An easy-to-use capsicum delivery system for crop-raiding elephants in Zimbabwe: preliminary results of a field test in Hwange National Park

Sébastien Le Bel[1], Russell Taylor[2], Mike Lagrange[3], Onias Ndoro[4], Marc Barra[1], Hillary Madzikanda[5]*

[1]CIRAD Zimbabwe, PO Box 1378, Harare, Zimbabwe; email: sebastien.le_bel@cirad.fr

[2]BIO-HUB, 3 Arcturus Road, Highlands, Harare, Zimbabwe.

[3]AWMC (Pvt) Ltd, Suite 1-5 Murandy Square West Newlands Harare, Zimbabwe.

[4]CAMPFIRE Association, Mukuvisi Woodland, PO Box 661, Harare, Zimbabwe.

[5]PWMA, PO Box CY 140 Causeway, Harare, Zimbabwe.

*Corresponding author

Abstract

With the increase of elephant populations in southern Africa and the expansion of human settlements into wildlife areas, local communities are faced with increasingly numerous cases of human-elephant conflict (HEC), which require a combination of mitigation approaches for there management. Although chilli has been tested with success on crop-raiding elephants, its utilization on a larger scale has been limited by the difficulty of finding a low-cost, easy-to-use capsicum delivery system. Two types of dispensers were developed: a catapult using clay balls and a gas-dispenser using ping-pong balls. The two prototypes were tested on a firing range and the gas-dispenser on elephants in Hwange National Park. The mean shooting distance was 46 m. Fifty-four percent of shots released chilli oil extract on the targeted animal. Following shooting, 46% of elephants ran away, 29% backed up walking and 25% did not change their behaviour. Significant variation in agonistic behaviour was due to the success of chilli oil extract spreading onto the elephant. Improvements in the ballistic performance of the gas-dispenser have been undertaken and trials in its application with communities are in progress. Further research is planned to separate the individual effect of projectile impacts, bang and chilli itself and to assess the longer-term deterrence properties of capsicum on elephants.

Résumé

Avec l'augmentation des populations d'éléphants en Afrique australe et l'expansion des peuplements humains jusque dans les aires de la faune, les communautés locales font face à des cas de plus en plus nombreux de conflits homme-éléphant (CHE) qui exigent une combinaison d'approches d'atténuation pour les gérer. Même si le piment a été testé avec succès à l'encontre des éléphants maraudeurs, son utilisation à une grande échelle a été limitée par la difficulté de trouver un système de livraison de piment peu coûteux et facile à utiliser. Deux types de distributeurs ont été développés: une catapulte qui utilise des balles en argile et un distributeur de gaz qui utilise une balle de ping-pong. Les deux prototypes ont été testés sur un champ de tir et le distributeur de gaz sur les éléphants dans le Parc national de Hwange. La distance moyenne de tir était de 46 m. Cinquante-quatre pour cent de coups ont dégagé un extrait d'huile de piment sur l'animal visé. Suite au tir, 46% des éléphants se sont enfuis, 29% ont fait marche arrière et 25% n'ont pas changé leur comportement. Une variation importante dans le comportement agonistique était due au succès de l'extrait d'huile de piment qui se répandait sur l'éléphant. Les améliorations dans la performance balistique du distributeur de gaz ont été entreprises et les essais dans son application avec les communautés sont en cours. Une recherche supplémentaire est prévue pour séparer l'effet individuel des impacts des projectiles, du coup et du piment lui-même et pour analyser les propriétés de dissuasion du piment à plus long terme sur les éléphants.

Introduction

With elephant populations in southern Africa increasing at 5% per annum (Blanc et al. 2005; Cumming and Jones 2005) together with the expansion of human settlement into wildlife areas, local communities living in marginal land adjacent to protected areas are faced with increasing occurrences of human-elephant conflict (HEC), in regard to crop raiding, granary destruction and in some cases even human casualties and death (Nelson et al. 2003). In Zimbabwe, between 2002 and 2006, more than 5000 of HEC were recorded, of which ~3000 were attended to, resulting in 774 elephants being killed during subsequent problem-animal-control operations (Campfire 2007). The elephant appears to be the main species (80% of cases) involved in crop raiding with destruction in some areas reported to be more than half the anticipated yield. In addition to this direct human cost of HEC, indirect impacts include restrictions on movement of people, access to key resources, such as water, firewood and thatching grass, as well as the transaction costs of guarding crops and property against wildlife degradation, resulting in negative attitudes towards wildlife and increases in unsustainable and unregulated hunting (WWF-SARPO 2005).

Human-wildlife conflict is a complex problem that requires a combination of approaches to manage the conflict, including wildlife barriers, property protection, traditional methods and removal of the specific problem animals (LaGrange 2006; Nelson et al. 2003; Parker et al. 2007; Sitati and Walpole 2006; WWF-SARPO 2005). For any human-wildlife conflict management strategy to succeed, it must be sustainable and therefore ideally administered by the local community itself (WWF-SARPO 2005).

Farmers' groups have been trained to use non-lethal methods for HEC, separated into three categories (Osborn and Parker 2002b; WWF-SARPO 2005): vigilance methods that aim to alert farmers to the presence of approaching wildlife, passive methods that aim to impede the passage of potential crop-raiding animals using simple physical barriers and deterrents, and another active method to scare off crop-raiding elephants using various forms of disturbance measures such as fires, noisemakers and chemical deterrents.

Chilli, the active ingredient of which is capsaicin, has been tested as a repellent with success in Hwange and the Gokwe Communal Lands (Osborn and Rasmussen 1995) and subsequently in the mid-Zambezi Valley (Osborn 2002) in areas where animals have become habituated to traditional deterrent and disturbance methods (Osborn and Parker 2002a; Osborn and Parker 2002b; Osborn and Welford 1995; Parker and Osborn 2006). These trials made use of a commercial oleoresin capsicum aerosol dispensing canister (Osborn 2002; Osborn and Parker 2002b; Osborn and Rasmussen 1995) but tests were not conducted on a larger scale with local communities due to the cost of commercial products and purchasing difficulties, notably from the US. Similar experimental trials were conducted in Transmara District, Kenya, highlighting the effectiveness of chilli grease as a repellent but also the importance of testing new innovations at broader scales (Sitati and Walpole 2006).

As part of an HEC toolbox for rural communities, the CAMPFIRE Association intends to develop a reliable chilli dispenser for use by communities for crop-raiding elephants to match the financial capacity and technical capabilities of these communities and individuals, as has been recommended by the IUCN/SSC African Elephant Specialist Group (Dublin et al. 1997).

The purpose of this paper is to present the preliminary results of two new types of capsicum dispensers recently developed in Zimbabwe as a response to an economic and social request for a reliable, low cost, easy-to-use elephant repellent at the local community level.

Material & Methods

Research design

Dispensers and projectiles

Two types of dispensers were developed and designed for propelling small balls (40–50 mm diameter) filled with either chilli powder or chilli oil extract.

The first type is a catapult mounted on a 1 m-long steel frame (Fig. 1). Projectiles utilized are handmade clay balls 40–60 mm in diameter and weighing 50 g, with a cavity inside of about 30–40 cc. In the loaded position, the projectile is held firm between the folding sear and the sling under tension from the surgical rubber.

The second type is a gas-dispenser built with two pieces of PVC pipe (Fig. 2) (Mostert 2008). A first section of pipe (100 mm diameter) constitutes the combustion chamber that is closed at one end by a backing cap and at the other end by a section of

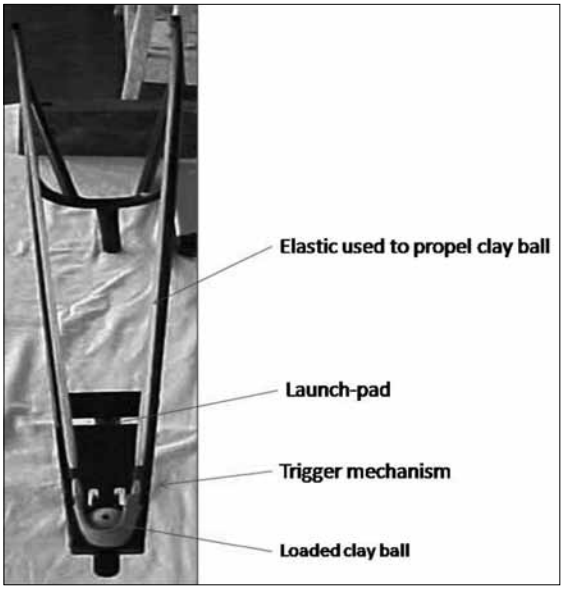

Figure 1. Catapult using clay balls as projectiles.

pipe of a lesser diameter (40 mm), which forms the barrel. The trigger mechanism is an igniter, such as a propane-gas lighter, which is attached to the dispenser. Two wires connect the igniter to the combustion chamber by means of two electrical connectors and self-tapping screws that act as sparking pins. Ignition of the device is triggered manually. The projectile is a standard ping-pong ball of 40 mm in diameter and a volume of 33 cc.

Placement of the chilli powder and oil extract

The powder was made of local dry chilli finely ground with a coffee grinder. The filling of the clay ball with 15–17 g of powder was achieved by pouring it through an opening with a small funnel and then sealed with wax. For the ping-pong ball, a hole was made with a needle, the projectile being filled in the same way with 18–20 g of powder and the opening sealed with a small piece of insulation tape.

The chilli oil extract was locally produced by extracting the capsaicin with ethanol, the main capsaicinoid found in chilli. This compound causes the sensation of heat by stimulating nocireceptors of the trigeminal system (watering eyes, burning sensation in the trunk mucosa, trigeminal pain). After extraction, the compound was diluted with vegetable oil to obtain a solution rating of 250,000 Scoville Heat

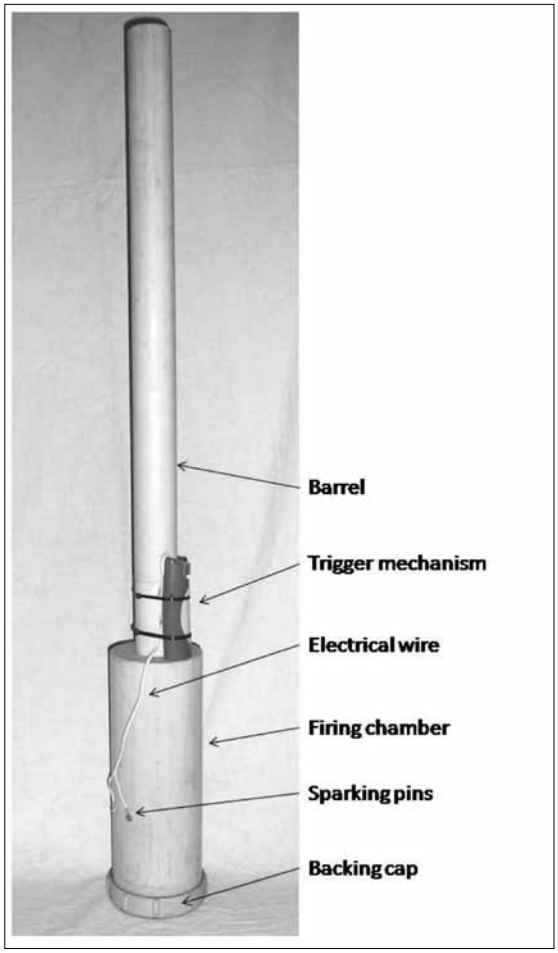

Figure 2. Gas dispenser using ping-pong balls as projectiles.

Units (SHU)[1] which corresponds to the commercially available 10% capsicum oleoresin (Counter Assault Tactical Systems 1996) utilized in previous tests (Osborn 2002). For both projectiles 30 cc of chilli oil extract is placed by means of a syringe and a large bore needle. The opening is sealed with wax for the clay ball and insulation tape for the ping-pong ball.

Dispensing the different projectile types

Upon firing the catapult, the sear collapses down below the launch ramp, which then releases the ball into the sling down system (Fig. 3).

[1] Chilli peppers, fruits of the *Capsicum* genus, contain capsaicin, a chemical compound which stimulates the chemoreceptor nerve of the mucous membranes. The number of Scoville Heat Units (SHU) indicates the amount of capsaicin present.

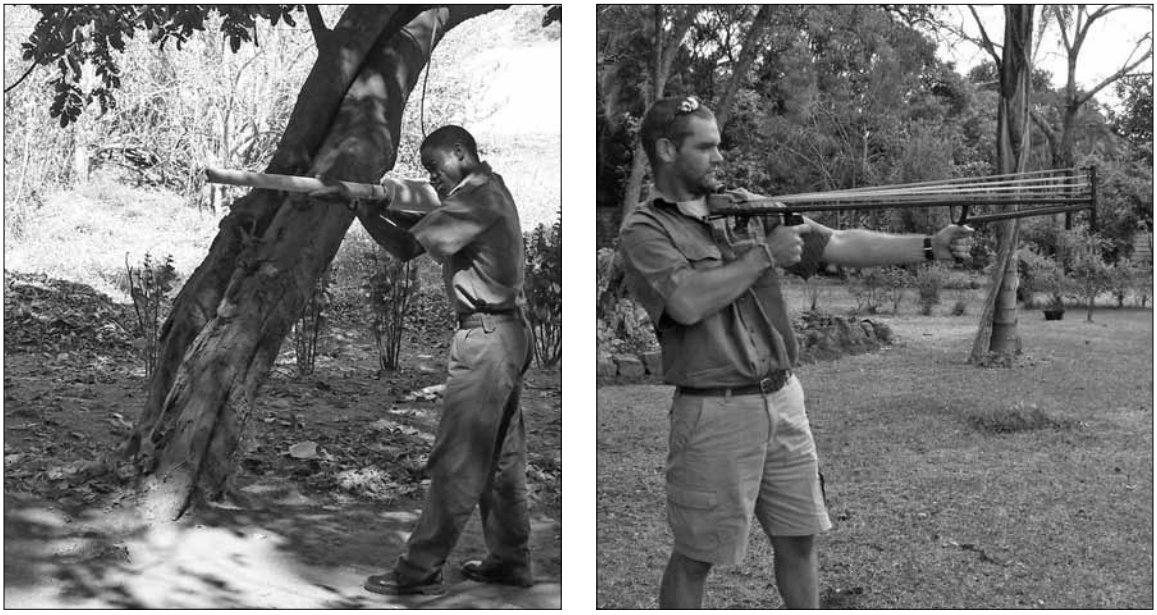

Figure 3. Firing positions for the gas-dispenser and the catapult.

With the gas-dispenser (Mostert 2008), the projectile is loaded into the dispenser by removing the screw-on backing cap, inserting the ball through the combustion chamber and seating the ball tightly into the base of the barrel. The loaded ball creates a seal between the barrel and combustion chamber. To fill the combustion chamber with gas, the screw-on backing cap is removed and a propellant is inserted into the combustion chamber while holding the dispenser down at a 45-degree angle. Two short squirts from any domestic aerosol containing inflammable gas are required to fill the combustion chamber. The screw-on backing-cap is then quickly and securely replaced before the dispenser is aimed and fired. The gas is ignited by the spark created by the trigger mechanism between the two firing pins (Fig. 3). Expansion of the gas by the resultant combustion forces the ball down the barrel at high velocity.

Study area

The study area is within Hwange National Park, with an area of approximately 14,651 km , situated in northwestern Zimbabwe. Hwange is characterized by its large elephant population of some 45,000 animals during the dry season. To avoid any interaction with tourism activities, a remote block of 10 km in the southern part of the park between Mbazo water point (S19 14'931"-E27 08'546") and Mabezu water point (S 19 15'061" E 27 01'855") 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.

Methods

Field tests at targets on a shooting range

Initially, the two prototypes were tested at a firing range by shooting at targets from a distance of 20–50 m. Five ballistic parameters were recorded to characterize each dispenser and define which of the four combinations was the most efficient: 1) catapult and clay ball filled with chilli powder, 2) catapult and clay ball filled with chilli oil extract, 3) gas-dispenser and ping-pong ball filled with chilli powder and 4) gas-dispenser with ping-pong ball filled with chilli oil extract.

- The targeting success was measured by recording the frequency of hitting a one-meter diameter circle painted on a plain board.
- The breaking up success was measured by recording the frequency of breaking when hitting the target or the ground.
- The dispersal success was recorded by measuring in cm the diameter of the splash left on the target by the spray of powder or oil after the breakage of the projectiles. For the projectiles filled with powder, the target surface was oiled slightly to retain the cloud of released compound.

- The level noise in decibels produced upon shooting was recorded with a microphone (cell phone NOKIA 5140).
- The reloading time in seconds was recorded with a watch.

Field tests with live elephants

Once acceptable performance parameters were achieved, the most promising system (dispenser and type of projectile) was tested on elephants found on the dust road or close to it between Mbazo and Mabezu water points to study its efficiency as a fast-acting-repellent by recording changes of agonistic behaviour as described by Estes (Estes 1995).

- Shooting distance was measured in metres with a range finder (Bushnell Corporation).
- The behaviour of each targeted elephant before shooting (Estes 1995) was classified into four categories: feeding, drinking, walking or resting.
- For the behaviour at shooting and one minute after shooting, three categories classified the observations: no reaction (continued feeding, drinking, walking or resting), walking away or running away.
- Shooting success and the release of the chilli product on the elephants were observed visually with both the naked eye and binoculars.
- For shooting success, the observations were classified into four categories: hitting the elephant, hitting the ground just in front of the elephant between the forequarters, shooting high or shooting too short.
    - For success of chilli product release on the elephant, observations were classified into three categories: release of chilli product on the targeted elephant, no release, uncertain when it was not obvious.

Data collection

Range tests on targets

One hundred and fifty-five range tests with the two types of dispenser were conducted on targets distanced at 20, 25, 30, 40 and 50 m on a golf driving range in Harare in September 2007. To avoid any further source of variation, all shooting was conducted by the same professional hunter.

Field tests on elephants at Hwange

Between 2–23 October 2007, 24 tests were conducted by the same professional hunter from a vehicle during daylight hours between 0930–1800h in the study area in Hwange National Park. Weather conditions were optimum for shooting with little or no wind, dry and sunny. 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.

Data analysis

The SPSS (2002) package was used to analyse the data. Data are presented as mean ±SE. One-Way ANOVAs were used to compare distances of shooting between classes. To test for independence between percentages of measured variables, the Pearson's Chi-square test was used. The null-hypothesis between classes was rejected at $P<0.05$. Results with $P<0.001$ were considered highly significant.

Results

Range test

Targeting success

The maximum range for the catapult was 40 m while it was possible to project ping-pong balls with the gas-dispenser further beyond the last target (50 m) up to 100 m. For both dispensers, the accuracy on a 1-m wide target decreased significantly with distance with 40% of success at 40 m with clay balls filled with powder and 20% of success at 50 m with the gas-dispenser using ping-pong balls filled with chilli oil extract. At different ranges, the type of chilli product utilized (oil vs. powder) did not modify significantly the targeting success of the two types of dispenser (Table 1).

Breaking up success

With the gas-dispenser utilizing ping-pong balls, all projectiles broke on impact at any distance, releasing chilli powder or chilli oil extract. For the catapult and clay balls, the breakage of the projectiles was not consistent; if 100% of the clay balls filled with chilli powder broke at the different ranges, only 73% of the clay balls filled with chilli oil extract burst on impact with a success of 40% at the 40 m target (Chi-square =8.523, n=30, p=0.014).

Dispersal success

At the different firing ranges, the mean splash diameter did not significantly differ for each type of projectile tested, even if a bigger splash was observed with

Table 1: Targeting success at different ranges with the catapult and gas-dispenser

Targeting success of the catapult					
	20 m*	25 m**	30 m***	40 m	50 m
Clay balls filled with chilli powder (n=no. of shots)	60% (n=10)	40% (n=10)	20% (n=10)	40% (n=10)	0% (n=10)
	Observed percentages are significantly different (Chi-square =9.6, n=50, p=0,05)				
Clay balls filled with chilli oil extract (n=no. of shots)	70% (n=10)	80% (n=10)	40% (n=10)	–	–
	Observed percentages are not significantly different				
* ** *** Observed percentages are not significantly different at 20, 25 and 30 m between the two types of projectiles.					
Targeting success of the gas-dispenser					
	20 m*	25 m	30 m**	40 m***	50 m
Ping-pong balls filled with chilli powder (n=no. of shots)	90% (n=10)	no result	70% (n=10)	30% (n=10)	–
	Observed percentages are highly significantly different (Chi-square =8.06, n=30, p=0.02)				
Ping-pong balls filled with chilli oil extract (n=no. of shots)	60% (n=10)	80% (n=10)	50% (n=10)	10% (n=10)	20% (n=10)
	Observed percentages are highly significantly different (Chi-square =13.5, n=50, p=0.009)				
* ** *** Observed percentages are not significantly different at 20, 30 and 40 m between the two types of projectiles.					

the ping-pong balls filled with chilli oil extract. For all types of projectile, mean sizes of splash observed increased significantly with the distance of shooting from a mean size of 43 cm at 20 m to a mean size of 120 cm at 50 m (Table 2).

Noise level

For the gas-dispenser the maximum noise recorded at shooting was 91 DB with a minimum of 87 DB. The catapult type produced least noise with 35–40 DB recorded.

Reloading time

The average time for reloading was ranked from 75 seconds for the catapult dispenser to 90 seconds for the gas-dispenser.

Taking in consideration that the maximum shooting distance was obtained with the gas-dispenser and that the optimum breaking-up success was observed with the balls filled with oil, we decided to test only the combination of the gas-dispenser with ping-pong balls filled with chilli oil extract on elephants for the second phase of this trial.

Field tests on elephants

Shooting distance

Twenty-four tests were done on elephants found on the dust roads (4%), in grassland (13%), thicket (13%), woodland (33%) and around water-holes (38%). Fifty four percent of targeted individuals were male (n=13) and 46% female (n=11). The average distance of shooting was 46±4 m (n=24), ranking from 15 m (minimum distance) to 110 m (maximum distance). Elephant bulls were shot significantly closer (38±4 m) than cows (55±6 m) (ANOVA F=6.1, n=24, p=0.022). The distance of shooting seemed to be related to the behaviour of the targeted elephants, even if the mean distance of shooting recorded was not significantly different. It seemed to be easiest to shoot elephant feeding, drinking or standing at 34-38 m than the ones walking at 61±8 m (ANOVA F=2.7, n=24, P=0.059).

Shooting success

The success of hitting or missing was independent from the type of vegetation, the category of elephant, their behaviour prior to shooting or distance of shooting grouped in three classes 0-30 m, 30-50 m and more than 50 m.

Table 2: Dispersal success at different ranges with the catapult and gas-dispenser

Dispersal success Mean size diameter of splash ± SE in cm					
	20 m (a)	25 m (a)	30 m (a)	40 m (a)	50 m (a)
Catapult with clay balls filled with powder	45±7 (n=10)	52±10 (n=10)	95±14 (n=10)	–	–
Catapult with clay balls filled with oil	43±4 (n=10)	33±6 (n=10)	60±18 (n=9)	57±10 (n=9)	94±15 (n=10)
Gas-dispenser with ping-pong balls filled with powder	30±7 (n=10)	no result	48±12 (n=10)	–	–
Gas-dispenser with ping-pong balls filled with oil	54±17 (n=10)	43±7 (n=10)	59±13 (n=10)	111±16 (n=4)	147±23 (n=0)
All type of projectiles (b)	43±5 (n=0)	43±5 (n=30)	66±7 (n=39)	73±11 (n=13)	120±15 (n=0)

(a) No significant difference between different types of projectiles at targets distanced from 20 to 50 m
(b) Dispersal success increasing significantly with firing range (ANOVA F=13.7, n=142, p=0.000)
N.B. (n=no. of shots)

Release of chilli oil extract

Five shots hit the ground in front of the elephant, with just one shot releasing chilli oil. Eight shots hit the body of the elephant and seven of these released chilli oil. Nine shots went above the elephant and two fell short. The success of releasing chilli oil extract on targeted elephants was not dependent on the type of vegetation, the category of elephant or behaviour prior to shooting; however, it was strongly linked with the success of the shot (Chi-square =17.27, n=24, p=0.008).

Change of behaviour

Behaviour before the shooting

One-third of the elephants were walking (n=8), 25% drinking (n=6), 25% standing (n=6), others feeding (8%, n=2) or resting (8%, n=2). Differences observed were significantly linked to the type of vegetation (Chi-square =31.6, n=24, p=0.01) and not to the type of elephant targeted.

Behaviour on discharge

At shooting, 46% of the 24 elephants ran away in the opposite direction (n=11), 29% changed their behaviour and walked away in the opposite direction (n=7) and 25% (n=6) did not change their behaviour. Significant variation of agonistic behaviour observed was due to the success of chilli oil extract spreading onto the elephant after the breakage of the ball on the animal itself or just in front of it between the forequarters (Chi-square =13.14, n=24, p=0.011).

The proportion of elephants running away (27%, 3 of 11) or walking back (72%, 5 of 6) without being affected by the chilli oil extract suggested that the bang produced by the gas-dispenser has its own repellent effect. Bulls (69%) were significantly more deterred than cows (18%) (Chi-square =6.28, n=24, p=0.04), linked to the fact that it was easiest to approach them from a shorter distance.

Behaviour after 1 minute

After 1 minute, 29% of the 24 elephants (n=7) were still running away, 4% (n=1) were walking away and 67% (n=16) were going back to normal behaviour. The interesting point was that 100% of elephants still running away after shooting were those which received some chilli oil extract (Chi-square =16.66, n=24, p=0.002).

Manufacturing and costs

For the present study, the costs of a both dispensers as handmade prototypes were less than USD 50. Locally manufactured, the cost of the gas dispenser could drop to USD 20 if a regional market for this type of product is developed.

Taking into account the cost of ping-pong balls (USD 0.11 per ball), commercial aerosol as a propellant (10 cc spray costing USD 0.13) and imported chilli oil extract rating 250.000 SHU (30 cc per ball costing USD 0.96), the cost of repelling an elephant is estimated at USD 1.20.

Discussion

Ballistic efficiency & shooting distance
Shooting effective distance

Data from this study showed that the maximum distance reached with the catapult was 40 m and greater than 50 m with the gas-dispenser (Table 1). With an elephant at an average range distance of 46 m in Hwange, the gas-dispenser seems to be preferable to the catapult. This range distance was approximately the same in a previous study where oleoresin capsicum aerosol was tested on elephants in Hwange National Park at a distance of 25-50 m, also during day time (Osborn and Rasmussen 1995). The study also shows that elephant bulls were shot at a significantly closer distance than cows, which confirms previous observations that bulls are often the dominant crop raiders (Kioko et al. 2006) and have a higher degree of tolerance to human disturbance and are more approachable than a cow herd (Hoare 1999).

Accuracy

Clearly the target elephant needs to be struck or the ping-pong ball should break up immediately in front of the target elephant so that chilli is liberated directly onto them to maximize the effect. Dispersal effect measured at the shooting range indicated that balls bursting near the elephant will have a repellent effect if it occurs within 1.5 m of the target animal (Table 2).

In Hwange, only 50% of shots either hit an elephant or the ground just in front of it, highlighting a weakness of the gas-dispenser using ping-pong balls filled with oil. It seems that after a certain distance the ping-pong ball, which is not a perfect sphere, is deviated from its trajectory by the combined effect of lateral wind, decreasing velocity and irregular rotation. This is confirmed by the results obtained on the shooting range with low targeting success after 30 m distance (Table 1). Ongoing development of new prototypes of gas-dispenser demonstrates that accuracy can be improved by modifying the diameter of the barrel (Fig. 2).

Impact on elephant behaviour

In the field trials conducted at Hwange, all elephants that received chilli oil extract ran or walked away quietly from the operator in charge of the dispenser; they would stop feeding, freeze momentarily and retreat. This fits with the tests conducted with capsicum oleoresin spray in communal land where no aggressive behaviour was noted (Osborn 2002). We did not observe behaviour modifications recorded in previous studies such as raising head in alarm, expelling air, shaking heads, vocalizing, rumbling, roaring or trumpeting (Osborn and Rasmussen 1995).

Sensitivity of elephants to capsaicin is well documented (Osborn 2002; Osborn and Rasmussen 1995). The present study provides strong evidence that this novel approach to spreading capsaicin on elephants has its own fast-acting repellent effect if we consider the cases of elephants running away after being sprayed with chilli oil extract without being hit by ping-pong balls and that after one minute, the only elephants still running away were those undoubtedly contaminated by the capsaicin.

In the Mid-Zambezi Valley, the Elephant Pepper Development Trust, http://elephantpepper.org, had a similar result on elephants affected by artificial capsaicin gas clouds produced by spraying a solution of chilli oil extract with a heat of 30,000 SHU (Nelson et al. 2003; Osborn and Parker 2002a) or from a commercial canister of capsicum oleoresin at 250,000 SHU (Osborn 2002). Van Wyk (pers. com. 2008) testing the same gas-dispenser in Namibia with ping-pong balls filled with water or chilli oil extract indicated that only elephants sprayed with chilli oil extract moved away a greater distance and one bull affected by the chilli oil extract was recorded moving 15km away after been repelled.

The immediate change of behaviour observed was most probably related to the combined effect of three factors: the great sensitivity of elephants to capsaicin, the noise on discharge of the gas-dispenser and the direct impact of the ping-pong ball hitting the elephant. The proportion of elephants walking away without being affected by the chilli oil extract suggests that the bang produced by the discharge of the dispenser may have its own deterrent effect, but this has to be confirmed with more field trials. The level of noise produced, 87-91DB, is similar to commercial firecrackers or locally made bangers traditionally

used as a deterrent by communities (Niskanen 2006; Osborn and Parker 2002a). Associating this loud sound with the adverse stimuli of the capsicum is one way forward to condition crop raiding elephants to avoid agricultural areas. Its potential success requests periodic reinforcement (Osborn 2002) and further assessment of the longer-term deterrence properties of the chilli oil extract not yet undertaken.

The present study does not provide strong evidence for the effect of a ping-pong ball hitting an elephant at a distance of 40-50 m. Even if this alerts the targeted elephant, previous records of traditional repellents such as throwing various types of projectiles on crop raiding elephants have shown that crop-raiders quickly habituate to false threats and learn to ignore or avoid them (Niskanen 2006; Osborn and Rasmussen 1995; WWF-SARPO 2005).

New tools for a human elephant conflict toolbox

There is no universal recipe or "blueprint" for controlling problem elephants but a range of control measures used flexibly and in combination can be employed to mitigate the effects on people and their property (Hoare 1995; Niskanen 2006; Taylor 1993). The development of this new type of chilli dispenser provides progress on how an encapsulated liquid form of capsicum can be fired at elephants with success (Hoare 2001).

The economic considerations of the application of this technique are also of great importance as it should be a low cost and locally made tool. Access to dry chilli locally produced (2.5 US$/kg) and to a simple distillation technique shows that with 500 g of chilli, finely ground and extracted (2 hours of labour) with one litre of petrol then mixed with cooking oil (300 cc) it is possible to produce 350 cc of a solution rating at 250.000 SHU for USD 6. This option not only reduces to USD 0.7 the cost of deterring an elephant but also indicates that the development and utilization of this new technique can be managed locally.

Future areas of research

In order to separate the discrete effects of projectile impacts, bang and chilli itself, more field trials will be conducted on elephants using a control gas dispenser which makes a bang but does not fire a projectile and also projectiles filled either with chilli or with water. The sample size for each treatment will be increased.

Utilization of this gas-dispenser at the community level is on going in selected sites in the Mid-Zambezi Valley, with systematic records of how easily applied by game scouts and how efficient it repels crop-raiding elephants. This is part of on going implementation while the ballistic performance has also been improved and the application for patent protection has been made[2].

Elephants that are prone to destructive behaviour should be targeted for behaviour modification. This type of study will assess the longer-term deterrence properties of the chilli oil extract. An experimental design studying the behaviour of habitually crop-raiding elephants equipped with GPS collars and then repelled with chilli oil extract and exposed to physical barriers impregnated with capsicum compound, will be undertaken during 2010 to explore the possibility of conditioning elephants to avoid agricultural areas.

Acknowledgements

Grateful thanks are expressed to French Global Environment Facility in Zimbabwe for financial support given to the BIO-HUB[3] project for HEC mitigation research, and ZPWMA for permission to test the dispensers in Hwange National Park. CAMPFIRE Association supported this initiative with the objective of strengthening the capacity of local communities to cope with problem elephants.

[2] Zimbabwe - Patent Application No. 20/2008

[3] a consortium of CIRAD, IGF, IUCN-ROSA & WWF-SARPO

References

Blanc J, Barnes R, Craig G, Douglas-Hamilton I, Dublin H, Hart J, Thouless C. 2005. Changes in elephant numbers in major savanna populations in eastren and southern Africa. *Pachyderm* 38:19–28.

Campfire. 2007. PAC statistics 2002-2006. Campfire Association, Harare, Zimbabwe.

Cumming D, Jones B. 2005. Elephants in Southern Africa: Management issues and options. WWF/ SARPO Occasional Paper.

Dublin HT, McShane TO, Newby J. 1997. Conserving Africa's Elephants. Current Issues & Priorities for Action. In: WWF International Publication. p. 28. WWF, Gland Switzerland.

Estes RD. ed., 1995. The behavior guide to African mammals: including hoofed mammals, carnivores, primates. Russel Friedman Books, South Africa.

Hoare RE. 1995. Options for the control of elephants in conflict with people. *Pachyderm* 19:54–63.

Hoare RE. 1999. Determinants of human-elephant conflicts in a land-use mosaic. *Journal of Applied Ecology* 36:689–700.

Hoare RE. 2001. A decision support system for managing human-elephant conflict situations in Africa, ed. IUCN, p. 110 pages. The African Elephan Specialist Group (AfESG).

Kioko J, Kiringe J, Omondi P. 2006. Human-elephant conflict outlook in the Tsavo-Amboseli ecosystem, Kenya. *Pachyderm* 41:53–60.

LaGrange M. 2006. The Capture, Care and Management of Wildlife. Van Schaik, Pretoria, South Africa.

Mostert JJ. 2008. Pepper Dispenser "Mhiri Piri Bomber" - The Manual., p. 16. BIO-HUB, Harare, Zimbabwe.

Nelson A, Bidell P, Sillero-Zubiri C. 2003. A review of human-elephant conflict management strategies, ed. P.W. Initiative, p. 25 pages. Wildlife Conservation Research Unit, Oxford University.

Niskanen L. 2006. Human-elephant conflict: Causes, Effects and Options for Mitigation., In IUCN/ SSC African Elephant Specialist Group. Human-Elephant Conflict Working Group, African Elephant Specialist Group, Nairobi, Kenya.

Osborn FV. 2002. Capsicium oleoresin as an elephant repellent: field trials in the communal lands of Zimbabwe. *Journal of Wildlife Management* 66(3):674–677.

Osborn FV, Parker GE. 2002a. Community-based methods to reduce crop loss to elephants: experiments in the communal lands of Zimbabwe. *Pachyderm* 33:32–38.

Osborn FV, Parker GE. 2002b. Living with elephants II: A manual for implementing an integrated programme to reduce crop loss to elephants and to improve livelihood security of small-scale farmers. Mid Zambezi Elephant Project.

Osborn FV, Rasmussen LEL. 1995. Evidence for the effectiveness of an oleoresin capsicum aerosol as a repellent against wild elephants in Zimbabwe. *Pachyderm* 20;55–64.

Osborn FV, Welford LA. 1995. Living with elephants: a manual for wildlife managers in the SADC region, Zimbabwe, p. 95. DNPWLM.

Parker GE, Osborn FV. 2006. Investigating the potential for chilli Capsicum spp. to reduce human-wildlife conflict in Zimbabwe. Cambridge.

Parker GE, Osborn FV, Hoare RE, Niskanen LS. eds. 2007. Human Elephant Conflict Mitigation: A Training Course for Community-Based Approaches in Africa. Trainer's Manual. Elephant Pepper Development Trust & IUCN/AfESG, Livingstone Zambia & Nairobi Kenya.

Sitati NW, Walpole MJ. 2006. Assessing farm-based measures for mitigating human-elephant conflict in Transmana District. Kenya. *Oryx* 40(3):279–286.

Taylor RD. 1993. Elephant management in NyamiNyami District, Zimbabwe: turning a liability into a asset. *Pachyderm* 17:19–29.

WWF-SARPO. 2005. Human wildlife conflict manual. WWF-SARPO, Harare, Zimbabwe.