People & Wildlife
Creating conservation solutions for living together

A review of human-elephant conflict management strategies

Alastair Nelson, Posy Bidwell & Claudio Sillero-Zubiri

People & Wildlife
A Wildlife Conservation Research Unit
Born Free Foundation partnership

About the Authors

Alastair Nelson *(MSc) is a conservation biologist currently based at WildCRU, conducting research on Grevy zebras.*

Claudio Sillero-Zubiri *(DPhil) is a Zoology Research Fellow at Oxford University, assisting with various conservation programmes, mainly in Africa. He coordinated the Ethiopian Wolf Conservation Programme for 12 years, for which he received the 1998 Whitley Award for Animal Conservation from the Royal Geographical Society. Claudio leads the People & Wildlife partnership between WildCRU and BFF.*

Recommended citation: Nelson, A. Bidwell, P. and Sillero-Zubiri, C. (2003). A review of humane elephant conflict management strategies. People and Wildlife Initiative. Wildlife Conservation Research Unit, Oxford University. www.peopleandwildlife.org.uk/crmanuals/HumanElephantConflictP&WManual

Contents

Introduction

Human-elephant interactions have always had profound consequences on their respective distributions, but more recently conflict has generally led to the exclusion of elephants (Hoare & Du Toit, 1999; Parker & Graham, 1989). In pre-colonial times elephants played a major role in the distribution of arable farming (Barnes, 1996; Graham, 1973; Parker & Graham, 1989; Ville, 1995). In the 19th and 20th centuries diverse factors contributed to a massive decline in elephant numbers and range (e.g. the monetary value attached to ivory, the availability and spread of firearms, tsetse fly control, the introduction of cash crops, colonial government).

The next major impact was the poaching epidemic of the late 1970s and 1980s, when the population of African elephants declined from 1.3 million to circa. 600 000 (Douglas-Hamilton, 1987; Douglas-Hamilton, Michelmore & Inamdar, 1992). The 1989 CITES ivory trade ban was largely responsible for halting that decline and allowing populations to stabilise. The most serious issues now facing elephants are habitat loss (through land-use change), habitat fragmentation, ivory poaching and persecution as crop-raiders (Armbruster & Lande, 1993; Barnes, 1999; FFI, 2002a; Nyhus, Tilson & Sumianto, 2000; Parker & Graham, 1989; Sukumar, 1991). Perversely, associated with increasing habitat loss and fragmentation is a concomitant increase in the human-elephant interface, and by extension an increase in human-elephant conflict and persecution.

This review focuses on current human-elephant conflict mitigation strategies, illustrating them where possible with examples of their success and/or failure. Each strategy 'group' is then discussed, with emphasis on its (potential) success, relevance, costs and benefits. The review begins by introducing human-wildlife conflict in general and then more specifically human-elephant conflict, covering the reasons for its increase, the significance of elephants as a pest species, and some background on which elephants might be responsible, and why.

Human-wildlife conflict: from definitions to elephants

Background to human-wildlife conflict

Conflict arises from a range of direct and indirect negative interactions between humans and wildlife. These can culminate in potential harm to all involved, and lead to negative human attitudes, with a decrease in human appreciation of wildlife and potentially severe detrimental effects for conservation (De Boer & Baquete, 1998; Nyhus *et al.*, 2000). Conflict generally arises from economic losses to agriculture, including loss of cattle through predation and destruction of crops. In arid areas it often occurs over access to water and competition for resources.

A wide range of species are responsible for conflict, with the principal culprits being primates, rodents, ungulates (including antelope, bushpig, elephant, hippo, buffalo and zebra), lions, leopards and hyaenas (Hill, 2000; Naughton-Treves, 1998; Naughton-Treves, Treves, Chapman & Wrangham, 1998; O'Connell-Rodwell, Rodwell, Rice & Hart, 2000; Saj, Sicotte & Paterson, 2001). Livestock also perpetrate significant damage, but there are often locally accepted measures of restitution (Naughton-Treves, 1998). Conflict situations can arise anywhere, but they are frequently concentrated at the fringes of reserves where wildlife enjoys protection and land is often fertile, leading to a wealth of agriculture.

There are other socio-economic costs associated with human-wildlife conflict which can outweigh the direct costs of agricultural damage and be a major component of the conflict as perceived by local people (WWF, 1997). The extreme example of this is human death, but other examples include restrictions on movement, competition for water sources, the need to guard property (which may lead to loss of sleep), reduced school attendance (through loss of sleep, or fear of travel), poor employment opportunities, increased exposure to malaria, and psychological stress (Hoare, 2000; Naughton-Treves, 1998; Sukumar, 1990;

Tchamba, 1996; Williams, Johnsingh & Krausman, 2001).

Human-elephant conflict

Humans and elephants, through a combination of crop-raiding and exploitation, have shaped each others distributions for centuries. Human-elephant conflict is not a new phenomenon and crop-raiding has been taking place for centuries. In the early nineteenth century 'slash and burn' subsistence farmers cultivating crops in central African forests were losing entire crops to elephants, while in other areas elephant crop-raiding caused food shortages and displaced settlements (Barnes, 1996; Graham, 1973; Parker & Graham, 1989; Ville, 1995).

Accounting for the increase in human-elephant conflict

Yet why, when across most of Africa habitat loss and local extirpation of wildlife is reducing the geographical range of human-elephant contact (Hoare, 1995) does human-elephant conflict appear to be on the increase? Only one out of more than 30 studies published during the 1980's and 1990's described a local decline in elephant crop-raiding. This question may best be answered by a combination of contemporary physical and social conditions which bring humans and elephants closer together with a simultaneous reduction in tolerance for elephants (Naughton, Rose & Treves, 1999). These conditions include:

Land-use and geographic changes

• There has been a marked increase in competition between humans and wildlife for land and resources (Barnes, 1996; Kiiru, 1995; Tchamba, 1996; Thouless, 1994; Thouless & Sakwa, 1995). Burgeoning human populations, along with voluntary or state settlement programs, which include policies encouraging pastoralists to settle, have led to the expansion of agriculture into land previously occupied only by wildlife. Remaining pastoralists are forced into more fragile, marginal areas, increasing habitat degradation and loss.

• Elephants are crammed into smaller areas by habitat loss and poaching. Localised high densities inexorably lead to crop-raiding in surrounding areas (Barnes, Azika & Asamoah-Boateng, 1995; De Boer, Ntumi, Correia & Mafuca, 2000; Naughton-Treves, 1998; Sukumar, 1990; Sutton, 1998; Thouless & Sakwa, 1995).

• In other areas, declining rural populations and farm abandonment result in a mosaic of farmland interspersed with secondary vegetation (Houghton, 1994). Correspondingly, soil degradation and other negative processes result in fields being planted in scattered patterns further from villages. This increases the area of interface between humans and elephants, and hence crop-raiding events (Hoare & Du Toit, 1999; Lahm, 1996).

• Similarly, human activities (e.g. logging in forests) create abundant secondary vegetation that attracts elephants, bringing them closer to human settlements (Barnes, Barnes, Alers & Blom, 1991; Barnes, 1999; Lahm, 1996; Sam, 1999).

• Artificially maintained water sources attract elephants during drought (Sukumar, 1990; Sutton, 1998; Thouless, 1994).

• Traditional migration routes can be severed by human intervention (e.g. canals, power installations and cattle fences), leading to aggressive behaviour in elephants and thus increasing conflict (Kangwana, 1995). Farmland might also be encroaching into areas that were previously avoided because they are elephant migration routes (Smith & Kasiki, 1999).

Human-induced changes in elephant behaviour and socio-ecology

• The increase in elephant numbers in protected areas following the CITES listing and improved anti-poaching measures has led to some elephants losing their fear of people (Kangwana, 1995; Naughton-Treves, 1998; Tchamba, 1996).

• Human conflicts displace elephants which in turn come to depend on crop-raiding to survive in resource poor habitats (Tchamba, 1995).

• In areas where there is intense culling or hunting, elephants form larger groups, causing greater damage to vegetation and crops (Southwood, 1977).

Socio-economic and political changes in human communities

• State or hunting concession ownership of wildlife, coupled with bans on local hunting decrease tolerance of crop-raiding animals (De Boer & Baquete, 1998; Hackel, 1999; Hart & O'Connell, 1998; Lindeque, 1995; O'Connell-Rodwell *et al.*, 2000; Sutton, 1998).

• Changes in land tenure, with a trend towards privatisation, erode traditional farming strategies based on joint properties and focus the impact of crop loss on individuals rather than communities. Similarly, at many sites farmers have abandoned communal hunting, planting and guarding activities that once reduced crop loss (Lahm, 1996).

• Crop guarding has decreased with men moving to cities to seek employment, while children are increasingly involved in education (Lahm, 1996).

• Politicians are paying more attention to local citizens who complain about crop-raiding, increasing the profile and awareness of conflict (Hoare, 1995; Kangwana, 1995).

The obvious conclusion to be drawn is that there is no one cause or explanation to account for human-elephant conflict; situations are circumstantial and complex. Rather, elephants and agriculture mix in numerous ways with varying consequences (Hoare, 1995). For example, human population growth may heighten conflict with elephants in Kenya, Uganda, Ghana and Sumatra, while declines in human population heighten conflict in Gabon and Congo (Naughton *et al.*, 1999; Nyhus *et al.*, 2000). However, it is generally the edges of protected areas that are the focal points for conflict (Hart & O'Connell, 1998)

Elephants as a pest species

Large vertebrates (>2kg) are rarely mentioned as pests in tropical agriculture, except as localised problems associated with protected areas (Goldman, 1996; Southwood, 1977). Elephants specifically are almost never mentioned, making it very difficult to quantify crop loss on a regional or national scale (Naughton *et al.*, 1999).

Naughton *et al.* (1999) reviewed wildlife management literature that quantified crop damage by elephants in Africa, and found that average loss ranged from 0.2% (Niger) to 61% (Gabon) of planted fields. Elephants consumed over 20 different crops, with maize ranking first. Many researchers have mentioned the localised and irregular (both spatially and temporally) nature of elephant crop-raiding, finding that it is often associated with forest or protected area boundaries, water sources, and/or elephant movement routes (Dudley, Mensah-Ntiamoah & Kpelle, 1992; Naughton *et al.*, 1999). Similar comments have been made regarding Asian elephants (Hart & O'Connell, 1998). Nonetheless, most African studies only concentrated on actual elephant damage incidents and did not quantify how common these events are on a regional scale (Hoare, 1999b; Naughton *et al.*, 1999).

When ranking wildlife pests in Africa (38 taxa mentioned), the five most common were: elephant (32 cases), monkeys and baboons (30), rodents (19), bushpigs (18) and antelopes (11) (Naughton *et al.*, 1999). Elephants were most frequently locally described as the 'worst animal', although never at national level (five assessments) and only in two out of 15 provincial or district level assessments. However, on the borders of protected area elephants commonly ranked worst, confirming the localised nature of their effect (Dudley *et al.*, 1992; Hart & O'Connell, 1998; Naughton *et al.*, 1999).

The cautionary note to introduce here is that tolerance to crop loss and damage events is often shaped by factors beyond just the economic value of the loss over time. These factors generally reflect human values and attitudes, e.g. human death is considered unacceptable, and total amount of crop loss on a single occasion is felt more than frequent raids, even if these cumulatively cause more damage (De Boer & Baquete, 1998; Hoare, 1999b; Naughton-Treves, 1997; Naughton-Treves, 1998).

In illustration; in East Caprivi, Namibia, elephants were responsible for 47% of total recorded conflict incidents between 1991 and 1994. However, lions caused far more economic damage (N$189 760 compared with N$85 156) but claims for elephant damage were double those of lion (O'Connell-Rodwell *et al.*, 2000).

Which elephants are responsible?

Hoare (1999c) found that the only consistent factor across a range of differing situations where problem elephant activity was recorded, was the preponderance of male elephant involvement in the incidents. Radio-collared male elephants were found significantly closer to human settlements than females, suggesting a degree of male tolerance (Hoare, 1999c). This male bias has been previously reported in both Africa and Asia, although never quantified (Bell, 1984; Hoare, 1995; Sukumar, 1991; Thouless, 1994). However, Smith (1999) found that the majority of crop-raiders in areas bordering Tsavo National Park in Kenya were family groups of six or more accompanied by mature bulls. Crop-raiding in this area was largely centred around elephant migration routes, which might in some way account for this discrepancy.

Males that are habitual fence breakers (Thouless & Sakwa, 1995) and/or regular crop raiders (Hoare, 1999c; Lahm, 1996; Sukumar, 1991) have also been noticed in several countries. Sukumar (1990), studying the feeding ecology of Asian elephants, believes that elephants are attracted to food crops because they are more palatable, more nutritious, and have lower secondary defences than wild browse plants. The crop-raiding effects of male Asian elephants were found to be five times that of females (Sukumar, 1990; Sukumar, 1991), a discrepancy that is ascribed to a male strategy of risk-taking that maximises reproductive success through better nutrition (Sukumar, 1991; Sukumar & Gadgil, 1988). The similar pattern found in African elephants, coupled with their comparable nutritional requirements, suggest the same strategy – which is entirely consistent with the predictions of optimal foraging theory (Hoare, 1999c; Sukumar, 1990).

Conflict alleviation techniques and deterrence techniques

Management of human-elephant conflict has been researched and documented throughout Africa and Asia. Numerous mitigation measures to control elephant damage are employed, some have been rigorously tested, many have not. A review of methods discussed in the literature follows.

Traditional methods

The term 'traditional methods' is vague, encompassing all self-defence measures taken by local farmers to protect their crops from elephant damage (Hoare, 2001a). Many of these strategies have been used for centuries, and the term loosely encompasses local methods used before local authority involvement in human-elephant conflict management and before the evolution of what are considered modern techniques. Traditional methods are still widely used, both for economic reasons and when modern methods fail or are tested with little or no success.

Traditional methods have local variations. They range from chasing elephants off fields with noise and fire, to collective prayer and magic (Tchamba, 1996), erection of human effigies (Thouless, 1994) and clothes and rags tied to trees (De Boer & Ntumi, 2001).

Crop guarding

Although not strictly a deterrence method, crop guards sleeping on watchtowers with some means of alerting the community to crop-raiding elephants (e.g. whistles) are an important part of any traditional deterrence system. Human effigies (scarecrows) are used in places, but elephants quickly become habituated (Hoare, 2001a).

Noise

Beating on drums or making a noise of any kind is one of the most common strategies. Farmers (n=79) around the Maputo Elephant Reserve all used noise made by drumming on tins and pots to frighten off elephants, but only 52% confirmed this to be an effective method (De Boer & Ntumi, 2001). Whip-cracking to imitate gunfire is used in both Africa and Asia (Hart & O'Connell, 1998; Hoare, 1995; Nyhus *et al.*, 2000), while bamboo is burnt, causing it to 'explode', by communities in and around the Dzanga-Sangha Reserve in the Central African Republic (CAR) (Kamiss & Turkalo, 1999).

Fire

Most wild animals avoid fire. Fires at field boundaries, or at elephant entry points to fields, serve as a short-term deterrent, but are unsustainable for any length of time without large tracts of forest being cut down. In some areas, elephants are indirectly destroying their own habitat as farmers cut down trees to maintain protective fires (Ngure, 1995).

Other materials can be burnt to increase the deterrent effect of fire. In the Democratic Republic of Congo capsicum seeds are added to fires (Hillman-Smith, de Merode, Nicholas, Buls & Ndey, 1995), while in Zimbabwe ‘brickettes’ of elephant dung mixed with ground chillies are used (Hoare, 2001a; Osborn & Rasmussen, 1995). Farmers in the Waza-Logone District of Cameroon believe that elephants dislike the smell of burnt sheep dung, but Tchamba (1996) found this to be ineffective. Villagers in Burkina Faso hang kerosene lamps on wooden poles around their fields as a deterrent, which can be expensive to maintain over time (Damiba & Ables, 1993), while in Sumatra flaming torches and powerful flashlights are used to deter crop-raiding (Nyhus *et al.*, 2000).

Air-borne missiles

These range from sticks and stones, to glowing tinder and spears. This often results in fatal incidents on both sides as the nature of the interaction is extremely aggressive. Wounded elephants generally become far more aggressive and are prone to attacks on humans. They often die from infected wounds months later (Tchamba, 1996; Thouless, 1994). Hoare (1995) proposed that immobilisation and treatment of injured problem animals might alleviate conflict situations which are exacerbated by injured animals. However, this is an expensive solution requiring skilled personnel.
With firecrackers more readily available and occasionally used to control livestock, they have entered the arsenal of deterrence methods – being thrown at elephants to scare them away (Hart & O'Connell, 1998; Nyhus *et al.*, 2000).

Cleared field boundaries

Clearing field boundaries as a simple buffer zone is used in some areas. The most effective purpose of these clearings is for crop guards to see elephants before they enter the fields. In the Dzanga-Sangha Reserve in the CAR the management plan enforces the location of fields along the main road through the reserve. It appears that elephants’ natural avoidance of the road lessens crop-raiding (Kamiss & Turkalo, 1999).

Simple barriers

In their most traditional form, these may be bark ropes or string, often with tins and cloth, and sometimes bells attached (De Boer & Ntumi, 2001; Kamiss & Turkalo, 1999; Thouless, 1994; Thouless & Sakwa, 1995). More recently single strand wire is also used.

Decoy foods

The simplest method is leaving fruit (e.g. bananas, watermelons, sugar-cane) as a decoy to attract elephants away from crops. Deterrents with unpalatable substances on them (e.g. chilli seeds) are also used around crops (Hoare, 1995). Poisoned decoys have been reported (Thouless, 1994).

Buffer crops (e.g. chillies) act as an unpalatable barrier, and have the added advantage of being available to use in fires and potential surplus production can be used as a cash crop (Hoare, 2001a); see 3.6.5. below).

Traps, spikes or home-made firearms

Sharpened stones, stakes and nails are sometimes placed on elephant paths approaching fields. Pit-traps have also been known to be used (Hoare, 2001a). Occasionally home-made firearms or small calibre weapons (e.g. air-rifles or light shotguns) are used to deter crop-raiding elephants, sometimes through intentional injury (Tchamba, 1996). This can have dire consequences for both humans and elephants, with wounded elephants becoming unpredictably aggressive, and often succumbing to infection (see 3.1.4 above).

The effectiveness of traditional methods

Most traditional methods are of limited use as a deterrent, usually only temporarily alleviating the problem, or shifting it to a neighbouring area (Kamiss & Turkalo, 1999; Nyhus *et al.*, 2000; Tchamba, 1995; Tchamba, 1996). The major problem associated with traditional methods, particularly in the longer term, is the ease with which elephants become habituated (Barnes, 1999; Hoare, 1999a; Nyhus *et al.*, 2000; O'Connell-Rodwell *et al.*, 2000; Osborn & Rasmussen, 1995; Sutton, 1998). They are intelligent animals and after a period of exposure soon overcome their fear of fire or noise or other disturbance, once they realise there is no real danger.

Traditional methods are also typically hard to evaluate objectively – often being used in combination with each other and sometimes other methods. Nonetheless, as a counter-measure they show some degree of success when compared to areas where no crop defence is practised, and most particularly where elephants, for whatever reason, do not continually challenge the deterrence system (Hoare, 1995; Naughton *et al.*, 1999).

In one area in Zimbabwe cheap farmer-based traditional methods have been shown to be successful when used in combination. The traditional methods were divided into three categories (Hoare, 2001a):

- **Vigilance methods:** Clearing 5m boundaries around fields; strategically placed watchtowers with a co-operative guard rotation system; use of whistles by the guards; cowbells on string fences.
- **Passive methods***:* fires on field boundaries and at known elephant entry points; 'brickettes' of dried elephant dung and ground chillies being burnt to create noxious smoke; a mixture of chilli pepper oil and grease being smeared on the string fences; the planting of chillies as an unpalatable buffer crop.
- **Active methods***:* using whips (made of tree bark) to imitate gunfire; throwing firecrackers at the elephants.

Combinations of the above were monitored for effectiveness. Maximum deterrence was achieved by the combination of the greatest number of methods.

To re-iterate a point above, injuring elephants with spears or low calibre weapons can result in unprovoked attacks, as well as slow death by infection for the elephant. The use of poisons is totally unethical, especially as it is extremely difficult, if not impossible, to target an individual or species.

Cost/Benefit summary

The disadvantages of traditional methods are habituation, the need to use methods in combination, the danger of using active methods near elephants and the (difficult to quantify) socio-economic and psychological stresses on families and communities. In their favour, they are cheap, can be locally applied by those directly affected, generally do not harm the elephants and have been shown to have some deterrent effect.

Disturbance methods

Disturbance methods are the 'traditional' realm of wildlife or local authorities, being the first step of these authorities when called on to supplement local traditional methods.

Lights, thunder-flashes and flares

Villagers in Sumatra use powerful flashlights to deter elephants in combination with noise and fire (Nyhus *et al.*, 2000). Thunder-flashes and flares have been used in Zimbabwe with initial success (Hoare, 2001a).

Firing weapons

Firing weapons over the heads of crop-raiding elephants to chase them from fields has been used in Zimbabwe (Hoare, 2001a), and Niassa Reserve in Mozambique (Macadona pers. comm.). In Niassa, it is used successfully in combination with electric fences (see 3.6.4. below). This technique is often employed when the elephants are of conservation or economic value.

Trip-wire alarms

O'Connell-Rodwell *et al.* (2000) experimented with trip alarms in villages (n=10) made up of individual farms (n=44) in East Caprivi, Namibia. They surrounded fields with a polyethylene trip cord attached to a trip switch that activated a 10W car alarm for 10 seconds. 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 – elephants initially moved into neighbouring farms before becoming habituated. However, the alarms did serve as a warning system to crop-guards sleeping in or near the fields.

Each alarm cost US$78, less than the average elephant crop-damage claim, while from 1993-1995 an estimated US$1 800 was saved.

Driving with aircraft, vehicles or people

Using a 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, 2001a).

The effectiveness of disturbance methods

Disturbance methods provide initial relief, with elephants appearing to be able to distinguish between local people and their traditional methods, and the wildlife authorities using stronger tactics. But elephants soon become habituated to these too (Bell, 1984; De Boer & Baquete, 1998; Hoare, 1995; O'Connell-Rodwell *et al.*, 2000; Osborn & Rasmussen, 1995; Thouless, 1994), especially if the same animals are regularly involved (Hoare, 1999a).

The shortcoming of disturbance methods used in isolation is the inability to move the elephants far enough away over a large enough area or to prevent their return and resultant habituation. These limitations have been documented for flashlights (Nyhus *et al.*, 2000), thunderflashes and flares (Hoare, 2001a), discharging weapons (Hoare, 2001a) – where elephants even treat shotgun pellets in the rump as an inconvenience and stay just out of range, trip alarms (O'Connell-Rodwell *et al.*, 2000) and large-scale drives (Hoare, 2001a). Their usefulness is in combination with other more permanent and expensive measures (e.g. barriers; see 3.6. below).

Cost/Benefit summary
Disturbance methods in isolation provide only local short-term relief before habituation, they require trained personnel and they can be dangerous because of proximity to the elephants. However, they are generally cheap to apply, they have been shown to have at least some effect, they are non-fatal for the elephants and the involvement of the authorities provides some public relations value.

Killing elephants

Killing problem elephants has been, and still is, widely used as a quick-fix solution to human-elephant conflict. It allows the local or wildlife authorities to demonstrate a show of force to appease the affected communities, while the communities generally believe it will provide a lasting solution, as well as being an obvious act of retribution, coupled with the bonus of free meat (Hoare, 1995; Hoare, 1999a; Taylor, 1993; Taylor, 1999). Traditional societies often appointed a hunter to kill problem animals (Lahm, 1996; O'Connell-Rodwell *et al.*, 2000), which might explain why local communities see this as the immediate solution.

Killing selected problem elephants

This relatively cheap method is employed with the aim of providing instant relief. It is historically popular with wildlife authorities and with those affected by elephant crop-raiding (see 3.3. above). Quick to carry out, elephants are often are shot on sight in damaged fields, mostly during the wet-season when crop-raiding is rife.

Problem animal control (PAC)
Control shooting is normally carried out by trained wildlife personnel operating as problem animal control teams. On a PAC program, attempts are made to identify a 'culprit' elephant that is a known and persistent crop raider, or has caused a human fatality. When properly managed, every animal shot is recorded and reported to the correct authorities. Unlike commercial hunting, there is normally no quota or limit set for PAC.

Identifying problem individuals
It is often difficult to pinpoint culprits, especially as crop-raiding mostly occurs at night, and individuals are rarely identified correctly, despite local communities claiming that they can do so after the fact (Hoare, 2001a; Ngure, 1995; Nyhus *et al.*, 2000). More seriously though, this method relies on the hypothesis that problem elephant activity is due to certain individual animals in a population. This assumption might well be flawed (Hoare, 1999a). The principle biases are:

- the ability to recognise individual elephants, often at night, or in forests,

• repeat offenders are more likely to be eliminated by the authorities,

• research projects are concentrated in areas of high conflict,

• local people promote this idea to exert social pressure on the authorities to act (Hoare, 1999a).

The cautiously proposed alternative is that within any elephant population there is a proportion of individuals responsible for problem incidents. The inadequacy of PAC programs to eliminate crop-raiding entirely provides strong evidence for the theory of replacements entering the problem component of the population (Hoare, 1999a; Hoare, 2001b; Ngure, 1995). Osborn (1998, in Hoare, 2001a) provides evidence for this 'component and replacement theory' from a site with severe conflict in Zimbabwe:

• first, despite elephants being repeatedly shot over decades the problem component still exists,

• and second, a radio-collared male was found to return to the site of its crop-raiding companion's death only four days after the event, negating the hypothesis that shooting teaches other elephants to avoid farmland, and providing possible support for crop-raiding being part of an elephant's optimal foraging strategy (Sukumar, 1990).

PAC examples

In Kenya, Kenyan Wildlife Service (KWS) records show that 119 elephants were killed in PAC programs from 1990-1993, with total numbers increasing each year (Kiiru, 1995). Similarly, in Kaélé, northern Cameroon, control shooting did not reduce the levels of crop damage, despite appeasing local communities (Tchamba, 1995). Which raises the question of whether PAC is often simply conducted for political expediency to satisfy local communities?

In Nyaminyami district, Zimbabwe, local communities have been found to over-exaggerate crop-damage in anticipation of free bushmeat. However, despite the high demands, an average of only eight animals a year have been shot between 1983-1992 (Taylor, 1993). More worryingly, in Nigeria a combination of under-financing of control teams, leading to poor recruitment and poor training, coupled with the need for the relevant Ministry to generate revenue, led to increasing numbers of elephants being shot for the sale of ivory and carcasses (Bita, 1997).

Commercial hunts to kill problem elephants

PAC can be combined with safari hunting quotas to generate income from the shooting of targeted individuals (Damiba & Ables, 1993; Hoare, 1995; Lewis & Alpert, 1997; Lewis, Kaweche & Mwenya, 1990; Tchamba, 1996). Schemes of this nature need to be closely monitored to ensure that there is no manipulation of quotas, but if wet season hunts were marketed (when the majority of crop-raiding occurs) it could lead to a reduction in the total number of elephants shot each year (Taylor, 1993). Revenue generated from safari hunts could be returned to people in the areas where they are shot, i.e. the points of conflict (see 3.8.1.1. below).

A positive aspect of trophy hunting is that only adult males are shot. The long generation time in elephants means that removing an adult male has far less impact on population demography than removing a female (Sukumar & Gadgil, 1988; Sukumar, 1991).

Reducing the elephant population through culling

A cruder lethal method to reduce conflict is culling to either reduce the population, or simply to depopulate the area. If the management goal is to eliminate the population entirely, then culling must be judged on economic and welfare grounds. However, the rising appreciation of elephants (for aesthetic, ecological or economic reasons) means that depopulation is generally not the goal.

Population reduction has also been attempted by shooting young cows from herds near the conflict area (Hoare, 2001a). The rationale is to create higher social disturbance, and thus a longer deterrent effect. But in many areas cow elephants with calves tend to avoid human disturbance anyway, and this only has the effect of adversely affecting reproductive rate because of long generation times (Hoare, 2001a; Sukumar, 1991).

Finally, culling to reduce elephant population density in the hope that this might alleviate levels of crop-damage is also questionable. Firstly, there is the replacement hypothesis (Hoare, 1999a; Hoare, 2001b), and secondly, there is also good evidence to suggest that problem elephant activity is dependent on the activities and behaviour of a segment of the population, rather than elephant density (Hoare, 1999c; Hoare, 2000).

The effectiveness of killing elephants

The notion of habitual problem elephants that are singly responsible for all crop-damage may well be erroneous, with the evidence being both circumstantial and possibly biased. Continent-wide evidence from Africa does not support the relative importance of habitual problem elephants, while the failure of PAC programs to eliminate crop-raiding entirely provides strong evidence for the existence of replacements entering the sub-population (Hoare, 1999a; Hoare, 2001b). This implies that problem incidents might well result from a variable segment of individuals in the population that are easily replaced.

Thus although killing elephants has a short-term effect, the likely existence of a problem component (with available replacements) within any elephant population renders this ineffective as an enduring solution. Further, evidence that killing does not work as a deterrent on other individuals in the population also reduces its merits. When coupled with the problems of correctly identifying habitual offenders (see 3.3.1. above), this becomes a management technique that needs to be evaluated extremely carefully, on a case by case basis, before it is employed.

In reality, most countries have laws that protect elephants (Taylor, 1999; WWF, 1997), and in certain countries (e.g. Gabon: Lahm, 1996`; Namibia: O'Connell-Rodwell *et al.*, 2000`; Zimbabwe Hoare, 1995; Taylor, 1993; Taylor, 1999) laws exist that stipulate the conditions under which problem elephant can be shot. Usually these require the identification of a culprit (Hoare, 1995; Lahm, 1996), that it can only be shot within 1km of the field (Hoare, 1995), and in some places written consent from a local authority to contract a professional hunter to shoot the animal (Hoare, 1995; O'Connell-Rodwell *et al.*, 2000; Taylor, 1993).

Even where protocols exist, adherence to them can vary; especially as killing ‘problem’ animals provides some immediate tangible relief (and benefit) to the affected community, and is thus often politically motivated. On the other side, the decision-making process can often result in undue delays when immediate action is required. However, with increasing value being placed on elephants (aesthetic, ecological and economic), and PAC management falling into the realm of trophy hunting, there should be an added economic incentive for local communities involved in participatory conservation schemes to tolerate elephant damage (see 3.8. below).

Cost/Benefit summary
Shooting ‘problem’ animals often has only a short term effect, it is difficult to identify the culprit(s), it has little or no effect on other elephants, requires skilled personnel and can be dangerous. Its advantages are that it does have some effect (even if short-term), it is relatively cheap and quick, and it has good public relations value in the affected community.

Translocation

In theory translocations seem to provide the perfect solution: removal of the ‘problem’ animal to an area where there will be reduced contact with people and their crops. It saves elephants from being shot, restocks reserves that have been affected by poaching, and provides concrete action for both the affected communities and donors. Translocations have been carried out and reported widely (e.g. India: Lahiri-Choudhury, 1993; Kenya: Litoroh, Omondi, Bitok & Wambwa, 2001; Njumbi, Waithaka, Gachago, Sakwa, Mwathe, Mungai, Mulama, Mutinda, Omondi & Litoroh, 1996; Malaysia: Stüwe, Abdul, Nor & Wemmer, 1998; South Africa: Garai & Carr, 2001; Sumatra, Indonesia: Nyhus *et al.*, 2000; Uganda: Wambwa, Manyibe, Litoroh & Gakuya, 2001; and Vietnam: FFI, 2002b).

The first and most obvious stumbling blocks with translocations are the specialist expertise required, the logistical difficulties of moving such large animals, and the enormous costs involved. But the expertise exists, as do the vehicles and the logistical know-how for transport. Further, animal welfare organisations are often prepared to foot the bill.

Before translocations can be undertaken, preliminary studies of the social structure of the elephants need to be conducted. Ideally, whole family units should be moved, or if males are to be moved it might be best to do so in pairs and to areas where established family units already exist (Garai & Carr, 2001). In India (Lahiri-Choudhury, 1993), Malaysia (Stüwe *et al.*, 1998) and South Africa (Garai & Carr, 2001) translocated males have either ranged widely, or returned to their points of capture in unfortunate circumstances (in India, an adult male returned 180km in three weeks, and was implicated in the death of one person and the injury of two more).

However, even with the expertise, money, resources and careful planning, translocation still faces numerous drawbacks. Firstly, as with killing problem animals (see 3.3.1. above), there is the identification of the culprit and the probable replacement of this animal with another from within the population (Hoare, 1999a; Hoare, 2001b). Secondly, it is impossible to know if the animal will continue its problem activities in the new area, or even just move back (Garai & Carr, 2001; Hoare, 1999a; Hoare, 2001b; Lahiri-Choudhury, 1993; Nyhus *et al.*, 2000). Nyhus (2000) cites an excellent example of this from Sumatra, Indonesia, where 70 problem elephants were translocated to a newly declared national park, only for crop-raiding to simultaneously begin in areas surrounding the park.

A third real issue that has emerged is the welfare of the animals during capture and in transit (FFI, 2002b; Hoare, 1999b; Njumbi *et al.*, 1996). In the Mwea-Tsavo translocation in Kenya, five out of 26 animals died from drug-related stress (Njumbi *et al.*, 1996), while in Vietnam, two out of six elephants died from injuries sustained during capture (FFI, 2002b). Finally, as with culling elephants, simply reducing the elephant population by translocation might not affect problem activity at all. Evidence exists that problem activity is more related to individual elephant behaviour than local density (Hoare, 1999c; Hoare, 2000). Tchamba (1995) also points out that translocation is inappropriate when the conflict is with migratory elephants, such as those in Kaélé, Cameroon, which are only present during the wet season.

The specific economics of translocation are not well documented. The moving of four elephants in Uganda cost just under US$100 000 (Wambwa *et al.*, 2001), while the vehicle alone in the Mwea-Tsavo Kenyan operation cost US$140 000 (Njumbi *et al.*, 1996).

The effectiveness of translocation

Translocations certainly have a role to play in elephant management. But typically this is more likely to be for restocking purposes, to areas of tourist value, or to hunting concession areas. And in fact, the successful translocations documented have almost all been with this intention. It is hard to justify the expense of translocations when evidence suggests that unless it is for the complete removal of an elephant population, it is unlikely to resolve conflict. The welfare concerns for the individual elephants involved must also be considered. Fisher & Lindenmayer (2000) in a general review of 180 animal translocations, explicitly state that translocations aimed to solve human-animal conflicts generally failed.

Cost/Benefit summary

The disadvantages of translocation are its expense, the need for skilled personnel, the likelihood of exporting the problem while it recurs at source with different elephants, the potential distortion of population structure, and welfare concerns for the elephants being moved. It is also of dubious public relations value if the problem is exported while still recurring at origin. However, its major benefit is that it is non-fatal to elephants.

Repellent methods

The use of specific repellents for elephants, both olfactory and auditory, is still in an experimental stage. There have been some successes, most particularly with olfactory repellents, and it is likely that they will have some role to play in conflict deterrent tools.

Olfactory repellents

The irritant in chillies (*Capsicum* spp) has been the focus of research for olfactory elephant repellents.

Oleo-resin capsicum spray

Capsicum-based repellents (in aerosol form) have a history of success in reducing bear attacks on humans in North America, on conditioning problem animals in captivity and in use against human criminals (Osborn & Rasmussen, 1995). The atomised cloud produces a severely irritating effect on any mucous membrane it comes into contact with (e.g. eyes, mouth, respiratory tract).

Osburn & Rasmussen (1995) tested the spray on wild African elephants in Zimbabwe to determine effect and to ascertain potential logistical modifications. The spray was tested on foot, from vehicles and from radio-controlled stands at water-holes. All gave a positive repellent reaction (although in three of the eight water-hole trials, the reaction appeared to be from the noise rather than the spray itself). The spray floats in a cloud and can remain effective for approximately 20 minutes. In light winds it can move an effective distance of up to 75m, but the wind-dependency in dispersal means accidental exposure to people is a constant problem (Hoare, 2001a). Another suggestion has been to shoot the capsicum irritant at elephants in encapsulated liquid form (e.g. like a paint-ball), but the delivery technology has been experiencing problems (Hoare, 2001a).

In 1995 the capsicum aerosol spray cost US$18 per unit. The spray only needs to be used when crop raiding is at its peak (e.g. February to May in Zimbabwe), which has obvious financial advantages.

Chilli grease on barriers

Chilli-grease as a repellent is currently being tested in Zimbabwe on simple traditional type barriers and fences around crops (Hoare, 2001a).

Burning repellents

Similarly, noxious smoke from burning 'brickettes' made with chilli seeds and elephant dung is also being tested in Zimbabwe (Hoare, 2001a). In the Democratic Republic of Congo, capsicum seeds are already added to fires to try and enhance the repellent effect of the smoke (Hillman-Smith *et al.*, 1995).

Other olfactory repellents

Tests are also currently being conducted using other chemical repellents, such as elephant pheromones (Osborn & Rasmussen, 1995).

Auditory repellents

Elephant distress calls

Elephants produce a wide range of calls, both audible to humans and not (infrasound). Ongoing research is attempting to categorise these calls (McComb, Moss, Sayialel & Baker, 2000). It is proposed that calls which invoke alarm and flight could be recorded and played back to elephants in the hope that they might serve as a deterrent (O'Connell-Rodwell *et al.*, 2000). A drawback is that the equipment required to record and play back these calls is complicated and expensive (McComb *et al.*, 2000; Osborn & Rasmussen, 1995)

In Namibia, experiments undertaken with low cost equipment played back elephant distress calls to both males and breeding herds. However, they proved inconclusive, sometimes invoking aggressive reactions, and having no deterrent effect on small groups of crop-raiding bulls (O'Connell-Rodwell *et al.*, 2000). The possibility of habituation has also been raised (Hoare, 2001a; Osborn & Rasmussen, 1995).

Other noises

Trip-wire alarms have been experimented with in Caprivi, Namibia (O'Connell-Rodwell *et al.*, 2000); see 3.2.3. above). Elephants are quickly habituated, but the alarms do serve as a useful warning system to crop-guards and farmers.

In a Maasai pastoralist area in Kenya, the sounds of domestic cattle and cow-bells have been played near elephants to gauge reactions (Kangwana, 1996 in Hoare, 2001a). Breeding herds reacted and retreated far more vigorously than did male groups.

The effectiveness of repellent methods

The use of repellents is still in the experimental stage. While oleo-resin capsicum spray has had some success as a short-term repellent of elephants, an effective delivery mechanism still needs to be adapted or found. Further, control tests to answer questions involving habituation, long-term effects, and possible effects on other wildlife and humans, still need to be conducted.

The effectiveness of capsicum seeds burnt in fires and in grease applied to fences and traditional barriers still needs to be evaluated. One of the major problems in gauging the effect of these measures is the subjective nature of assessing elephant reaction.

Elephants also appear to have sensors at the ends of their trunks which might detect irritant substances before their inhalation and contact with the delicate mucous membranes inside the trunks (Hoare, 2001a). These might render chilli-grease deterrents ineffective.
Auditory repellents have so far proved to be mostly futile. However, ongoing research into the specific meaning of different vocalisations might eventually produce results.

Nonetheless, the repellent effect (albeit short-term) of these techniques (most specifically capsicum based sprays), imply that they most certainly have a role to play in human-elephant conflict management.

Cost/Benefit summary
Comment can only realistically be made on olfactory (capsicum-based) repellents. Their disadvantages lie in their relative expense, the training required to use them, the need to be close to the elephants, the stochastic effect of wind, potential accidental exposure to people and other animals, the difficulty in quantifying and evaluating their effect, and the fact that they may require 'aversive' conditioning of elephants to associate the repellent with human settlements. To their advantage, they are 'low-tech' and can be produced locally, and initial results show that they have no long-term harmful effects.

Physical barriers

Following on from discussion above, merely killing or removing individuals of a pest species seldom provides a lasting solution; rather it is by denying them access to their target food, or a refuge, that control is often achieved (Hoare, 2001b).

Physical barriers are often seen as the enduring solution in human-elephant conflict situations. There is a tendency to place barriers anywhere where the conflict is severe. However, they are an expensive option and the results have often fallen below expectations because of the expense and effort required for maintenance.

Trenches and moats

Trenches have been used with some success in Asia. Along the border of Way Kambas National Park in Sumatra, Indonesia, trenches (2m wide by 3m deep) were found to be effective, and avoided by elephants, until crossed by a stream or river which made a natural crossing point, and generally resulted in erosion (Nyhus *et al.*, 2000). Dug by an excavator, their effectiveness was increased by erosion-resistant clay soils, vegetative ground-cover and regular maintenance by villagers.

Trenches and/or moats have not been utilised much in Africa. In Laikipia district, Kenya, trenches and moats were constructed along the boundaries of the Aberdares and Mount Kenya. They were found to be ineffective as elephants soon learnt to break down the walls and climb through (Thouless & Sakwa, 1995). Incorporation of fences with ditches proved effective as long as they were well maintained (Woodley, 1965).

The main drawbacks of trenches are the large investment required for construction, their vulnerability to soil erosion and hence regular maintenance costs, and their weakness at water crossing points. Elephants also learn to kick the sides in to make crossing points. Moats do not add any extra deterrence as elephants readily cross narrow stretches of water.

Stone walls

Stone walls also suffer from relatively expensive construction costs and in most areas a lack of usable stones for construction. Stone walls have been used in Laikipia District, Kenya, with varied success (Thouless & Sakwa, 1995). Elephants are able to break them with their chests, and in a 3 month period one wall was breached 101 times. Another wall in the same area was moderately effective, but this has been attributed to the forceful action taken against animals that breached it. Thouless & Sakwa (1995) suggest that stone walls with a concreted top, or an electrified wire running along the top of them might be viable alternatives. The advantages of stone walls are their minimal environmental impact, and their relatively low material costs if the stones are readily available and tractors do not have to be used. The stone wall in Laikipia cost US$3 500 per km.

Standard (un-electrified) fences

Un-electrified standard fencing, and even stouter game fences, generally does not serve as an efficient barrier to elephants. Even cabling run through stout poles just inside a game fence, that effectively 'rhino-proofs' the fence, is not entirely effective. Languy (1996 in Hoare, 2001a) believes that in forest ranges, where elephants are not such persistent raiders, unelectrified fences will suffice. However, standard fencing is just one of many ways of demarcating a barrier to elephants and serves as a warning that to cross the barrier will result in harassment, or at worse death. As with most deterrent techniques, it is only useful in combination with other methods.

Electrified fences

Electrified fences are perceived to be the best solution for human-elephant conflict. However, as many projects will testify, they are never the panacea initially believed. It is only with careful planning, costly construction, commitment to maintenance, and in combination with some other means of evicting and/or punishing offending elephants that they are successful.

Most local communities believe they are the ultimate solution and clamour for immediate construction once aware of their potential installation. Around the Maputo Elephant Reserve in Mozambique, 81% of farmers believed that electrified fences would control crop-raiding elephants (De Boer & Ntumi, 2001). If fences are not effective they only serve to habituate elephants to electricity and 'fence-busting' (be it by breaking through or walking around), and lead to frustration within the local communities after their failure.

Planning a fence
Initial planning, layout and design of the fence are especially important for non-target species (Hoare, 1992), e.g. a two strand electrified fence at 1-1.5m will allow other non-target species to pass freely. Knowledge of the ecology, distribution and movement patterns of the local elephant population is also vital. Ignoring these might result in a fence in the wrong place, or an unacceptable maintenance demand. Fence design and fence type are also important (De Boer & Ntumi, 2001; Hoare, 1992; Hoare, 1995; Hoare, 2001a; O'Connell-Rodwell *et al.*, 2000; Smith & Kasiki, 1999; Thouless & Sakwa, 1995). Hoare (2001a) suggests the following general rule for fencing: "the smaller the project, the less it costs and the better it works".

Fence design
Fence design generally falls into three categories:

- enclosing agricultural land and/or houses and people;

- enclosing the elephants and their range;

- a straight line barrier between elephants and agriculture (e.g. along a park boundary).

The latter design has been shown to be ineffective, with elephants just walking along the length of the fence and then around it to get to their target (De Boer & Ntumi, 2001; O'Connell-Rodwell *et al.*, 2000; Smith & Kasiki, 1999; Taylor, 1993; Thouless & Sakwa, 1995). Problem elephants appear not to be easily deflected, rather it seems to make most sense to identify their target and then to keep them out (Hoare, 1995; Hoare, 2001a; Ngure, 1995). This suggests that of the remaining two designs above, the first should be the more effective. The high construction and maintenance costs of enclosing an elephant population's range with electrified fencing bear this out.

Various fence designs for enclosing agricultural land and/or the communities that farm it, have been tested in many areas (Hoare, 1995; Hoare, 2001a; O'Connell-Rodwell *et al.*, 2000; Smith & Kasiki, 1999; Taylor, 1993; Thouless & Sakwa, 1995). These fencing projects normally differ in the size of the area being fenced; enclosing just fields, or a household and its fields, or around a whole community and its facilities and fields. Beyond referring back to Hoare's (2001a) rule of simplicity (see 3.6.4.1. above), none of these designs can be effectively compared from the literature. The mitigating factors are fence type (i.e. construction cost), local elephant behaviour, policies employed in reaction to fence-breaking elephants, and possibly most importantly, maintenance regime.

Fence construction and type
Electrified fence types reported in the literature vary from simple one or two strand fences, to three and six strand fences, and robust 11 or 12 strand fences (De Boer & Ntumi, 2001; Hoare, 1995; O'Connell-Rodwell *et al.*, 2000; Thouless & Sakwa, 1995). Thouless & Sakwa (1995), working in Laikipia district, Kenya, found that elephants managed to break through all fence types, including the 12 strand fence. However, one 11 strand fence was never breached, despite having posts broken. They conclude that it is not necessarily fence construction that is important,

but rather maintenance, local elephant demography (most importantly the number of males), reaction to fence breakers, and the type and distribution of crops grown within the fence. O'Connell-Rodwell *et al.* (2000), working on deterrence measures in Caprivi, Namibia, concur, finding two strand fences to be effective, and that number of male elephants and maintenance regime were more significant factors in determining effectiveness.

The only real conclusion that can be drawn about fence construction is that single strand fences are often ineffective, especially in places where soil moisture content is low and grounding therefore poor (O'Connell-Rodwell *et al.*, 2000; Sukumar, 1991; Thouless & Sakwa, 1995).

Fence voltage

There is no consensus in the literature for optimal voltage. Garai & Carr (2001), reporting on elephant translocations in South Africa, estimate that voltages need to be maintained at 6-9 kV to keep elephants inside fences. While in Kenya, Thouless & Sakwa (1995) recorded voltages between less than 2kV and 8kV, and found no relationship between voltage and effectiveness. O'Connell-Rodwell *et al.* (2000) in Namibia, maintained fences at 40kV, but found other factors more important for assessing fence effectiveness (see 3.6.4.3. above). Simply put, constant high voltages will deter most elephants, but low voltage, a common symptom of poor maintenance, will render the fence ineffective, and may only serve as an irritant, resulting in elephants destroying sections of fence (Hoare, 2001a).

Fence maintenance

A general theme throughout this section on electrified fences has been the importance of maintenance for the long-term success and effectiveness of the fence. Failure of electrified fences is most strongly related to maintenance regime (De Boer & Ntumi, 2001; Hoare, 1995; Hoare, 2001a; Kamiss & Turkalo, 1999; Ngure, 1995; O'Connell-Rodwell *et al.*, 2000; Taylor, 1999; Thouless & Sakwa, 1995). Maintenance problems are normally associated with power supply (usually solar panels with batteries in rural areas) and vegetation growth, which causes power leakages and obscures the fence, preventing it from being an obvious barrier. Potential theft of vital components also needs to be taken into account, which has implications for ownership of the system. However, except for the last point, these are not structural, institutional or methodological failures, and can be improved with training and discipline.

Hoare (2001a) proposes the following strategies to overcome maintenance deficiencies (currently being tried and tested in Zimbabwe):

- stoutly constructed (and thus expensive) fences, that act as barriers even when the power supply is interrupted;

- private sector participation in fencing projects and most importantly maintenance. Private sector fencing projects are usually successful and sustainable;

- simple design (e.g. one or two strands approximately 1-1.5m above the ground). Cheaper construction, maintenance easier (particularly vegetation clearing), and allows smaller non-target animals to pass;

- small, individually-owned fencing projects protecting one household's fields and abode. These only require small power units, can be changed with crop rotation, and might reduce some of the maintenance difficulties inherent in community owned projects, including potential theft.

Elephant demography

The phenomenon of male elephants taking more risks than breeding herds and learning how to disable and/or break fences has been found in many areas in Africa and Asia (O'Connell-Rodwell *et al.*, 2000; Santipillai & Suprahman in Nyhus *et al.*, 2000; Sukumar, 1991; Sukumar & Gadgil, 1988; Thouless & Sakwa, 1995). Tusks function as excellent insulators and are often used when destroying fences. This might go some way to explaining why electrified fences in Asia (where all females and a proportion of male elephants are tuskless) appear to have been more successful than those in Africa. Soil moisture content and thus effective grounding might also play a role (see 3.6.4.3. above).

In Laikipia district, Kenya, the distal third of the tusks of eight habitual fence-breaking male elephants were removed in an attempt to reduce their ability to destroy fences. However, all eight appeared completely unaffected and went on to break 20 fences in the ensuing five days (Thouless & Sakwa, 1995). The authors also reported a significant decrease in the proportion of females and calves crossing a farm boundary after the erection of an electrified fence.

Shooting elephants to establish the boundary
It is argued that a policy of shooting or removing habitual fence-breakers might be the most successful deterrent, and might teach elephants to respect the fence as a boundary (Hoare, 1995; O'Connell-Rodwell *et al.*, 2000; Thouless & Sakwa, 1995). Some fences in Kenya that have been successful over a ten year period have been accompanied with a vigorous policy of shooting fence-breakers, and it appears that they might learn to respect the fence as a boundary (Thouless & Sakwa, 1995). Over time the absence of elephants within a fenced area, and hence a dearth of signs and/or smells, might act as a significant deterrent to any elephants that do break through. An example of a male elephant that broke a fence on a Kenyan ranch that had successfully excluded elephants for ten years, and immediately broke out again, provides some circumstantial evidence for this (Thouless & Sakwa, 1995).

Crops within fences
The effectiveness of electrified fences can be significantly reduced by either growing crops too close to the fence in larger fencing schemes, or by growing crops that elephants favour. Buffer crops unpalatable to elephants might enhance the success of electrified fence systems (see 3.6.5. below).

Economics of electrified fencing
The costs of constructing and maintaining electrified fences seem to vary markedly between areas, and are not always well documented (most especially maintenance costs). Thouless & Sakwa (1995) estimate construction costs in Kenya to be about US$2 000 per km, and maintenance costs approximately US$150 per km (no time period given), while Smith (1999) reports that a 30km fence bordering Tsavo cost US$324 000 (US$10 800 per km) in 1996. Hoare (1995) quotes construction figures from Zimbabwe of approximately US$1 350 per km for community enclosure type fences, and US$170 per km for low specification household enclosure type fences. He estimates annual maintenance costs to be 6.5% (i.e. US$87.75 per km and US$11.05 per km respectively) of the fence price.

O'Connell-Rodwell *et al.* (2000) only quote costs for one of their fences (9.5 km) in Namibia, a two strand wire fence, at US$620 per km (US$5 900 in total). No maintenance costs are quoted. In the two years prior to fence construction elephant damage cost US$1 868, while in the year post-construction, there were no claims. The fence (38km) being constructed adjoining the Maputo Elephant Reserve in Mozambique, is estimated to cost US$1 081 per km for construction and a year's maintenance (US$41 100 in total). Average annual crop damage in the area is an estimated US$8 800 (De Boer & Ntumi, 2001). In Ghana electrified fencing is estimated to cost US$2 500 per km (Barnes, 1999).

Have electrified fences reduced incidents of crop-damage?
Taylor (1993) recorded a 65% decrease (122 incidents p.a. to 42 incidents p.a.) in crop-raiding incidents in Nyaminyami district, Zimbabwe. Hoare (1995) uses a four category (poor to good) qualitative scale to rate fence efficacy in Zimbabwe, and found community enclosure type fences scored best, with small community fences enclosing households and fields eliminating crop-raiding incidents.
In Laikipia district, Kenya, Thouless & Sakwa (1995) also used a qualitative scale to rate fence efficacy. They found no fence or barrier to be completely elephant proof, and two strand fences in combination with a policy of shooting fence-breakers could be as effective as 11 strand fences. The 30km fence built along Tsavo's boundary in Kenya was found to have no significant effect on conflict density when comparing six months prior and post construction (Smith & Kasiki, 1999). Finally, O'Connell-Rodwell *et al.* (2000) in Namibia, report that a two strand wire fence eliminated crop-damage claims in an area where there had been an average of 15.5 claims p.a. for the two previous years. They also found Polywire © (polyurethane cord threaded with wire strands) fences around small farms to be effective.

Buffer crops
Crops that elephants dislike (e.g. chilli, tea, sisal, tobacco, timber) has been planted around food crops to create a buffer. However, the elephants have been found to render these buffer crops ineffective by simply traversing them en route to their preferred food crop (Bell, 1984), and in some cases have even been observed eating sisal (Hoare, 1992). This is not to say that this idea has no merit, but simply that it does not seem to work in isolation.

The effectiveness of physical barriers

Physical barriers are most definitely an important part of managing any human-elephant conflict situation. As mentioned in the introduction to this section (see 3.6. above), denying a pest species access to its food item is a tried and tested strategy for bringing the problem under control (Hoare, 2001b). However, barriers do not work in isolation, and they have to be part of an integrated conflict management strategy to be successful. The examples above often show that it is not only the quality of the barrier that is important, but also the reaction to fence-breakers. If elephants can be taught to respect the barrier as a boundary, its success is generally assured.

Numerous types of barriers have been tried and tested, and all are reviewed above. None are without their problems, but electrified fences around fields and/or homesteads certainly seem to be the most effective solution. Trenches and moats are easily breached; stone walls without vigorous enforcement are also vulnerable, similarly for standard un-electrified fencing. Buffer crops have yet to prove their effectiveness, although they might well enhance the efficacy of an electrified fence system.

Electrified fence systems have been covered extensively above. Maintenance stands out as the most important proximate factor in the success of an electrified fence. This is probably because it reflects deficiencies in all the other areas that must be considered. A badly planned fence will either be regularly broken by non-target animals or by elephants if it crosses a major movement route. A badly designed fence project might not have envisaged how a community plans to work together to maintain the fence, and internal divisions, theft or a long chain of responsibility could cause it to fail. Poor maintenance will also lead to periods of absent or low voltage in the fence, which affords elephants (particularly males) opportunities to learn how to break the fence. This increases confidence in dealing with electricity, reduces fear, diminishes its effectiveness as an ultimate no-go barrier, and puts more pressure on the reaction strategies, especially if trained personnel have to be called in with the obvious time delay.

The factors discussed above point to small, low-specification, low-cost electrified fences around homesteads, where one family or individual with a vested interest in the fence's success is responsible for maintenance, backed by a management policy that treats the fences as no-go areas and punishes elephants accordingly. This might involve shooting individual elephants that initially break the fence: as examples from Kenya show (Thouless & Sakwa, 1995) initial vigorous policies like this can result in fences that are respected over time. It is also typically the males that break fences, thus a policy of shooting fence-breakers is likely to have minimal impact on reproductive rates.

Cost/Benefit summary

Physical barriers, and in particular electrified fences, are expensive to build, are entirely dependent on regular, sometimes expensive and continual maintenance for ever, they are vulnerable to theft of components, and they limit potential land use options by creating defined boundaries (see 3.9. below). In their favour, they can be a more permanent solution, they can assist in land zonation or law enforcement, and they have high public relations value among both beneficiaries and the donor community who have a tangible result.

Compensation schemes

Naturally, one of the first reactions to property being destroyed by elephants is a request for compensation, especially when the animals are legally or effectively owned by the state. This normally comes at the same time as demands to kill them. Compensation is a highly emotive issue and the demands for it normally overshadow discussion about any other conflict management measure (Hoare, 2001a). The following few examples provide some idea of the issues associated with compensation schemes.

In Kenya there was a national policy of paying compensation for wildlife damage until 1989. The scheme was suspended that year because widespread cheating on claims, high administration costs and lack of disbursable funds made it untenable (Thouless, 1994). Compensation for human injury or loss of life still exists, but is not well regarded because payouts fail to keep pace with inflation and because of the bureaucracy involved (assessment is done by the semi-autonomous KWS, but payouts are made through a workmen's compensation scheme from another government department).

In southern Africa, only one (Botswana) of the six countries covered in a review on problem elephant management still retains a compensation scheme (Taylor, 1999).

In Malawi, trials during the 1980's in an area bordering a national park were found to have no positive effect on relations between wildlife authorities and neighbouring communities (Bell, 1984).

In Zimbabwe, a compensation scheme tested in Nyaminyami district was abandoned when claims quadrupled in the second year of operation (1991) – either a result of fraudulent claims, or a cessation of crop-guarding (Taylor, 1993). Interestingly, this same district has been able to retain revenue from a locally administered wildlife utilisation program since 1988, and despite considerable growth in revenue has not re-instituted the scheme (Hoare, 2001a).

Finally, Botswana has a government compensation policy for five species, of which elephant tops the list. In the first five years of this scheme, US$1.13 million was paid (Hoare, 2001a). A recent sociological study on this compensation scheme identified several problems (Hoare, 2001a):

- farmers and officials complained that the compensation was disproportionately low, and took too long to be paid;
- officials believed that the scheme did not help to reduce conflict, nor promote a good relationship with the wildlife authorities;
- it was noted that when species were removed from the compensation list reports of damage attributed to that species dropped, while they increased for other species still on the list;
- the only positive comment was that incidents of crop-damage were reported, allowing the areas of high human-elephant conflict to be identified.

Despite these shortcomings, compensation schemes *per se* might not be completely devoid of use. In instances where, for example, water storage or supply facilities, or food storage facilities are destroyed, there might be reasonable grounds for compensation. There also might be some value in the idea of distributing basic foodstuffs to people who can demonstrate serious crop-loss that might be life-threatening (similar to emergency food-relief post natural disasters). It has also been shown that elephant damage only seriously affects very few people in a community (Hoare, 1999b).

The effectiveness of compensation schemes

Compensation schemes, almost without fail, have been unsuccessful. A major flaw from the outset (unlike most other conflict management strategies), is that they attempt to address the effects, rather then the causes of the conflict (Bell, 1984; Hoare, 1995). They are typically dogged by the same problems:

- failure to decrease the level of the problem (by not tackling the root cause);
- an immediate increase in claims, suggesting either corruption (through bogus or inflated claims) or a decrease in crop-guarding, or both (the lack of motivation for self-defence might in fact aggravate the problem);
- complaints of unreasonably low payments and/or the inability to cover all claims (usually driven by an overall shortage of central funding);
- unequal disbursement (e.g. only to some people), creating social disputes and resentment;
- bureaucracy through cumbersome, expensive and slow administration (brought about by the need to train assessors, the huge areas to be covered and the verification needed for fraud prevention);
- the inability to quantifiable some socio-economic and opportunity costs for people affected by the threat of elephants;
- no apparent end point;
- possibly most importantly, the schemes have absolutely no effect on the relationship between local communities and the wildlife authorities.

They are also almost always accompanied by demands to kill culprit elephants, i.e. they have no discernable effect on managing or reducing conflict. This alone provides a strong argument for wildlife utilisation schemes that attempt to attach value to the animals and look for ways for animals and communities to co-exist (see

3.8. below). People who live on the frontline of human-elephant conflict need some way of deriving benefit from what is otherwise a demotivating and costly situation.

Cost/Benefit summary
The disadvantages of compensation schemes are listed above. The only advantage mentioned is that they help to identify serious human-elephant conflict areas.

Wildlife utilisation schemes

Community involvement in conservation, or simply community conservation, incorporates a broad diversity of projects. This diversity can be perceived as a continuum (Barrow & Murphree, 2001). At one end lie national park initiatives, typically 'protected area outreach activities', in the middle lie 'collaborative management' projects between states and local communities (and sometimes the private sector), while at the other end of the continuum are community based natural resource management (CBNRM) initiatives (Barrow & Murphree, 2001). CBNRM projects characteristically aim to achieve rural development through the use of wildlife or other biological resources in places or ways unconnected with protected areas (Adams, 1998; Adams & Hulme, 2001; IUCN, 1997).

Community based natural resource management (CBNRM)

CBNRM initiatives have been instigated in many areas of the world (e.g. Central and South America, Asia and Africa), and are often not only based on the 'big animal' definition of wildlife, but include wild plants, smaller animals and habitats in general (Kothari, 2001). They are also not always 'resource-based, revenue generation strategies' (Adams & Hulme, 2001), and are often motivated by cultural factors (e.g. the conservation of sacred spaces), or ecological functions (e.g. forests as water catchments) (Kothari, 2001). These initiatives typically involve devolution of some responsibility for wildlife management from central government to local government or community level (Adams, 1998; Adams & Hulme, 2001; Barrow & Murphree, 2001; IUCN, 1997).

Elephants and CBNRM
Elephants generally play a central role in CBNRM initiatives, both as the most valuable asset for revenue generation and the most problematic species in conflict with people (Hoare, 1995; Hoare, 2000; Taylor, 1993; Taylor, 1999). Thus local participation in elephant management strategies is fundamental to the success of CBNRM initiatives. However, experience has shown that it takes time before local CBNRM structures are prepared to take responsibility for the management of elephant problems, rather than just the benefit side of the equation (Hoare, 2000). Following on from this, ways of combining problem elephant control and legitimate elephant utilisation have been investigated.

Schemes like this (combining problem elephant control and safari hunting) have been tested with some success in southern Africa (see 3.3.2. above) (Hoare, 1995; Hoare, 2000; Lewis & Alpert, 1997; Lewis *et al.*, 1990; Taylor, 1993). Benefits from the hunts (e.g. meat, skin, revenue from hunting fees and products) are returned to the local community fund, while combining hunting with problem animal control might also reduce the total population offtake (Taylor, 1993). But the future for income-generation in CBNRM schemes lies in non-consumptive use (principally tourism) with its spin-off benefits (e.g. employment and revenue-sharing with protected areas). This changes local communities' perceptions of elephants from burdens to revenue-generating assets, simultaneously increasing tolerance for conflict and ongoing conflict management strategies.

While the basis for CBNRM might make intuitive sense, it is not always so easy to apply. There are many obstacles to be overcome; those of most relevance to elephant management follow:

- there might be no resource base that can yield a sustainable harvest/income, or the market itself might be unsustainable (Adams & Hulme, 2001; IUCN, 1997);

- there is often institutional reluctance to devolve power at all levels (e.g. from central to local government, or from local government to community level) , particularly in developing countries (IUCN, 1997);

- creating the partnerships between all stakeholders can be difficult or problematic (e.g. wildlife authorities, local authorities, private sector partners and local citizens) (Hoare, 2001a);

• once CBNRM programs exist, the unjust discrepancy of benefits accruing to the wider community, while the effects of crop-raiding are felt by individuals, often creates disharmony and means that negative attitudes can be slow to change (Hoare, 2000; O'Connell-Rodwell *et al.*, 2000);

• communities do not always function as units and preconceived notions that they do can seriously hamper the negotiation and management process (O'Connell-Rodwell *et al.*, 2000).

Using elephants for work
Contrary to common myth, African elephants can be domesticated and trained for work. Barnes (1996) suggested that more elephants could be trained to carry tourists on safari, thus generating income; in similar vein to operations like those at Gangala-na-Bodio in Gabon and Maun in Botswana.

The effectiveness of wildlife utilisation schemes

CBNRM with its cost/benefit approach and active local participation might well offer the best chance of local communities coming to accept living with wildlife, and in particular elephants which are both valuable and problematic. Evidence suggests that if problem elephant management is addressed at the same social level as that at which benefits accrue, then CBNRM has a chance of success. Thus local community participation in human-elephant conflict mitigation is essential. However, to have any chance of success, CBNRM initiatives have to be grounded in reality. Untenable promises will certainly backfire, and the expectations of all concerned need to be managed. It is not only revenue-generation and development potential that CBNRM offers, but relevant locally managed human-wildlife conflict resolution strategies too. The link between responsibility for the costs as well as the benefits must never be broken.

Cost/Benefit summary
CBNRM is a long-term complex process, dependent on policy and legislation from higher administrative levels that promotes decentralisation and power-sharing. However, by involving people who are affected by the problems in the solutions and the benefit side of the equation, it has both conservation potential (especially for species and habitats not included in protected areas), and development potential (income-generation) in areas unsuitable for agriculture. This makes its public relations value high where it is successful, but can be potentially damning if it fails or falls below expectations.

Land use planning

Land use and human-elephant conflict

Land use planning is a fundamental human-elephant conflict management strategy and offers possibly the best chance of overall success. However, because of the diversity of sites where human-elephant conflict occurs there are few guidelines or principles for addressing this process. Hoare (1995) defines three main types of interface between elephants and people: hard edge (a clear, but open ended divide between people and elephants); isolated settlement, and mosaic (small clusters of farms intertwined with elephants).

Human-elephant conflict is often an entry point for dialogue between the relevant stakeholders (e.g. local authorities concerned with agricultural, administrative and conservation interests, local organisations and even individuals). Participation in this dialogue allows some influence on wide-ranging decisions, including land use (Hoare, 2000). In places where wildlife utilisation and local natural resource management programs (e.g. CBNRM, see 3.8.1. above) have been initiated, it is obviously much easier to influence such decisions (Hoare, 2001a).

Initiating the types of changes listed below (3.9.2.) is obviously aimed at realising co-existence between elephants and people, with low levels of direct conflict (Hoare & Du Toit, 1999). Conflict is only one part of a complex relationship between elephants and people that exist in the same area. This relationship differs significantly across sites of human-elephant conflict, but the basis of the conflict is typically spatial (i.e. the distribution of and interface between people and elephants) and temporal (i.e. seasonal) in nature, as opposed to numerical or density dependent (i.e. how many people and elephants live together) (Barnes *et al.*, 1995; Hoare, 1999c; Hoare & Du Toit, 1999; Smith & Kasiki, 1999).

Suggested land use changes for human-elephant conflict mitigation

The following land use changes have been proposed for their potential to address the spatial component of human-elephant conflict (Bell, 1984; Hoare, 1999c; Hoare, 2000; Kangwana, 1995; Lahm, 1996; Smith & Kasiki, 1999; Taylor, 1999; Thouless, 1994). It is still too early to evaluate them. They are listed in four general categories based on their goals (after Hoare, 2001a):

Reducing the conflict interface

- reduce human settlement encroachment into elephant range;
- relocate agricultural activity out of elephant range;
- consolidate human settlement patterns near elephant range.

Facilitating defence against problem elephants

- reduce the size of crop fields;
- change the location of crop fields (e.g. to close proximity with dwellings);
- change the cropping regime (e.g. to crops not affected by elephants, diversify into more types of crops possibly reducing overall exposure, use intercropping layout, change timing of harvest).

Increasing efficiency in agricultural and economic production

- the last two points above are relevant here, plus;
- reducing the dependency of the local economy on agriculture.

Modifying problem elephant movement

- create or secure elephant movement routes/corridors;
- secure elephant and human access to different water points (e.g. by manipulating the water supply to change elephant distribution, or by using salt licks to facilitate elephant redistribution);
- reposition protected area boundary;
- expand protected area(s);
- designate new protected area(s).

Discussion: The effectiveness of land use planning

The focus of human-elephant conflict mitigation strategies is often on manipulating elephant behaviour and/or creating defendable boundaries that deny elephants access to certain areas. But this is a two way process, and the underlying motivation for these strategies is as much about elephant existence (and conservation) as it is about human existence. At least as many elephants in Africa live in unprotected areas as do in protected areas, with unprotected areas accounting for 80% of total elephant range in Africa (Hoare, 1999c; Hoare, 2000). Thus managing human-elephant conflict is vital for conserving elephant populations in unprotected areas, and still very important for those in protected areas where conflict prevails along the boundaries.

Modifying the spatial distribution of humans and/or their crops, changing the cropping regime (e.g. temporally, spatially and/or by introducing different crops), and possibly even developing the economy from agriculturally dependent to whatever might be locally viable, thus all fall into the realm of conflict management. The simple objective is to accommodate elephants in current and future land use plans (Hoare, 2000; Hoare & Du Toit, 1999). As Hoare (2001a) points out, dealing with a difficult human-elephant conflict situation provides an entry point for much wider conservation action, often culminating in issues far beyond those normally associated with elephants.

Cost/Benefit summary

Involvement in land-use planning is typically a long term process that requires government support, often legislative and/or policy changes, and can be extremely expensive to implement. But it has long-term benefits for mitigating human-elephant conflict, improving conservation for other species and habitats and establishing a positive relationship with local communities.

Conclusions

Two themes have emerged from this review of human-elephant conflict alleviation strategies: firstly, that no single method works in isolation, but rather that combinations provide the best chance of success; and secondly, that it is of fundamental importance to include those who are most affected by the problem in the solution. This is best achieved by transferring ownership of the management strategies to the local communities that are affected, especially where they are 'high-tech' and prone to maintenance needs and skill acquisition.

When dealing with issues as emotive as elephant conservation and conflict alleviation, it is to be expected that the way forward will be complex. It follows that the future will bring new technologies, advances and understanding, and that any management strategy *must* be adaptive in nature.

As previously mentioned, conflict alleviation is a two-sided equation. Both elephants and people are in conflict, and the goal is to enable co-existence and sharing of resources on some scale. This is best achieved by addressing both sides of the equation. Increasing tolerance for elephants and adapting the human landscape will always be the most difficult. But approaches based on sharing the benefits and management of elephants with those most affected by them (e.g. by CBNRM) and a willingness to get involved in long-term processes like land-use planning and economic development are fundamental. It is very likely that land-use planning to reduce the human-elephant interface offers the best solution. By zoning the landscape at a larger scale, elephant habitat can be retained and will no doubt offer far better opportunities for income-generation from tourism. The essential difficulty to be resolved remains equitable sharing of the benefits from such zonation, particularly for those living at the interface who bear the brunt of the problem.

On the other side of the equation, strategies need to be developed and continually revised with new knowledge and technology to address elephant crop-raiding. Previous experience suggests that the best way to achieve this is through a combination of barrier methods and vigorous enforcement of a no-go zone. Despite numerous difficulties (e.g. initial expense and maintenance) electric fences with planning and forethought seem to provide the most effective barrier. The maintenance issue seems best addressed through small projects, as incentive to maintain and enforce the fence correlates directly with personal crop-loss.

Enforcing the barrier is possibly the most emotive issue, especially with funding agencies. Despite evidence to suggest that shooting problem elephants as a stand-alone policy is ineffectual (Hoare, 1999a; Hoare, 2001b), there is further evidence that shooting elephants in combination with an effective barrier might well have the desired effect of creating a recognised no-go boundary (Thouless & Sakwa, 1995). Such a stringent policy would require the fences to be continually well maintained and rapid reaction from the PAC team, especially at the outset. But a policy this contentious would need continual evaluation, both to assess its efficacy, and if effective whether it can be relaxed with time.

Where other methods of 'punishing' elephants are required (e.g. when shooting proves unsuccessful, or the policy is relaxed, or diplomacy and politics exclude it) then combinations of all other methods need to be experimented with and adapted locally. The process of adapting and combining methods in novel ways will no doubt be never-ending as an armsrace develops between combinations of methods and elephants' abilities to learn and habituate.

Human-elephant conflict is likely to be an eternal problem, but its very existence is cause for optimism. As long as there are elephants to conserve there are opportunities for income-generation and local management of the costs and benefits, including conflict management. It is unlikely that there will ever be a widespread remedy, but rather each area and problem will need to be tackled independently, locally and on an appropriate scale. The key concept is adaptive management.

Bibliography

Adams, W.M. 1998. Conservation and development. Pages 286-315 in W.J. Sutherland, editor. *Conservation science and action*. Blackwell, Oxford

Adams, W.M. & Hulme, D. 2001. If community conservation is the answer in Africa, what is the question? *Oryx*, 35: 193-200.

Armbruster, P. & Lande, R. 1993. A population viability analysis for the African elephant (*Loxodonta africana*): How big should reserves be. *Conservation Biology*, 7: 602-610.

Barnes, R.F.W. 1996. The conflict between humans and elephants in the central African forests. *Mammal Review*, 26: 67-80.

Barnes, R.F.W. 1999. Is there a future for elephants in West Africa? *Mammal Review*, 29: 175-199.

Barnes, R.F.W., Azika, S. & Asamoah-Boateng, B. 1995. Timber, cocoa, and crop-raiding elephants: A preliminary study from Southern Ghana. *Pachyderm*, 19: 33-38.

Barnes, R.F.W., Barnes, K.L., Alers, M.P.T. & Blom, A. 1991. Man determines the distribution of elephants in the rain forests of northern Gabon. *African Journal of Ecology*, 29: 54-63.

Barrow, E. & Murphree, M. 2001. Community conservation from concept to practice: A framework. Pages 9-23 in M. Murphree, editor. *African wildlife and livelihoods: The promise and performance of community conservation*. James Currey, Oxford and Heinemann, New Hampshire.

Bell, R.H.V. 1984. The man-animal interface: an assessment of crop damage and wildlife control. Pages 387-416 in E. Mcshane-Caluzi, editor. *Conservation and wildlife management in Africa*. US Peace Corps, Malawi.

Bita, B.B. 1997. Current elephant conservation problems in Borno State, Nigeria. *Pachyderm*, 23: 19-23.

Damiba, T.E. & Ables, E.D. 1993. Promising future for an elephant population. A case study in Burkina Faso, West Africa. *Oryx*, 27: 97-103.

De Boer, W.F. & Baquete, D.S. 1998. Natural resource use, crop damage and attitudes of rural people in the vicinity of the Maputo Elephant Reserve, Mozambique. *Environmental Conservation*, 25: 208-218.

De Boer, W.F. & Ntumi, C.P. 2001. Elephant crop damage and electric fence construction in the Maputo Elephant Reserve, Mozambique. *Pachyderm*, 30: 57-64.

De Boer, W.F., Ntumi, C.P., Correia, A.U. & Mafuca, J.M. 2000. Diet and distribution of elephants in the Maputo Elephant Reserve, Mozambique. *African Journal of Ecology*, 38: 188-201.

Douglas-Hamilton, I. 1987. Elephant population trends and their causes. *Oryx*, 21: 11-24.

Douglas-Hamilton, I., Michelmore, F. & Inamdar, A. 1992. African elephant database. UNEP, New York.

Dudley, J.P., Mensah-Ntiamoah, A.Y. & Kpelle, D.G. 1992. Forest elephants in a rainforest fragment: Preliminary findings from a wildlife conservation project in southern Ghana. *African Journal of Ecology*, 30: 116-126.

FFI. 2002a. Asian Elephant Conservation Programme. *Fauna & Flora*, April 2002: 24-27.

FFI. 2002b. The perils of elephant translocation. *Fauna & Flora*, April 2002: 27.

Fischer, J. & Lindenmayer, D.B. 2000. An assessment of the published results of animal relocations. *Biological Conservation*, 96: 1-11.

Garai, M.E. & Carr, R.D. 2001. Unsuccessful introductions of adult elephant bulls to confined areas in South Africa. *Pachyderm*, 31: 52-57.

Goldman, A. 1996. Pests and disease hazards and sustainability in African agriculture. *Experimental Agriculture*, 32: 199-211.

Graham, A.D. 1973. *The gardeners of Eden*. London: Allen & Unwin.

Hackel, J.D. 1999. Community conservation and the future of Africa's wildlife. *Conservation Biology*, 13: 726-734.

Hart, L.A. & O'Connell, C.E. 1998. Human conflict with African and Asian elephants and associated conservation dilemmas. Pages 14. Workshop on co-operative regional wildlife management in southern Africa.

Hill, C.M. 2000. Conflict of interest between people and baboons: Crop raiding in Uganda. *International Journal of Primatology*, 21: 299-315.

Hillman-Smith, A.K.K., de Merode, E., Nicholas, A., Buls, B. & Ndey, A. 1995. Factors affecting elephant distribution at Garamba National Park and surrounding reserves, Zaire, with a focus on human-elephant conflict. *Pachyderm*, 19: 39-48.

Hoare, R.E. 1992. The present and future use of fencing in the management of larger African mammals. *Environmental Conservation*, 19: 160-164.

Hoare, R.E. 1995. Options for the control of elephants in conflict with people. *Pachyderm*, 19: 54-63.

Hoare, R.E. 1999a. Assessing the evidence for the existence of habitual problem elephants. Pages 1-2. IUCN African Elephant Specialist Group Report.

Hoare, R.E. 1999b. Data collection and analysis protocol for human-elephant conflict situations in Africa. Pages 1-40. IUCN African Elephant Specialist Group Report.

Hoare, R.E. 1999c. Determinants of human-elephant conflict in a land-use mosaic. *Journal of Applied Ecology*, 36: 689-700.

Hoare, R.E. 2000. African elephants and humans in conflict: the outlook for co-existence. *Oryx*, 34: 34-38.

Hoare, R.E. 2001a. A decision support system for managing human-elephant conflict situations in Africa. Pages 1-110. IUCN African Elephant Specialist Group Report.

Hoare, R.E. 2001b. Management implications of new research on problem elephants. *Pachyderm*, 30: 44-49.

Hoare, R.E. & Du Toit, J.T. 1999. Coexistence between people and elephants in African savannas. *Conservation Biology*, 13: 633-639.

Houghton, R. A. 1994. The worldwide extent of land-use change. *Bioscience*, 44: 305-313.

IUCN. 1997. Community wildlife management in southern Africa: A regional review. Pages 38. Southern Africa: IUCN - Southern Africa Sustainable Use Specialist Group.

Kamiss, A. & Turkalo, A.K. 1999. Elephant crop raiding in the Dzanga-Sangha reserve, Central African Republic. Pages 1-7. IUCN African Elephant Specialist Group.

Kangwana, K. 1995. Human-elephant conflict: the challenges ahead. *Pachyderm*, 19: 11-14.

Kiiru, W. 1995. The current status of human-elephant conflict in Kenya. *Pachyderm*, 19: 15-19.

Kothari, A. 2001. Time to move *Out of Africa!* - A response to Adams and Hulme. *Oryx*, 35: 204-205.

Lahiri-Choudhury, D.K. 1993. Problems of wild elephant translocation. *Oryx*, 27: 53-55.

Lahm, S.A. 1996. A nation-wide survey of crop-raiding by elephants and other species in Gabon. *Pachyderm*, 21: 69-77.

Lewis, D. & Alpert, P. 1997. Trophy hunting and wildlife conservation in Zambia. *Conservation Biology*, 11: 59-68.

Lewis, D., Kaweche, G.B. & Mwenya, A. 1990. Wildlife conservation outside protected areas - lessons from an experiment in Zambia. *Conservation Biology*, 4: 171-180.

Lindeque, M. 1995. Conservation and management of elephants in Namibia. *Pachyderm*, 19: 49-53.

Litoroh, M., Omondi, P., Bitok, E. & Wambwa, E. 2001. Two successful elephant translocations in Kenya. *Pachyderm*, 31: 74-75.

McComb, K., Moss, C., Sayialel, S. & Baker, L. 2000. Unusually extensive networks of vocal recognition in African elephants (*Loxodonta africana*). *Animal Behaviour*, 59: 1103-1109.

Naughton, L., Rose, R. & Treves, A. 1999. The social dimensions of human-elephant conflict in Africa: a literature review and case studies from Uganda and Cameroon. Pages 1-82. IUCN African Elephant Specialist Group Report.

Naughton-Treves, L. 1997. Farming the forest edge: Vulnerable places and people around Kibale National Park. *The Geographical Review*, 87: 27-47.

Naughton-Treves, L. 1998. Predicting patterns of crop damage by wildlife around Kibale National Park, Uganda. *Conservation Biology*, 12: 156-168.

Naughton-Treves, L., Treves, A., Chapman, C. & Wrangham, R. 1998. Temporal patterns of crop-raiding by primates: Linking food availability in croplands and adjacent forest. *Journal of Applied Ecology*, 35: 596-606.

Ngure, N. 1995. People-elephant conflict management in Tsavo, Kenya. *Pachyderm*, 19: 20-25.

Njumbi, S., Waithaka, J., Gachago, S., Sakwa, J., Mwathe, K., Mungai, P., Mulama, M., Mutinda, H., Omondi, P. & Litoroh, M. 1996. Translocation of elephants: The Kenyan experience. *Pachyderm*, 22: 61-65.

Nyhus, P. J., Tilson, R. & Sumianto. 2000. Crop-raiding elephants and conservation implications at Way Kambas National Park, Sumatra, Indonesia. *Oryx*, 34: 262-274.

O'Connell-Rodwell, C.E., Rodwell, T., Rice, M. & Hart, L.A. 2000. Living with the modern conservation paradigm: can agricultural communities co-exist with elephants? A five-year case study in East Caprivi, Namibia. *Biological Conservation*, 93: 381-391.

Osborn, F.V. & Rasmussen, L.E.L. 1995. Evidence for the effectiveness of an oleo-capsicum aerosol as a repellent against elephants in Zimbabwe. *Pachyderm*, 20: 55-64.

Parker, I.S.C. & Graham, A.D. 1989. Elephant decline: Downward trends in African elephant distribution and numbers. Parts I & II. *International Journal of Environmental Studies*, 34: 13-26 & 287-305.

Saj, T.L., Sicotte, P. & Paterson, J.D. 2001. The conflict between Vervet monkeys and farmers at the forest edge in Entebbe, Uganda. *African Journal of Ecology*, 39: 195-199.

Sam, M.K. 1999. The distribution of elephants in relation to crop damage around Bia conservation area during the 1999 rainy season. Pages 1-2. IUCN African Elephant Specialist Group Report.

Smith, R.J. & Kasiki, S.M. 1999. A spatial analysis of human-elephant conflict in the Tsavo Ecosystem. IUCN African Elephant Specialist Group Report.

Southwood, T. 1977. The relevance of population dynamic theory to pest status. Pages 36-54 in G.R. Sagar, editor. *Origins of pest, parasite, disease and weed problems.* Blackwell, Oxford.

Stüwe, M., Abdul, J.B., Nor, B.M. & Wemmer, M. 1998. Tracking the movements of translocated elephants in Malaysia using satellite telemetry. *Oryx*, 32: 68-74.

Sukumar, R. 1990. Ecology of the Asian elephant in southern India. II. Feeding habits and crop raiding patterns. *Journal of Tropical Ecology*, 6: 33-53.

Sukumar, R. 1991. The management of large mammals in relation to male strategies and conflict with people. *Biological Conservation*, 55: 93-102.

Sukumar, R. & Gadgil, M. 1988. Male-female differences in foraging on crops by Asian elephants. *Animal Behaviour*, 36: 1232-1235.

Sutton, W.R. 1998. The costs of living with elephants in Namibia. Pages 15. Workshop on co-operative regional wildlife management in southern Africa.

Taylor, R.D. 1993. Elephant management in Nyaminyami District, Zimbabwe: Turning a liability into an asset. *Pachyderm*, 17: 19-29.

Taylor, R.D. 1999. A review of problem elephant policies and management policies in southern Africa. Pages1-4. IUCN African Elephant Specialist Group Report.

Tchamba, M.N. 1995. The problem elephants of Kaele: A challenge for elephant conservation in northern Cameroon. *Pachyderm*, 19: 26-31.

Tchamba, M.N. 1996. History and present status of the human elephant conflict in the Waza-Logone Region, Cameroon, West Africa. *Biological Conservation*, 75: 35-41.

Thouless, C.R. 1994. Conflict between humans and elephants on private land in northern Kenya. *Oryx*, 28: 119-127.

Thouless, C.R. & Sakwa, J. 1995. Shocking elephants: Fences and crop raiders in Laikipia District, Kenya. *Biological Conservation*, 72: 99-107.

Ville, J.L. 1995. Man and elephant in the Tsavo area of Kenya: an anthropological perspective. *Pachyderm*, 20: 69-72.

Wambwa, E., Manyibe, T., Litoroh, M. & Gakuya, F. 2001. Resolving human-elephant conflict in Luwero District, Uganda, through elephant translocation. *Pachyderm*, 31: 58-63.

Williams, A.C., Johnsingh, A.J.T. & Krausman, P. R. 2001. Elephant-human conflicts in Rajaji National Park, north-western India. *Wildlife Society Bulletin*, 29: 1097-1104.

Woodley, F.W. 1965. Game defence barriers. *East African Wildlife Journal*, 3: 89-94.

WWF. 1997. Conserving Africa's elephants: Current issues and priorities for action. In H.T. Dublin, T.O. McShane and J. Newby). World Wide Fund for Nature International Report, Gland, Switzerland.