach, eds. *Indigenous forests and woodlands in South Africa – policy, people and practice*. University of KwaZulu-Natal Press.

Pepeh, K., 1996. *A preliminary assessment of crop damage by wild animals in and around Gashaka Gumti National Park.* (Unpublished report). Nigerian Conservation Foundation, World Wildlife Fund and National Park Service.

Perkins, J.S. & Ringrose, S., 1996. *Development cooperation objectives and the beef protocol: the case of Botswana. A study of livestock/wildlife/tourism development linkages*. Metroeconomia Ltd. Consultancy Report (B-7-5040/94). Gaborone: Department of Environmental Science, University of Botswana.

Perkins, J. Stuart-Hill, G. & Kgabung, B., 2002. The impact of cattle-keeping on the wildlife, vegetation, and veld products. In: D. Sporton & D. S. G. Thomas, eds. *Sustainable livelihoods in Kalahari environments: contributions to global debates*. Oxford: Oxford University Press, pp.67-90.

Perry, B. McDermott, J. & Randolph, T., 2001. Can epidemiology and economics make a meaningful contribution to national animal-disease control? *Preventative Veterinary Medicine,* 48, pp.231-260.

Pickup, G. Bastin, G. N. & Chewings, V. H., 1998. Identifying trends in land degradation in non-equilibrium rangelands. *Journal of Applied Ecology,* 35(3), pp.365-377.

Pienaar, U. de V., 1960. *Conditions in the area of the western boundary with respect to the migratory game after the completion of the Ngwenyene Dam, Airforce Dam, and pit dams at Lipape and Pswaeni.* (Unpublished map). Skukuza: National Parks Board.

Pienaar, U. de V., 1983. Management by intervention: the pragmatic /economic option. In: N. Owen-Smith, ed. 1983. *Management of large mammals in African conservation areas.* Pretoria: Haum Education Publishers.

Plumptre, A.J., 2000. Monitoring mammal populations with line transect techniques in African forests. *Journal of Applied Ecology*, 37, pp.356-368.

Pollard, S. Shackleton, C. & Carruthers, J., 2003. Beyond the fence: people and the Lowveld landscape. In: J.T. du Toit, K.H. Rogers, H.C. Biggs, eds. *The Kruger experience: ecology and management of savanna heterogeneity.* Washington, DC: Island Press. pp. 422-446.

Porter, R.N., 1970. *An ecological reconnaissance of the TPNR Private Nature Reserve.* (Unpublished report). Hoedspruit, South Africa: Timbavati Private Nature Reserve.

Potgieter, de W., 1995. *Contraband. South Africa and the international trade in ivory and rhino horn*. Cape Town: Queillerie Publishers.

Price Waterhouse Coopers, 1998. *Wildlife electric fencing projects in communal areas of Zimbabwe: current efficacy and future role.* Harare, Zimbabwe: WWF Programme Office.

Pratt, D.J., 1967. A note on the overgrazing of burned grassland by wildlife. *East African Wildlife Journal*, 5, pp.178-179.

Prins, H.H.T., 2000. Competition between wildlife and livestock in Africa. In: H.H.T. Prins, J.G. Grootenhuis & T.T. Dolan, eds. *Wildlife conservation by sustainable use*. Boston; Dordrecht ; London: Kluwer Academic Publishers, pp.51-80.

Provenza, F.D., 2003. *Foraging behavior: managing to survive in a world of change*. Logan: Utah State University.

Provenza, F.D., 2007. What does it mean to be locally adapted and who cares anyway? *Journal of Animal Science*, 86, pp.271–284.

Provenza, F.D. & Villalba, J.J., 2006. Foraging in domestic vertebrates: linking the internal and external milieu. In: V.L. Bels, ed. *Feeding in domestic vertebrates: from structure to function*. Oxfordshire, UK: CABI Publications, pp.210-240.

Putnam, R., 1988. Diplomacy and domestic politics: the logic of two-level games. *International Organization*, 42(3), pp.427-60.

Ramutsindela, M.F., 2002. The perfect way to end a painful past? Makuleke land deal in South Africa. *Geoforum*, 33, pp.15-24.

Ramutsindela, M., 2004. Globalisation and nature conservation strategies in the 21st century southern Africa. *Journal of Economic and Social Geography*, 95(1), pp.61-72.

Rankmore, B.R. Griffiths, A.D. Woinarski, J.C.Z. Ganambarr, B.L. Taylor, R.J. Brennan, K.E.C. Firestone, K.B. & Cardoso, M., 2008. *Island translocation of the northern quoll* (Dasyurus hallucatus) *as a conservation response to the spread of the cane toad* (Chaunus [Bufo] marinus) *in the Northern Territory*. Canberra, Australia: Australian Natural Heritage Trust.

Razac. O., 2002 (2000). *Barbed wire. A history.* London: Profile Books.

Redfern, J.V. Grant, C.C. Gaylard, A. & Getz, W.M., 2005. Surface water availability and the management of herbivore distributions in an African savanna ecosystem. *Journal of Arid Environments*, 63, pp.406-424.

Redfern, J.V. Grant, R. Biggs, H. Getz, W.M., 2003. Surface-water constraints on herbivore foraging in the Kruger National Park, South Africa. *Ecology*, 84, pp.2092–2107.

Reid, R.S. Nkedianye, D. Said, M.Y. Kaelo, D. Neselle, M. Makui, O. Onetu, L. Kiruswa, S. Ole Kamuaroa, N. Kristjanson, P. Ogutu, J. BurnSilver, S.B. Goldman, M.J. Boone, R.B. Galvin, K.A. Dickson, N.M. & Clark, W.C., 2010. Evolution of models to support community and policy action with science: Balancing pastoral livelihoods and wildlife conservation in savannas of East Africa. *Proceedings of the National Academy of Sciences.* pp.1-6.

Reid, R.S. Gichohi, H. Said, M.Y. Nkedianye, D, Ogutu, J.O., 2008. Fragmentation of a Peri-Urban Savanna, Athi-Kaputiei Plains, Kenya. In: K.A. Galvin, R.S. Reid, R.H.Jr. Behnke & N.T. Hobbs, eds. *Fragmentation in Semi-Arid and Arid Landscapes: Consequences for Human and Natural Systems*, Fort Collins: Springer, pp.195-224.

Reimers, E. Dahle, B. Eftestøl, S. Colman, J.E. & Gaare, E., 2007. Effects of a power line on migration and range use of wild reindeer. *Biological Conservation,* 134, pp.484–494.

Reisen, W.K., 2010. Landscape epidemiology of vector-borne diseases. *Annual Review of Entomology*, 55, pp 461-483.

Reed, M. & Sautereau, D., 2005. *Makgadikgadi monitoring project progress report*. (Quarterly Report). Maun, Botswana: Department of Wildlife and National Parks.

Richards, J.D. & Short, J., 2003. Reintroduction and establishment of the western barred bandicoot (*Perameles bouganville)* (Marsupialia: Peramelidae) at Shark Bay, Western Australia. *Biological Conservation*, 109, pp.181-195.

Richer, R. Coulson, I. & Heath, M., 1997. Foraging behaviour and ecology of the Cape pangolin *(Manis temminckii)* in north-western Zimbabwe. *African Journal of Ecology*, 35, pp.361-369.

Ringrose, S. Vanderpost, C. & Matheson, W., 1997, Use of image processing and GIS techniques to determine the extent and possible causes of land management/fenceline induced degradation problems in the Okavango area, northern Botswana. *International Journal of Remote Sensing,* 18(11), pp.2337-2364.

Robinson, J. & Bennett, E., 2004. Having your wildlife and eating it too: an analysis of hunting sustainability across tropical ecosystems. *Animal Conservation*, 7, pp.397-408.

Ross, K., 1997. The Okavango's noose. *BBC Wildlife Magazine,* 15, p.4.

Ross, K., 2003. *Okavango, jewel of the Kalahari.* Cape Town: Struik.

Rowntree, K. Duma, M. Kakembo, V. & Thornes, J., 2004. Debunking the myth of overgrazing and soil erosion. *Land Degradation & Development,* 15(3), pp.203-214.

SABCNews, 2010. Available at: www.sabcnews.com/SABCNews/menuitem.5c4f8fe7ee929f602ea12ea1674daeb9/

SADC, 1999. *SADC protocol on wildlife conservation and law enforcement.*

Available at: www.tbpa.net/docs/pdfs/SecMan/SecManSADCProtocol.pdf

SADC, 2006. *SADC regional biodiversity strategy.* Gaborone: SADC Biodiversity Support Programme.

SADC FMD, 2008. *Achieving compatibility between the Transfrontier Conservation Area (TFCA) concept and international standards for the management of Trans-boundary Animal Diseases (TADs)*. (Workshop report), Chobe Marina Lodge, Kasane, Botswana: 11-14 November 2008. SADC FMD Project FANR, SADC Secretariat, Gaborone.

Available at: http://www.wcsahead.org/documents/sadc_tfcas_tads_nov08.pdf

Sandenbergh, J.A.B., 1947. *The greatest handicap to game conservation in the Kruger National Park.* (Unpublished internal memorandum). Skukuza: National Parks Board.

Sanderson, J. Alger, K. da Fonseca, G.A.B. Galindo-Leal, C. Inchausty, V.H. & Morrison, K., 2003. *Biodiversity corridors: planning, implementing, and monitoring sustainable landscapes.* Washington, DC: Conservation International.

Sandford, S., 1983. *Management of pastoral development in the Third World*. Chichester, UK: John Wiley.

SANP/PPF, 2003. *Gaza-Kruger-Gonarezhou Transfrontier Park, a new era in ecosystem management and co-operation for southern Africa*. Brochure published by SANParks in co-operation with the Peace Parks Foundation.

Saunders, C., 2006. *Gonarezhou, a place for elephants*. Mutare, Zimbabwe: Lowveld Lodge Entreprises.

Schafer, J. & Bell, R., 2002. The State and community-based natural resource management: the case of the Moribane Forest Reserve, Mozambique. *Journal of Southern African Studies*, 28(2), pp.401-420.

Schneider, R. & Dyer, S., 2006. *Death by a thousand cuts: impacts of in situ oil development on Alberta's boreal forest*. Calgary, Alberta: Pembina Institute and CPAWS.

Scholes, R.J., 1987. *Response of three semi-arid savannas on contrasting soils to the removal of the woody component.* Ph.D. Johannesburg, South Africa: University of the Witwatersrand.

Scoones, I. Bishi, A. Mapitse, N. Moerane, R. Penrith, M-L. Sibanda, R. Thomson, G. & Wolmer, W., (In press). Foot-and-mouth disease and market access: challenges for the beef industry in southern Africa. *Pastoralism Journal*.

Scott Wilson Resource Consultants, 2000a. *Environmental assessment of veterinary fences in Ngamiland, Volume 6: consultation plan & methodology*. Report prepared for Department of Animal Health & Production, Botswana.

Scott Wilson Resource Consultants, 2000b. *Environmental assessment of veterinary fences in Ngamiland – summary report.* Consultants' report to the Department of Animal Health and Production of Botswana. Basingstoke, UK: Scott Wilson Resource Consultants in association with The Environment and Development Group.

Scott Wilson Resource Consultants, 2000c. *Environmental assessment of veterinary fences in Ngamiland, Volume 2: environmental audits of the existing fences – the Setata, Ikoga and Samochima fences, the northern buffalo fence and the Caprivi Cordon fence*. Report prepared for Department of Animal Health & Production, Botswana.

Scott Wilson Resource Consultants, 2000d. *Environmental assessment of veterinary fences in Ngamiland, Volume 1: strategic environmental assessment of livestock disease control strategies in Ngamiland*. Report prepared for Department of Animal Health & Production, Botswana.

Scott Wilson Resource Consultants, 2000e. *Environmental assessment of veterinary fences in Ngamiland, Volume 3: EIA of joining the northern & southern buffalo fences*. Report prepared for Department of Animal Health & Production, Botswana.

Scott Wilson & Ecosurv, 1991. *Environmental appraisal for the construction of a game proof fence around Makgadikgadi Pans National Park*. (Issues and Options Report) (CTB 7/2/2/2001/2002).

Scott Wilson, Kirkpatrick & Partners, 2002. *Environmental appraisal for the construction of a game proof fence around Makgadikgadi Pans National Park*. (Part 1, Final Report) (CTB 7/2/2/2001/2002). Report prepared in association with Ecosurv for the Department of Wildlife & National Parks, Botswana. 155pp.

Sefe, F. Perkins, J.S. & Toteng, E., 1997. *Boteti River resource assessment*. Serowe , Botswana. District Office of Lands..

Selolwane, O.D., 1996. *Silence of the lambs? Ineffectual NGO influence on policy on the fencing of Botswana's communal rangelands*. University of Botswana.

Setata Fence Task Team, 1998. *Environmental impact assessment report on Setata Fence*. Maun, Botswana: Department of Wildlife & National Parks, Department of Animal Health & Production, Okavango Peoples Wildlife Trust & Cgae-Cgae Tlabololo Trust.

Short, J., 2009. *The characteristics and success of vertebrate translocations within Australia*. Canberra, Australia: Department of Agriculture, Fisheries and Forestry, p. 103.

Short, J., Richards, J.D. & Turner, B., 1998. Ecology of the western barred bandicoot (*Perameles bouganville*) (Marsupialia: Peramelidae) on Dorre and Bernier Islands, Western Australia. *Wildlife Research*, 25, pp.567-586.

Short, J. & Turner, B., 1999. Ecology of burrowing bettongs *(Bettongia lesueur)* (Marsupialia: Potoroidae), on Dorre and Bernier Islands, Western Australia. *Wildlife Research*, 26, pp.651-669.

Short, J. & Turner, B., 2000. Reintroduction of the burrowing bettong *(Bettongia lesueur)* (Marsupialia: Potoroidae) to mainland Australia. *Biological Conservation*, 96, pp.185-196.

Sibley, D., 1995. *Geographies of exclusion. Society and difference in the West*. London: Routledge.

Sibley, D.A., 2001. *The Sibley guide to bird life and behaviour.*New York: Alfred A. Knopf.

Silberbauer, G.B., 1981. *Hunter and habitat in the central Kalahari desert*. New York, USA: Cambridge University Press. 330pp.

Silviera, L. Jácomo, A.T.A. & Diniz-Filho J.A.F., 2003. Camera-trap, line transect census and track surveys: a comparative evaluation. *Biological Conservation*, 144, pp.351–355.

Sitati, N.W. Walpole, M.J. Smith, R.J. & Leader-Williams, N., 2003. Predicting spatial aspects of human elephant conflict*. Journal of Applied Ecology*, 40, pp.667-677.

Sitati, N. W. & Walpole, M., 2006. Assessing farm-based measure for mitigating human-elephant conflict in Transmara District, Kenya, *Oryx* 40, pp.279-286.

Skarpe, C. Aarestad, P.A. Andreassen, H.P. Dhillion, S. S. Dimakatso, T. du Toit, J.T. Halley, D.J. Hytteborn, H. Makhabu, S. Mari, M. Marokane, W. Masunga, G. Modise, D. Moe, S.R. Mojaphoko, R. Mosugelo, D. Motsumi, S. Neo-Mahupeleng, G. Ramotadima, M. Rutina, L. Sechele, L. Sejoe, T.B. Stokke, S. Swenson, J. E. Taolo, C. Vandewalle, M. & Wegge, P., 2004. The return of the giants; ecological effects of an increasing elephant population. *Ambio,* 33, pp.276–282.

Skinner, J.D. & Chimimba, C.T., 2005. *The mammals of the southern African subregion*. Cape Town: Cambridge University Press.

Slotow, R., Hunter, L.T.B., 2009. Reintroduction decisions taken at the incorrect social scale devalue their conservation contribution: African lion in South Africa., In: M.W. Hayward & M.J. Somers, eds. *The reintroduction of top-order predators.* Oxford: Blackwell Publishing. pp.43-71.

Smit, G.N., 1992. *Bos-gras interaksies in savanna. (Prestige farmers day proceedings, 1991–92).* Scottsville: Special publication of the Grassland Society of Southern Africa.

Smit, I.P.J. Grant, C.C & Devereux, B.J., 2007. Do artificial waterholes influence the way herbivores use the landscape? Herbivore distribution patterns around rivers and artificial surface water sources in a large African savanna park. *Biological Conservation*, 136, pp.85-99.

Smit, I.P.J. Grant, C.C. & Whyte, I.J., 2007a. Elephants and water provision: what are the management links? *Diversity and Distributions,* 13, pp.666-669.

Smit, I.P.J. Grant, C.C. & Whyte, I.J., 2007b. Landscape-scale sexual segregation in the dry season distribution and resource utilization of elephants in Kruger National Park, South Africa. *Diversity and Distributions*, 13, pp.225-236.

Smithers, R.H.N., 1983. *The mammals of the southern African subregion*. Pretoria, South Africa: University of Pretoria Publishers, pp.157-159.

Smuts, G.L., 1972. *Seasonal movements, migration and age determination of Burchell's zebra* (Equus burchelli antiquorum, [H. Smith 1841]) *in the Kruger National Park.* M.Sc. Pretoria: University of Pretoria.

Smuts, G.L. 1982. *Lion.* Johannesburg: Macmillan.

Somers, M.J. & Hayward, M.W., 2010, eds. (In press). *Fencing for Conservation.* New York: Springer-US.

South African National Parks, 2005. *Report on the elephant management strategy*. Report to the Minister: Environmental Affairs and Tourism on developing elephant management plans for National Parks, with recommendations on the process to be followed. Available at: http://www.sanparks.org/about/acts/info_act.php

Sparks, A., 1990. *The mind of South Africa. The story of the rise and fall of apartheid*. London: Mandarin.

Spierenburg, M., Steenkamp, C. & Wels, H., 2006. Resistance against the marginalization of communities in the Great Limpopo Transfrontier Conservation Area. *Focaal, European Journal of Anthropology,* 47, pp.18-31.

Spierenburg, M. Steenkamp, C. & Wels, H., 2008. Enclosing the local for the global commons: community land rights in the Great Limpopo Transfrontier Conservation Area. *Conservation and Society*, 6(1), pp.87-97.

Spierenburg, M. & Wels, H., 2006. Securing space: mapping and fencing in transfrontier conservation in southern Africa. *Space & Culture*, 6(3), pp. 294-312.

Spierenburg, M., Wels, H. van der Waal, K. & Robins, S., 2009. Transfrontier tourism, relations between local communities and the private sector in the Great Limpopo Transfrontier Park. In: P. Hottola, ed., 2009. *Tourism strategies and local responses in southern Africa*. Wallingford: CABI, pp.167-182.

Spinage, C., 1992. The decline of the Kalahari wildebeest. *Oryx*, 26(3), pp.147-150.

Spinage, C. A. & Matlhare, J.M., 1992. Is the Kalahari cornucopia fact or fiction? A predictive model. *Journal of Applied Ecology*, 29, pp.605-610.

Sporton, D. & Thomas, D.S.G., 2002. *Sustainable livelihoods in Kalahari environments: contributions to global debates*. Oxford: Oxford University Press, p.223.

Sporton, D. & Twyman, C., 2002. Politics, policy, and livelihoods. In: D. Sporton & D.S.G. Thomas, eds. *Sustainable livelihoods in Kalahari environments: contributions to global debates.* Oxford: Oxford University Press.

Stanley, S., 2007. Rhino Ark Fence. *Swara.* January-March 2007. Nairobi: East African Wildlife Society.

Starkey, M. Birnie, N. Cameron, A. Daffa, R.A. Haddelsey, L. Hood, L. Kapapa, L. Makoti, J. Mwangomo, E. Nyingi, J. Rainey, H. & Robertson, W., 2002. *The Kilombero Valley wildlife project: an ecological and social survey in the Kilombero Valley, Tanzania*. Edinburgh, UK: Kilombero Valley Wildlife Project.

Steele, N., 1992. *Poachers in the hills: Norman Deane's life in Hluhluwe Game Reserve*. Melmoth: Nick Steele.

Stevenson-Hamilton, J., 1937. *South African Eden.* London: Cassell.

Stevenson-Hamilton, J., 1993 (1937). *South African Eden. The Kruger National Park*. Cape Town: Struik Publishers.

Stevenson-Hamilton, J., 1945. *Annual report of the Warden*. (Unpublished memorandum). Skukuza, South Africa: National Parks Board.

Stevenson-Hamilton, J., 1947. *Wildlife in South Africa*. London: Cassel & Co. Ltd.

Stokes, C. J. McAllister, R. R. J. & Ash, A. J., 2006. Fragmentation of Australian rangelands: processes, benefits and risks of changing patterns of land use. *The Rangeland Journal,* 28(2), pp.83-96.

Stokke, S. & du Toit, J.T., 2002. Sexual segregation in habitat use by elephants in Chobe National Park, Botswana. *African Journal of Ecology*, 40*,* pp.360–371.

Strum, S.C., 1994. Prospects for management of primate pests. *Rev. Ecol. Terre Vie*, 49, pp.295-306.

Sukumar, R., 1991. The management of large mammals in relation to male strategies and conflict with people. *Biological Conservation,* 55, pp.93-102.

Sukumar, R. & Gadgil, M., 1988. Male-female differences in foraging on crops by Asian elephants. *Animal Behaviour*, 36, pp.1233-1235.

Sutmöller, P. & Anderson, E.C., 1998. *Risk assessment of foot and mouth disease policies in Zimbabwe*. Animal Health Consultant's Report to the Director of the Department of Livestock and Veterinary Services in Zimbabwe*.* pp.40.

Sutmöller, P. Thomson, G.R. Hargreaves, S.K. Foggin, C.M. & Anderson, E.C., 2000. The foot-and-mouth disease risk posed by African buffalo within wildlife conservancies to the cattle industry of Zimbabwe. *Preventive Veterinary Medicine*, 44(1), pp.43 – 60.

Swart, J., 1996. *Foraging behaviour of the Cape pangolin* (Manis temminckii) *in the Sabi Sand Wildtuin*. M.Sc., University of Pretoria.

Swart, J., 1997. Order Pholidota. In: G. Mills & L. Hes, eds., 1997. *The complete book of southern African mammals*. Cape Town, South Africa: Struik Winchester Publishers, pp.112-113.

Swart, J.M. Richardson, P.R.K. & Ferguson, J.W.H., 1999. Ecological factors affecting the feeding behaviour of pangolins *(Manis temminckii)*. *Journal of Zoology*, 247, pp.281-292.

Tanner, R.J., 2003. *Transfrontier Conservation Areas of southern Africa and community involvement in the context of international law.* M.Sc., University of Montana.

Tasch, W., 2008. *Inquiries into the nature of Slow Money*. USA: Chelsea Green.

Taylor, R.T. & Martin, R.B., 1987. Effects of veterinary fences on wildlife conservation in Zimbabwe. *Environmental Management*, 11(3), pp.327–334.

Thirgood, S. and Hopcraft, G., 2008. Fences and the conservation of migratory ungulates. *Annual meeting of the International Congress for Conservation Biology.* Convention Center, Chattanooga, TN. 23 May 2009. Available at: http://www.allacademic.com/meta/p243775_index.html

Thomas, B. Holland, J.D. & Minot, E.O., 2008. Elephant *(Loxodonta africana)* home ranges in Sabi Sand Reserve and Kruger National Park: a five-year satellite tracking study. *PLoS ONE*, 3 (12): e3902. doi: 10.1371/journal.pone.0003902.

Thomas, D.S.G. & Twyman, C., 2005. Equity and justice in climate change adaptation amongst natural-resource-dependent societies. *Global Environmental Change,* 14, pp.115-124.

Thomson, G.R., 1999. Alternatives for controlling animal diseases resulting from interaction between livestock and wildlife in southern Africa. *South African Journal of Science*, 95, pp.71-76

Thomson, G.R. et al., (In preparation). *Human, animal and environmental health: is a geographic approach compatible with the 'One World, One Health' paradigm?*

Thomson, G.R. Leyland, T.J. & Donaldson, A.I., 2009. De-boned beef – an example of a commodity for which specific standards could be developed to ensure an appropriate level of protection for international trade. *Transboundary & Emerging Diseases*, 56, pp.9-17.

Thomson, G.R. Tambi, E.N. Hargreaves, S.K. Leyland, T.J. Catley, A.P. van 't Klooster, G.G.M. & Penrith, M-L., 2004. International trade in livestock and livestock products: the need for a commodity-based approach. *Veterinary Record*, 155, pp.429-433.

Thouless, C.R., 1994. Conflict between humans and elephants in Sri Lanka. Unpublished report for the GEF, 33pp. typescript, EDG, Oxford, UK.

Thouless, C. R. Georgiadis, N. & Olwero, N., 2002. *A wildlife fencing strategy for Laikipia*. Nanyuki, Kenya: Laikipia Wildlife Forum.

Thouless, C.R. & Sakwa, J., 1995. Shocking elephants, fences and crop raiders in Laikipia District, Kenya. *Biological Conservation*, 72, pp.99-107.

Todd, S. W. & Hoffman, M. T., 1999. A fenceline contrast reveals effects of heavy grazing on plant community composition in Namaqualand, South Africa. *Plant Ecology,* 142, pp.169-178.

Transfrontier Conservation Consortium, 2006. *Pre-feasibility study of the proposed Kavango - Zambezi Transfrontier Conservation Area. Volume 1*. (Final Report). Stellenbosch: Peace Parks Foundation.

Tuttle, M.D., 1977. Gating as a means of protecting cave dwelling bats. In: T. Aley & D. Rhoades, eds. *National cave management symposium proceedings*, 1976. Albuquerque, NM, USA: Speleobooks, pp.77-82.

Tweheyoa, M. Hill, C. M. & Obua, J., 2005. Patterns of crop raiding by primates around the Budongo Forest Reserve, Uganda. *Wildlife Biology,* 11, pp.237-247.

Twigg, L.E. Martin, G.R. & Lowe, T.J., 2002. Evidence of pesticide resistance in medium-sized mammalian pests: a case study with 1080 poison and Australian rabbits. *Journal of Applied Ecology*, 39, pp.549-560.

van Aarde, R. & Jackson, T., eds., 2005. *Final report on the restoration of the Tembe-Futi-Maputo coastal plains elephant population*. US Fish and Wildlife Service, pp.107-133.

van Aarde, R.J. & Jackson, T.P., 2007. Megaparks for metapopulations: addressing the causes of locally high elephant numbers in southern Africa. *Biological Conservation,* 134, pp.289-297.

van de Koppel, J. & Rietkerk, M., 2000. Herbivore regulation and irreversible vegetation change in semi-arid grazing systems. *Oikos,* 90, pp.253-260.

van Doorn, A. O'Riain, M.J. & Swedell, L., 2010. The effects of extreme seasonality of climate and day length on the activity budget and diet of semi-commensal chacma baboons (*Papio ursinus*) in the Cape Peninsula of South Africa. *American Journal of Primatology.*

van Dyk, G. & Slotow, R., 2003. The effects of fences and lions on the ecology of African wild dogs reintroduced into Pilanesberg National Park, South Africa. *African Zoology*, 38, pp.79-94.

van Haaften, E.H. Olff, M. & Kerste, P.H., 2004. The psychological impact of the Foot and Mouth Disease crisis in Dutch dairy farmers. *NJAS Wageningen Journal of Life Sciences,* 51, pp.339-349.

van Ierland, J., 2009. *Greater Giyani Biogas Project, description of the village-scale Biogas System*, June 2009.. Wageningen, The Netherlands: Stichting Innovative Development Solutions, pp.16.

van Oosten, V., 2000. *The conflicts between primates and the human population in a protected area in north Cameroon.* Centre d'Etude de l'Environnement et du Developpement au Cameroun (CEDC), Centre des Etudes de l'Environnement Universite de Leiden (CML) & Organistation Neerlandaise de Developpement (SNV).

van Oudtshoorn, F., 1999. *Guide to grasses of southern Africa*. Pretoria: Briza Publications.

van Vegten, J.A., 1981. *Man-made vegetation changes: an example from Botswana's savanna.* Working paper No. 40. Botswana: National Institute of Development and Cultural Research (NIR), 81pp.

van Wieren, S.E. & Worm, P.B., 2001. The use of motorway wildlife overpass by large mammals. *Netherlands Journal of Zoology,* 51, pp.97–105.

Vaughn, C. & Long, A., 2007. Bushmeat, wildlife management and good governance: rights and institutional arrangements in Namibia's community-based natural resource management. In: G. Davies, & D. Brown, eds. *Bushmeat and livelihoods*. Oxford: Blackwell, pp.177-196.

Venter, F.J. Naiman, R.J. Biggs, H.C. & Pienaar, D.J., 2008. The evolution of conservation management philosophy: science, environmental change and social adjustments in Kruger National Park. *Ecosystems*, 11, pp.173-192.

Verlinden, A. & Gavor, I.K.N., 1998. Satellite tracking of elephants in northern Botswana. *African Journal of Ecology*, 36, pp.105-116.

Verlinden, A. Perkins, J.S. & Murray, M., 1998. How are people affecting the distribution of less migratory wildlife in the southern Kalahari of Botswana? A spatial analysis. *Journal of Arid Environments*, 38, pp.129-141.

Vetter, S., 2005. Rangelands at equilibrium and non-equilibrium: recent developments in the debate. *Journal of Arid Environments,* 62(2), pp.321-341.

Victurine, R. & Curtin, C., 2010. Financial incentives for rangeland conservation. In: J. du Toit, R. Kock, & J.C. Deutsch, eds. *Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems*. Oxford: Wiley-Blackwell Publishers, pp.152-187.

Vieira, M.E. Conner, M.M. White, G.C. & Freddy, D.J., 2003. Effects of archery hunter numbers and opening dates on elk movement. *Journal of Wildlife Management*, 67, pp.717-728.

Viljoen, P.J. & Bothma, J.D.P., 1990. Daily movements of desert-dwelling elephants in the northern Namib Desert. *South African Journal of Wildlife Research*, 20, pp.69-72.

Walker, C., 2008. *Landmarked: land claims and land restitution in South Africa*. Jacana Press. Auckland Park

Wall, J. Douglas-Hamilton, I.D.H. & Vollrath, F., 2006. Elephants avoid costly mountaineering. *Current Biology*, 16, pp.527-529.

Wallgren, M. Skarpe, C. Bergstrom, R. Danell, K. Bergstrom, A. Jakobsson, T. Karlsson, K. & Strand, T., 2009. Influence of land use on the abundance of wildlife and livestock in the Kalahari, Botswana. *Journal of Arid Environments,* 73, pp.314-321.

Wato, Y. Wahungu, G. & Okello, M., 2006. Correlates of wildlife snaring patterns in Tsavo West National Park, Kenya. *Biological Conservation*, 132, pp.500-509.

Weaver, J.L. Paquet, P.C. & Ruggiero, L.F., 1996. Resilience and conservation of large carnivores in the Rocky Mountains. *Conservation Biology*, 10, pp.964–976.

Weaver, L.C., 1997. *Background and potential impacts resulting from construction of game & livestock proof fence by the government of Botswana, south off the West Caprivi Game Reserve*. WWF/LIFE Programme Report

Webster, D.J., 1991. Abafazi baThonga bafihlakala. Ethnicity and gender in a KwaZulu border community. In: A.D. Spiegel & P.A. McAllister, eds. *Tradition and transition in Southern Africa: Festschrift for Phillip and Iona Mayer*. Johannesburg: Witwatersrand University Press. pp.243-271.

Wels, H., 2000. *Fighting over fences: organisational co-operation and reciprocal exchange between the Savé Valley Conservancy and its neighbouring communities*. Ph.D. Amsterdam: Free University..

Wels, H., 2004. About romance and reality: popular European imagery in postcolonial tourism in southern Africa. In: C.M. Hall, & H. Tucker, eds. *Tourism and*

postcolonialism: contested discourses, identities and representations. London: Routledge, pp.76-94.

West, P. & Carrier, J.G., 2004. Ecotourism and authenticity: getting away from it all? *Current Anthropolog*y, 45, pp.483-498.

Western, D. & Nightingale, M., 2005. Keeping the East African rangelands open and productive. *Conservation and People*, 1, pp.1-8.

Western, D. Groom, R. & Warden, J., 2009. The impacts of subdivision and sedentarization of pastoral lands on wildlife in an African savanna ecosystem. *Biological Conservation*, 142, pp. 2538-2546.

Western, D., 2009. Foreword: The Future of Maasailand: Its People and Wildlife. In: K. Homewood, P. Kristjanson & P. Chevenix Trench, eds. *Staying Maasai? Livelihoods, Conservation and Development in East African Rangelands*. New York: Springer Press. pp.v-viii.

Western, D. Groom, R. & Worden, J. 2009. The impact of subdivision and sedentarization of pastoral lands on wildlife in an African savanna ecosystem. *Biological Conservation* 142, pp. 2538–2546.

White, A.C., 1951. *The call of the bushveld.* Bloemfontein: A.C. White P. & P. Co. Ltd.

White, R, 1992. *Livestock development and pastoral production on communal range-lands in Botswana*. Gaborone: The Botswana Society.

Whitehouse, A.M. & Hall-Martin, A., 2000. Elephants in Addo Elephant National Park, South Africa: reconstruction of the population's history. *Oryx*, 34, pp.46-55.

Whyte, I.J., 1985. *The present ecological status of the blue wildebeest (*Connochaetes taurinus taurinus [Burchell, 1823]) *in the Central District of the Kruger National Park.* M.Sc. Pietermaritzburg: University of Natal.

Whyte, I., 1993. The movement patterns of elephants in the Kruger National Park in response to culling and environmental stimuli. *Pachyderm*,16, pp.72-80.

Whyte, I.J., 2001. *Conservation management of the Kruger National Park elephant population*. Ph.D. Pretoria: University of Pretoria.

Whyte, I.J. & Joubert, S.C.J., 1988. Blue wildebeest population trends in the Kruger National Park and the effects of fencing. *South African Journal of Wildlife Research,* 18(3), pp.78-87.

Whyte, I.J. & Swanepoel, W., 2006. *An aerial census of the Shingwedzi basin area of the Limpopo National Park in Mozambique, 16th–21st October, 2006.* (Scientific Report 02/2006). Skukuza: South African National Parks.

WILD Foundation, 2009. *Cattle and wildlife: finding a solution*. Available at: http://www.wild.org/field-projects/veterinary-fence-issue

Wilk, J. & Kgathi, D., 2007. Risk in the Okavango Delta in the face of social and environmental change. *GeoJournal*, 70, pp.121-132.

Wilkie, D. & Carpenter, J., 1999. Bushmeat hunting in the Congo Basin: an assessment of impacts and options for mitigation. *Biodiversity and Conservation*, 8, pp.927-955.

Wilkie, D. Curran, B. Tshombe, R. & Morelli, G., 1998. Modelling the sustainability of subsistence farming and hunting in the Ituri forest of Zaire. *Conservation Biology*, 12, pp.137-147.

Williamson, D., 2002. Dimensions and dilemmas of conservation in the Kalahari. *The Open Country*, 4 (Summer), pp.15-24.

Williamson, D. & Mbano, B., 1988. Wildebeest mortality during 1983 at Lake Xau, Botswana. *African Journal of Ecology*, 26, pp.341–344.

Williamson, D. & Williamson, J., 1981. An assessment of fences on the large herbivore biomass in the Kalahari. *Botswana Notes and Records*, 13, pp.91-94 and 107–110.

Williamson, D. & Williamson, J., 1984. Botswana's fences and the depletion of the Kalahari wildlife. *Oryx*, 18(4), pp.218–222.

Williamson, D.T, & Williamson, J.E, 1985a. Botswana's fences and the depletion of Kalahari wildlife. *Parks,* 10(2), pp.5-7.

Williamson, D. & Williamson, J., 1985b. *Kalahari ungulate movement study*. Frankfurt Zoological Society.

Williamson, D. Williamson, J. & Ngwamotsoko, K.T., 1988. Wildebeest migration in the Kalahari. *African Journal of Ecology*, 26, pp.269-280.

Williamson, R., 1994. *Botswana: environmental practices under scrutiny*. Cape Town, South Africa: The Lomba Archives. Lindlife.

Wisner, B. Blaikie, P. Cannon, T. & Davies, I., 2004. *At risk: natural hazards, people's vulnerability and disasters*. 2nd Ed. London and New York: Routledge.

Wittemyer, G. Polansky, L. Douglas-Hamilton, I.D.H & Getz, W.M., 2008. Disentangling the effects of forage, social rank, and risk on movement autocorrelation of elephants using Fourier and wavelet analyses. *Proceedings of the National Academy of Sciences*, 105, pp.191-198.

Wolmer, W., 2003. Transboundary conservation: the politics of ecological integrity in the Great Limpopo Transfrontier Park. *Journal of Southern African Studies*, 29(1), pp.261-278.

Wolmer, W., 2007. *From wilderness to farm invasions: conservation and development in Zimbabwe's south-east Lowveld.* London: James Currey Publishers.

Wolski, P. & Murray-Hudson, M., 2006. Flooding dynamics in a large low-gradient alluvial fan, the Okavango Delta, Botswana, from analysis and interpretation of a 30-year hydrometric record. *Hydrology and Earth System Sciences,* 10, pp.127-137.

Woodroffe, R. & Ginsberg, J.R., 1998. Edge effects and the extinction of populations inside protected areas*. Science*, 280, pp.2126–2128.

Worboys, G. Francis, W.L. & Lockwood, M., eds., 2010. *Connectivity conservation management.* London: Earthscan.

Wordon, J. Reid, R. & Gichohi, H., 2003. Land-use impacts on large wildlife and livestock in the swamps of the greater Amboseli ecosystem, Kajiado District, Kenya. In: *LUCID Project Working Paper, Vol. 27*. Nairobi, Kenya: International Livestock Research Institute.

World Travel and Tourism Council, 2007. *Botswana: the impacts of travel and tourism on jobs and the economy.* London: WTTC.

WWF, 2005. *Human wildlife conflict manual.* (Wildlife management series) Harare: WWF-Southern African Regional Program Office.

Young, D.A. Courtney, R.F. Bjornson, C.P. & Kerr, D.S., 1989*. An evaluation of ungulate interactions with corridors, including above-ground pipelines in the Wolf Lake Project Area, north-eastern Alberta*. Calgary, Alberta: Environmental Management Associates, for BP Resources Canada Limited.

Young, E., 1970. *Water as a faktor in die ekologie van wild in die Nasionale Krugerwildtuin*. Ph.D. South Africa: University of Pretoria.

Young, T.P. Okello, B. Kinyua, D. & Palmer, T., 1998. KLEE: a long-term multi-species herbivore exclusion experiment in Laikipia, Kenya. *African Journal of Range and Forage Science*, 14, pp.92–104.

Young, T.P. Palmer, T.A. & Gadd, M.E., 2005. Competition and compensation among cattle, zebras, and elephants in a semi-arid savanna in Laikipia, Kenya. *Biological Conservation*, 122, pp.351-359.

Zambia Wildlife Authority, 2008. *Integrated Development Plan: Zambian component of the KAZA TFCA, June 2008.* Stellenbosch: PPF.

10. APPENDICES

Appendix 10.1 Technical aspects of fencing

Kelly, H.L.P. & Hardman, N.W.
T.N.H. Fencing, Postnet Suite 24, Private Bag X6625, Thabazimbi, 0380, South Africa. tnhfence@mweb.co.za

Introduction

Fences are essential for the management of animals, both livestock and wildlife in extensive and intensive conditions. Modern fences used for the management of livestock and wildlife are generally wire fences which consist of posts, stays, line posts, droppers and wire. These are referred to as conventional fences. Electrification of these fences improves their effectiveness and largely alleviates the need for overly strong materials to be used in fence construction. Careful consideration should be taken of all factors which will influence the fence layout and design before construction proceeds. The most important of these are the topography of the area and the species which are to be controlled. Future expansion should also be considered. Failure to plan adequately may result in costly alterations to the fence being necessary.

Conventional wire fences and their components

Posts: Straining posts should be placed at all corners and changes in direction of the fence as well as in-line at intervals not exceeding 200m. These posts should be concreted into the ground and supported by stays. Where the distance between successive straining posts exceeds 100m, it is recommended that an intermediate post be placed midway between the straining posts. This post can be physically lighter than the straining posts and does not need stays, but should be concreted into the ground. In mountainous terrain, straining posts should be placed at the top and bottom of each hill. Wire is strained from the straining posts, while the function of the intermediate post is to ensure the fence does not lean or fall to one side. There are three main types of posts which can be used for fences.

(i) Timber posts should have a minimum diameter of 150mm at the top end, and should be treated for outdoor use to prevent insect damage. These posts have a shorter lifespan than steel posts, are susceptible to fire and lightning damage and are more difficult to install.

(ii) Railway track posts generally need to be cut and welded which means that their use as strain posts increases construction time on the fence. The result of this is unnecessary additional cost.

(iii) Steel pipe straining posts should have a minimum wall thickness of 4mm, and a diameter of at least 89mm. Commonly available sizes are 89mm, 101mm, 114mm and 127mm. These posts should be fitted with a cap to prevent water entering the posts as well as a footplate to support the post underground. They can either be painted or galvanised. The latter is a superior finish, but due to the costs associated with galvanising is generally only used in coastal environments. Where posts with a paint finish are used, it is recommended that the posts are re-painted within the first two years after installation. During construction of the fence, on-site transport of posts and installation of the wire results in scratching of the paint and rusting of the

posts. As steel posts are the most practical, unless specified, further discussion in this article refers to steel pipe posts. Posts should be buried in the ground to a depth of at least 600mm. In sandy areas, it is recommended that posts are buried to at least one metre. The posts should be concreted into the ground. The concrete block should be narrower at the top than at the bottom to provide better support for the post, but in practice this is seldom possible and holes tend to have vertical sides. The hole should be 600mm x 600mm at the top and 800mm x 800mm at the bottom (Fig. 10.1.1). The depth of the hole should match the length of the section of the post which will be buried. The post should be placed in the centre of the hole with the base on sand. Concrete, with a cement:sand:stone ratio of 1:2:3 should then be poured into the hole.

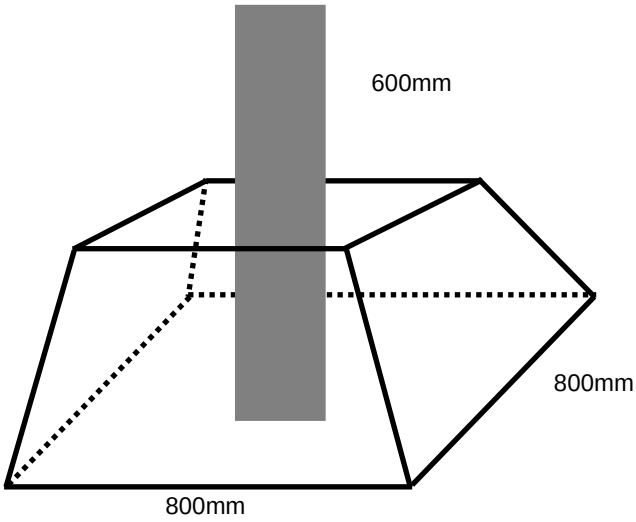


Figure 10.1.1. Shape and dimensions of concrete block for straining posts

Stays: These should be the same length as the post. Steel pipe stays should have a diameter of 50mm or greater and a wall thickness of 3mm or more. They should be fitted with a footplate and be flattened on the other end. Stays should be attached to the straining post one third of the way from the top of the exposed section of the post. The angle formed between the ground and the stay should not be greater than 45 degrees. The stay can be bolted or welded to the post, but if welded, care should be taken to treat the welded area to prevent rusting. Stays should be concreted into the ground in a 400mm x 400mm x 400mm block. The concrete mix is as for posts. For timber fences, the stays should have a minimum diameter of 100mm at the narrow end. In sandy soils, additional support can be given to the fence by either placing a large rock at the footplate before concreting or by driving a Y-profile standard into the ground at the footplate. Alternatively an H brace assembly or box anchor can be used. This consists of a second post planted approximately two metres from the strain post in the line of the fence. One or two cross-braces are then attached in a horizontal position to both posts. A diagonal stay is added to the inside post.

Line posts: These posts are installed in line between straining posts. The spacing of these is crucial to the strength and elasticity of the fence. A ten-metre spacing between successive line posts is suitable for most applications, but this can be adjusted based on the individual requirements. Timber line posts should have a minimum top diameter of 100mm. Steel pipe with a

diameter of 50mm or more and a wall thickness of 2mm or more can also be used. H or Y- profile steel standards make the most practical line posts. These can be driven into the ground using a specially designed post rammer, which alleviates the need to dig holes for the posts and due to their small diameter, less tying wire is used in the construction of the fence.

Droppers: A number of different items can be used as droppers. Their function is to strengthen the fence and maintain the spacing between the line wires of the fence. They are attached to the fence at regular intervals between the line posts using tying wire. Maintaining spacing on timber droppers can be problematic as the cutting of grooves weakens the droppers. An alternative to this is to drill holes through the droppers through which the wire can run. Both the drilling and installation of a fence in this manner is time consuming and hence costly. Timber droppers should have a minimum diameter of 32mm. There are a few different droppers manufactured from steel which have grooves and ridges for wire spacing. These are easy to use, but can be costly. Spacing of wires on fences can also be maintained using binding wire, lengths of cable or HDPE (plastic) droppers, but steel droppers are by far the best. Some manufacturers of prefabricated mesh fencing claim that droppers are not needed on these fences. Omitting all droppers from a prefabricated fence is not recommended as the fence begins to look untidy after a short time.

Wire: The type of wire used is dependant on the function of the fence, in particular which animals need to be controlled. Barbed wire is not commonly used for game fences. It is more costly than smooth wire, difficult to work with, less resilient and can injure animals. Smooth wire and wire mesh are therefore the most popular products for use on game fences. High strain steel wire should be used for fencing when mesh is not required. This is available in 2mm, 2.24mm and 2.5mm diameter varieties. Both 2.24 and 2.5mm wire are suitable for most fences, but 2mm wire is too light to be used for game and livestock control. In East Africa, 2.5mm steel wire is common, but 2.24mm wire is the most readily available in southern Africa. Heavy, fully or double galvanised wire (SANS 675) is recommended over the lightly galvanised (SANS 935) version even in moderate to low rainfall areas as it has a much shorter lifespan than heavy galvanised wire. The initial cost savings of purchasing lightly galvanised wire do not warrant its use. When strained, tension should not exceed 200kg.

The spacing of wires on a fence is dependant on the animals to be controlled. Any combination of wire spacing can therefore be used. On game fences, the lower wires are usually spaced 50-100mm apart, with the spacing near the top of the fence widening to as much as 200mm. Commonly used wire spacing of a 2400mm high fence with 21 strands is wires 1-15 at 100mm apart, above which wires are spaced at 150mm.

Mesh should be used on fences where small game or predators need to be controlled. Diamond mesh, netting wire and pre-fabricated mesh are all economical alternatives for this. While diamond mesh and netting wire need to be attached to supporting wires, prefabricated mesh can be used in isolation. Prefabricated mesh, also known as field fence is made by most wire manufacturers, but is often referred to by the trade names of "Bonnox" and "Veldspan." While some manufacturers claim that this type of mesh does not need supporting wires or droppers, if droppers are not used, the wire tends to sag after a few months. The use of droppers is therefore recommended. Supporting wires at 400mm - 600mm intervals are also recommended as this makes the installation of the mesh far simpler. Unlike diamond mesh and netting wire, prefabricated mesh needs to be tensioned. The best results are achieved using a tool known as a clamp bar which is attached to either side of

the mesh on the end being strained. A hand winch or wire tensioner should then be used to strain the mesh.

Electrification of fences

An electric fence system for animal control consists of an electric fence energiser, fence wires supported on insulators, attached to the fence posts and an earth system. The earthed energiser provides regular pulses of electricity to the fence at a rate of approximately one per second. These pulses travel along the fence, and when an animal touches the fence it completes the circuit between the fence and the ground and receives a short, sharp but safe shock. The strength of the shock the animal receives depends upon the power available from the energiser, and the total resistance of the circuit. Animals learn to associate contact with the fence and the shock. Because the electric fence is also a psychological barrier, it does not require great strength to be effective. It should however, be well designed and constructed to absorb some pressure from animals and wind. The energizer must have enough power for the length of the fence and for the animals being controlled. There are two basic types of electric fence system, namely the earth return system (Fig. 10.1.2) and the fence return system (Fig. 10.1.3). The earth return system uses one or more fence wires to deliver the pulse from the energiser. To complete the circuit, current must flow through the animal and back to the energiser by way of the earth. The circuit is therefore closed between the live wire and the ground when the animal makes contact with a live wire. This system therefore relies on the animal making good electrical contact with the ground, and the ground being sufficiently moist to provide a low resistance circuit back to the energiser's earth terminal. These conditions usually apply in high rainfall areas and on irrigated pastures. Generally, earth return systems are not as effective during the dry season, or on long runs of permanent fencing in natural pasture areas. Earth return is most commonly used for strip grazing.

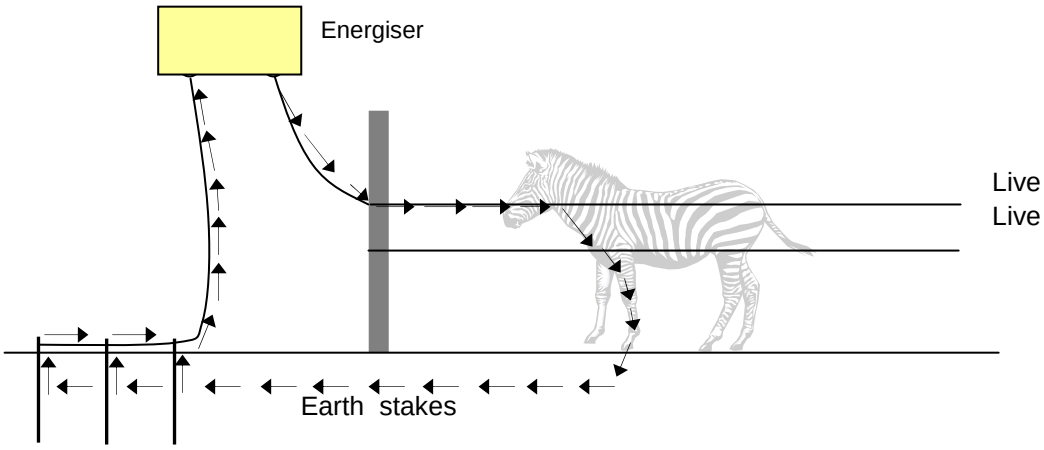


Figure 10.1.2. Earth return systems.

The system recommended for use in extensive ranching systems and for wildlife is the fence return system. This system uses both live and earth wires in the fence. Therefore, the fence construction involves the use of two or more wires. To complete the circuit, current can flow through the animal from the live wire to the earth wire and back to the energiser. If the ground is sufficiently moist for the earth return to work, then the animal will receive a

shock by touching only the live wire. If however the earth return is not working, then the animal will receive a shock when it makes contact with both a live and earth wire simultaneously. The animal will not receive a shock if it touches only the earth wire. Fence return systems are widely used for all types of temporary and permanent fencing and are well suited to the dry African environment. When installing an earth return system, earth connections should be made at regular intervals along the length of the fence. This is achieved by simply connecting the earth wires to additional earth stakes, periodically spaced. Connections should be made using line clamps and insulated cable or steel wire. Where possible intermediate earths should be established in moist ground such as that found near a dam or stream.

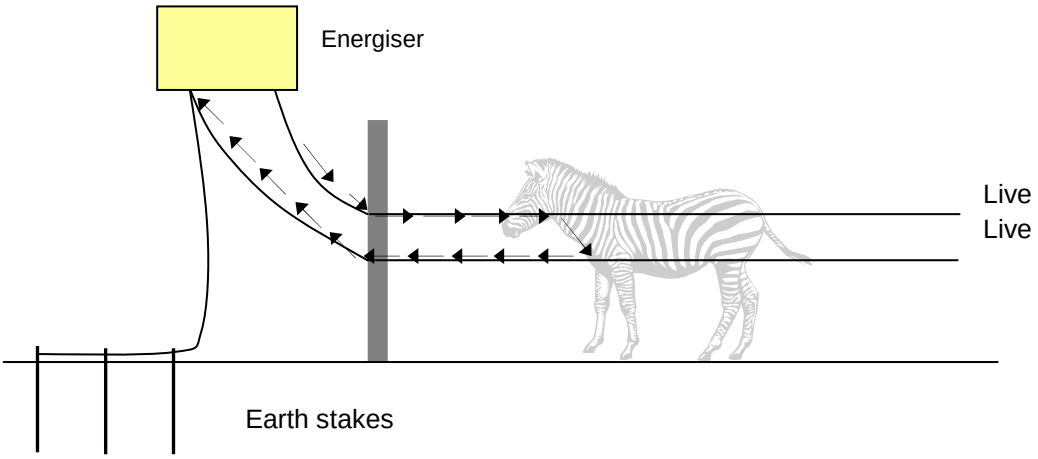


Figure 10.1.3. Fence (earth wire) return system

Multi-wire fences can be wired either in parallel or in series. Series wiring is usually used on security fences where the fence needs to be monitored. Parallel wiring is better suited to wildlife and agricultural applications as there is less resistance and a fault on one wire does not necessarily compromise the entire fence.

Energisers: An energiser is an "electron pump" that converts an A.C. or D.C. electric power source into high voltage pulsed energy. The power output of an energizer is measured in Joules. The output Joule capability of an energizer is a measurement that can be used to compare energisers and can be likened to Horsepower of an engine. As voltage is the only criteria that can be easily measured it is often over emphasised. Good voltage can mean a good fence line, and not necessarily a powerful energiser. Under load, the energiser can break down and lose its power. The Joule rating is a more accurate indication of an energisers capability. Some manufacturers rate their energisers capability in terms of stored energy, while others use output energy. Power is lost when an energiser discharges (internal resistance) so output energy is a more reliable source of power rating. Manufacturers often give an indication of the distance of fence which can be powered by an energiser. While these may be true for a perfect electric fence used to control trained livestock in a high rainfall environment, the units cannot power these distances of fence in dry African conditions. They undoubtedly do not supply sufficient power over these distances to control wildlife. The use of a single energiser to power long distances of fence-line has a number of drawbacks. The most critical of these is that a fault or short close to the energiser will affect a long section of fence and could result in animals breaching the fence. Maintenance and the location of faults on the fence is also made more difficult when energisers power overly long distances. It is therefore recommended that no energiser is used to power

any section of fence longer than 12km. As energisers can potentially be lethal, it is recommended that only energisers that have been tested and found to comply with the relevant safety standards are used for electric fencing.

Insulators: Fencing insulators are made from plastic, porcelain or fibreglass. Plastic insulators, even those that are UV stabilised, do not last in southern African conditions due to the intensity of sunlight to which they are exposed. The cost to restring a fence outweighs the savings made when using plastic insulators, so the construction of electric fences using plastic insulators should be avoided. Porcelain insulators have excellent insulating properties, are fireproof and are not affected by sunlight. Porcelain bobbins used in offset brackets can burst when the fence is struck by an animal. They should not be tied directly onto steel profiles such as those used for trip wires as the glazing chips and water enters the bobbin. Fibreglass insulators (also known as GFT insulators) are not affected by UV light and are fire resistant. They do not break easily and are the most practical albeit currently the most costly type of insulator for game fences.

Earthing: This is the most important component of an electric fencing system. Most problems which occur with electric fences are caused by poor earthing. Soil that is very dry, sandy or pumice does not conduct the electric current as effectively as clay or slightly damp soil. In these less than ideal conditions, it is more difficult to get an adequate earth system to ensure the animal receives the maximum shock. Earth spikes should be installed in a damp area where possible. For best results a location with permanently moist ground, such as near a stream, dam, trough, septic absorption trench or water tank overflow should be used for the earth installation.

Purpose manufactured earth stakes are the easiest to use and consist of either galvanized steel rods or galvanised angle iron. The stakes are connected to each other and to the earth terminal of the energiser, using galvanized nuts and bolts. Alternatively, a length of galvanized water pipe can be used, but it is harder to drive in and is difficult to connect to the earth wire satisfactorily.

Wire: Wire used for conventional fencing is chosen primarily for its physical characteristics of strength and durability (corrosion resistance). While these two properties are important in electric fencing, the electrical properties of the wire are critical. Use of the correct wire is essential to maintain good conductivity throughout the fencing system. High powered energizers require large capacity wire or cable. Small diameter cable will restrict current flow with a subsequent loss of power on the fence. Long fences such as those used for game should therefore be constructed with 2.24mm or 2.5mm diameter high strain steel wire. Barbed wire should never be electrified. When using galvanised (zinc coated) wire, all components such as earth spikes and line clamps should be zinc coated. The mixing of metals such as copper and zinc will result in electrolysis. The electric fence wires should be tensioned to approximately 90kg. Atlas or Donald tensioners should be used to tension the earth wires and combi-tensioners for the live wires. Over long distances, permanent tensioners should be used on both ends so the wire can be pulled in from both ends. Wire should be handled with care to avoid damage to the galvanising and should be stored in a dry place away from fertilizers, lime or other corrosive chemicals.

Wire spacing and joining: There are two main categories of electric fence, freestanding electric fences and piggyback or offset fences (Fig. 10.1.4). In the former category, all fence wires form part of the electric fence. These fences are particularly suited to controlling livestock where the animals have been trained to respect the fence and for security applications.

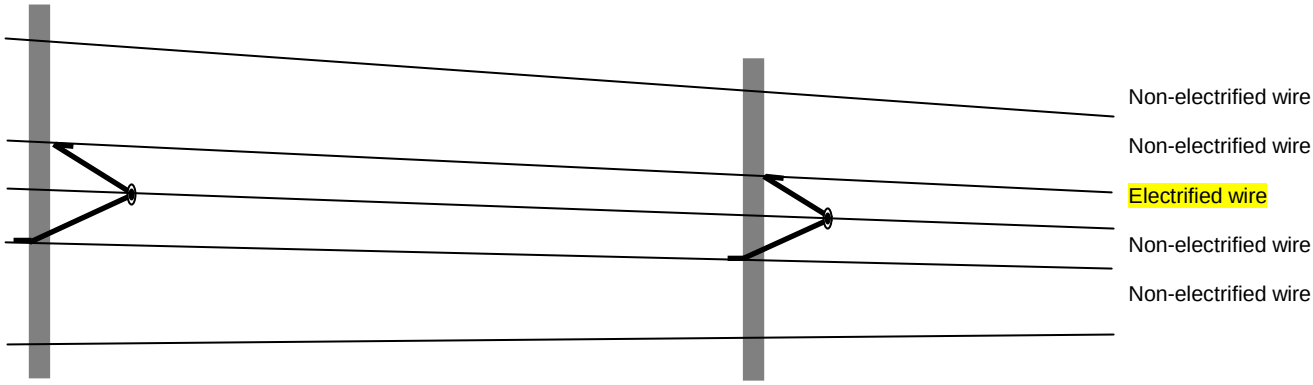


Figure 10.1.4. Conventional fence with electrification on offset brackets

The use of offset brackets or standoffs is recommended for wildlife fences. These are used in conjunction with a conventional fence to add power to the fence thereby reinforcing it and increasing its lifespan. The offset brackets carry either live or both live and earth wires at a distance of approximately 200mm to 400mm away from the fence. These brackets should be placed on the fence to carry the wires at the shoulder or nose height of the animals which need to be controlled. At each connection of an electric fence, power can be lost to the fence. It is therefore imperative to ensure tight wire connections that line or joint clamps are used at each connection. Twisting of the wires is not sufficient to prevent power loss. When joining wires together in the middle of the fence-line, a figure 8 or reef knot should be used. The knot should provide multiple contact points for carrying the energiser's pulse should not weaken the wire too much, should not flex after the wire is strained and loose ends should be cut back close to the knot to avoid short circuits and animals injuring themselves.

Fence maintenance

All fences and particularly electric fences require maintenance if they are to work at their optimum. Growth of vegetation along the fence-line should be controlled either mechanically or by means of herbicides. This is imperative to prevent damage to the fence from fire as well as a loss of power to electric fences. Regular checking of electric fences is necessary to identify possible short circuits or faulty components. The electric fence is reliant on the psychological effect to function properly. If allowed to be without power for extended periods, the electric fence will not be effective. Where energisers are solar powered, solar panels need regular cleaning and batteries should be kept free of corrosion and full of water. If a fence is well planned, correctly installed and properly maintained, it will become a priceless asset for any ranch or game reserve.

T.N.H. Fencing was formed in 1990 by Newton (Tubby) Hardman who had previously been the national sales manager for Gallagher electric fencing products in South Africa. TNH have successfully completed projects for private ranchers, game breeders and provincial and national conservation authorities throughout Africa and the Middle East. Some of the South African Reserves where TNH have carried out fencing projects include Madikwe Game Reserve, Pilanesberg National Park, Lapalala Wilderness Reserve, Tswalu Kalahari Reserve, Marakele Park and Glen Lyon Game Reserve. They have also been involved in projects in Botswana, Zimbabwe, Mozambique, Zambia, Malawi, Uganda, Rwanda, Tanzania and Saudi Arabia.

Appendix 10.2 The present state of TFCA development within the Southern African Development Community[25]

Hanks, J.
Consultant, P.O. Box 254, Greyton 7233, South Africa.
hanksppt@iafrica.com

Southern Africa's first TFCA, the Kgalagadi Transfrontier Park, was formally opened on 12 May 2000 by the Presidents of Botswana and South Africa (Fig. 10.2.1). The international treaty that established Kgalagadi was signed in April, 1999.

Figure 10.2.1. President Mbeki (South Africa) and President Mogae (Botswana) at the opening of the world's first formally designated transfrontier park.

On 22 June 2000 the governments of Mozambique, South Africa and Swaziland signed five protocols on the establishment of the Lubombo Transfrontier Conservation and Resource Area. A year later, on 8 June 2001 the governments of Mozambique and Zimbabwe signed an agreement to establish the Chimanimani TFCA in the Chimanimani Mountains.

These milestones were followed by the signing of a Memorandum of Understanding (MoU) between the governments of the Kingdom of Lesotho and South Africa on 11 June 2001, which paved the way for the establishment of the Maloti-Drakensberg Transfrontier Conservation and Development Area.

[25] The Southern African Development Community consists of the following 14 countries: Angola, Botswana, DRC, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

On 9 December 2002, the Great Limpopo Transfrontier Park (GLTP) (Fig. 10.2.2) was proclaimed with the signing of an international treaty at Xai-Xai, Mozambique by the heads of state of Mozambique, South Africa and Zimbabwe. The MoU had been signed on 10 November 2000.

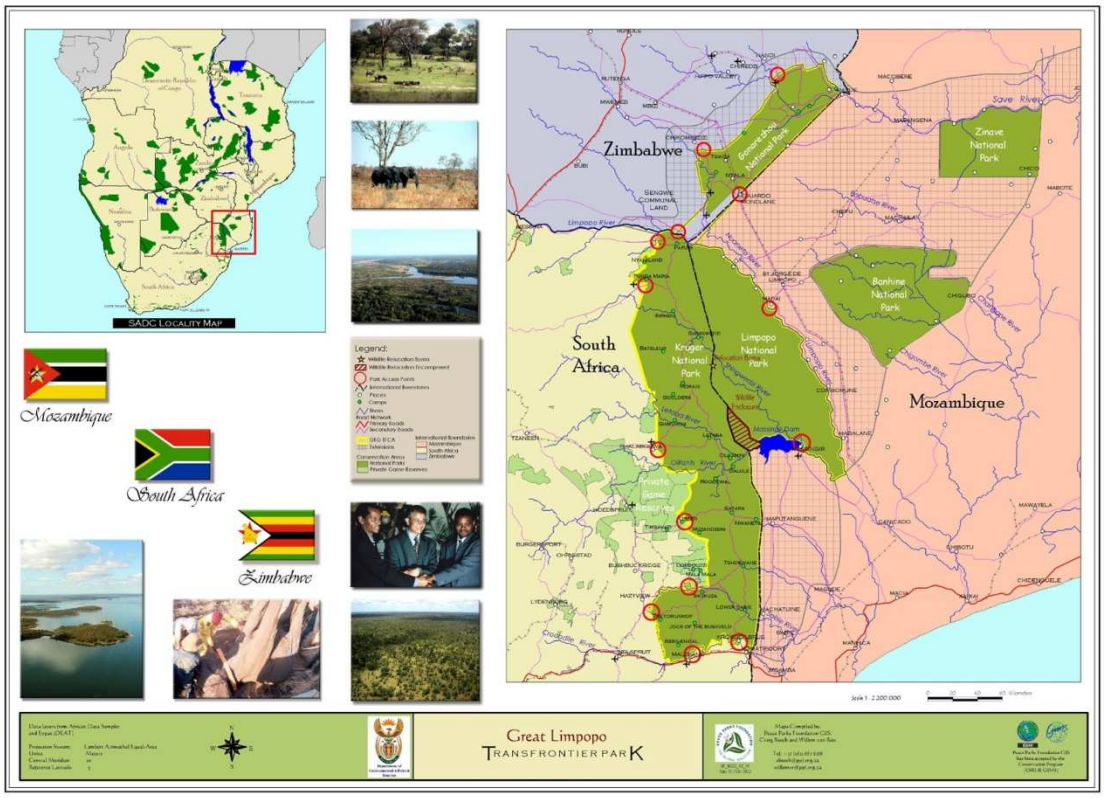


Figure 10.2.2 Great Limpopo Transfrontier Park.

Following its MoU signing on 17 August 2001, a treaty on the establishment of the |Ai-|Ais/Richtersveld Transfrontier Park was signed by the Presidents of Namibia and South Africa in Windhoek on 1 August 2003. On the same day the governments of Namibia and Angola signed an agreement to establish Iona/Skeleton Coast TFCA.

A little more than a year later, on 13 August 2004, the governments of Malawi and Zambia signed an agreement to develop the Malawi/Zambia TFCA.

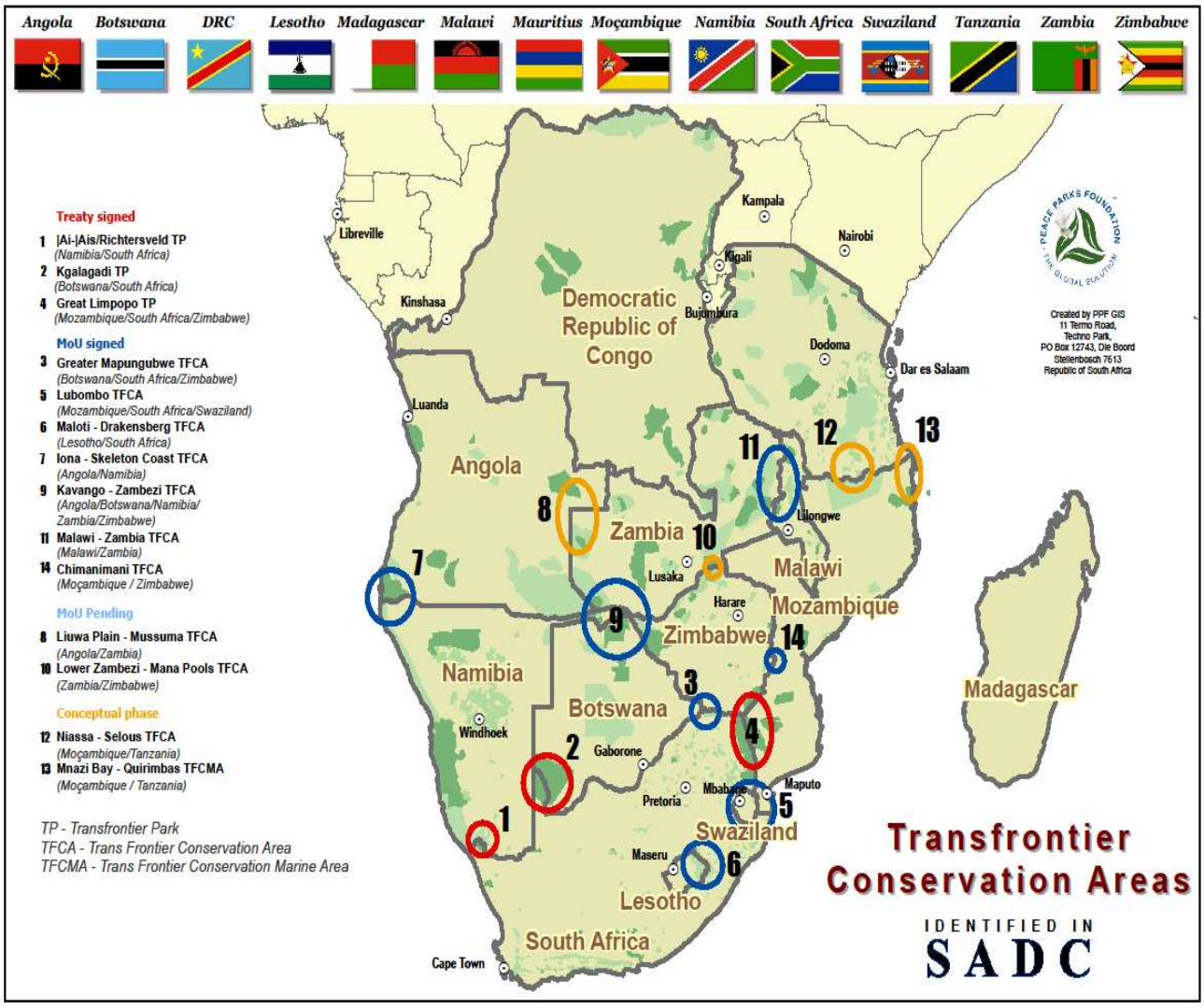
The year 2006 was an important one for transfrontier conservation. On 22 June 2006 the governments of Botswana, South Africa and Zimbabwe signed an agreement to establish the Limpopo/Shashe TFCA, now the Greater Mapungubwe TFCA. History was made on 7 December 2006 when the cornerstone for Africa's largest TFCA, the Kavango-Zambezi or KAZA was laid with the signing of an MoU by the five participating countries to jointly work towards the establishment of the TFCA.

A further four Southern African TFCAs are in various stages of development:

- Liuwa Plain/Mussuma (Angola/Zambia)
- Lower Zambezi-Mana Pools TFCA (Zambia, Zimbabwe)
- Niassa-Selous TFCA (Mozambique, Tanzania)
- Mnazi Bay/Quirimbas Marine TFCA (Mozambique/Tanzania)

This summary was taken with permission of the Peace Parks Foundation from: http://www.peaceparks.org/Content_1020400000_Progress+made.htm

Figure 10.2.3 Tranfrontier conservation areas in the SADC Region (Courtesy C. Beech, Peace Parks Foundation).



Box 10.2: Extent of fencing within the TFCAs*

It is difficult to estimate the total length of veterinary cordon fencing in the two TFCAs and in the sub-region as a whole. The lack of accurate data is compounded by the different types of fencing that may or may not serve the purpose of controlling animal movement. Veterinary cordon fencing can encompass FMD 'red-line' or tsetse fly control fences, with both being designed to stop the crossing of livestock or wildlife. National border fences, cattle-ranch stock fences, road and rail fences, private game/conservancy and other agricultural fencing (e.g. erected by sugar cane companies that border Kruger National Park) and protected area fencing may also serve to block the movement of large mammals and fragment landscapes. In Namibia, for example, 'veterinary cordon fencing' can include the Etosha National Park fence which serves as a park fence and a secondary buffalo-proof fence to the more southerly and major red-line (*cordon sanitaire*) fence. A further caveat is that some fences are dilapidated and the status of these as effective barriers is largely unknown.

Our estimate of the total length of such fencing is therefore tentative and based on several sources (Albertson, 1998; TCC, 2006; Williamson, 2002; Martin, 2005). Within the currently delimited range of KAZA TFCA we estimate approximately 1,400km of veterinary fencing (excluding tsetse fencing in Zambia). To this figure can be added fences in southern Botswana that lie outside of KAZA TFCA, giving a total of at least 3,000km (including some border fences) for the entire country. Namibia (excluding fencing that borders its neighbours) has approximately 1,100km of internal fencing. Therefore, for KAZA TFCA and including the major fences of the countries that lie just outside of the KAZA boundary, the total length of veterinary fencing is in the order of 5,500km.

The GLTFCA is easier to calculate. Kruger National Park has a total boundary length of 1,050km, which at one stage, was entirely fenced. Small sections have been removed (see section 6.4) and further fencing in the northern part of the GLTFCA (e.g. Gonarezhou National Park) is largely moribund except for small sections of private conservancy fencing (see section 3.5). The total estimate of fencing lengths in the GLTFCA is therefore approximately 1,000km. Combined, the two TFCAs have (approximately) a formidable 7,000km of major veterinary fencing (equivalent to the distance between Cape Town and Cairo). Perhaps, just as importantly is the length of further proposed border/veterinary fencing. Such schemes may/may not occur, namely Angola-Namibia (300km), Botswana-Zimbabwe (re-erect 550km) and Angola-Zambia (1,000km), making a potential total of nearly 2,000km. However, recently there has been speculation that some major fences in the region may be removed (e.g. the Caprivi border fence between Botswana and Namibia; Anon 2010), and therefore the total lengths of veterinary fencing will always be subject to change.

These calculations cannot attempt to answer the specific questions raised in this review. The alignment of each fence (sometimes in relation to each other) in relation to landscapes and species distribution (and densities) is far more likely to lead to detrimental environmental impacts rather than simply the total lengths observed. It is also worth noting that the extent of fencing can be compared between private and state concerns. Bothma, et al. (2009) state that in South Africa that private wildlife properties cover 16.8% of the country, compared with 6.1% in the case of provincial and national protected areas. Whilst most of the latter two categories are larger in area (than most private farms) and mostly fenced we cannot be sure whether the total number of kilometres of legally obligated fencing on private lands is less than or exceeds the state total in this country (see section 7.5 and 7.6 and Fig. 4.3.4 for a graphic example of the extent of private fencing in Namibia).

**With thanks to Daniel McGahey*