Chapter 12
Ecological, Social and Financial Issues Related to Fencing as a Conservation Tool in Africa

Peter A. Lindsey, Chap L. Masterson, Andrew L. Beck, and Stephanie Romañach

Introduction

Fencing has taken on an increasingly important role in wildlife management in parts of Africa in recent years, particularly in southern Africa. Fencing is a legal requirement for ranchers to own wildlife in Botswana, Zambia and South Africa and facilitates the process of obtaining permits for some forms of consumptive utilization of wildlife on ranches in Namibia. Large areas of private land are broken up into small parcels by high game fencing across parts of the region as a result (Bond et al. 2004; Barnett and Patterson 2006). A number of protected areas in Africa are also partially or completely fenced, with the objective of limiting the movement of wildlife out of, and people into parks. While historically barriers were typically used to keep wild animals out, fencing developed as a tool in African conservation to keep wild animals inside protected areas. For example, Etosha National Park in Namibia, Matobo and Hwange national parks in Zimbabwe, and the Aberdare and Meru national parks in Kenya are partially or completely fenced (Boone and Hobbs 2004; Purchase 2008). Fencing of parks is particularly prevalent in South Africa, where virtually all parks are fenced, including most of the 20,000 km^2 Kruger National Park. Several lengthy veterinary fences have been constructed in parts of Africa

P.A. Lindsey (✉)
Mammal Research Institute, University of Pretoria, Pretoria 0002, South Africa
e-mail: palindsey@gmail.com

C.L. Masterson
Zvakanaka Wild Vets, Hluhluwe, South Africa

A.L. Beck
Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg, South Africa

S. Romañach
African Wildlife Conservation Fund, Doral, FL, USA

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with the objective of preventing disease transfer between wildlife and livestock, notably in Botswana, Namibia and Zimbabwe (Taylor and Martin 1987; Martin 2005; Mbaiwa and Mbaiwa 2006). In other parts of Africa, however, and particularly in West, Central Africa, and most of East Africa, the use of fencing in wildlife management is rare.

Despite the prevalence of fencing in southern Africa, and potentially significant ecological, financial and social impacts, relatively little has been written on the use of fencing as a wildlife management tool in the region. Hoare (1992) provided a review of the practical issues related to fencing wildlife in Africa. Several authors have assessed the conservation implications of veterinary fencing (Taylor and Martin 1987; Albertson 1998; Martin 2005; Mbaiwa and Mbaiwa 2006). Others have discussed the role of fencing in controlling human-wildlife conflict (Kassilly 2002; Nelson et al. 2003; Ogada et al. 2003), some have addressed the ecological impacts of fencing (Ben-Shahar 1993; Burger and Branch 1994; Boone and Hobbs 2004) and some coverage has been given to the social issues related to fencing (Wels 2000; Spierenburg and Wels 2006). Hayward and Kerley (2009) provided a recent global review of the issues relating to fencing. However, as yet, the literature lacks a comprehensive review of the ecological, social and financial issues relating to fencing as a conservation tool in Africa, which is what we set out to achieve in this chapter.

Types of Fencing

A variety of fencing types are employed to restrict the movement of wildlife, including galvanized steel wire (which may or may not be electrified) with metal or wooden poles, stone walls, live fences comprised of prickly pear *Opuntia littoralis* or other cactus species and thorn fences comprised of heaps of branches from trees such as *Acacia* spp. Throughout this review, unless otherwise specified, we restrict discussion to wire fencing, which represents the only type of fencing commonly used to create barriers over large distances. It is important to bear in mind that, no matter what their design, fences cannot be relied upon as being absolute barriers, especially with regard to the mega-herbivores, but their effectiveness is greatly enhanced by the appropriate use and maintenance of electrification.

Commonly used types of wire fencing include:

(a) Fencing designed to restrict the movements of mega-herbivores such as rhinoceroses *Diceros bicornis* and *Ceratotherium simum*, hippopotamuses *Hippopotamus amphibius*, elephants *Loxodonta africana* and buffaloes *Syncerus caffer*, allowing passage of most other species. Although in most cases more robust designs are used a single, electrified wire is often sufficient to discourage the passage of mega-herbivores, strung at a height of approximately 1.5 m for elephants, or 300–500 mm for a hippopotamus. Examples of the effective use of fencing for the containment and management of mega-herbivores include, inter alia: the containment of elephants and other mega-herbivores in reserves; the exclusion of elephants from sensitive habitat patches (e.g. from an area of sand forest in Phinda Resource Reserve, Zululand); the exclusion of mega-herbivores from tourist and staff camps; and, the confinement of hippopotamuses to single bodies of water during capture. Elephants frequently become adept at challenging fences, including those that have been electrified, by either avoiding electrified strands while pulling fence posts over or by targeted snapping of electrified wires using their tusks (which have low electrical conductivity). The subsequent material damage, need to recapture escaped animals, and possible crop-damage can be costly. In such cases, innovative fence designs are required to prevent elephants from challenging the fence. For example, at Ol Pejeta conservancy in Kenya, protruding wires (fixed to the fence about a metre above the ground) of ~1.5 m long, angled upwards at 45° and spaced about a metre apart (outriggers), serve to keep elephants away from the fence and prevent them from hooking their tusks under a fencing wire and snapping it (Graham et al. 2009). Relatively short (1–1.2 m) fencing is often used to contain buffaloes and rhinoceroses, comprised of four to six strands of thick (10 mm) cable wire.

(b) Fencing designed to restrict the movement of medium-sized wild ungulates: several antelope species, and notably eland *Taurotragus oryx*, waterbuck *Kobus ellipsiprymnus*, greater kudu *Tragelaphus strepsiceros* and impala *Aepyceros melampus* are prodigious jumpers, and so fences have to be constructed to a height of at least 2.4 m to contain them. Such fences are typically comprised of 12–21 strands of high tensile steel wire and/or barbed wire (80–170 mm apart) and may be electrified (van Rooyen et al. 2002). Where fences are electrified, electrified wires are typically offset from the main fence by a distance of ~300 mm at various heights above ground level to accommodate game of various sizes; for example at 250–300, 1,000, 1,500 and 2,000 mm above ground level. Meshed wire fencing (e.g. Bonnox™ or Veldspan™) of approximately 100–200 mm mesh size may also be used. To constrain "non-jumping" ungulates, a standard 1.5 m wire mesh fence with a strand of wire 150 mm above the mesh, and another strand 150 mm above the first strand is generally sufficient (van Rooyen et al. 2002). Non jumping ungulates include inter alia: bushbuck *Tragelaphus scriptus*; blesbok *Damaliscus dorcas*; grey duiker *Sylvicapra grimmia* red hartebeest *Alcelaphus bucelaphus*; oribi *Ourebia ourebi*; oryx *Oryx gazella*; roan antelope *Hippotragus equinus*; sable antelope *Hippotragus niger*; springbok *Antidorcas marsupialis*; and tsessebe *Damaliscus lunatus* (van Rooyen et al. 2002). The use of fencing to contain non-jumping wild ungulates is particularly common in Namibia where oryx, red hartebeest and springbok are among the most widespread and common species (Lindsey 2011).

(c) Predator-proof fencing. Predator-proof fencing generally involves similar materials as for the fences used to restrain wild ungulates, but with reinforcing at the base. Predator-proof fences are always electrified. The lower half of the fence is comprised of tight wire (pig) meshing, which may be dug into the soil to a depth of up to 50 cm, or alternatively be folded into an apron extending along the ground up to 1 m on the inside of the fence. Both arrangements may or may not be rock packed or incorporate a low off-set and electrified trip wire, 50–100 mm above ground level, to discourage digging under the fence. The installation of "swing-gates" permits passage of digging species such as aardvarks *Orycteropus afer* or warthogs *Phacochoerus africanus* (Schumann et al. 2006).

Advantages of Fencing as a Wildlife Management Tool

Ecological and Epidemiological Issues

Fencing and the Utilization of Small Habitat Fragments

With burgeoning human populations competing for land, natural habitat is becoming increasingly fragmented and patches of available habitat are shrinking in size (Norton-Griffiths 2007). Fencing permits the utilization of small habitat patches by reducing edge effects associated with wildlife moving out, or humans moving in to the area encompassed (edge effects are impacts imposed on organisms by the juxtaposition of human-modified landscapes on natural habitat (Murcia 1995)). Wildlife moving out of habitat patches is vulnerable to being hunted or being persecuted in response to human-wildlife conflict. Similarly, people moving into habitat patches can threaten wildlife through disturbance, hunting or by extracting crucial resources. By limiting movement of wildlife and people to and from small habitat patches, fencing can reduce the gradual loss of species from protected areas (Caro and Scholte 2007). Fencing has particular applicability to fertile, high rainfall areas which often have high densities of humans and fragmented natural habitat, and where the prevailing habitat types are under-represented in protected area networks (that were generally delineated on the basis of poor suitability for agriculture, Cumming 2004a). Fencing is also potentially useful for enhancing the prospects for the conservation of wide-ranging predators in habitat patches in which edge effects would otherwise cause local extinction (Woodroffe and Ginsberg 1998). In South Africa, for example, species such as wild dogs *Lycaon pictus*, cheetahs *Acinonyx jubatus*, lions *Panthera leo* and spotted hyenas *Crocuta crocuta* have been successfully reintroduced into a number of small, fenced reserves albeit with ongoing population and genetic management necessitated by virtue of restricted reserve size (Lindsey et al. 2005a; Hunter et al. 2007; Hayward and Somers 2009). However, while fences may impart benefits through reducing edge-effects on large-bodied animals, they may actually impose edge-effects on smaller species through mortality associated with entanglement and electrocution (discussed in detail below, Beck 2007). Counter-intuitively, fences may be to the disadvantage of certain species within protected areas by obliging them to compete for resources with other wild species within a restricted fenced area. An example of this is provided by the thriving population of suni antelope *Neotragus moschatus*, found in the KwaNgwenya Communal Area (in northern Zululand, South Africa) whereas the same species is markedly under-represented in the adjacent Kube Yini Private Game Reserve.

This discrepancy is plausibly due to the competition between suni and nyala, *Tragelaphus angasi* which are abundant within the reserve but rare or absent outside.

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. For example, fencing can be used to separate black rhinoceros bulls, which may otherwise suffer high mortality rates due to fighting (Hrabar and du Toit 2005). Fencing is sometimes used to create enclosures to protect locally rare ungulates such as roan antelope or tsessebe from predation and competition, as has been attempted in Kruger National Park (Grant et al. 2002). 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 by reducing post-release dispersal (Hofmeyr 2001).

Fencing can be used to protect sensitive habitats within wildlife areas from pressure from herbivores. In Addo Elephant National Park and Phinda Resource Reserve in South Africa, for example, fencing has been used to protect endemic plant species from impacts from elephants (Grant et al. 2007). Fencing is also used to protect individual trees and infrastructure such as windmills, taps or pipes from damage by elephants (Grant et al. 2007).

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). For example, fences 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 disease from buffaloes 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 have also been used to control transfer of other diseases, including corridor disease, rinderpest, African swine fever, contagious bovine pleuropneumonia, malignant catarrhal fever and trypanosomiasis (Taylor and 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. Conversely, with the formation of trans-frontier parks, wild animals are free to move across international boundaries, thus facilitating the cross-border spread of important restricted trans-boundary animal diseases. For example bovine tuberculosis is now known to have spread from buffaloes in Kruger National Park in South Africa to populations in Gonarezhou National park in Zimbabwe (Foggin 2008).

Social Issues

Fencing and Human-Wildlife Conflict

Well constructed and maintained electrified fencing represents an effective tool in limiting several forms of human-wildlife conflict. Most commonly, fencing is used to prevent the movement of animals from protected areas into adjacent agricultural lands. Fencing can permit the retention of wildlife or establishment of wildlife-based land uses in areas dominated by agriculture. For example, the 766 km^2 Aberdare National Park in Kenya is surrounded by high densities of humans practising small-scale agriculture, and fencing is crucial for controlling the movement of elephants from the park and permitting coexistence with neighbouring communities. In Savé Valley Conservancy in Zimbabwe, the removal of electrified fencing by settlers during land "reform" resulted in an upsurge in conflict and human fatalities caused by elephants due to movement of the species into adjacent agricultural areas (Lindsey et al. 2008).

In some cases, fencing is used to reduce human-wildlife conflict by creating enclaves of human activity within wildlife areas. For example, some villages in Niassa Game Reserve in Mozambique are fenced in to reduce crop raiding by elephants (Osborn and Anstey 2002). Similarly, the Masoka community in the Guruve area of Zimbabwe used donor funds to fence settlements, leaving the rest of their land for wildlife production in response to potential benefits from the CAMPFIRE programme (Taylor 2009). Similarly, in Kenyan pastoral lands, thorn "fences" enclosing livestock corral are effective at reducing losses of cattle and sheep to lions and spotted hyaenas (Ogada et al. 2003). In Namibia, electric fencing is used in some communal land conservancies to protect cattle from crocodiles *Crocodilus niloticus* at drinking sites on rivers (Lamarque et al. 2008).

Fencing and the Security of Wildlife Areas

Electrified fencing is used as a tool to restrict access to wildlife areas by people to reduce illegal extraction of natural resources and for security where crime is prevalent (such as in South African wildlife ranching areas). Fencing as an anti-poaching strategy is particularly important for areas containing high-risk, valuable wildlife such as black and white rhinoceroses. In addition to reducing access, cleared areas adjacent to fences enable fence patrols to scan for human and animal footprints crossing the 4–10 m open patch of ground generally maintained on the inside of fence lines. The same patch of open ground also plays a role in controlling fires by acting as a firebreak and may reduce the cross-fence transference of arthropod disease vectors such as the brown ear tick *Rhipicephalus appendiculatus*, the vector responsible for the transmission of Corridor Disease *Theilleria parva lawrencii* from buffalo to cattle. The brown ear tick is an "ambush tick" (as opposed to a "hunting tick") and thus is less likely to cross a fence with an adjacent cleared area than if vegetation grew right up to the fence on both sides.

The majority of fences present little hindrance to human's intent on entering an area. However, fences nonetheless clearly delineate legal boundaries to persons illegally entering wildlife reserves and if such people are apprehended within the fenced area they may then be liable to prosecution. In South Africa, for example, persons who cross into reserves at sites other than at designated entry points will be deemed to have read the indemnities, terms and conditions of entry displayed at such designated entry points in the case of such persons making claim for damages against landowners.

Financial Issues

Allocation of User Rights over Wildlife

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 (Boshoff 2008). Legislation requires that fences are present for landowners to effectively own wildlife in South Africa, Botswana, and Namibia (in the case of huntable and exotic wildlife) (Bond et al. 2004; Barnett and 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 of southern Africa by enabling landowners to benefit financially from wildlife. In Namibia and South Africa, for example, wildlife ranches comprise at least 288,000 km^2 (with 32,000 km^2 used exclusively for wildlife production [i.e. lacking livestock], Lindsey, 2011) and approximately 205,000 km^2 respectively (National Agricultural Marketing Council 2006).

Disadvantages of Fencing as a Wildlife Management Tool

There are a number of potential social, ecological and financial problems associated with the use of fencing as a conservation tool which must be considered by wildlife managers. They include the following issues.

Ecological and Epidemiological Issues

Fencing Inhibits 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 and 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). For example, meta-population management of wild dogs in a series of small reserves in South Africa has enabled the re-establishment of a viable population comprising several sub-populations in a network of small fenced reserves, and similar plans are in place for cheetahs (Davies-Mostert et al. 2009; Lindsey and Davies-Mostert 2009).

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 and Hobbs 2004). The veterinary fences of Botswana for example, reduced access of Burchell's 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 and Mbano 1988; Albertson 1998; Mbaiwa and Mbaiwa 2006). Fences in northern Botswana have been implicated in the decline of populations of species of conservation significance in the Caprivi Strip of Namibia, including tsessebe, sable antelope and roan antelope (Martin 2005). 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 and 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 (Lindsey et al. 2009). Perhaps most seriously, 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 2004b).

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 and Hobbs 2004; Hayward and Kerley 2009). For some wildlife, such as the white rhinoceros, 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 (Davies-Mostert et al. 2009; Hayward and Kerley 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 and kudu more frequently than is typical in the absence of fencing (van Dyk and Slotow 2003).

Similarly, fencing may increase the local impacts of wild dogs on prey populations during the time that they have puppies at a den site by preventing the return of prey to an area following departure of the pack (Romañach and Lindsey 2008).

Fencing and Disease Control Objectives

Fencing is effective at controlling diseases (e.g. corridor disease) that are transferred by non-flying arthropods. However, there is evidence that fences are not entirely effective at controlling diseases transferred by aerosol, such as foot-and-mouth disease and bonvine tuberculosis (Boone and Hobbs 2004; du Toit 2005). Though buffaloes, which are the primary maintenance host for foot-and-mouth disease are constrained by fences, other ungulates such as the impala, greater kudu and warthog frequently traverse fences. Data from Kruger National Park and from Zimbabwe indicate that 18.4% of antelopes and 7.8% of small wildlife species have antibodies to foot-and-mouth disease, indicating that there is risk of it being transferred to cattle outside of fenced wildlife areas when those species escape (Stutmoller 2002). Correspondingly, the foot-and-mouth disease fence in Zimbabwe has failed to prevent multiple outbreaks of the disease (du Toit 2005). The use of fencing to control tsetse fly and trypanosomiasis has become obsolete due to the development of the technique of using pesticides to control tsetse flies in the presence of wildlife populations (Taylor and Martin 1987).

Fencing and Animal Welfare Implications

Electrified fencing has implications for animal welfare due to the frequency with which small animals are entangled in fence lines and are killed either through electrocution or dehydration. Fencing may also prevent escape of animals from bush fires. In South Africa, a recent study conducted in a number of study areas (Fig. 12.1) over 2 years recorded 33 species (16 Mammals, 14 Reptiles and 3 Amphibians) killed due to entanglement or electrocution on fence lines. The mean mortality rate for reptiles was calculated to be 0.48 reptiles/km/year with the bulk of deaths occurring on electrified strands at heights of 50–200 mm (Beck 2007; Table 12.1). Chelonians appear to be particularly affected: one study recorded 52 tortoises being killed along a fence of 8.4 km during 132 days (Burger and Branch 1994), with 91% of all reptile mortalities involving the leopard tortoise *Geochelone pardalis*.

Social Issues

Negative Community Perceptions

The development of preservationist conservation strategies by colonial and post-colonial governments excluded rural people from the natural resources that they had

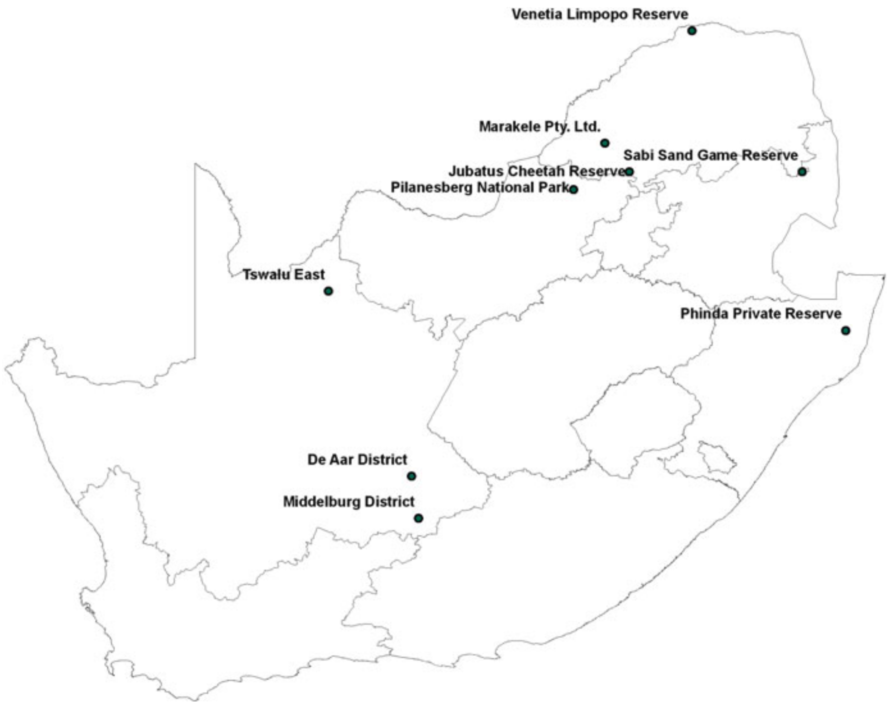

Fig. 12.1 Geographic location of the study areas in South Africa (Beck, unpublished data)

historically utilized (Els 2002). Wildlife fencing represented both a functional and symbolic barrier to local communities and became perceived by them as representing a negative, exclusive, imposition designed by wildlife authorities to protect wildlife with little consideration for human welfare (Spierenburg and Wels 2006). In Botswana, additional complaints of communities regarding fencing include the fact that it prevents the movement of wildlife into traditional hunting areas, and that fences have divided communities spatially, preventing interaction among family members (Albertson 1998). Though more recently, conservation efforts have aimed to "move beyond fences" and extend benefits from protected area management to neighbouring communities, negative perceptions persist in some areas (Spierenburg and 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.

Theft of Fencing Materials to Make Snares for the Bushmeat Trade

The use of wire snares to capture animals for illegal bush-meat is a major threat to wildlife populations in Africa (Noss 1998). Steel and barbed wire of the kind used to construct wildlife-fencing are ideal material for making snares, and thus, wildlife-

Table 12.1 Indigenous South African fauna killed or injured by electrified fences in all study areas between July 2007 and June 2008 (Beck, unpublished data)

Species	Common name	Rate of recurrence		
		Frequent	Infrequent	Occasional
Mammals				
Atelerix frontalis	South African hedgehog			*x*
Canis mesomelas	Black-backed jackal			*x*
Cephalopus natalensis	Red duiker			*x*
Crocuta crocuta	Spotted hyaena			*x*
Galago moholi	Lesser Bush-baby		*x*	
Genetta genetta	Small spotted genet		*x*	
Hystrix africaeaustralis	Porcupine	*x*		
Manis temminckii	Pangolin	*x*		
Mellivora capensis	Honey badger		*x*	
Oreotragus oreotragus	Klipspringer			*x*
Orycteropus afer	Aardvark		*x*	
Oryx gazella	Gemsbok			*x*
Otolemur crassicaudatus	Thick tailed bushbaby		*x*	
Phacochoerus africanus	Warthog		*x*	
Potamochoerus larvatus	Bushpig			*x*
Simia aethiops	Vervet monkey		*x*	
Reptilians				
Chameleo dilepis	Flap necked chameleon		*x*	
Dendroaspis polylepis	Black mamba			*x*
Dispholidus typus	Boomslang			*x*
Kinixys belliana	Bells hinged tortoise		*x*	
Kinixys lobatsiana	Lobatse hinged tortoise	*x*		
Pelomedusa subrufa	Marsh terrapin		*x*	
Philothamnus semivariegatus	Spotted bush snake			*x*
Psammobates oculiferus	Kalahari tent tortoise			*x*
Psammophis mossambicus	Olive grass snake			*x*
Psammophis subtaeniatus	Stripe-bellied sand snake Snake			*x*
Python natalensis	Southern African python	*x*		
Geochelone pardalis	Leopard tortoise	*x*		
Thelotornis capensis	Southern vine snake			*x*
Varanus albigularis	Rock monitor	*x*		
Amphibians				
Bufo pantherinus	Leopard toad			*x*
Pyxicephalus adspersus	Giant bullfrog		*x*	
Bufo rangeri	Raucous toad		*x*	

proof fences provide enormous quantities of potential snare material. In Savé Valley Conservancy for example, >84,000 snares were removed by anti-poaching teams during an 8-year period, most of which were comprised of wire stolen from the fence (Lindsey et al. 2011). In parts of Africa where wire is less readily available, poachers are forced to use alternative methods which may be easier to control. In central Mozambique for example, poachers use steel gin traps which if confiscated by anti-poaching scouts are costly to replace (Lindsey et al. 2011). In the Zululand region of KwaZulu-Natal in South Africa, most ranchers use mesh Bonnox fencing for various practical reasons including the fact that meshed fencing is less conducive to snare construction than steel wire (Lindsey et al. 2005b).

Financial Issues

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. 2005b). By contrast, where neighbouring wildlife ranchers have removed internal fencing to create conservancies, the full complement of mammal fauna can be reintroduced, and more profitable land uses such as high-end ecotourism, and “big game” trophy hunting can be practised. In conservancies, several of the conservation problems inherent with small fenced ranches (e.g. persecution of predators, over-stocking of ungulates, unethical hunting practices) generally fall away and natural ecological processes are allowed to recover (Lindsey et al. 2009).

The Cost of Constructing and Maintaining Wildlife-Proof Fences

In Kenya, the 3.3 m tall electrified perimeter fence surrounding Aberdare National Park cost ~US $20,000/km to construct (Lamarque et al. 2008). Wildlife-proof fencing in South Africa currently costs approximately US $4,500–6,500/km for mesh fencing designed to contain antelopes and US $5,250–7,250/km for predator-proof fencing (Masterson, unpublished data). Costs are significantly influenced by the terrain (costs may be double for mountainous vs. flat terrain), the shape of the ranch/reserve and whether or not public roads are present which may require fencing.

Fence maintenance is also costly: in South Africa, on a reserve with 100 km of fencing, fence maintenance costs are likely to be ~US $32,000/year (Masterson, unpublished data). Following rainfall, gaps often appear under fences along erosion gulleys or stream beds and fences are frequently bridged by species such as warthogs, porcupines and aardvarks which burrow under the bottom wire creating gaps for other animals to pass through. These breaches in security impose intensive and costly maintenance requirements. Maintenance costs can be reduced by installing swing-gates, concrete drainpipes or old vehicle tyres to allow passage of warthogs, aardvarks and other “fence-challengers” (van Rooyen et al. 2002) provided that no large predators are meant to be contained by the fence. The costs per km of maintaining fencing are likely to be higher on smaller reserves, due to the loss of economies of scale associated with fixed costs such as vehicle purchase.

The components of electrified fencing (such as solar panels, batteries, chargers and fence wire) are valuable and vulnerable to theft, which affects fence integrity and efficacy. In Kruger National Park, for example, break outs of elephants through the fence have been attributed to vandalism and theft from the fence (Grant et al. 2007). Due to the expenditure and diligence required for maintenance, fencing can be quickly compromised under conditions of political instability as has occurred in Zimbabwe recently (Lindsey et al. 2009).

In southern Africa, the expense of fencing is justified by the fact that wildlife is a valuable, tradable asset. In most of the rest of Africa, ownership of wildlife is retained by the state and such value does not exist. Furthermore, most African countries are grappling with severe funding shortages for protected area networks, and many lack the finance to provide anything more than nominal protection for parks (Wilkie et al. 2001; Child et al. 2004). As a result, outside southern Africa, the use of fencing is restricted to a handful of smaller parks and areas experiencing severe human-wildlife conflict.

Fencing as a Conservation Tool

In light of the problems and limitations that are commonly associated with fencing, we outline several issues that should be considered when designing conservation strategies involving fences:

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 fencing employed per unit area. A practical means of achieving this is through the creation of transfrontier conservation areas whereby fences are removed between protected areas occurring on the borders of adjacent countries. For example, fences have been removed between the Kruger National Park in South Africa and Limpopo National Park in Mozambique, which will ultimately be linked with Gonarezhou National Park in Zimbabwe to create a single large (35,000 km^2) protected area, the Great Limpopo Transfrontier Park. Even fenced parks as large as Kruger (20,000 km^2) have suffered population declines related to isolation (Hayward and Kerley 2009). Creating linkages with adjacent parks may limit the occurrence of such trends in future. On private land, similar ecological benefits can be achieved through the creation of 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 which are more closely aligned with conservation objectives than the high off-take meat hunting typical of small, fenced ranches (Lindsey et al. 2009). National governments should consider repealing legislation which requires perimeter fencing to be present for landowners to own/utilize wildlife. In Zimbabwe, land owners are not required by law to have perimeter fencing on their property, and consequently, fencing was less prevalent in wildlife ranching areas than in South Africa, creating more open ecological systems with a lower prevalence of the problems associated with fenced wildlife ranching. Conservancies containing charismatic mega fauna attract ecotourists and have potential to generate significant foreign currency income, 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 equitable access among neighbouring ranchers to the mobile resource, and which take into account and address differential initial investments in wildlife. The development of such agreements can effectively remove the need for physical barriers between adjacent wildlife ranches.

2. Re-thinking fences for veterinary purposes

A re-think of the strategy of fencing for veterinary purposes is required. Veterinary fences in Botswana have resulted in high mortalities of wildlife due to the disruption of migration routes. Moreover, in several southern African countries, restrictions imposed by veterinary fencing severely limit the profitability of wildlife-based land uses (Albertson 1998; du Toit 2005; Mbaiwa and Mbaiwa 2006). Efforts of southern African countries to develop foot-and-mouth disease-free zones preclude the reintroduction of buffalo over large areas. Buffaloes are the most important species for generating income from trophy hunting as they can be hunted in relatively large numbers, they command high trophy fees and daily hunting rates, and are used to sell hunting packages (du Toit 2005; Lindsey et al. 2007). On Namibian wildlife ranches, and most communal land conservancies, the reintroduction of buffalo is precluded by veterinary restrictions (Lindsey et al. 2011). As a result, hunting safaris on private land in Namibia target almost entirely of low-value "plains game" hunts (Humavindu and Barnes 2003; Lindsey et al. 2007) reducing income significantly relative to what could be achieved if buffalo reintroductions were permitted. Veterinary fencing is typically supported by state or international funding, whereas the benefits accrue to private beef producers. Such subsidies artificially inflate the profitability of livestock-based land uses (Scoones & Wolmer 2008), while undermining wildlife-based land uses through associated restrictions on buffalo reintroductions and translocation of other species (Lindsey 2011). The advisability of these subsidies is declining in some cases as the profitability and productivity of livestock production appears to be waning in some areas. For example, the livestock industry in Botswana now acts as a net drain to the treasury (McLaughlin 2010). Similarly, in Botswana, the beef export industry is supported by subsidies from the European Union, providing livestock production with an unfair advantage over wildlife-based land uses and promoting continued erection and maintenance of veterinary fences. Furthermore, tourism (relying largely on wildlife) has already exceeded beef production in its contribution to Gross Domestic Product, and would increase further in profitability if veterinary fences were removed and wildlife populations allowed to recover (Mbaiwa and Mbaiwa 2006). Research is required to compare the profitability of livestock farming vs. potential returns from wildlife-based land uses unhindered by veterinary restrictions to assess the appropriateness of current foot-and-mouth disease control policies. Such a review would determine whether the promotion of wildlife-based land uses through an expansion of foot-and-mouth disease endemic zones was justified in economic terms. In Zimbabwe, for example, several authors have suggested that the foot-and-mouth disease fence in the South East of the country could be realigned to create a larger foot-and-mouth disease zone without adversely affecting potential for beef exports (Taylor and Martin 1987; du Toit 2005).

Ideally, alternative strategies for the control of wildlife-borne diseases are required which do not impose limitations on the development of wildlife-based land uses. One option would be to create protected enclaves for livestock from which wildlife is excluded and where wildlife diseases are strictly controlled, while allowing unfettered development of wildlife-based land uses elsewhere (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 foot-and-mouth disease virus (e.g. 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).

Where fences will continue to be used to control diseases, it is important that the design of fence employed in disease control be appropriate to contain the applicable animal hosts of that disease. For example, a fence aimed at restriction of African Swine Fever should be constructed in such a way as to be pig-proof and would not need to be higher than 1 m whereas a fence to contain foot-and-mouth disease within a wildlife area should incorporate a corridor to prevent direct contact between animals on either side of the fence as well as being appropriate to contain all cloven-hoofed wildlife (i.e. being pig and "digger" proof at the bottom while being high enough to contain "jumpers").

3. Adequate environmental and social impact assessments

Environmental and social impact-assessments should be a legal prerequisite for the development of fences for conservation purposes in all African nations (as is already the case in South Africa), a process that would ensure that the more obvious problems associated with fences are avoided. Had environmental impact assessments been conducted prior to the construction of veterinary control fences in Botswana, for example, wildlife die-offs may have been avoided by employing different fence designs or alignments, or by advising alternative veterinary control strategies (Albertson 1998).

The erection of fences around wildlife areas adjacent to rural communities should only occur following consultation with and acceptance from those communities. Fences are more likely to be accepted if efforts are made to provide communities with a stake in the management and use of wildlife and of the fence line. Employment opportunities for communities can be created in this way. Similarly, allocating shareholdings in protected areas to communities have the potential to increase tolerance of fences. In Kenya, wildlife populations in protected areas with outreach programmes involving adjacent rural communities performed better than those in parks lacking such efforts (Western et al. 2009). Community stake holdings in protected areas could be achieved by moving fences out to incorporate community land, as was recently done along the southern border of Savé Valley Conservancy in Zimbabwe (Lindsey et al. 2009). Alternatively, by engaging in co-management agreements with communities, park agencies could improve neighbour relations and effectively reduce the negative symbolism of fences. For example, in South Africa, South African National Parks have engaged in agreements with several communities to form contractual parks within existing national parks (e.g. Kruger and Kgalagadi) following successful land claims from communities evicted from by the apartheid government (Grossman and Holden 2009). Similar models have potential to extend benefits "beyond fences" in other countries where rural communities were dispossessed of land during the creation of parks and game reserves.

4. Re-designing of wildlife-proof fences

All wildlife proof fences should be designed to minimize the loss of wild animals due to entanglement or electrocution. For example, Burger and Branch (1994) recommend that the lowest electrified wire should be positioned at ≥250 mm above the ground to minimize tortoise mortality. Such a placement may also minimize the extent to which the fences are damaged by warthogs, aardvarks and porcupines, but would mean that predators and smaller species would not be effectively contained. Beck (2007) suggests the following additional modifications:

- The lowest electrified strand be offset by at least 400 mm to reduce the likelihood of tortoises being trapped between the mesh fence and an electrified strand.
- Where possible, rock-packed aprons should be used instead of low-level trip wires to reduce tortoise mortality.
- If low-level trip wires must be used, then a paired earth wire should be offset by an additional 100 mm to prevent direct contact with the live wire.

The frequency with which fences are challenged (and that entanglements occur) can be reduced by increasing the visibility of the fence by using wire of at least

2.5 mm diameter, and attaching objects such as cans or sheet material to the fence (du Toit 2005) as well as by avoiding construction of acute corners in fences. Finally, care is required when constructing fences to ensure that the material used cannot readily be made into snares, especially in areas where the supply of metallic wire is limited.

Conclusions

Fencing is an important tool in the management of wildlife and one that has played a significant role in the development of wildlife-based land uses in southern Africa. Furthermore, fencing is likely to become increasingly important as human populations continue to encroach on wildlife areas and habitats become more fragmented. However, due to financial constraints, fencing is likely to be of limited applicability in many countries in Africa. In addition, there are a number of conservation problems that can result from the improper use of fencing. Cognizance of all ecological, financial and social issues related to fences during planning can reduce problems and optimize conservation and economic gains achieved. Conservation planners should aim to achieve maximum gain with the minimum use of fencing, conduct thorough environmental and social impact assessments before establishing a fence, obtain support from local people, and give careful consideration to the alignment and type of fencing to be used.

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