MANAGEMENT

Clarification: The Editorial Board of *Pachyderm* wishes to provide the clarification that Francesco Nardelli's article: *The last chance for the Sumatran rhinoceros?*, published in Issue 55 does not reflect the views of Save the Rhino International.

Repelling elephants with a chilli pepper gas dispenser: field tests and practical use in Mozambique, Zambia and Zimbabwe from 2009 to 2013

Sébastien Le Bel

Cirad Dept ES UPR BSEF, Campus International de Baillarguet, 34398 Montpellier Cedex 5, France
email: sebastien.le_bel@cirad.fr

Abstract

In elephant range states, human-elephant conflict (HEC) is considered a serious handicap to the possibility of peaceful coexistence between free ranging elephants and their neighbouring human communities. Among measures promoted to mitigate HEC, the use of chilli pepper as an olfactory repellent has been popularized as a passive form of deterrent. To extend its use, a gas dispenser was developed that employed ping-pong balls filled with chilli oil extract as projectiles. Following an initial test in Hwange National Park, Zimbabwe, in 2007, a further series of field tests was conducted in Mozambique, Zambia and Zimbabwe over the 2013 period to improve the dispenser and to separate off the specific effects of chilli pepper. From >300 attempts to deter problem elephants, it was concluded that of the combination of noise, the impact of the projectile on the elephant and the release of a cloud of chilli pepper, only the exposure to chilli pepper functioned as an efficient deterrent. The paper discusses the problem of sourcing chilli pepper in sufficient quantities, and describes an advanced prototype of the dispenser using an industrial moulding process. Successful integration of this new device with other more traditional mitigation approaches may increase human tolerance of elephants by teaching the latter to respect established boundaries and stay away from farmed crops.

Additional key words: Mitigation, crop raiding, communal land, urban area.

Résumé

Dans les pays abritant des populations d'éléphants, les conflits hommes–éléphants sont considérés comme un défi majeur pour une coexistence harmonisée entre ces animaux et les sociétés rurales. De toutes les mesures d'atténuation promues depuis les années 90, l'utilisation de piment comme un répulsif olfactif a été popularisée sous des formes passives. Pour en étendre son utilisation un propulseur à piment a été développé utilisant comme projectiles des balles de ping-pong remplies d'extrait huileux de piment. Après un test initial dans le Parc national de Hwange en 2007, de nouveaux essais ont été conduits au Mozambique, en Zambie et au Zimbabwe entre 2009 et 2013 pour améliorer l'invention et étudier les effets spécifiques d'une projection de piment. Avec plus de trois cents essais de dissuasion sur des éléphants à problème, nous avons conclu que si la combinaison d'une détonation, de l'impact du projectile et de l'émission d'un nuage de piment a dissuadé efficacement les éléphants, seule l'exposition au piment est réellement dissuasive. Hormis le problème d'approvisionnement en piment, les améliorations du prototype pour une efficacité optimale sont détaillées. En complément des mesures d'atténuation traditionnelles, l'utilisation du propulseur à piment vise à générer un processus de mémoire virtuelle des frontières, qui améliorerait la protection des récoltes et faciliterait la coexistence des populations humaines avec leurs éléphants.

Mots clés supplémentaires: Atténuation, dégâts aux cultures, piment, zone communale, zone urbaine.

Introduction

Human–elephant conflict (HEC) and the problem of what to do about so-called "problem elephants" that coexist alongside human communities, in combination with the illegal trade of ivory and the degradation of wilderness for elephant habitats, is considered as a major threat and challenge to elephant conservation programmes throughout Africa (FAO 2009; Hoare 2001; Lee and Graham 2006; Taylor and Martin 1987; WWF 2005). Problems have been reported from most of the 37 countries where elephants range on the African continent (Hoare 2000), so that mitigation of HEC means determining an effective regional strategy. In southern Africa, the Southern African Development Community (SADC) Technical Committee on Wildlife has declared that HWC and its elephant component are one of the main problems for Africa's rural populations with regard to personal security and economic loss (Le Bel et al. 2011). In central Africa COMIFAC (Commission des Forêts d'Afrique Centrale;Kamgakamdem 2012) urged member states to develop national HEC mitigating strategies similar to the one recently developed in Gabon (Mekuibiyogo 2010).

Lessons from 15 years of HEC mitigation have indicated areas of progress, with a better understanding of the behaviour of "problem" elephants and an assessment of the various mitigation methods available. Low-tech and sustainable defences using chilli pepper-based olfactory repellents have produced some promising results in deterring elephants from entering crop fields or human habitations (Hoare 2012). The most widely popularized methods are using chilli pepper grease on traditional fences (Sitati and Walpole 2006) or burning elephant dung mixed with chilli pepper powder. Packages of chilli pepper-based measures suitable for small farmers were developed and disseminated during training courses organized by NGOs (Osborn and Parker 2002; Parker and Anstey 2002). These measures, taken from various manuals (Parker et al. 2007; WWF 2005), were recently compiled with others as a set of handy solutions in a human-wildlife conflict tool box developed by FAO (LeBel et al. 2010). Although chilli pepper has been tested with success on crop-raiding elephants (Osborn and Parker 2002; Osborn 2002; Osborn and Rasmussen 1995) its use on a larger scale has been limited (Sitati and Walpole 2006) with unreliable impacts (Hedges and Gunaryasi 2009). The local production of strong chilli pepper oil extract with a high deterrent effect remains a challenge, as does the production of reliable chilli pepper dispensers for use by communities on crop-raiding elephants. Using a paint-ball gun was suggested, but its utilization in African rural areas has encountered problems (Nelson et al. 2003).

As a response to this challenge, a chilli pepper gas dispenser was developed that matched the financial and technical capabilities of local communities and individuals. This dispenser, the Mhiripiri Bomber™, is intended for use by communities against crop-raiding elephants. The first preliminary results of field tests carried out in Hwange National Park, Zimbabwe, published in 2010, showed promising results (Le Bel et al. 2010). From these first attempts, it was agreed that further field trials should be conducted to improve the system and separate off the discrete effects of projectile impacts; namely the bang produced on firing and the chilli pepper itself. During on-site training over the same period, a few chilli pepper gas dispensers were supplied to some of the communities based in HEC hotspots for testing. Records were established on how it performed with particular investigation of their deterrent capabilities on crop-raiding elephants.

The purpose of this paper is to present the results of additional tests conducted at Hwange National Park in 2010 and in HEC hotspots in Mozambique, Zambia, and in Zimbabwe from 2009 to 2013, and to discuss how such an innovation could best be part of local strategies to improve crop protection.

Material and methods

Homemade chilli pepper oil extract

The chilli pepper oil extract was locally produced by extracting capsaicin, the main capsaicinoid found in chilli pepper. Capsaicin is a chemical compound which stimulates chemoreceptor nerves of the mucous membranes, causing a sensation of heat, watering eyes, a burning sensation in the trunk mucosa, and trigeminal pain. After grinding dry chilli pepper as finely as possible with a pestle and mortar, the powder was placed in a sealed bottle and then soaked with unleaded petrol for 48 hours. The chilli pepper residue was filtered out using a perforated tin with cotton wool. The pepper residue was further 'washed' by adding more fuel to it until the dark 'redness' of the draining liquid lessened and it was then placed in a large open container in the shade to evaporate slowly to half of its volume. The solution was then further diluted with locally made vegetable oil at a ratio of half a volume of vegetable oil to one volume of fuel. The solution was bottled and stored in the shade. The final solution, rated at about 300,000 Scoville Heat Units, indicating a high concentration of capsaicin, was extremely irritating and required careful handling, wearing suitable rubber gloves, a protective mask and safety glasses. Approximately ½ kg of ground chilli pepper produced ~600 ml of chilli pepper oil extract.

Dispenser and projectiles

The custom-made Mhiripiri Bomber™ gas-dispenser (Mostert, 2008) is made with two pieces of PVC pipe (Figure 1). Its description and use are detailed in a previous paper which reported on the preliminary results of a field test conducted in 2007 in Hwange National Park (Le Bel et al. 2010). The dispenser propels a standard ping-pong ball of 40 mm diameter and a volume of 32 cm3. Each ping-pong ball was filled with either chilli pepper oil extract or water by means of a syringe and a large bore needle; the opening was then sealed with a drop of cyanoacrylate glue.

The Mhiripiri Bomber™ chilli pepper gas dispenser being demonstrated in Niassa, Mozambique - see centre pages Plate 7; (iv).

Study areas

The first study area was Hwange National Park in Zimbabwe, which is characterized by its large elephant population of some 45,000 animals during the dry season. To avoid any interaction with tourism activities, the remote block Central B, with a density of 1 to 2 elephants per km² (Dunham et al. 2007), was allocated to the research team by the Zimbabwe Parks and Wildlife Management Authority (ZPWMA) to test the behaviour change of elephants in response to the repellent.

The second set of study areas (Figure 2) were places currently affected by the intrusion of elephants in urban areas (Victoria Falls urban district, Zimbabwe), the Forestry Commission estate (Sikumi Forest, Zimbabwe), orchards (Savé Valley Conservancy and Chirundu town, Zimbabwe) and subsistence farming areas in Niassa Reserve, Mozambique (Araman, 2009), Kakumbi Chiefdom, Zambia (Chomba et al. 2012) and Hwange rural district, Zimbabwe (Guerbois et al. 2013).

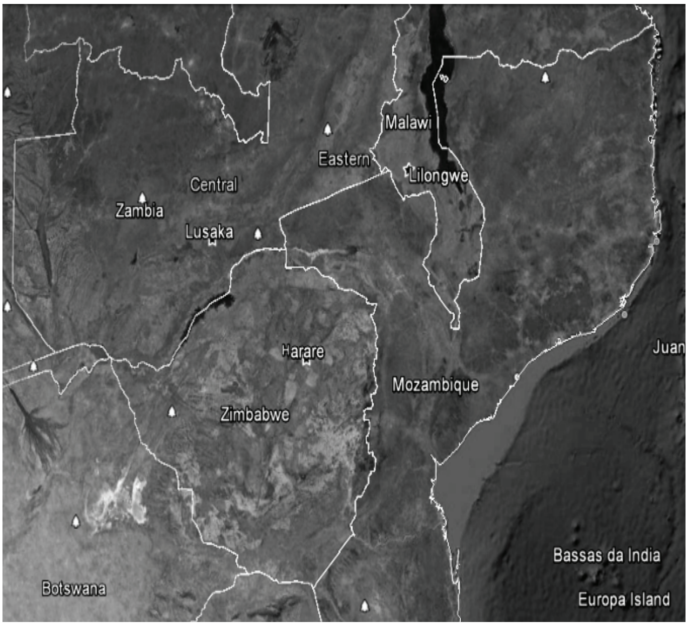

Figure 1. Location of the study areas: (a) Niassa Game Reserve; (b) Kakumbi Chiefdom, Lupande Game Management Area, South Luangwa National Park; (c) Chirundu town; (d) Savé Valley Conservancy; (e) Hwange National Park Hwange rural district and Sikumi Forest; (f) Victoria Falls urban district.

Recording parameters

Field tests at Hwange National Park: The dispenser and ping-pong projectiles were tested on elephants found on the dust track, or close to it, to study its efficiency as a fast-acting repellent by recording changes in agonistic behaviour. The protocol for recording the shooting events, slightly modified from the previous study (Le Bel et al. 2010), was as follows.

The observations were classed in four categories depending on the combination deterrent effects:

- *Noise:* a single deterrent effect with the bang produced on firing
- *Noise & Hit:* a double deterrent effect with the bang and the projectile full of water hitting the elephant
- *Noise, Hit & Chilli pepper*: a triple deterrent effect with the bang, the hit and the release of chilli pepper onto the elephant (Figure 3)
- *Noise & Chilli pepper*: similar to the previous situation but where the projectile missed the elephant burst on impact, releasing chilli pepper directly onto the elephant.

On shooting the following information was recorded:

- The shooting distance was measured in metres with a range finder (Bushnell Corporation).
- Targeted elephants were classed in four categories as adult male, adult female, sub-adult, or family unit.
- The behaviour of each targeted elephant before shooting was classed in five categories as unaware, on alert, moving off, threatening, or charging.
- The placement of the ball on the elephant was classed in five categories as front, side, back, near-by hitting the soil or vegetation, missed, or off-target.
- The behaviour after shooting was classed in four categories as no reaction, ambling off and stopping, moving off completely, or running away with a sign of panic (trumpeting and defecating).

Field tests in urban and farming areas: The same gas dispenser using only ping-pong balls filled with the chilli pepper oil extract was tested on elephants intruding in crop lands, orchards or urban areas. Trained practitioners recorded the same parameters, with the exception of the shooting distance and the behaviour before shooting.

Figure 2. Elephant hit on the rear right leg with the release of a cloud of chilli pepper to its right.

Data collection

Field tests at Hwange National Park: Between the 24 and 27 November 2010, 49 tests were conducted by the same professional hunter from a vehicle during daylight hours between 08:00 h and 19:00 h in the study area at Hwange National Park. Weather conditions were optimum for shooting: dry and sunny, and with little or no wind. As in the previous study (Le Bel et al. 2010), the elephants were sighted at random (i.e. the first encounter on the off-road network). Those that reacted to the vehicle were avoided and not tested.

Field tests in forestry, urban and communal lands: Between April 2009 and April 2013, 329 attempts at deterring problematic elephants were conducted: 74% in Zambia (February to April 2013), 22% in Zimbabwe and 4% in Mozambique (May 2011). Most of the tests were conducted from a vehicle approaching the animals.

Data analysis

The XLSTAT Version 2010 package was used to analyse the data. Data were presented as mean ± SE (n: xx). The impact of the category of deterrent was studied using a Pearson's Chi-square test. A Multiple Correspondence Analysis (MCA) was conducted to study the association between the explanatory variables after transformation of quantitative variables into percentages. The principal coordinates obtained for all observations were then utilized for Agglomerative Hierarchical Clustering (AHC), in order to group data in a suitable number of classes, building a typology of deterred elephants. The null-hypothesis between classes was rejected at $p < 0.05$. Results with $p < 0.001$ were considered highly significant.

Results

Field tests

Out of the 138 tests for which the description of the targeted animals was determined, the tested elephants were mainly adult males (55%, n = 76) shot at from about 30 metres (30 ± 1 m, 17–72 m; n = 135). When it was possible to observe the hit of the projectile, in 27% of the observations (n = 86), it was mainly on the front (41%), followed by the side (35%) and the rear of the animal (24%).

Observations in Zimbabwe and in Mozambique (n = 138) revealed that most of the elephants where on alert when being approached (48%); 18% were unaware, and a similar percentage (22%) started to move away slowly from the operator. Only a few elephants were threatening (8%) or displayed aggressive behaviour with a mock charge (4%).

Impact of deterrent category

Most of the elephants moved away completely after firing (61%, n = 229). A few ran away in a state of panic (12%, n = 45); more frequently they ambled off and stopped at viewing distance (21%, n= 81). Only a small number seemed not to be disturbed at all (6%, n = 22). If we consider the four categories of deterrent measures, the differences observed in the behaviour displayed after shooting were highly significant (Table 1).

With the combination of noise, hit and release of chilli pepper, we observed the highest percentage of elephants (68%, n = 252) displaying a retreat and avoidance behaviour). With the other type of deterrent, the attempt of repelling was lower with the combination of noise and chilli pepper dispersal, only 9% (n = 9) of elephants moving off completely or running off. Producing a bang even with a hit seemed

Table 1. Elephant behaviour displayed after shooting with regard to the type of deterrent (n = 372).

Type of deterrent	Category of behaviour response as a percentage (%)			
	Indifferent	Ambling off	Moving off completely	Running away
Noise	2	10	1	0
Noise & Hit	1	3	0	0
Noise & Chilli pepper	3	3	6	3
Noise, Hit & Chilli pepper	0	5	54	8

to have had a minor deterrent effect. However, it was not possible to separate the direct effect of the impact of the chilli pepper strike; and only the release of the spray breathed in by the elephant served to completely deter the target animal.

Chi-square (observed value) = 207, df = 9, $p < 0.0001$, $\alpha = 0.05$.

The risk of rejecting the null hypothesis when it was true was lower than 0.01%.

Typology of deterred elephants

The MCA was conducted on a sample of 135 individuals with the set of six qualitative variables related to the information recorded during the attempt; shooting distances have been classed in 4 categories. Seventy percent of the variance was explained by the first five axes. Selecting the principal coordinates of the observations for those five axes, the ACH classed the elephants in three clusters:

- The first group comprised a category of elephants (36%, n = 49), which reacted positively to the combination of noise, hit and chilli pepper (92%) moving off completely or running away from the study area (92%, n = 45). They were shot at from a shorter distance (76%, n = 37 from less than 25 m), on the front or the side (80%, n = 39), and were mostly adult males (61%, n = 30). The majority were on alert (55%, n = 27) or moving off (29%, n = 14) when approached by the investigator.
- In contrast, the second group comprised elephants (30%, n = 40), which did not react to the deterrent action, or were indifferent or moved slowly from the study site (96%, n = 38) after the noise produced by the gas-dispenser (65%, n = 26). They were shot at from a greater distance (55%, n = 22 from between 37 and 72 m), and were adult males (45%, n = 18) or females (35%, n = 14), on alert (35%, n = 14) or moving off (28%, n = 11) from the investigator.
- The third group (34%, n = 46) comprised a mix of situations characterized by an unclear hit (98%, n = 45) on adult males (59%, n = 27) or family units (33%, n = 15) shot at from a short distance (78%, n = 36 from between 10 and 25 m). The mix of combined deterrents (Noise 46%, n = 21; Noise & Chilli 39%, n = 18; Noise Hit & Chilli 15%, n = 7) might explain the mix of behaviours observed, with approximately two thirds of elephants not reacting (63%, n = 29) and the remainder effectively deterred (37%, n = 17).

Discussion

The deterrent effect of chilli pepper-based olfactory repellents

The deterrent effect of chilli pepper on elephants has been studied and assessed since the 1990s (Osborn 2002; Osborn and Rasmussen 1995). Its popularized use was then mainly as a chemical barrier with the use of grease and hot chilli pepper extract mixed together and applied to string, or by burning elephant dung mixed with ground chilli pepper to produce a noxious smoke (Osborn and Parker 2002; Parker et al. 2007; Sitati and Walpole 2006), or combined with other deterrent measures such as electric fences and bees (Nyirenda et al. 2012). However, pilot projects to introduce chilli pepper as an elephant deterrent strategy have been slow to develop (Gupta 2013), not always effective (Hedges and Gunaryasi 2009) and often require intensive maintenance to ensure efficacy (Pinter-Wollman 2012).

Nevertheless, in the extended field tests conducted in both protected areas and farming areas, it was possible not only to confirm the strong deterrent effect of locally made chilli pepper oil extract, but also to demonstrate the positive added value of the locally assembled gas dispenser as a handy and safe tool to repel potential crop-raiding elephants from a distance. The chilli pepper dispersed spray, loud bang and physical hit used in combination seemed to have the strongest deterrent effect.

It became apparent during the field tests that success or failure depended very much on the skill of the user. In fact, the technique could be potentially dangerous for inexperienced persons, especially when crop-raiders need to be deterred at close quarters. This suggests the need for a better designed and functional dispenser guaranteed to work each time.

Improving the chilli pepper gas dispenser

The improved dispenser needs to separate loading from discharge, to eliminate the need to fire immediately after loading (Le Bel et al. 2010), it should be easy to aim at the common distances elephants are encountered and it should be possible to repeat the loading and priming action quickly for subsequent shots even during hours of darkness.

The production of an advanced prototype (Figure 4)

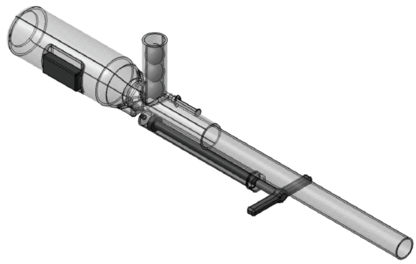

Figure 3. Design of the advanced gas dispenser prototype.

through an industrial moulding process will incorporate (1) an injection system regulating the precise volume of standard petroleum fuel to be squirted in the combustion chamber, (2) an ignition system providing a continuous and more powerful spark to ignite the atomized fuel-air mix, (3) a telescopic barrel allowing quick reloading, (3) a pump to vent exhaust gasses while replacing the oxygen/air mix in the combustion chamber and (4) a laser unit to optimise the aim at up to 50 metres.

Practical use on problematic animals

To improve the effectiveness of chilli pepper, use of the chilli pepper gas dispenser in the field has to overcome two major constraints: firstly, by enabling potential users to secure a good source of chilli pepper and, secondly, by incorporating the system in a holistic approach for HEC mitigation.

Sourcing chilli pepper

Chilli pepper production in Africa is a labour-intensive cash crop which can be grown in low rainfall areas (FINTRAC, 2009) with an expected yield of 400 kg to 1200 kg per hectare of fresh African bird's eye chilli pepper (Makoka et al. 2010). With sun drying reducing the average moisture from 75% (fully ripened chilli pepper) to 10% (dry chilli pepper) (Wiriya et al. 2009), a maximum of about 100 g per m2 of dry chilli pepper can be expected with an average planting density of 3.5 plants per m². From our experience 500 g of ground dry chilli pepper produces about 600 ml of chilli pepper oil extract, loaded into ~20 "hot" ping-pong balls; in other words, for a hundred projectiles it takes 25 m2 of planted chilli pepper, which needs to be grown locally and regularly harvested.

If we consider the various and well-documented HEC hotspots in Botswana (Gupta 2013; Hanks 2006), Ghana (Danquah et al. 2006), Kenya (Gichohi et al. 2013; Graham et al. 2009; Kamweya et al. 2012; Sitati et al. 2005), Mozambique (Le Bel et al. 2011; Osborn and Anstey 2002), Namibia (Hanks 2006), Tanzania (Malima et al. 2005), Zambia (Hanks 2006; Nyirenda et al. 2012) and Zimbabwe (Hanks 2006; Le Bel et al. 2011), we can expect that farmers will need to respond to hundreds of crop raids at district level each year. If chilli pepper is to be considered seriously as a local deterrent this cannot be based solely on side production of chilli pepper by the affected farmers, but will require the formal establishment of nurseries or greenhouses dedicated to production for HEC mitigation purposes.

This social investment has been partly addressed by the Elephant Pepper Development Trust (EPDT), which has not only promoted the use of chilli pepper as a means of keeping elephants away from sources of human food, but has also introduced a viable cash crop in southern and eastern Africa (WCS 2006). Through the World Bank's Development Marketplace initiative, EPDT (http://www.elephantpepper.org) managed to replicate its Zimbabwean model in two other southern African countries, Mozambique and Zambia (World Bank 2012) and provided some interesting data, for example demonstrating that local farmers were able to produce 250 kg of chilli pepper once they were experienced in growing the crop (Parker and Anstey 2002).

Integrating the chilli pepper gas dispenser in a boundary strategy

Small, scattered settlements surrounded by natural bush land are more vulnerable to crop depredation by elephants than consolidated barriers of agricultural land (Lee and Graham 2006). In Mount Kenya local communities pooled their resources in on-going fencing projects and managed to keep elephants away from farming areas (Kamweya et al. 2012). Electric fencing seems to reduce elephant damage at community level (O'Connell-Rodwell, et al., 2000) but it has to be very well maintained (O'Connell-Rodwell, et al., 2000) and lack of maintenance, vandalism and theft of components have been frequent problems at the community level (Hoare 2012). Other examples showed that an early warning system with a guarding component can drastically reduce crop raiding incidents (Sitati et al. 2005). Small-scale farmers will only have resources for cheaper fence configurations with the support of simple farm-based deterrents (Graham et al. 2009; Graham et al. 2010), but this strategy requires support and investment in the maintenance of deterrent devices.

Improving traditional fences with a virtual fencing approach (La Grange et al. 2012) is based on the observation that elephants remember boundaries and landscapes that affect their general movement patterns. The ability to associate and remember conflict areas, thereby establishing a pattern, means that elephants can be taught to respect boundaries and stay clear of crops. Over the years of problem animal control and veterinary fence protection in the late 1980s to control trypanosomiasis and foot-and-mouth disease in Zimbabwe (Taylor and Martin 1987), elephants were trained to respect boundary fences; the policy of shooting or removing habitual fence-breakers effectively taught elephants to respect the fence as a boundary (Nelson et al. 2003).

This lethal practice is no longer accepted, but an array of reminder measures repeatedly applied at the boundary could train crop raiders to stay away from areas of agricultural activities. The potential exists to keep elephants away from conflict zones where crop-raiding incidents are regular for a sustained period by establishing a boundary firmly in their memory that they remember even when the physical boundary no longer exists. The deterrent action has to be administered at the interface where the elephants are not wanted. When crops are protected by permanent traditional boundary fences, the chilli pepper gas dispenser can effectively target individuals persistently breaking through, combined with the use of a passive chilli pepper repellent on twine or cloth, as an olfactive reminder to enforce the boundary dynamics (Plate 8; see centre pages iv).

Conclusion

As HWC mitigation seeks to increase human tolerance towards wildlife species and decrease negative interactions with them, the improvement of community tolerance towards wildlife must start by enabling them to protect themselves and to adopt less risky responses when confronting dangerous animals. While no "stand alone" solution to HEC currently exists (Gunaratne and Premarathne 2006), existing traditional approaches provide the basis for development of a range of applicable solutions that are adapted to local conditions, enabling targeted intervention on specific problematic elephants at the crop interface. When employing the concept of memory fences, using an active chilli pepper dispenser will help crop-raiding elephants to respect human activities and settlements through a discipline learning curve. In addition to crop protection this approach could improve the functioning of elephant corridors, for example in the Selous Game Reserve which is in the process of being blocked off with the result of an increased level of HEC (Malima 2012). However, all the tools and strategies being developed should not divert attention from the need to promote and improve wildlife-based revenue ventures, which are essential for ensuring long-term human-wildlife coexistence.

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