THE EFFECTS OF PROTECTED AREA AND VETERINARY FENCING ON WILDLIFE CONSERVATION IN SOUTHERN AFRICA

Ken Ferguson[1*] and John Hanks[2]

* Corresponding author, kenneth.ferguson@glasgow.ac.uk
1 Institute of Biodiversity, Animal Health and Comparative Medicine, College of Medical, Veterinary and Life Sciences, Graham Kerr Building, University of Glasgow, G12 8QQ Scotland
2 Consultant , P.O. Box 254, Greyton 7233, South Africa

ABSTRACT

The use of park and veterinary fences to separate wildlife, people and livestock is increasingly threatening greater fragmentation of African rangelands. However, the curtailment and eradication of wildlife borne animal diseases has necessitated the use of fencing as a blunt instrument. The dilemma inherent in the removal of fences to make way for large contiguous transfrontier conservation areas is that wildlife reservoir disease vectors may spread and cause hardship to rural communities and harm national livestock exports. New and creative thinking is required to balance these opposite outcomes so an era that will encourage the sustainable development of African rangelands can be ushered in.

INTRODUCTION

The conservation of protected areas and large mammals in Africa is inextricably linked in terms of ecological dependency and historical necessity (Craigie et al., 2010). The migration of large mammalian herbivores in the savannahs of east and southern Africa either delimit the boundaries of ecosystems that are in need of protection or simultaneously underline the hazards that exist for these populations if the migration range is partially or wholly unprotected. An added concern is the role of fencing which frequently aids and abets the fragmentation of the landscapes that surround protected areas and furthermore can result in impassable barriers to the dispersal of highly mobile species (Ferguson & Hanks, 2010).

Human-wildlife conflict (HWC) is increasing in those places where the boundaries have hardened between wild and domestic use of rangelands. A less publicised form of HWC is the transmission of endemic and emerging animal diseases that filter across the human-wildlife interface. Fencing is seen as one method of reducing this by directly halting host/ pathogen traffic, but inevitably protected areas will then be seen as reservoirs of economically important diseases that risk a spill-over into economically struggling communities (Bengis *et al.,* 2005). However, the expansion of conservation paradigms into the realm of sustainable natural resource utilisation and a move away from the 'fines and fences' approach (Brockington, 2002), has blurred the boundaries of protected areas by benefitting both human social development and conservation. Transfrontier Conservation Areas (TFCAs), which are growing in acceptance and extent in southern Africa, have the potential to turn conflict into consensus by advocating a mixed (wildlife and agriculture) economy where conservation areas and people are not seen to be mutually incompatible.

Threats to rangelands (natural or semi-natural) come from three primary sources. Habitat conversion for arable production is the most irreversible and inevitably leads to steep declines in wildlife. Habitat degradation due to overstocking of livestock can increase bush encroachment and lower carrying capacities of wildlife and livestock, but this can be reversed by sustained management and by allowing wildlife to decrease woody growth (Augustine & McNaughton, 2004). Habitat fragmentation dissects the landscape into smaller parcels of land that may or may not be interspersed with degraded or converted habitat. Fencing can play a role in all three of these modes of rangeland manipulation, but is especially effective at fragmenting large tracts of lands into compartments for disease control purposes.

Whilst large migratory mammals are the most obvious casualties of rangeland conversion and fragmentation, these species are also threatened when they leave a protected area to utilise external resources. Controlled killing of 'fence escapees' and the payment of compensation to neighbouring communities for the loss of human lives, crops and livestock are generally not well

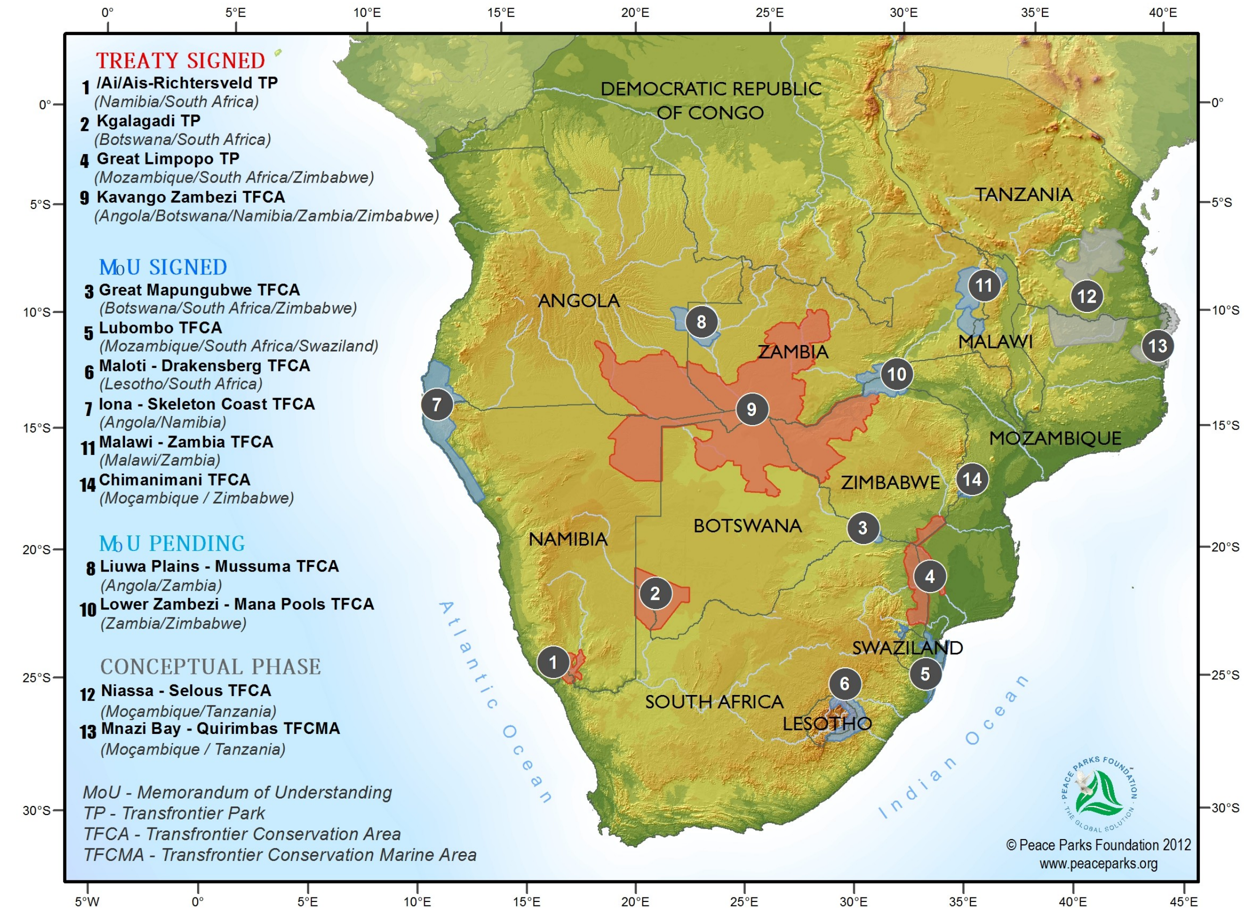

Figure 1: TFCAs identified in the SADC Region (Courtesy of Peace Parks Foundation)

or rigorously documented. Animals escaping through fences can lead to a cascade of HWC and disease-related events, which places renewed pressure on the control of the movement of these animals either lethally or by enhancing the efficacy of the barrier. An additional threat to wildlife comes from snaring, often using fence wire meant to protect these species. The same fences can also initiate profound ecological and biodiversity changes due in part to excluding certain guilds of species and by hastening the change in land use activities by the creation of hard edges (McGahey, 2010).

Fencing if correctly maintained can of course have short-term positive benefits for conservation, such as giving protection to highly endangered or 'expensive to replace' species such as black rhino, and reducing the incidents of HWC.

FENCING EXTENT AND DISEASE TRANSMISSION IN TWO TFCAS

The veterinary fences erected since the 1950s in southern Africa are present in order to protect domestic stock from disease, but it is only relatively recently that there has been recognition of a fundamental association between disease epidemiology 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 (and host) in question (Reisen, 2010). At the southern African wildlife/livestock disease interface, wildlife fences seem set to remain a part of the landscape, with their presence during the development of TFCAs increasingly coming into question. Two major TFCAs in southern Africa, namely the Great Limpopo (GLTFCA) and the Kavango-Zambezi (KAZA TFCA), epitomise the areas of concern.

Veterinary cordon fencing varies in structure and purpose, and it is surprisingly difficult to get accurate data on the total length of fences in these two TFCAs and even more so in the sub-region as a whole. The fencing can encompass foot-and-mouth disease (FMD) 'red-line', or tsetse fly control fences, with both being designed to stop the crossing of livestock or wild herbivores. In addition there are national border fences, cattle-ranch stock fences, road and rail fences, private game/conservancy and other agricultural fencing such as those erected by sugar cane companies that border Kruger National Park (KNP) and protected area fencing, all of

Carmine bee eater **(Merops nubicoides)** *using a fence at Kruger National Park to hunt © Ken Ferguson*

which were placed to block the movement of large mammals and which inevitably fragment landscapes. Some of these types of fences are dilapidated and their status as effective barriers is largely unknown.

Our estimate of 5,500km of fencing in and around the KAZA TFCA is tentative and based on several sources (Albertson, 1998; TCC, 2006; Williamson, 2002; Martin, 2005). This could increase significantly if unconfirmed proposals to erect border/veterinary fencing (Angola-Namibia (300km), Botswana-Zimbabwe (re-erect 550km) and Angola-Zambia (1,000km)) go ahead, but this should be countered by recent discussions on the possible removal of the Caprivi border fence between Botswana and Namibia. The GLTFCA is easier to calculate. KNP's boundary is 1,050km. It used to be entirely fenced, but small sections have been removed (Alexander & Ferguson, 2010). 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, giving a total of no more than 1,000km of fencing in and around the GLTFCA.

In addition to a veterinary function, fences in and around conservation areas have several other important roles, such as excluding large herbivores from areas of sensitive biodiversity, isolating disease-free breeding herds of buffalo (*Syncercus caffer*), securing tourist rest camps and staff quarters, securing the boundaries of the protected area and preventing the flow of animals and humans to and from the external matrix (Joubert, 2007). None of the major parks in the KAZA TFCA are completely fenced, in marked contrast to the Etosha National Park in Namibia, which lies outside of the TFCA, and which is entirely fenced (MET, 2007). The prevalent fences in the KAZA TFCA serve a veterinary function, either FMD long-term structures or as medium to short-term 'emergency' fences that can be erected relatively quickly to contain a fast spreading disease like Contagious Bovine Pleuropneumonia (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.

THE ECONOMICS OF PARTITION BY THE USE OF FENCING

The delineation of rangeland, promulgated by fencing policies, into 'biodiversity friendly' versus 'human and livestock' dominated landscapes has significant economic implications. The associated fencing creates not only a physical barrier but a fiscal one as well, with fences being expensive to build and maintain, and with all fences having unintended and at times costly environmental impacts. Ultimately, 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, which will be 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 rainfall, therefore delimit the most economically viable rangeland areas by virtue of the creation of spatial-temporal heterogeneity (maintained by large herbivores) in key and contested landscapes. 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, where the conflict between wildlife and social development (and in some cases, traditional pastoralism) is likely to become more intense (Olff & Hopcraft, 2008; Ogutu et al., 2010).

The role and impacts of fencing are best separated by making the primary distinction between their veterinary functions and other uses, such as protecting a protected area or preventing HWC around rural settlements. Fences can be multi-purpose (e.g., KNP'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

New fencing damaged by elephants at Kruger National Park © Ken Ferguson

motivations. An additional factor is the difference between the use of fencing by the state and by private entities. The development or wildlife commercialism in South Africa is influenced by the use of fencing to control 'externalities' (such as laws requiring fencing, control of disease in a private area, etc.). In Zimbabwe such externalities "*avoided the financial and ecological disadvantages of fences with a rather elegant common property solution*" (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.

Wildlife fencing is expensive 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. Thus the economic impacts of fencing can be scaled from the macroeconomic (e.g., external beef subsidies received by Botswana) to the microeconomic such as the 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 macroeconomic scale, climate change in relation to the livestock industry in semi or arid rangelands takes pre-eminence. For example, the anticipated 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), all of which will magnify the restrictive role of fences. Such changes may then interact with the need for equity and justice for natural resource-dependent societies (Thomas & Twyman, 2005). 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, resulting in new disease transmission pathways.

Livestock produces livelihoods for 1.3 billion people worldwide and makes productive use of some 33 per cent of the world's arable land. Eighty eight per cent of Kenya's landmass is populated by 4.5 million people with approximately nine million head of livestock. Most of Kenya's protected areas fall within this 'catchment' area and some 70 per cent or more of the wild large mammals

Lioness caught on camera trap leaving the KNP western fence to feed on livestock, it was killed the next night by local people using the poison carbofuradan, the parks' first recorded case, her young cubs were never again located © Ken Ferguson

live seasonally outside of the parks (Norton-Griffiths and 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 for the sale of cattle ranches to urbanites, who wish to parcel them up still further into 'ranchettes'. The costs of the reorganization of land tenure 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 per cent 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 and Said, 2010).

The economic role of veterinary fencing in southern Africa is distorted by another type of barrier – trade. Africa produces a mere 2 per cent 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 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. 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. The financial loss incurred by an FMD outbreak in the source country is dwarfed by the potential loss to an uncontrolled outbreak in an importing country. For example, during the UK's 2001 FMD outbreak, losses to the agricultural and support industries and to the outdoor leisure industry amounted to US$12.2 billion (Kitching et al., 2005). Fencing has consequently 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-GLTFCA, 2008). More research is needed on the macroeconomic connections between fencing, foreign subsidies and sustainable livestock development in general.

Buoyed by these and other foreign subsidies, the commercial ranching systems that demand 'red-line' zonation in Ngamiland, Botswana have 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 per cent of the land surface and commercial ranches 6 per cent. Surprisingly, 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. 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 had only 60 years ago."* Part of this missed opportunity relates to the role of fencing in de-populating wildlife areas, and in a comparative economic assessment this role 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 per cent, beef prices by 60 per cent or capital costs would need to be reduced by 60 per cent. Investing in new large scale commercial ranches is beset by prohibitively high capital costs of which fencing is but one of these costs. Positioning commercial farms near wildlife areas or veterinary fences obviously increases the risk of herd contamination and predation (Hemson et al., 2009) and this in turn will influence land prices which could deter the expansion of ranches. Barnes et al., (2003) take a 'common-sense' approach to the sub-division of land-use practices, noting that "*wildlife-based tourism in high quality wildlife areas…should get priority where these conditions exist*", and that 'where the economic values (of wildlife) exceed those of livestock' 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 (*Connochaetes taurinus*) 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.

Currently 'travel and tourism' in Botswana account for 16 per cent of non-mining GDP, and is forecast to grow on average by 7.3 per cent per annum for the next ten years, far outcompeting the majority of other African countries. The ethos for the tourist plan for Botswana is 'high-yield and minimal impact' (WTCC, 2007). For this market to grow as is predicted the natural capital assets must be protected and the issue of fencing and fragmentation addressed as a priority concern. 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. For example a drop in tourism due to a global recession could be compensated for by a temporary increase in livestock production). Kreuter and Workman (1997) examined a mixed ranching scheme in Zimbabwe and concluded that with regards to fencing, less investment was required in wildlife than cattle enterprises (11 to 20 per cent 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. 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., 2012) and relate this to the economic, epidemiological or environmental importance of the disease concerned or the impact of carrier species on the integrity of the fence and HWC impacts. Thus in terms of FMD, buffalo are a high disease risk species and elephants do not represent such a risk but they do break fences more often therefore potentially allowing buffalo to escape through a fence. The scaling of disease risk in relation to fence permeability would be more suited to risk probability modelling exercises. The number of disease outbreaks per unit time would give a coarse level of cost efficiency of the fence as a barrier, a figure which would have to be compared with the total amount of months of disease 'clean-up' costs due to a 'leaky' fence

Elephant bull inspecting the new 'I' beam fence, Kruger National Park © Ken Ferguson

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 which may require less or no fencing, 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, such as around Nairobi National Park (partially fenced), where wildlife dispersal areas are being blocked by the subdivision of the land into parcels 'protected' by fencing. Reid et al. (2008) argue that this fencing will isolate 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 or accidentally eradicated or excluded. Curtailment of wildlife dispersal corridors by fencing will also be exacerbated by drought, increasing urbanisation and the selling of land for infrastructural development. All of these fragmentary drivers 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 from 1990-1998 cost approximately US$1,900 per kilometre, but this would be considerably higher today (Price Waterhouse Coopers, 1998). Ideally estimates of fence 'capital costs' should include 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 and auditing in general, especially in the case of community based fencing projects whereby early successes with electric fencing in the longer-term lead to most projects 'being stuck in a partially functioning state' as the electric fence degrades (Price Waterhouse Coopers, 1998).

The Karoo National Park in South Africa has recently upgraded its original 'cattle-stock' fence to a fully operational 2.4m electrified fence with a length of 175km and a cost of US$1.86 million to meet the legal requirements for the re-introduction of species such as cheetah (*Acinonyx jubatus*) and buffalo. It is assumed that benefits of the expected tourist increases related to the presence of more 'desirable' viewing species and the

13mm cable fencing damaged by elephants at Kruger National Park © Ken Ferguson

natural regulation of prey by introduced predators outweighs the cost to the public purse of the initial capital outlay.

De Boer et al. (2007) introduced a fencing element directly into a cost-benefit analysis of elephant conservation efforts in southern Africa. A projection of tourist numbers and increasing 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 in Mozambique. They concluded that 'costs generated' through elephant poaching and elephant crop raiding were higher than fence construction costs at a population size >100 for this species. Fence capital outlay became profitable only after elephants exceeded this number.

Perry et al. (2001) suggested that the discipline of veterinary epidemiology should be directly integrated into the economics of disease control implementation and also into 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.

Measuring the livelihood and health impacts on livestock owners and their dependents of serious zoonotic outbreaks is not often attempted. 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 livestock herds from disease and HWC has to be offset against the potentially negative impacts on conservation. There is a clash between these two objectives when it comes to prioritising the Millennium Development Goals, all of which are required to be met by 2015. Perhaps unsurprisingly the sustainable environment goal (Goal 7) is the one that is most unlikely to reach its target and it is the goal which has 'fencing issue' nested as a minor subset within it. In summary fencing structures undoubtedly have far reaching regional and global environmental and economic impacts, extending beyond the physical situation of the fence itself.

LOCAL COMMUNITY PERSPECTIVES AND FENCING

People are rarely asked what they think about a fence that restricts their movement (Chaminuka, 2010). Various social studies appraising attitudes by people (amongst them some of the poorest people in South Africa) who live next to the KNP and are separated from it by a fence have shown that despite this obstruction there is a level of goodwill and understanding of why the park should continue to exist (e.g., see Lagendijk & Gusset, 2008). Several years ago, KNP 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), an approach which could be extended to new ways of enticing participatory co-management (between state and local communities) for the future benefit to both the park and people.

Van Ierland (2010) has explored ways that people could be brought into conservation around KNP's border. His community '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 when lions exit the park via its porous fence, and hopefully at the same time decrease the rate of lion

Cattle outside the fence at Kruger National Park © Ken Ferguson

poisonings in the area. The win:win scenario would be that cattle are protected, free domestic gas produced, lions protected and there is less pressure on the riverine forests to produce charcoal in order to provide household energy.

FENCING AND GOVERNANCE ISSUES

The combined total area of the GLTFCA and KAZA TFCA is nearly half a million square kilometres (Cumming, 2008; AHEAD-GLTFCA, 2008), with an ambitious vision of creating a diverse approach in terms of a conservation strategy. But, fulfilment of this innovative approach is called into question when fences appear to 'stand in the way'. Alexander & Ferguson (2010) have shown how, over a long period of time (over eight years thus far), fences can be successfully removed within a TFCA. The removal of KNP'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 the neighbouring Limpopo National Park.

The process of fence removal, realignment or erection is long and arduous and it is well explained in political terms by Schoon (2010) and in practical terms by Bewsher (2010). What emerges from these recent contributions is that the involvement of all stakeholders is critical to the success or otherwise of reducing the negative impacts of fencing. The issues of concern encapsulate '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 are often viewed as a front-line defence against epizootic outbreaks (Burroughs, 2010; Thomson, 2010). The rationale, perhaps flawed in some cases, of a disease control fencing strategy can be subverted if nation states begin to fail. Zimbabwe shows clearly how marked societal change can impact massively on fencing structures and wildlife/livestock related disease control strategies (Foggin, 2010).

Placing fencing into its human cultural and historical dimension illustrates once again that a fence may look simple but that its impacts can be wide reaching, and its construction and use can even be related to the quest for power and control by dominant social forces. 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, with the perception generated that fences 'seize' and fragment the natural capital of land (Nkedianye, 2010), even on occasion causing 'fence rage' amongst rural people. Kloppers (2010) 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 KwaZulu 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 newly formed Lubombo TFCA.

FUTURE DIRECTION

Containing wildlife by means of fencing has four main purposes, namely (i) reduction of HWC, (ii) reduction of the disease transmission risk between wild and domestic animals, (iii) increase the security of a protected area, and (iv) where applicable to demarcate an international boundary (Newmark, 2008). The complexity of boundary management and the use of fences is well-illustrated by the KNP where the entire 480km western boundary is demarcated by a veterinary fence, primarily designed to contain the FMD virus, carried by its major wild host, the African buffalo, within the park (Bengis et al., 2003). The western fence varies in structural types and different sections can be exposed to different degrees and causes of damage and permeability to large mammals; issues which are quantified in Ferguson et al., 2012 and 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. A new participatory fence monitoring system has been developed by Ferguson et al. (2012) which forms a time-series of data that highlights areas of permeability. We believe that sound scientifically validated data are required as the first step to coming to terms with the impacts of fencing on biodiversity conservation. New thinking will also be required on the role of fences within TFCAs.

The review by Ferguson and Hanks (2010) 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 relatively 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. This approach is especially important given the recent stated intention by the Uganda Wildlife Authority to fence all of its national parks in a bid to stem human-wildlife conflict (Government of Uganda, 2012).

ACKNOWLEDGMENTS

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 of those who facilitated his work in the park and especially Drs. Dewald Keet and Roy Bengis and Messrs. Ruhlani Patrick and Robert Mahlanga. John Hanks and Ken Ferguson extend their thanks to those who contributed to their recent review on the environmental and social impacts of fencing sponsored by the Wildlife Conservation Society's AHEAD programme.

REFERENCES

Africa Geographic. (2007). 6 degrees from catastrophe. *Africa Geographic* 15(7):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

Albertson, A. (1998). *Northern Botswana veterinary fences: critical ecological impacts.* Gaborone, Botswana: The Wild Foundation/Kalahari Conservation Society.

Alexander, A. and Ferguson, K. (2010). Delineating and decommissioning of park and veterinary fences. In: Ferguson, K. and Hanks, J. (eds.), pp 223-227, op cit

Augustine, D.J. and McNaughton, S.J. (2004). Regulation of shrub dynamics by native browsing ungulates on East African rangeland. *Journal of Applied Ecology* 41:45-58.

Barnes, J. Boyd, C. and Cannon, J. (2003). Economic incentives for rangeland management in northern Botswana: implications for biodiversity. In: Palmer, A.R., Milton, S.J., Kirkman, K.P., Kerley, G.I.H. and Hurt, C.H.R. (eds.) *Proc. VIIth International Rangelands Congress*; 26 Jul – 1 Aug 2003; Durban, South Africa:.203–212.

Barnes, J., Cannon, J. and Morrison, K. (2001). *Economic returns to selected land uses in Ngamiland, Botswana.* Botswana: Conservation International.

Bengis, R.G., Grant, R. and de Vos, V. (2003). Wildlife diseases and veterinary controls: a savanna ecosystem perspective. In: du Toit, J.T., Rogers, K.H. and Biggs, H.C. (eds.) *The Kruger experience: ecology and management of savanna heterogeneity,* pp.349-369. Washington DC: Island Press,..

Bengis, R.G. (2005). Transfrontier conservation area initiatives in sub-Saharan Africa: some animal health challenges. In: Osofsky, S.A., Cleaveland, S., et al. (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

Bewsher, P. (2010). TFCA integrated development planning processes and fences: 'babble, babble, toil and trouble'. In: Ferguson, K. and Hanks, J. (eds.), pp 209-222, op cit

Brockington, D. (2002). *Fortress conservation. The preservation of the Mkomazi Game Reserve, Tanzania*. Oxford: James Currey.

Burroughs, B. (2010). Current policies for epizootic disease containment in the southern Africa sub-region. In: Ferguson, K. and Hanks, J. (eds.), pp 56-61 op cit

Chaminuka. P. (2010). What do the local communities say about fences? In: Ferguson, K. and Hanks, J. (eds.) pp 53-55, op cit

Child, B. (2009). Private conservation in southern Africa: practice and emerging principles. In: Suich, H., Child, B. and Spenceley, A. *Evolution and Innovation in Wildlife Conservation Areas: Parks and game Ranches to Transfrontier Conservation Areas,* pp.103-111. London: Earthscan,.

Craigie, I.D., Baillie, J.E.M, Balmford, A., et al. (2010). Large mammal population declines in Africa's protected areas. *Biological Conservation*, doi:10.1016/j.biocon.2010.06.007.

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.

de Boer, W.F., Stigter, J.D. and Ntumi, C.P. (2007). Optimising investments from elephant tourist revenues in the Maputo Special Elephant Reserve. *Journal of Nature Conservation* 15: 225-236.

Ferguson, K. and 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

Ferguson, K., Adam, L. and Jori, F. (2012). An adaptive monitoring programme for studying impacts along the western boundary fence of Kruger National Park, South Africa. In: Somers, M.J and Hayward, M.W. (eds.) *Fencing for Conservation*. New York: Springer-US.

Fleischner, T.L. (2010). Livestock grazing and wildlife conservation in the American West: historical policy and conservation biology perspectives. In: du Toit, J., Kock, R. and Deutsch, J. (eds.) *Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems*, pp.235-265. Oxford: Wiley-Blackwell Publishers.

Foggin, C. (2010). Zimbabwe's livestock disease control policy in relation to fencing. In: Ferguson, K. and Hanks, J. (eds.) pp 75-82, op cit

Government of Uganda. (2012). UWA to fence off protected areas. Media centre press release 11th April 2012. Available at: http://www.mediacentre.go.ug/details.php?catId=3&item=1653

Hemson, G., Maclennan, S., Mills, G., Johnson, P. and 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: 2718–2725

Hess, G.R., Randolph, S.E., Arnebeg, P., et al. (2002). Spatial aspects of disease dynamics. In: Hudson, P. Rizzoli, A., Grenfell, B., Heesterbeek, H. and Dobson, A. (eds.) *The Ecology of Wildlife Diseases*, pp. 102-118*.* Oxford: Oxford University Press,.

Jori, F., Vosloo, W., Du Plessis, et al. (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.,* 28(3): 917-931.

Joubert, S.C.J. (2007). *The Kruger National Park – a history.* 3 volumes. Johannesburg: High-Branching.

Kioko, J., Muruth, P., Omondi, P. and Chiyo, P.I. (2008). The performance of electric fences as elephant barriers in Amboseli, Kenya. *South African Journal of Wildlife Research* 38:52–58.

Kitching, R.P, Hutber, A.M. and Thrusfield, M.V. (2005). A review of foot-and-mouth disease with special consideration for the clinical and epidemiological factors relevant to predictive modelling of the disease. *The Veterinary Journal* 169(2): 197-209.

Kloppers, R. (2010). Fences and conflicts in the Lubombo TFCA. In: Ferguson, K. and Hanks, J. (eds.), pp 49-52, op cit

Kock, R., Kock, M., Cleaveland, S. and Thomson, G. (2010). Health and disease in wild rangelands. In: du Toit, J., Kock, R. and Deutsch, J. (eds.) *Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems*, pp.235-265. Oxford: Wiley-Blackwell Publishers.

Krueter, U.P. and Workman, J.P. (1997). Comparative profitability of cattle and wildlife ranches in semi-arid Zimbabwe. *Journal of Arid Environments* 35: 171-187.

Lagendijk, G.D. and Gusset, M. (2008). Human–carnivore coexistence on communal land bordering the greater Kruger area, South Africa. *Environmental Management* 42: 971-976.

Martin, R.B. (2005). The influence of veterinary control fences on certain wild large mammal species in the Caprivi, Namibia. In: Osofsky, S.A., Cleaveland, S., Karesh, W.B., et al. (eds.) *Conservation and development interventions at the wildlife/livestock interface: implications for wildlife, livestock and human health*, pp.165-180*.* Gland, Switzerland and Cambridge, UK: IUCN.

McGahey, D. (2010). Veterinary cordon fences and environmental change in northern Botswana. In: Ferguson, K. and Hanks, J. (eds.), pp 44-48, op cit

MET. (2007). *Etosha Management Plan, April 2007.* Windhoek, Namibia: Ministry of Environment and Tourism.

Nerlich, B. *and* Döring, 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*,* 165-80

Newmark, W.D. (2008). Isolation in African protected areas. *Frontiers in Ecology and Environment* 6: 231-328.

Nkedianye, D.K. (2010). Nairobi National Park Wildlife Conservation Lease Project and the fencing problem. In: Ferguson, K. and Hanks, J. (eds.), pp 263-266, op cit.

Norton-Griffiths, M. and Said, M.Y. (2010). The future of Kenya's rangelands: An economic perspective. In: du Toit, J., Kock, R. and Deutsch, J. (eds.) *Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems*, pp.367-392. Oxford: Wiley-Blackwell Publishers,.

Oguto, J.O., Piepho, H-P., Reid, R.S., et al. (2010). Large herbivore responses to water and settlements in savannas. *Ecological Monographs* 80: 241-266.

Olff, H. and Hopcraft, G.C. (2008). The resource basis of human wildlife interaction. In: Sinclair, C. Packer, A.R.E., Mduma, S.A.R and Fryxell, J.M. (eds.) *Serengeti III: Human Impacts on Ecosystem Dynamics*, pp. 95-133. Chicago: Chicago University Press.

Perry, B. McDermott, J. and Randolph, T. (2001). Can epidemiology and economics make a meaningful contribution to national animal-disease control? *Preventative Veterinary Medicine* 48: 231-260.

Price Waterhouse Coopers. (1998). *Wildlife electric fencing projects in communal areas of Zimbabwe: current efficacy and future role.* Harare, Zimbabwe: WWF Programme Office.

Reid, R.S., Gichohi, H., Said, M.Y., Nkedianye, D. and Ogutu, J.O. (2008). Fragmentation of a Peri-Urban Savanna, Athi-Kaputiei Plains, Kenya. In: Galvin, K.A., Reid, R.S., Behnke, R.H.Jr. and Hobbs, N.T. (eds.) *Fragmentation in Semi-Arid and Arid Landscapes: Consequences for Human and Natural Systems*, pp.195-224. Fort Collins: Springer.

Reisen, W.K. (2010). Landscape epidemiology of vector-borne diseases. *Annual Review of Entomology* 55: 461-483.

Schoon, M., 2010. Governance and decision-making: Fencing in the Great Limpopo and the Kavango-Zambezi Transfrontier Conservation Areas. In: Ferguson, K. & Hanks, J. (eds.), pp 36-39, op cit

Scott Wilson Resource Consultants. (2000). *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.

Spinage, C. (1992). The decline of the Kalahari wildebeest. *Oryx*, 26(3):147-150.

Thomas, D.S.G. and Twyman, C. (2005). Equity and justice in climate change adaptation amongst natural-resource-dependent societies. *Global Environmental Change,* 14:115-124.

Thomson, G. (2010). New ideas that may impact on future fencing strategies in sub-Saharan Africa. In: Ferguson, K. & Hanks, J. (eds.), pp 62-65, op cit

TCC (Transfrontier Conservation Consortium). (2006). *Pre-feasibility study of the proposed Kavango - Zambezi Transfrontier Conservation Area. Volume 1. (Final Report)*. Stellenbosch: Peace Parks Foundation.

van Haaften, E.H. Olff, M. and 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: 339-349.

Van Ierland, J. (2010). Land use management on the border of Kruger National Park, the case of the Nghunghunyani buffer zone project. In: Ferguson, K. and Hanks, J. (eds.) op cit

Victurine, R. and Curtin, C. (2010). Financial incentives for rangeland conservation. In: du Toit, J., Kock, R. and Deutsch, J. (eds.) *Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems*. Oxford: Wiley-Blackwell Publishers, pp.152-187.

Williamson, D. (2002). Dimensions and dilemmas of conservation in the Kalahari. *The Open Country* 4: 15-24.

World Travel and Tourism Council. (2007). *Botswana: the impacts of travel and tourism on jobs and the economy.* London: WTTC.

ABOUT THE AUTHORS

Ken Ferguson is a zoologist and teacher by training who has worked in eastern and southern Africa on a variety of conservation projects over the last 25 years. He is currently a Research Associate with the Institute of Biodiversity, Animal Health and Comparative Medicine, College of Medical, Veterinary and Life Sciences at the University of Glasgow.

John Hanks is a zoologist by training with 45 years of experience in a wide variety of conservation management and research projects in East and southern Africa. He is currently working as an independent consultant.