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CONTROLLING THE DISTRIBUTION OF ELEPHANTS

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> The general impression left on my mind was that, with civilization closing in on all sides, ultimately something must be done to segregate the game areas from those used for farming; otherwise sooner or later some excuse for liquidation of the wild animals will be found … North of the Letaba River the country West of the Park consists mainly of native locations and areas. Here the Park itself might be fenced off.
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> Of course, a suitable fence over 200 miles long would be a most expensive undertaking, and its upkeep considerable. It would have to traverse all kinds of country, including stony hill ranges, and dense bush, but to my mind one of the chief difficulties would lie in the wide sand rivers running from west to east, and subject to annual heavy floods, which would carry away any kind of fence, and on their subsidence leave the way open for animals to pass freely up and down the river bed.
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> J Stevenson-Hamilton, 23 January 1946, *Annual Report of Warden, Kruger National Park – 1945* (National Parks Board of Trustees, 1946, pp. 11–12)

INTRODUCTION

THE CONTAINMENT of elephants is an important aspect of their management when and where control of their movements is required. Physical barriers such as fences are passive control measures (Cumming & Jones, 2005) and are often seen as the most effective approach to containing elephants. Fences are not the only way to influence the distribution of elephants, however. Several other options are discussed in this chapter, including deterrents, water manipulation and behavioural manipulation. There are several reasons for the containment of wildlife, and particularly elephants. One is animal disease control (Freitag-Ronaldson & Foxcroft, 2003) – to protect livestock from wildlife-associated diseases, and also to protect wildlife from diseases of domestic species. Containment is a second important reason for fencing – to protect neighbouring communities and infrastructure from damage (especially by elephants and predators). Furthermore, by fencing a property, ownership of the species present is established and animals are somewhat protected from illegal hunting (see detailed discussion of this issue in Chapter 11).

PURPOSE OF FENCING

The containment of wildlife

Many small wildlife areas in South Africa are distributed amongst farms and villages with people, domestic stock and crops. This often leads to conflict between humans and elephants (Chapter 4). Fences allow people and elephants to share a landscape without the problems associated with this conflict (Hoare, 2001) (Chapter 4). To achieve this fences have to be upgraded to be able to contain the wildlife and elephant when elephant are included in a wildlife area (Chapter 11). Relatively small conservation areas located within agricultural areas require very efficient and sturdy fencing to avoid conflict. The legal requirements stipulated for such fences are described in various acts, for example the Animal Diseases Act 35 of 1984 and the National Environmental Management: Biodiversity (NEMBA) Act 10 of 2004 (Chapter 11).

Only in southern Africa, and South Africa in particular, does fencing play a large role in the wildlife and conservation industry (South African Savannas Network, 2001). In most other parts of Africa the national parks and game reserves have never been fenced, and yet seek to maintain and support wildlife populations. In addition, many of these conservation areas also seasonally support pastoralists. These communities had to adapt to the activities of their wild neighbours, and many types of localised (village level) physical barriers and deterrents (thorn bomas and ditches), as well as noise and smell, have been used to protect crops and livestock.

The wildlife industry in southern Africa has greatly expanded since the early 1980s (Smith & Wilson, 2002; South African Savannas Network, 2001). Much of this expansion took place in the middle of existing agricultural areas, or close to community settlements. Furthermore, while most of the remaining large wildlife used to be conserved in the larger national and provincial parks, smaller private reserves and game farms are playing an increasingly important role in the conservation of individual species and in ecotourism related to the presence of these species.

It is the responsibility of the landowner or manager of the particular conservation area, whether state- or privately-owned, to ensure that the animals they keep in the conservation areas do not interfere with neighbouring communities' livelihoods, including damage to their property or crops. The landowner has a legal obligation to all adjacent owners for damage that escaped animals can cause, as well as public liability in case of death or injuries or damage to property in the event of the animals breaking through the perimeter fence (Chapter 11).

Disease control

Elephants can be the major cause of fence breakages that allow the mingling of wildlife and livestock populations. Thus, although elephants do not carry these diseases, they are instrumental in their spread.

Diseases that can be transmitted from wildlife to domestic stock

Certain indigenous animal diseases carried and maintained by wild animals can be highly infectious to livestock and constitute a threat to the livestock industry. In southern Africa, the use of fencing (and other disease control measures such as proclamation of animal disease control zones, and permit requirements) to strictly control the movement of wildlife and livestock has enabled access to beef and other livestock markets in Europe and elsewhere in the developed world. Directly contagious diseases such as rinderpest, foot-and-mouth disease (FMD) and malignant catarrhal fever as well as diseases transmitted by flightless vectors such as African swine fever and corridor disease (theileriosis) can be effectively managed by barrier fencing (Bengis *et al.*, 2002). In contrast, barrier fences are ineffectual when dealing with diseases transmitted by winged vectors, such as trypanosomiasis, African horse sickness, bluetongue and Rift Valley fever.

FMD, rinderpest and African swine fever have the potential for very rapid spread, and are listed by the Organisation International Epizooties (OIE = World Organisation for Animal Health) as important animal health threats, because these diseases may have serious local, national and international animal health implications. These diseases not only cause local losses during outbreaks, but due to their epidemic character, they can become international in nature with serious socio-economic consequences.

In southern Africa, buffalo constitute the greatest risk in disease transfer to domestic livestock. They carry several diseases that affect livestock, including FMD, corridor disease, bovine tuberculosis and brucellosis. The Animal Diseases Act (35 of 1984) highlights specific responsibilities of owners or managers of properties with buffalo, including effective containment.

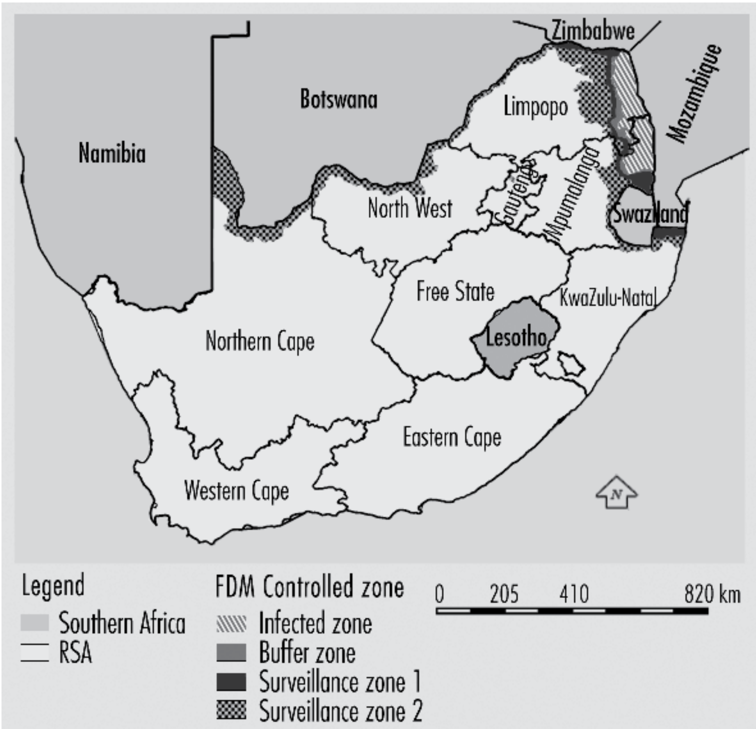

Figure 1: A map indicating the foot-and-mouth disease control areas in South Africa. Elephant-caused fence breakages on the boundary of these areas have serious consequences for disease control

In South Africa, FMD only occurs in the lowveld buffalo population (figure 1) of Mpumalanga and Limpopo provinces. This highly contagious 'trade sensitive' disease is therefore controlled by law (Standing Regulations of the Animal Diseases Act 35 of 1984) and was one of the major reasons for the erection of the animal disease control fence on the western and southern boundaries of Kruger by the Department of Agriculture in 1961–1963. At that time, the fence was constructed to contain cloven-hooved ungulates, including buffalo. Elephants (at that time) were present in relatively low numbers (population

Box 1: Diseases that can be transmitted from domestic stock to wildlife

Certain animal diseases can also spread from domestic animals to wildlife and constitute a threat to conservation efforts. A current example is bovine tuberculosis (BTB), which is considered an alien infection, and which entered the Kruger ecosystem relatively recently (about 1960). Indications are that it entered the Kruger across the southern boundary, from infected domestic cattle herds on two farms bordering the Crocodile River, just north of Hectorspruit. From there, the infection spread amongst the southern buffalo herds in the 1980s, and then progressed through the central district buffalo population in the 1990s, finally reaching the northernmost buffalo herds in the Levubu/ Limpopo drainage in 2005. To date, spillover infection from buffalo has been documented in other sympatric species such as lion, leopard, kudu, warthog baboon, hyaena, cheetah, bushbuck, honey badger and genet (Keet *et al.*, 1996; Bengis *et al.*, 2001; Keet *et al.*, 2001). Although buffalo appear to be the main maintenance host of BTB in this ecosystem (De Vos *et al.*, 2001), recent indications are that kudu and warthog may also act as long-term maintenance hosts, and lions may act as short- to medium-term maintenance hosts.

There are also several viral infections that can spread from domestic stock to wildlife, including rinderpest, rabies, and canine distemper (Anderson, 1995). Historically, rinderpest, which is an alien viral infection, was introduced from Asia to the Horn of Africa with a shipment of cattle in 1888. This disease then rapidly spread westwards and southwards and killed millions of cattle and untold numbers of cloven hoofed wildlife in Africa. Many of the current distribution anomalies of certain African ungulates may have resulted from this pandemic. This disease eventually dissipated in 1902, and in more recent years, it has sporadically re-occurred in equatorial and eastern Africa.

Canine distemper, a disease of domestic dogs, is a threat to free-ranging carnivores, particularly small populations of endangered and susceptible species. In addition, canine rabies remains an ever-present threat to social wild carnivores and kudu.

estimate around 3 000), especially in the southern and central districts, with minimal pressure on the fences. The fences that were erected were 1.8 m high, consisting of 10 strands of barbed wire with no electrification (that technology did not yet exist), and were found to be adequate to prevent the movement of most ungulates. After the erection of these fences, the number of outbreaks of FMD in neighbouring cattle fell progressively, and not a single outbreak was detected in livestock adjacent to Kruger during the period 1983–1999.

Since the 1994 moratorium on lethal elephant population management in Kruger, the total elephant population has almost doubled (figure 2), and pressure on the Kruger fences has increased significantly. As an inferred result, during the period 2000–2006, five outbreaks of FMD have occurred in cattle adjacent to Kruger, four of which could be directly linked to buffalo escaping through fence breaks. This in spite of the fact that the fences had been upgraded to a 2.4 m, 20 strand fence electrified at 5 levels. However, many of these breaks probably occurred where electrification was not functioning properly. This can be attributed to poor quality of the fence workmanship and poor maintenance. Theft and vandalism have also played a role in providing opportunities for animals to escape from KNP. In addition to solar panels, fence wire, batteries, chargers, fencing standards, and droppers have also been stolen from the fence, rendering it ineffective.

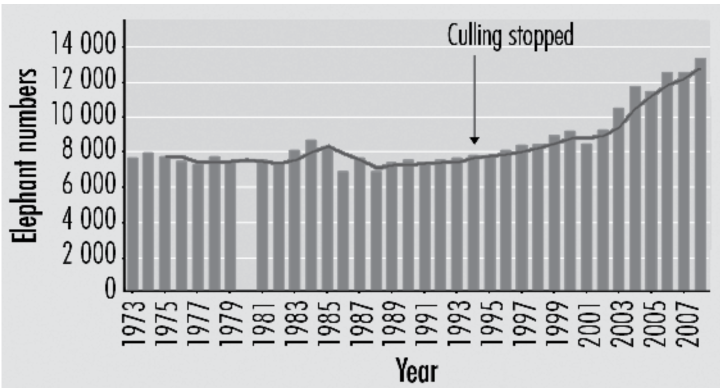

Figure 2: Elephant population numbers in the Kruger National Park between 1972 and 2007. The line represents the three point moving average to show the trend in population increase

Protection of livestock and crops

With increasing densities of elephants and depletion of natural foods in conservation areas (Smith & Kasiki, 2000), especially during dry seasons, the pressure for elephants to break out and look for more nutritious food sources increases (Naughton-Treves, 1998; O'Connell-Rodwell *et al.*, 2000). Most of the fence breaks are caused by single bulls that are brazen and strong enough to break the fence. Often conflicts with expanding human habitation displace elephants which then become dependent on crop-raiding to survive in resource-poor habitats (Tchamba, 1995). Cultivated crops are the perfect attractant for elephants; they are often highly nutritious (grains), and/or taste good (fruits and vegetables). The result is that elephants become crop raiders (Wasilwa, 2003) (see also figure 3).

Figure 3: Maize, inter-cropped with pumpkin and beans, cultivated adjacent to KNP fence near Altein village. Note elephant path leading from KNP (foreground) towards crop (photo courtesy of Brandon Anthony)

Taylor (1994) reported that fences can decrease the incidence of crop-raiding. In Negande (Zimbabwe), crop-raiding incidents dropped by 65 per cent after the erection of an elephant-proof fence but rose again by 42 per cent the following season, indicating that under specific circumstances, fences are not very effective in reducing crop losses. A small circular fence erected around irrigated crops was also successful in avoiding crop loss. However, in spite of agreeing to the project, villagers were reluctant to maintain the fence after the first success. The net economic benefit of the erection of elephant-proof fences is questionable. The main benefit may be that fewer animals are killed because of causing damage.

Thus farming of crops and livestock in areas which contain free-ranging elephants and lions (fence breaks by elephants facilitates the escape of lions) results in increased human-wildlife conflict. In arid environments, communal agricultural activity is concentrated along riparian zones. These zones are also favoured by elephants.

Elephant habitat expansion corridors will increase the human contact interface. In most situations, such corridors will need to be fenced. Where elephants have learned to avoid contact with humans, fencing corridors may pose an unnecessary expense. Douglas-Hamilton *et al.* (2005) found that elephants crossed corridors at significantly faster travelling speeds and during the cover of darkness to avoid conflict with humans. These results indicate that elephants are aware of danger within a space and time context. Consequently, where corridors are short enough to enable overnight travel from food and water sources within protected areas and where disturbance mechanisms are present that would prevent elephants from lingering along corridors, movement across corridors will likely occur with minimal incidents of conflict with people. However, the value of unfenced corridors to other animals is still not understood and requires further investigation.

In smaller protected areas that have elephants (e.g. Addo), more substantial and robust fences are needed because the rate of contact of elephants with the fence increases as the length of the fence decreases. This type of fence does not have to be electrified to be effective if the animals are trained to respect the fence (Anderson, 1994). Simple electric fences with only three strands and a voltage of 5.5 kV have been successful in controlling damage-causing animals in Mwea District, Kenya. This required very active community involvement and a full-time fence attendant, paid by a development agency (Omondi *et al.*, 2004).

CONSEQUENCES OF FENCE BREAKAGES

Over and above the negative consequences that elephant breakouts may have due to crop-raiding, or creating conduits for large carnivores or disease-carrying wildlife to exit protected areas (as discussed above), there are several other consequences.

Loss of animals

Animals that escape from conservation areas, including those considered dangerous, have to be returned to the conservation area, or destroyed where they are. In the case of elephants, the costs can be high (Lubow, 1996). The capture and transport of elephants needs specialised equipment, helicopters and vets experienced in elephant capture to be a success (Nelson *et al.*, 2003). If the elephants are close enough to the conservation area, they can be chased back (Hoare, 2001); a helicopter is usually necessary for this to succeed. The more common option is to destroy the animal/s (SANParks, 2005).

Several reserves which have elephant also have expensive, rare or endangered species including rhino, roan, sable, and tsessebe. These species have usually been introduced at great expense to the reserves, and although these species would seldom cross fences themselves, they can escape through fences damaged by elephants.

DOMESTIC STOCK ENTERING WILDLIFE AREAS

Economic impacts

Domestic stock entering wildlife areas, especially those aimed at tourism, can have a negative effect on the product on offer. Studies done in the Zambezi valley named wild animal species roaming free, indigenous plant species and lack of people as important factors in the perception of the tourist of an area to be wild. Pollution, litter, vehicles, noise, and the presence of domestic animals are factors that negatively influence tourists' perceptions of wilderness (Wynn, 2003) (see also figure 4 below).

OTHER USES OF FENCES IN CONSERVATION AREAS

Protection of vegetation

In Addo, exclosure fencing has been used effectively to protect endemic plants from utilisation by elephants. Five botanical reserves were identified within the Park which would represent 91 per cent of the Park's special plant species in less than 8 per cent of its area (Lombard *et al.*, 2001). Mature plants within such enclosures can then act as valuable seed banks to populate surrounding areas (Western & Muitumo, 2004).

Figure 4: Three head of cattle approximately 30 km within KNP, east of Hlomela village (October 2004). It was later discovered that these were part of a stolen herd that was being taken through KNP to Mozambique. Lions killed one of these animals, and the remaining two were killed by KNP rangers to control the threat of disease transfer (photo courtesy of Brandon Anthony)

Understanding system function

Enclosures have been very useful in studies of the effect of browsers and grazers on selected areas in Kruger. This information is essential for management decisions such as avoiding mistakenly controlling elephant populations to address impact concerns that they are not responsible for. Differences between areas inside and outside the enclosure help to understand the effect of elephant on the vegetation (Trollope *et al.*, 1998).

Enclosures are also useful to develop an understanding of the time needed for different plant types to recover after heavy use by elephant and other browsers (African Elephant Specialist Group Meeting, 1993). In Addo, such enclosures have contributed substantially to our understanding of how the thicket vegetation responds to elephant use (Kerley & Landman, 2006) (Chapter 3).

Protection of individual trees

Individual large trees can be physically protected from elephants. In East Africa and in the Associated Private Nature Reserves (APNR) on the western boundary of Kruger, 13 mm mesh wire netting wrapped around the trunk of mature tree stems has prevented such trees from being extensively bark stripped by elephants (Gordon, 2003; Henley & Henley, 2007) (figure 5). Heavy wire netting was more efficient in protecting trees against debarking and required less maintenance but was also more visible than 13 mm mesh wire at distances further than 5 m from the protected tree. Wire netting techniques did not protect trees from being uprooted or broken. Results from these studies indicate that the absolute use or avoidance of protected trees may not be as important as the degree to which the wire-netting reduces bark-stripping and consequently increases the survival rate of trees that are susceptible to bark-stripping by elephants.

Figure 5: Wire netting can be used to protect large trees from ring barking. It does not stop trees from being pushed over or broken (photos from Mapungubwe National Park)

Protection of infrastructure and people

Sturdy fences have been specifically designed to protect infrastructure such as water tanks, pipelines, windmills, dams, weirs, and buildings from elephants. In addition, tourist facilities, aircraft, and landing fields need barrier protection.

In the Mwea region of Kenya, an electric fence was erected to separate people and elephants. Before fence construction, an average of three people were killed yearly by elephants. Since the fence was completed, no elephant-related deaths have been reported (Omondi et al., 2004).

EFFICACY OF FENCES

To contain elephants

The long-term existence of small wildlife areas will probably depend on the efficacy of barriers to prevent animals escaping. Well-maintained fencing, especially electric fencing, appears to be the most effective barrier to restrict movement for most of the larger wildlife species (Nelson *et al.*, 2007). Elephants are capable of going through the most sophisticated barriers, including fences that are highly electrified, although this is often associated with a break in the electric current (figure 6). Elephants in particular are difficult to restrict as a result of their large size and the ease with which they can break fences, which make them the most important fence-breaking species (SANParks, 2005) (also see figure 7). Their home ranges are large, and migration and movement patterns often extend not only beyond park or reserve boundaries, but national boundaries as well (Craig, 1997) (Chapter 2).

Elephants most often cross fences because of the availability of water and food in adjacent areas (Buss, 1961). Studies on crop-raiding by elephants at Kibale Forest National Park, Uganda, showed that crop-raiding occurred throughout the year with peaks in dry seasons when crop availability was high. Bananas and maize were the main crops raided. Monthly crop-raiding incidences were not influenced by forage quality but by ripening of maize. Crop availability seems to be a more important driver of elephant breakages in forest habitats, whereas in savanna habitats large seasonal fluctuations in forage quality have a greater influence on temporal patterns of crop-raiding (Chiyo *et al.*, 2005). Osborn (2004) also found that the point at which the quality of the available forage declined below the quality of crop species corresponded to the movement of bull elephants out of a protected area and into fields. However there are differences in the behaviour of bulls and cows towards fences – bulls tend to be more inclined to break fences than females (Sakumar & Gadgil, 1988). Breakages in the Kruger fence in Limpopo Province in South Africa are illustrated in figure 7 and seem to also coincide with periods when forage may be scarce in the park.

Figure 6: Male elephant returning to KNP over border fence (photo courtesy of Peter Scott)

There seems to be a spatial and temporal correlation between elephant densities and the number of fence breaks. The elephant population of Kruger has almost doubled since 1995 when culling stopped. Using the incomplete reports available, Anthony (2006) recorded 386 incidents of damage-causing animals in the area between the Shingwedzi and Klein Letaba rivers between October 1998 and October 2004 (figure 7). Elephants caused 55 of these incidents and eight reports indicate that elephants were destroyed. The most common problem animals were buffaloes (137), lions (72), elephants (55), hippopotamuses (33) and crocodiles (18). It is important to note that many of the problem buffaloes, lions and even hippos probably exited through elephant fence breaks.

Standard electric fences work well to protect small areas for experimental purposes or to protect infrastructure. The maintenance of the fence is essential (see box 2). Breakages are relatively rare and breakages that did occur into these enclosures were due to failure of the electric fencing.

Box 2: The maintenance of fences

Fences need to be permanently maintained to restrict elephant movement effectively. Once elephants realise that they can cross a barrier they will be more inclined to repeat the effort. Thus the maintenance of fences must be financially and technologically within the capacities of the people maintaining them, if they are to be long-term solutions (Kangwana, 1995). Studies in Laikipia, Kenya, confirmed this statement and found that there was no clear relationship between the effectiveness of fences and their design and construction. Some simple fences worked, some high-tech fences (including high-voltage electric fencing) did not. Fences built to keep elephants and people apart may only be efficient if their construction follows a particular process which imbues a clear sense of common ownership and responsibility (Dublin *et al.*, 1997). This aspect is very important, as some communities rather remove parts of the fencing material to use around their homesteads, while others may cut the fence to gain entry into the wildlife areas. Nevertheless, in South Africa and in some parts of Zimbabwe, fencing is used fairly effectively to contain elephants within protected areas.

The integrity of the Kruger Park western boundary fence is regularly compromised by certain human activities. These include:

- sabotage of the electrification by illegal transmigrants from neighbouring countries
- theft of electrical components, especially solar panels and batteries
- theft of structural components and material for own use or for sale.

Thus in areas where there are significant human pressures on the fence, and in areas where cable (Eskom) power is unavailable, electrification is not a good option because electric fences are easily sabotaged and solar panels and batteries have a high theft potential. In such situations, a more robust structure made of cables and 'I' beams that is elephant resistant but people friendly is a better option.

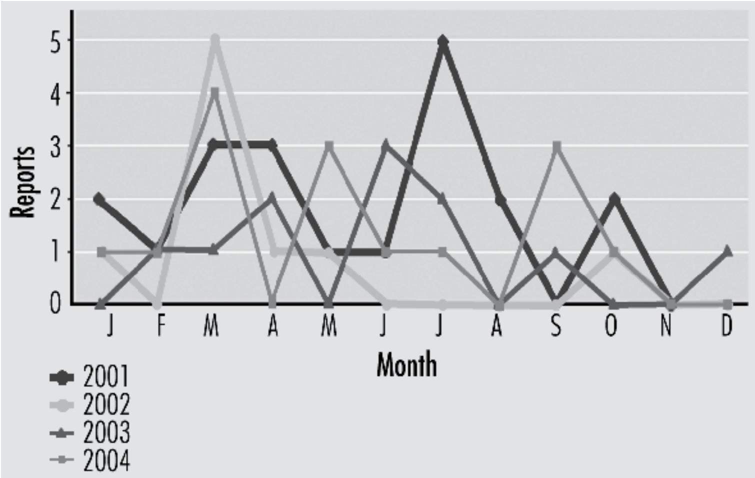

Figure 7: Reports of elephant breakages of fences between Kruger and the Limpopo province from January 2001 to October 2004 (Anthony, 2006)

Disease control

Between 1983 and 1999, the elephant density in Kruger was relatively low (about 0.4 elephant.km^{-2}) and in that period no outbreaks of FMD were detected in livestock adjacent to the park. Fence-breaking bulls and problem peripheral herds were frequently targeted as part of problem animal and border control management. Therefore during this period, elephant fence-breaking activities were sporadic and rapidly dealt with.

However with the increasing elephant density (0.46–0.62 elephant.km^{-2} between 2000 and 2006), five major FMD outbreaks occurred in the adjacent livestock populations. Four of these outbreaks (Bushbuckridge 2001, Masisi 2003, Mopani 2004, and Thulamela 2006) could be linked directly to buffalo exiting Kruger through fence breaks.

The Bushbuckridge outbreak cost the tax payer ZAR20 million, the Masisi outbreak cost ZAR4 million, and the Mopani outbreak cost ZAR90 million to control. Mass vaccination in and around the outbreak as well as road blocks and the erection of additional cordons and barrier fences were necessary to avoid the further spread of the disease. Further costs of such outbreaks include indirect costs to farmers due to movement restrictions on agricultural products. Additional financial losses would have been incurred if the outbreak had not been contained within the declared FMD control area, as a result of trade barriers and millions of rand (ZAR) lost in export earnings.

There has been a striking spatial and temporal correlation between the number of elephant fence breaks and the number of vagrant buffalo incidents (State Veterinarian – Skukuza, quarterly reports 2005–2007). There is also a temporal correlation between the number of fence breaks and elephant densities. In the winter of 2005, up to 35 elephant fence breaks were recorded per day in the 12 km section of fence stretching from Sawutini to Naladzi (State Veterinarian – second quarterly report 2005). These elephants were breaking out to drink and bathe in one of the few remaining pools in the Klein Letaba River.

Sporadic outbreaks of other wildlife diseases in livestock are under-reported, because local communities frequently consume the carcasses, and no diagnosis can be made.

Corridor disease (theileriosis), with close to 100 per cent mortality of infected cattle, was also sporadically reported in areas where buffaloes crossed fences broken by elephants and dropped infected ticks (Skukuza, Nelspruit & Mkhuhlu State Veterinary Reports, 2006; 2007; 2008).

To give an idea of the potential scale of African swine fever outbreaks, one that was well documented in southern Mozambique in 1997 resulted in the deaths of an estimated 180 000 pigs (Penrith pers. com.).

CONSEQUENCES OF RESTRICTION OF MOVEMENT BY FENCES

In the African context restriction of elephant movement is generally a result of human encroachment or habitat change (Hoare & Du Toit, 1999). In South Africa, movement is mostly restricted by fencing which has been erected with the express intent of restricting the animals to a certain area. Contrary to the situation in open landscapes, where animals are not restricted and can select from all available resources and habitats, fences restrict direct access to other resources. Some of these may be key resources, such as water, as in the case of the elephants in Tembe Elephant Park, which no longer have access to the Pongola River. Apart from the fact that these restrictions may have significant effects on the elephant population dynamics (Illius & O'Connor, 2000), the ecology of the animals may be affected (Van Aarde & Jackson, 2007). The relative importance of how the different resources change with climatic and seasonal changes and the long-term effect of fencing in this regard is not well understood and requires further targeted research (Owen-Smith *et al.*, 2006).

The 'overabundance' of elephants has often been attributed to fences restricting elephants to confined areas (Gillson & Lindsay, 2003; Van Aarde & Jackson, 2007). The argument is that by restricting movement the natural regulators of elephant populations are weakened and this results in excessive impact and homogenisation of the local biodiversity, particularly the vegetation (Owen-Smith *et al.*, 2006).

The mechanisms underlying this hypothesis are not well understood, but may be linked to elephants being very adaptable in their ability to eat poor-quality food (Owen-Smith, 1988). Thus even when confronted with limited choice in quality and quantity of forage, they can continue to increase in numbers. There seems to be general agreement that fencing elephants into small areas will have a greater negative effect on the natural system heterogeneity than in larger areas, possibly because larger areas have an inherently wider range of different habitats (Owen-Smith *et al.*, 2006). Another argument is that the range of habitats which elephants normally have access to includes areas that serve as dispersal sinks (*sensu* Dias, 1996). By preventing animals from moving into these areas, the remaining areas are exposed to continuous high impacts, leading to loss of habitat variability (Van Aarde & Jackson, 2007).

A large build-up of elephant numbers in small, fenced areas is often followed by a decline in woodland cover due to a combination of tree destruction by elephants and often also by the interaction of the effects of fire (Jachmann & Bell, 1984). In a number of parks this has led to the temporary disappearance of large areas of *Acacia* (Mwalyosi, 1990) and *Commiphora* woodland (Leuthold, 1996), and in some cases local extinction of tree species including baobab (*Adansonia digitata*), which is highly favoured by elephants. Because of the fences the elephants were not capable of responding through migration to these radical changes in the food supply, and thus had a more severe effect than they would have had in an unfenced system.

Prior to the erection of a veterinary fence on the western boundary of Kruger in the 1960s, there was evidence of an east–west seasonal migration of herbivores (figure 8) (Whyte, 1985). With the initial erection of the fence, many animals were killed, such as giraffe, wildebeest, zebra, and kudu (Whyte & Joubert, 1988; Albertson, 1998). In Botswana the disease control veterinary fences also prevented vital wildlife movements, fragmented populations, separated young animals from herds, and caused the death of animals that got stuck in the fence (Albertson, 1998).

Fences do not only affect the migration routes of animals between resource areas, but also affect other ecological factors such as fire. Increased grazing pressure due to the confinement of animals led to reduction in the frequency of hot fires, and this commonly precipitated bush thickening (Peel, 2005). Wildlife-based tourist operations in the region are adversely affected by such bush encroachment because the dense woody layer reduces game visibility.

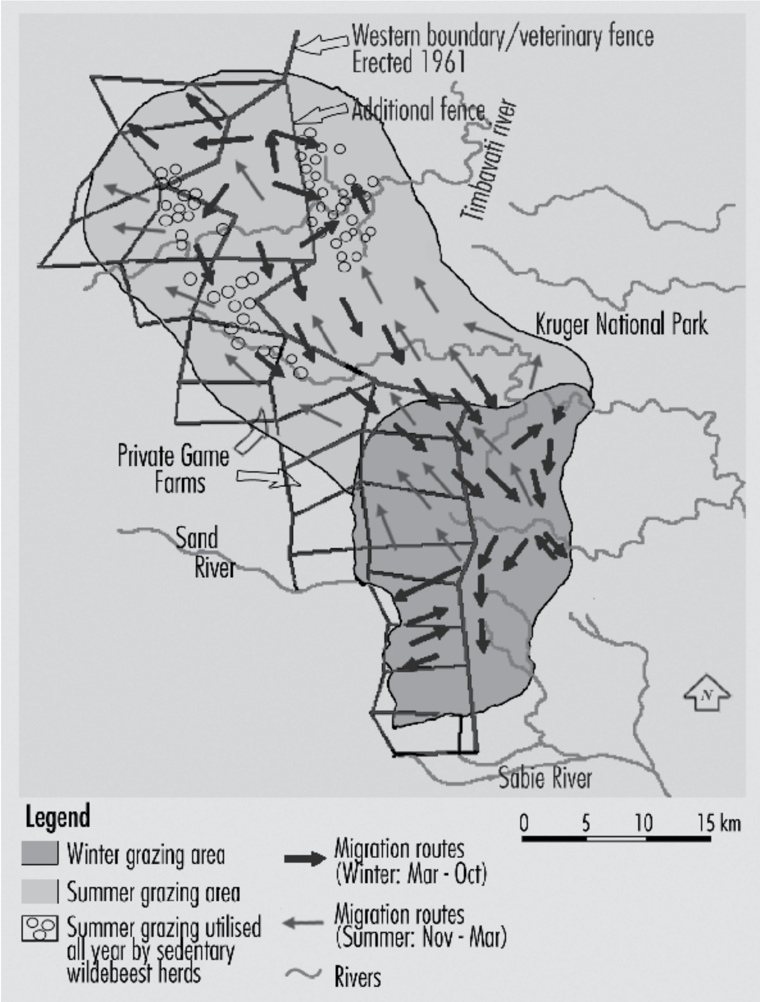

Figure 8: Hypothesised animal migration routes prior to the erection of the foot-and-mouth fence (Whyte, 1985)

The erection of the veterinary fence between the Kruger and private land to the west also led to the provision of water in previously seasonally waterless areas of both Kruger and the private reserves. Water shortages in such a confined area with inadequate surface water may increase fence breakages, conflict with humans (especially around water sources) and risk of disease spread. Artificially provided water sources will counter this effect, but alter the spatial and temporal foraging and trampling patterns of both elephants and other water-dependent animals (Chamaillé-Jammes *et al.*, 2007a; Smit *et al.*, 2007a). This may ultimately influence the vegetation (e.g. Thrash, 2000; Brits *et al.*, 2002), soil (e.g. Thrash, 1997) and nutrient patterns (e.g. Tolsma *et al.*, 1987) on multiple scales (multiple piosphere effect). Additional permanent water sources have also been blamed for influencing predator/prey relationships (Harrington *et al.*, 1999; McLoughlin & Owen-Smith, 2003; Mills and Funston, 2003), creating unnaturally high herbivore numbers with consequent population crashes during droughts (Walker *et al.*, 1987), compromising system resilience (Grant *et al.*, 2002), and degrading the quality of the herbaceous layer (Parker & Witkowski, 1999). The effects of fencing and water provision are thought to be reflected in the change in the status of impala. Impala did not occur west of 31°30'E in the 1800s (Kirby, 1896) and were in fact not found west of the Orpen Gate until the 1920s (Porter, 1970). They are now the most prolific herbivore in the lowveld. Both elephant and impala are strong competitors, have a great impact on areas they inhabit and are ultimately able to change the habitat to suit their requirements by maintaining the forage in an actively growing and palatable state. They can also switch easily from their preferred grazing to browsing when the quality or quantity of the grazing drops too low for their maintenance (Collinson & Goodman, 1982). According to Collinson & Goodman (1982), weak competitors such as roan, sable, and tsessebe cannot compete with species such as elephant and impala and are only successful within intensive breeding camps such as found at Selati Game Reserve.

Table 1 summarises the situation on two adjacent protected areas, both less than 15 km^2 in extent. The annual vegetation survey indicated that both areas were under nutritional stress due to drought conditions and high stocking densities. This was confirmed by the annual aerial game count and it was recommended to remove some game from both properties. Only reserve 2 implemented the suggested game control.

Subsequent aerial game counts showed large-scale mortalities on reserve 1 compared to a few mortalities on reserve 2. The latter example serves to illustrate the need for hands-on management, particularly in small fenced areas.

A further consequence of fencing is that depending on the timing of the fence erection, it may split a population of elephants, as in the case of the Tembe Elephant population, which was split between South Africa (Tembe Elephant Park) and Mozambique (Maputo Special Elephant Reserve).

Fences also separate local communities from resources such as water and medicinal plants, and this leads to people cutting the fences to obtain these resources, which then acts as an entry point for damage-causing animals.

	Animal biomass (kg.km^{-2})		Impala		Wildebeest		Economic value at gate (ZAR)
	Pre-drought	Post-drought	mortality (%)	removal (*n*)	mortality (%)	removal (*n*)	
Reserve 1	5 499	2 881	81	0	93	0	–343 000 (mortality)
Reserve 2	4 607	3 347	<5	35	35	28	–33 000 (mortality) +59 500 (live removal)

Table 1: Case study illustrating the ecological and economic effect of fencing and water provision on the ecology of areas of small size when animals are removed or not, according to predictions of available forage (Peel, 2006)

FENCES AND ELEPHANT WELFARE

From a welfare perspective, the needs of an elephant population could be satisfied in an enclosed area as small as 150 km^2. Elephants do not immediately increase their ranges when boundary fences are removed (Druce *et al.*, 2007) from areas of this size.

Additionally, work done by Space For Elephants Foundation indicated that the summer peak in animals breaking out of conservation areas coincided with the rainy season when cloud formations are consistently low. This allowed easier communication and was associated with the attraction of the abundance of suitable forage and marula fruit. Furthermore, elephant attempts to escape seemed to be due to confrontational stress, and they often tried to return to the area from whence they came (http://www.space4elephants.org).

TECHNICAL SPECIFICATIONS FOR FENCES AND THEIR MAINTENANCE

Given the present state of technology, well-constructed electric fences can act as a powerful deterrent to elephant entry and trespass (Hoare, 1992). A typical electrified game fence is illustrated in figure 9. The different types of fences and their efficacy are summarised in table 2.

ENSURING EFFICIENCY OF FENCES

Long-term success using fences to contain elephants is dependent on meticulous routine maintenance and the use of solid, durable material that is well anchored. Electric fencing technology is simple and definitely deters elephants, but has to be continuously maintained to be efficient (Hoare, 2003). Fencing is very expensive as a management tool, especially in view of the damage and the direct costs involved in fixing and/or replacing fences that have been destroyed by elephants (WWF, 1998; Hoare, 1995).

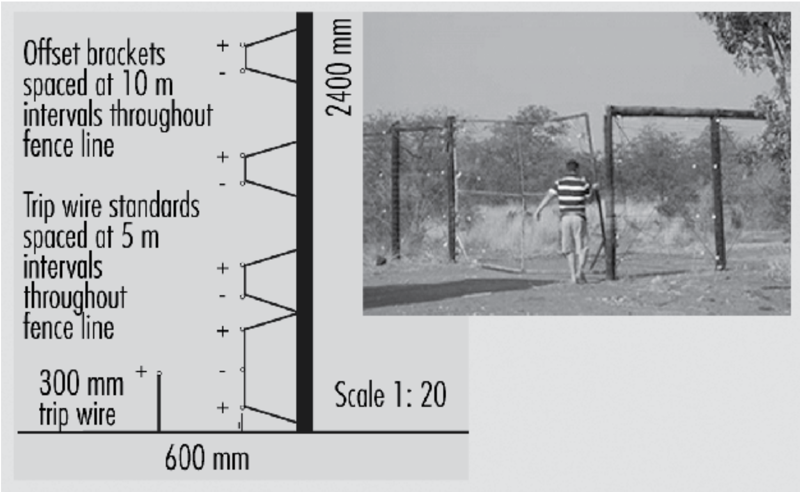

Figure 9: Diagram of electric wires for elephant-proof fence with an example of such a fence in Mapungubwe National Park

To ensure that fences are effective against elephants requires that:

- sufficient trained staff and transport must be available to ensure that fences are patrolled every day on a rotational system to effect fence repairs
- responsibilities for maintenance and costs associated are defined clearly and appropriately budgeted for
- neighbouring communities agree about the importance of fences and do not remove fencing material for their private use
- human interference is avoided by using cabling instead of wire as it is less sought after
- there is a reliable supply of electricity with sufficient power to deliver the required voltage

Fence type	Height (m)	No. electrified strands	No. & type of other strands	Type of straining post	Density of straining post	Erection cost (ZAR. km^{-4})	Maintenance cost (incl. staff cost)	Breakages by elephant	Comments
Legal requirements for elephant containment	2.4	3	20	NS*					
Recommend Elephant Managers & Owners Association	2.4	4	17 min			34 000	25 000 per month	Very few	Sacrificial fence at river crossings
Stout mechanical fence	2.4	0	4 x 12 mm cable 6 x straying wire 3 x barbed wire 1.9 m high diamond mesh	30 kg.m post 5 m apart planted 1 m deep		190 000	5 000 000 per year		Works fairly well if maintained. Mainly bulls that try to cross. Skilled and dedicated personnel needed to maintain. Used in Kruger.
Electrified Armstrong fence	2.4	6	6 cables	Railway tracks 2 m deep every 10 m		150 000	Very low, if any	0	Costly to construct, very little if no maintenance, but electrified part has a very high maintenance cost
Twenty-one-strand fence	2.4	5	21 steel wires		10 m intervals	51 666	90 000 per year	4 per year	Cost exclude grading costs and warden's salary
Nineteen-strand fence reserve	2.4	4 Top at shoulder height & bottom 1 m from ground	19			62 568.74	300 000 per year	None	

Fence type	Height (m)	No. electrified strands	No. & type of other strands	Type of straining post	Density of straining post	Erection cost (ZAR. km^{-4})	Maintenance cost (incl. staff cost)	Breakages by elephant	Comments
Standard 17-strand game fence with wire netting	2.4	5	17 and 1.2 m mesh			46 000	Approx. 5 000 per month	Approx. 3 per year	Maintenance costs include a person to patrol all fences daily on motorbike
Six-strand fence	2	3	6	NS	NS	29 000			
Three-strand fence		3	3	NS	NS	29 000	Broken less than 6 strand press		
Chili paste fence poles painted	2					820	Needs repainting after each rainfall event		
Wire mesh around trees	1.25					50 per tree			
Trip alarms around individual farms						560			Decline in conflicts around homestead
Note: NS = not specified									

Table 2: Specifications, erection and maintenance costs (2007) for different types of fences. All electrified strands must have a minimum voltage of 6 000 V and must have sufficient energisers to supply power to maintain this voltage over a distance of 8 km

- vegetation around fences is removed to avoid shorts in the electric current and damage by fire; this can be achieved by physically clearing the area or the judicious use of herbicides
- fences are checked after fires, flash floods, and lightning
- gates at access points are securely closed
- there may be a strategic opening of boreholes during the dry season to reduce fence breaks in areas where elephant movements are associated with accessible water outside the fenced area.

ALTERNATIVE METHODS OF MANAGING ELEPHANT DISTRIBUTION

Drinking water manipulation as a management tool for elephant distribution

Elephant distribution is often associated with the distribution of surface water and rivers (Stokke & Du Toit, 2000; Redfern *et al.*, 2003; Chamaillé-Jammes *et al.*, 2007a; Smit *et al.*, 2007a & b). It has been shown that the addition of surface water to areas with limited natural water availability can increase the density of elephants (Cumming, 1981) and expand their spatial distribution (Chamaillé-Jammes *et al.*, 2007a). Surface water manipulation has therefore been proposed as a 'non-intrusive and natural' management tool with which to alter elephant distribution patterns (Owen-Smith, 1996; Chamaillé-Jammes *et al.*, 2007a & b). However, considering the mobility of elephants (e.g. Viljoen & Bothma, 1990; Verlinden & Gavor, 1998), it is arguable how effective surface water manipulation will be to manipulate elephant distribution in areas like the Kruger National Park, where water is usually widely available (South African National Parks, 2005; Redfern *et al.*, 2005; Owen-Smith *et al.*, 2006; Smit *et al.*, 2007c). Depending on the availability of natural water, artificial waterholes may not influence large-scale elephant distribution patterns as much as they affect the local-scale activity patterns (i.e. piosphere effect). In Kruger, for example, the landscape-scale dry season distribution of mixed herds and breeding herds is more closely linked to the river system (figure 10) than to the artificial waterhole network, which tends to be more preferred by bull groups (Smit *et al.*, 2007a & b). Considering this, together with the ability of elephants to move between the (usually widespread) ephemeral and permanent water sources, it is debatable how effectively the density and distribution patterns of the elephants could be manipulated under normal conditions by means of water provision in Kruger (Redfern *et al.*, 2005; Smit *et al.*, 2007c); this is an area that requires further research.

The effect of the provision of artificial water on elephant distribution is much more pronounced in an arid system, as can be seen in the Addo Elephant National Park. In Addo the impact on the endemic subtropical thicket has been very extensive around the artificial waterholes where elephant tend to concentrate, while areas far from the waterpoints have been substantially less used (Knight *et al.*, 2002). Other studies have also indicated that the distribution and subsequent use of vegetation by elephants is higher in closer vicinity to water (e.g. Ben-Shahar, 1983; Thrash et al., 1991; Nelleman *et al.*, 2002). If water is artificially provided, it should preferably be restricted to areas close to localities where natural sources occur, minimising spatial alterations to grazing patterns (Pienaar *et al.*, 1997). Thus, a uniform distribution of water by the addition of artificial water sources may homogenise the natural variability in impact brought about by the uneven natural water availability. This is not desirable for biodiversity conservation (Owen-Smith, 1996; Knight *et al.*, 2002).

Figure 10: Distribution and density patterns of elephants in Kruger. Note the concentration along the larger perennial and seasonal rivers (courtesy of Sandra MacFayden (Grant, 2005))

The effectiveness of surface water manipulation as a management tool for elephant distribution will depend, *inter alia*, on (1) natural surface water availability, (2) forage quality, (3) local densities, and (4) size and objectives of the confined area – that is, whether objectives are defined by biodiversity or sustainablility (Peel *et al.,* 1999). Surface water manipulation will be most effective as a management tool in large systems with very limited natural water distribution. In such systems the distribution patterns may be substantially influenced by water provision (Jackson & Erasmus, 2005). In small, enclosed areas with adequate natural water, artificial water provision can be expected to have a relatively small and localised effect, since any water provided will effectively be within walking distance for elephants.

Disturbance as a way to deter elephants

Disturbance methods may be used to deter elephants, but elephants soon become habituated (Hoare, 1995; O'Connell-Rodwell *et al.*, 2000; Osborn & Rasmussen, 1995), especially if the same animals are regularly involved (Hoare, 1999). These methods require trained personnel and they can be dangerous because of proximity to the elephants. They are generally cheap to apply and have been shown to have at least some effect. They are not fatal to the elephants and the involvement of the authorities provides some public relations value (Nelson *et al.,* 2007).

Villagers in Sumatra use powerful flashlights to deter elephants, in combination with noise, fire, and explosives, while fireworks and flares have been used in Zimbabwe with initial success (Hoare, 2001). Firing weapons over the heads of crop-raiding elephants to chase them from fields has been used in Zimbabwe (Hoare, 2001) and Niassa Reserve in Mozambique (Macadona, pers. comm.). In Niassa, it is used successfully in combination with electric fences.

O'Connell-Rodwell *et al.* (2000) experimented with trip alarms in villages in East Caprivi, Namibia. They found shorter wires around individual farms to be effective in the short term, but there was no impact on the overall number of conflict incidents reported in a year as elephants initially moved into neighbouring farms before becoming habituated. Each alarm cost US$78, less than the average elephant crop-damage claim. Between 1993 and 1995 an estimated US$1 800 was saved.

Massive disturbance (e.g. people, vehicles and/or helicopters) to drive elephants away from a conflict area has been tried with some immediate, although short-term, success in Zimbabwe (Hoare, 2001).

CHANGING BEHAVIOUR AS A MANAGEMENT TOOL

Elephants are intelligent animals capable of learning, and these attributes may be used to influence their distribution. This is currently a very active area of behaviour and ecosystem management research (Provenza *et al.*, 2003; Provenza & Villalba, 2006; Davis & Stamps, 2004; Provenza, 2003; Provenza, 2007).

This research is based on the fundamental understanding that all animals choose their behaviour based on the consequences they experience: positive consequences increase and negative consequences decrease the likelihood of behaviours recurring. Consequences involve two general behavioural systems in animals – skin-defence systems evolved under the threat of predation and gut-defence systems evolved under the threat of toxins in foods (Garcia *et al.*, 1985). These two systems form the basis for changing food and habitat selection behaviours in animals. Changing food/habitat selection behaviours requires making the food/habitat an animal is currently using less desirable (stick) relative to other foods/habitats (carrots).

Strategic hunting

Hunting can have significant and lasting impacts on the movement and distribution of game animals (Conner, 2002; Vieira *et al.*, 2003). As an example of this approach: elk are hunted in locations where they are not wanted, such as the former feeding areas, and they are not hunted in areas where they can stay. For instance, prior to 1986, both bull and cow elk migrated to lower elevations on the eastern portion of a ranch in Utah, USA. In mid-October in 1986, 100 hunters were allowed access to the ranch to hunt cow elk; they harvested 86 cows in one morning. For the past 20 years since that date cow elk have not migrated to lower elevations until snow pushes them down later in November or December. Bull elk, which have not been hunted in the lower elevations of the ranch, have continued to migrate to lower elevations in mid-October. One of the most striking examples of this involves a population of moose in central Norway that migrates from low-lying summer areas to high-elevation winter areas, contrary to the general pattern of migration (Andersen, 1991). Archaeological evidence shows their migratory behaviour follows a traditional pattern unchanged since 5000 BP despite deterioration in the quality of their winter range. Incongruously, there are no physical barriers preventing the moose using better habitat. Rather, the barriers are cultural, and they began

5000 BP when humans hunted (pit trapped) the moose. Humans no longer pit trap the moose and the behaviours are held in place by 'culture'.

In making such major changes in management, from field experience it is assessed that a minimum of three years typically are required to change the behaviours of long-lived social animals. The first year is the most difficult, as none of the adults has any experience with the new system. The second year is better because all those involved have a year of experience with the new system and the animals that were unable to adjust to the new system have been weaned. By the third year, all of the adults have two years of experience with the new system and young animals born into the new system are becoming members of the herd. In behaviour-based management, people become agents of change over time in animal cultures. Social organisation leads to culture, the knowledge and habits acquired by ancestors and passed from one generation to the next about how to survive in an environment (De Waal, 2001). A culture develops when learned practices contribute to the group's success in solving problems. Cultures evolve as individuals in groups discover new ways of behaving, as with finding new foods or habitats and better ways to use foods and habitats (Skinner, 1981).

Similarly, extended families with matriarchal leadership may provide a means for changing elephant behaviour. Efforts could be focused on individual families, and given the importance of the matriarch in behaviour of the family, specific efforts might be directed at the matriarch of each family. It may be best to test how to train elephants using a variety of techniques with a small number of families. Long-term mother-daughter associations should lead to the learning behaviour being transferred thus limiting the time needed to train the animals to avoid certain areas (Douglas-Hamilton, 1973; Moss & Poole, 1983).

Repellents

The use of chili extracts has shown particular promise not only because *Capsicum*-based products are non-toxic and environmentally friendly, but specifically because elephant's advanced olfactory and memory capabilities make them suitable for aversion conditioning (Osborn & Rasmussen, 1995; Osborn, 1997). Numerous evaluations with chili extracts have been completed, particularly in Zimbabwe where the objective was to protect crops belonging to rural populations that adjoin nature reserves or where elephants have caused extensive damage to crops (Osborn & Parker, 2002, 2003). These evaluations have been directed mainly at a practical and cost-effective means of applying *Capsicum* oleoresin in different forms like sprays and treated ropes which are strung around crops. Research has shown the effectiveness of chili extracts as a spray, when administered upwind of elephants and compared to traditional methods of trying to deter elephants during crop-raiding. When traditional measures are utilised, there is normally an aggressive reaction from elephants, whereas in the case of aerial spraying of *Capsicum* oleoresin, the response by the elephants was more rapid and resulted in prompt withdrawal from the crops without aggression (Osborn, 2002).

Other ways to protect crops or particular specimens of vulnerable trees include the placement of bee hives in strategic trees as elephants are sensitive to the sound and sting of bees (Karidozo & Osborn 2005; King *et al.*, 2007; Vollrath & Douglas-Hamilton, 2005a & b). Using bees as a selective repellent offers the added benefit that as a deterrent, bees could pay for themselves through the sale of honey (Vollrath & Douglas-Hamilton, 2005a; King *et al.*, 2007).

Buffer crops

Unpalatable crops such as tea, spiny plants such as sisal, timber plantations, and *Opuntia* barriers have all been tried but none have deterred elephants (Hoare, 2003). The cactus species *Opuntia dillenii* was used as a barrier in some parts of Laikipia and Narok, Kenya. Its potential to spread as a weed, however, is a major limitation. Another species, Mauritius thorn (*Caesalpinia decapetala*), has also been tried in Transmara, albeit with little success (Omondi *et al.*, 2004).

Moats and ditches

Ditches and moats have been tried in the past in Laikipia, Mt Kenya and Aberdares. However, due to lack of proper maintenance, they have not been successful in containing the elephants in protected areas. This method may be ideal only for small-scale sites of 3 or 4 km^2 and is not recommended for high rainfall areas as they may cause considerable soil erosion (Omondi *et al.*, 2004).

Stone walls

This method can only be considered where stones are available on site and the size of the area to be fenced is not extensive. Stone walls are not effective for containing elephants, as they soon learn to remove the rocks (Omondi *et al.*, 2004).

Sonic barriers

The use of sonic barriers may prove effective in deterring elephants from entering demarcated areas. High-frequency sound devices have already proved effective in preventing motorists from colliding with wildlife. In Australia vehicles are fitted with devices that provide a safety sound zone of 400 m and 50 m either side of the vehicle (http://www.shuroo.com/). As humans cannot hear the sound emitted by these sonic barriers and as they are not visible, such techniques may prove to be effective and aesthetically appealing when controlling elephant movements in particular areas.

EFFECTS OF FENCE REMOVAL OR THE LACK OF FENCING

Elephants typically disperse at rates of 7–10 km per year after the removal of a fence. Hence the 20 000 km^2 of Kruger was colonised within 50 years due to migration from Mozambique and the establishment of breeding herds in the Kruger National Park (Porter, 1970), after starting off with very few elephants in the early 1900s (Kirby, 1896).

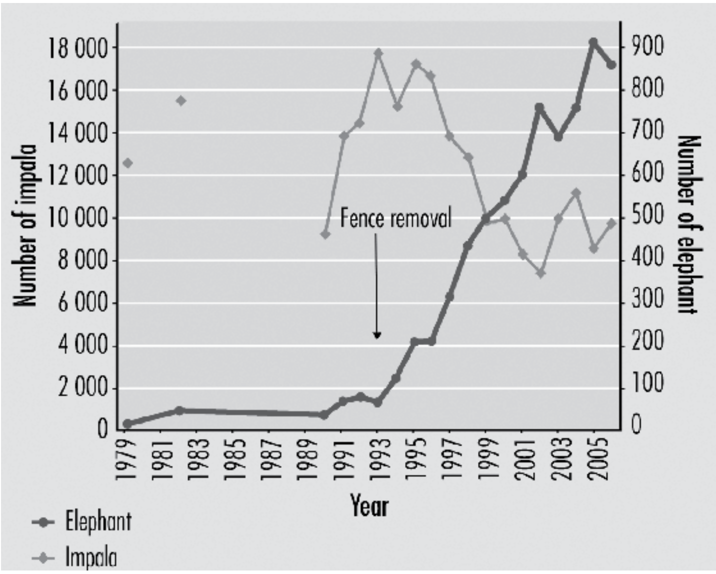

Figure 11: There was a steady increase in the elephant population in the Sabi Sand Wildtuin after the removal of the fence between Kruger and the private reserves in 1993

Elephants may readily move into new, unexplored areas, as can be seen by the increase in the elephant population in the private reserves next to Kruger after removal of part of the western boundary fence in 1993 (Peel & Grant, Chapter 8 in Grant, 2005) (figure 11).

The most recent addition to the Associated Private Nature Reserves is the Balule Nature Reserve, which had a low elephant density. Numbers in this area have increased from zero in the 1990s to almost 500 in 2006 (Peel, 2006). Even though it may still be too early to note the re-establishment of migration paths after the removal of the fence between Kruger and Sabi Sand Wildtuin it does appear that there is some seasonal movement in and out of areas such as the Sabi Sand (15 years). Satellite-collared animals are followed over time and movement between Kruger and Sabi Sand is already apparent in certain groups in both summer and winter (figure 12).

Figure 12: Seasonal movement of three elephant families between Sabi Sand Game Reserve and Kruger

During August 2004, the boundary fences between Phinda Private Game Reserve and two neighbouring reserves were removed. Initially family groups only moved into the new area at night and spent minimal time there, while older bulls spent longer periods of time, regardless of time of day. One year after the fence removal, most of the elephants had only expanded their home ranges slightly into the new area (Druce *et al.*, 2007). Similarly, elephants that were introduced into Marakele National Park in 1996 took a few years to move to the adjacent Marakele Pty Ltd after the fence was removed in 2001 (Bezuidenhout, 2004).

LEGAL OBLIGATIONS FOR FENCING

In any area where wildlife may be carriers of foot-and-mouth disease, the Animals Diseases Act (Act 35 of 1984) requires that the animals are separated from domestic stock. Any damage-causing animal that can be clearly identified by marking, collars, branding, microchip, etc. must be monitored and cases of damage need to be investigated thoroughly using these identification techniques as proof.

The quality of fences for wildlife is legally stipulated and defined for each type of animal to be contained. See Chapter 11 for a further discussion on the legal implications of fencing.

CONCLUSION

Fences are probably the most efficient barriers to restrict elephant movement. Electric fences can work very well if they are maintained at all times. These fences have to be sturdy and durable as elephants will tend to re-cross a fence once they have been previously successful. Fences are more efficient when the animals are trained to respect them.

Other barriers can be of some use, and may be cheaper than fencing, but maintenance is also essential.

'Teaching' animals to avoid certain areas is an option worth investigating. Disturbance in the form of noise or even local culling/hunting can be used to teach the animals to avoid certain areas. If this could be done successfully it may be possible to protect sensitive areas, at least to a certain extent, without fencing or other barriers.

RESEARCH GAPS

- Examine further ways of controlling elephant movement, e.g. learned behaviour or barriers.

- Understanding the factors, in particular water distribution, that determine distribution and density of elephant in enclosed areas.
- Examine effective techniques for fence line monitoring to enable fence-breaking individuals to be identified.

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