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Efficacy of chilli *Capsicum oleoresin* guns usage by local hunters as African elephant repellent from crop raiding in the Luangwa Valley, Zambia

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Chilli *Capsicum oleoresin* guns have been utilised by local hunters in Luangwa Valley, Zambia in the recent years as Community Based Conflict Mitigation (CBCM) for human-elephant conflict (HEC) situations. Through use of *C. oleoresin* guns, transformation of local hunters from elephant poachers to sustainable agriculturalists has been a milestone for conservation efforts. In this study, authors systematically evaluated efficacy of *C. oleoresin* guns usage by the local hunters as African elephant repellent from crop raiding in the Luangwa, Zambia using statistical multivariate regression modelling approaches. Out of nine potential factors influencing effectiveness of *C. oleoresin* guns, two factors were significantly associated with impacts of *C. oleoresin* aerosols: rain conditions and elephant head size. These factors were, in addition to wind direction, determinants of effectiveness of *C. oleoresin* aerosols on target elephants. CBCM innovations are encouraged and we suggest building capacity in training, access to materials and implementation monitoring by local hunters and wildlife managers to enhance local participation in non-lethal preventive and mitigation interventions, especially those which are robust to elephant habituation.

Key words: Luangwa Valley, Zambia, *Capsicum oleoresin*, counter-measures, human-elephant conflicts, biodiversity conservation.

INTRODUCTION

African elephants (*Loxodonta africana*) devour a wide array of food stuff (Poole, 1996), and are among mega-herbivores that cause considerable damage to woody vegetation (Guldemond and van Aarde, 2008) and crops, especially at maturity stages in elephant-agrarian land-scapes (Chiyo et al., 2005; Hoare, 2012; Naughton-Treves, 1998; Nyirenda et al., 2011). Elephants conflict with local farmers over crop damage, property destruction,

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water-points damage, human injuries and fatalities (Chomba et al., 2012;Lamarque et al., 2009). As a result, local farmers could reduce their support towards wildlife conservation due to being fraught by food and livelihood insecurity (Gadd, 2005; Naughton-Treves et al., 2003). In some cases, the affected local farmers avenge their loss of crops by killing marauding elephants. However, O'connell-Rodwell et al. (2000) contended that agricultural communities would support conservation better if the benefits exceed costs of living with elephants. Hence, Dalal-Clayton and Child (2003) posited commercialisation of elephants killed on management control operations. For instance, between 2004 and 2011, an average of 12 elephants was destroyed per annum during management control operations in Lupande area, central Luangwa Valley, Zambia. No economic value was realised from controlled elephants. Albeit, elephants are one of the highly protected animal species due to their high conservation status (Hoare, 2001a). Though, the pressing problem of HECs has attracted considerable conservation interest and is being increasingly studied in Africa (Hoare, 2001b), testing of effectiveness of individual counter-measures has rarely been conducted. Past countermeasures experimental tests on HECs, how-ever, include use of canisters of *C. Oleoresin* in Zim-babwe (Osborn and Rasmussen, 1996; Osborn, 2002). Most recently, King et al. (2011) claimed that use of African honeybees *Apis mellifera scutellata* attracted to interconnected hive fence line prevented crop raiding by African elephants. These experiments were faced with the challenge of high expenses and limitation in geographical scale of application.

Use of *C. oleoresin* guns was developed in Luangwa Valley due to its high potential of wide geographical application, non-lethal, low labour demands and low cost considerations. The *C. oleoresin* guns were first tried in Lupande Game Management Area (GMA) in 2008 when 48 local hunters were trained and deployed, following claims by Wildlife Agency that it was an effective counter-measure. Initially, anecdotal field trials of *C. Oleoresin* guns were conducted by Wildlife Agency in the Luangwa Valley on warthogs (*Phacochoerus aethiopicus*) and no data was documented, yet the method was considered by field staff as effective in repelling warthogs from crop fields. Due to widespread and severe HECs in the Luangwa Valley, Wildlife Agency extended the use of *C. Oleoresin* gun countermeasures against invading elephants. In the interim, local hunters received annual refresher training. In the adjoining areas of Musalangu in Chama and West Petauke, additional 40 and 16 local hunters were trained by Wildlife Agency in 2010 and 2012 as roll-over strategy. Despite long term claims of effectiveness of locally developed *C. Oleoresin* guns usage, the *C. Oleoresin* guns performance was not systematically and scientifically tested.

Chilli resin saturated by capsaicin, an active constituent in *C. Oleoresin*, has been experimented on various animals species and yielded promising results on American bears (Hunt, 1985), ungulates (Andelt et al., 1992) and African elephants (Osborn, 2002; Sitati and Walpole, 2006) as an effective ingredient in chilli counter-measures. In the case of *C. Oleoresin* trials on African elephants, commercially available 10% *C. oleoresin* canisters were used. However, these canisters have been out of reach by impoverished substance farmers, prompting suitable and affordable alternatives. Therefore, in this study, we sought locally appropriate, socially acceptable, reliable, accessible and easy-to-utilise technologies by local farmers. These local farmers have also once been local hunters who were intolerant to elephants. By getting involved in usage of *C. Oleoresin* guns as local innovative elephant counter-measure, local farmers were protecting crops from elephant invasions, while contributing to reduced wanton retaliatory elephant killings.

Past studies underpinned that elephant killing for various reasons as counter-measures such as retaliation, public relations and problem elephant control programme were ineffective (Balakrishnan and Ndhlovu, 1992; Muruthi, 2005). Insight that type and nature of farm-based counter-measures in place determine whether crop raiding would occur or not (Nyirenda et al., 2012), further motivated this particular study. We explored efficacy of locally developed innovation involving local hunters in promoting elephant conservation while enhancing food and livelihood security in the Luangwa Valley, Zambia. Therefore, this study aimed at contributing to the systematic and scientific assessments of factors that influence chemo- effectiveness of C. Oleoresin guns in preventing elephant damage or reducing elephants' residence in the crop fields.

MATERIALS AND METHODS

Study site location

The study was conducted in six chiefdoms (Jumbe, Kakumbi, Malama, Mnkhanya, Msoro and Nsefu) of Lupande GMA, located at 12° 57' to 13° 49' S and 31° 32' to 32° 23' E in central Luangwa Valley, eastern Zambia and covered an area of 4 840 km^2 (Figure 1).

Socio-economic characteristics

Central Luangwa Valley is inhabited by Kunda people, who are historically both traditional bushmeat hunters and subsistence agriculturists. Lupande GMA has 13,196 households and 68,918 people, with high growth rate of 3.8 (regional mean: 2.6) (Central Statistical Office, 2012). Traditional hunting is mainly for subsistence purposes and occasionally for commercial reasons especially during times of droughts and floods for domestic livelihood supplements. The subsistence agriculture has in the resent year's expanded into cash crop growing. Commonly cultivated crops include maize (*Zea mays*), cotton (*Gossypium hirsutum*), tobacco (*Nicotiana tabacum*), millet (*Eleusine sp*.), sorghum (*Sorghum vulgare*), beans (*Phaseolus vulgaris*), pumpkin (*Curcubita maxima*) and sweet potato (*Ipomoea batatas*). In addition to high incidences (60%) of drought (Gilvear et al., 2000), crop production; however, is constrained by increasing wildlife crop raiding with agrarian activities.

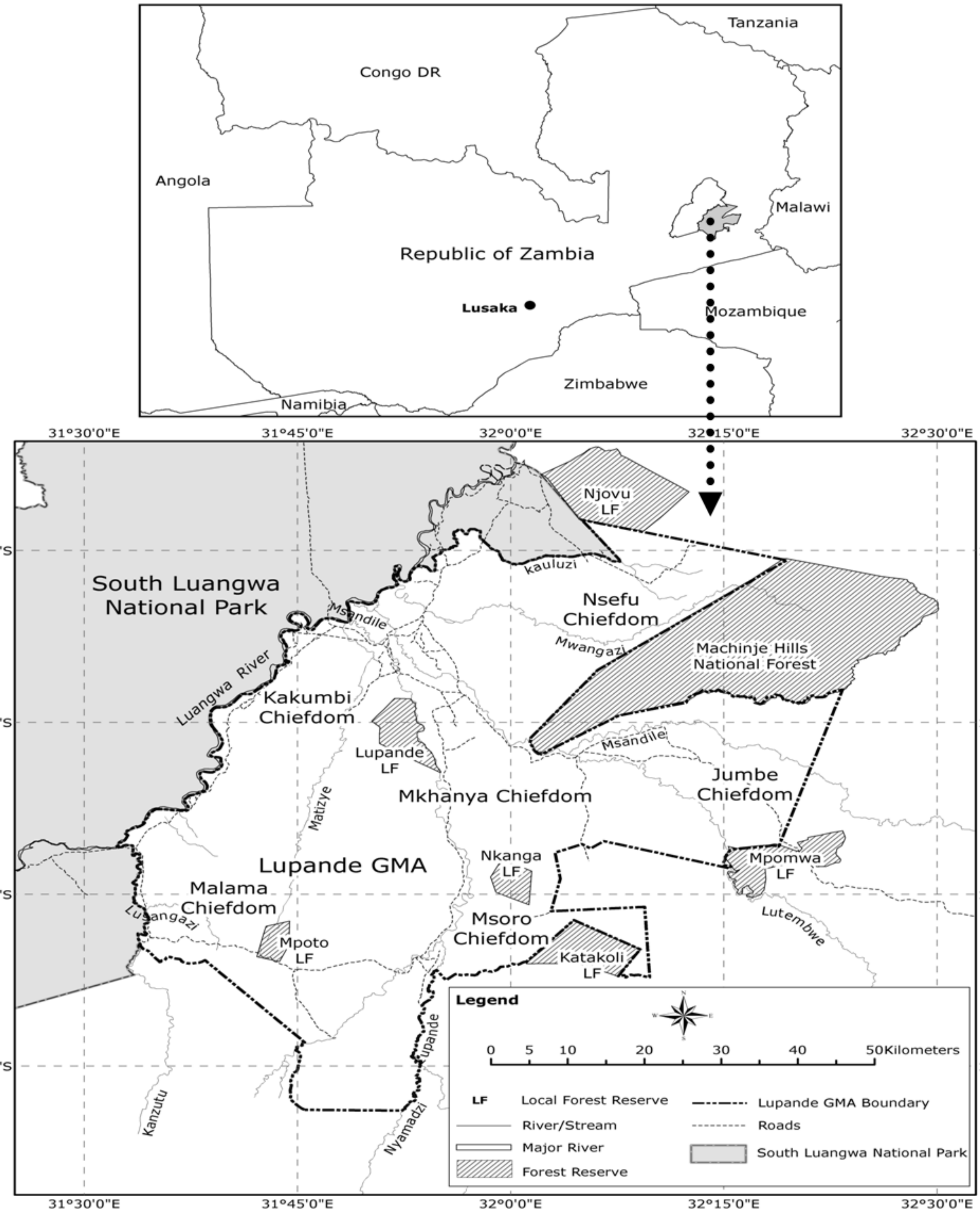

Figure 1. Location of Lupande game management area in eastern Zambia.

Artisan fishing, timber harvesting, photographic tourism and safari hunting businesses are among other main economic activities in the Luangwa Valley.

Vegetation communities

Vegetation communities of the Luangwa Valley are predominantly *Brachystegia* dominated Miombo woodlands on the plateau while Miombo-Mopane, *Acacia-Combretum*, *Faidherbia-Combretum*, *Colophospermum* Mopane and riparian woodlands form vegetal mosaics on the valley floor (Phiri, 1994; Smith, 1998). The vegetation communities occupy six distinguishable topographic units of relief and topography in the Luangwa Valley, from escarpment zone, hill zone, ridges and high undulating surfaces, plains and pans, old alluvial zone to floodplains (Gilvear et al., 2000). In the Lupande GMA in particular, elephants though utilise a wide array of vegetation communities, they confine themselves across seasons to vegetation in proximity to the Luangwa River due to human encroachment (Simukonda, 2011; Becker et al., 2013).

Climate

There are three distinct climatic seasons: hot-wet season from late November to April; a cool-dry season from May to August; and a hot-dry season from September to early November. The study area is situated in agro-ecological zone I of Zambia, with mean annual rainfall ≤ 830 mm per annum in the valley trough; whereas, records in excess of 1 220 mm per annum, are noted in the northern sector of the Luangwa Valley. The mean daily maximum temperature ranges from 32 to 36°C in the hot season. The minimum mean temperature in the cold season (June to July) is 15°C and maximum mean temperature in hot season (October) is 36°C in the valley floor. On the escarpment and surrounding areas, it is colder and less arid than on the valley floor as observed several decades ago by Archer (1971).

Elephant as a problem animal

According to McIntyre (2004), the Luangwa Valley (144 000 km^2) is one of the areas in Africa with high species diversity and large elephant population size. For instance, the country-wide survey conducted by Simukonda (2008) shows that 72% (n = 18,634 ± 3,592) of Zambia's elephant population inhabit the Luangwa Valley. The large African elephant population size results in increased conflicts as elephants compete for food and space (Balfour et al., 2007). Elephants cause more crop damage than other sympatric problem wild animals in the Luangwa Valley (Nyirenda et al., 2011).

Data capture procedures

Field data on trials from sample size n = 73 was collected with assistance of 29 trained local hunters, but transformed poachers, during 2012 farming season (January to June). Data recording was done by field assistants who accompanied local hunters. Wildlife agency provided the local hunters with functional muzzle loading guns, confisticated from poachers. Prior to trials on farms located in proximity of 34 villages randomly selected in six chiefdoms, local communities were sensitised to report any marauding elephants to trained local hunters, participating in the study. Upon receipt of such report, local hunters and their assistants positioned themselves at the site of invasion to discharge the trials, and would wait for 5 min control time to ensure that elephants are not responding to their sighting local hunters but to chemo-effects of *C. Oleoresin*. Within the 5 min, elephants would continue with their activities. Timings were estimated by use of stopwatches. The local hunters were equipped with functioning muzzle loading guns, which would be stuffed with dry *C. oleoresin* powder during their usage. Approximately, USD 12 worth of *C. oleoresin* powder (15 kg) was adequate for operations on each farm. The cost of *C. oleoresin* reduces further with collaborative use within neighbourhood network of farms. Farmers were also encouraged to grow their own chilli crop. For the purpose of the trials, local farmers were provided with commercially available "Peter Soda" sodium compound used in the production of gun powder, which was relatively cheap and could be afforded by local farmers. A scoop of gun powder costing USD 5 was adequate for the full farming season per local farmer's use. Locally available additive to gun powder in proportionally equal amounts by mixing with sodium compound was traditionally prepared in burnt and dry state of either wild jasmine (*Holarrhena pubescens*) occurring natural in the wild and river beans (*Sesbania sesban*) already promoted by Agricultural extension workers as soil fertility enhancing plant. Once gun powder was stuffed in muzzle loading guns, small quantities of dry Baobab (*Kigelia africana*) fibre or common sisal (*Agave sisalana*) fibre is used to hold gun powder together. Local hunters and their assistants masked themselves from irritating effects of *C. oleoresin* by use of wet clothing to protect nasal and mouth zones, goggles to protect eyes and ear pieces to protect ears from possible excessive gun sounds. In rainy conditions, rain coats were used for protection of local hunters and their assistants as well as keeping the materials such as gun and chilli powder dry. Precaution was taken by local hunters by ensuring safe distance of at least 12 m from possible counter attack by disturbed elephants. Data for each event was recorded on prescribed form.

Weather parameters recorded included prevailing winds vigour whether calm (no noticeable wind), light winds (1 to 6 km^{-h}) or strong winds (>6 km^{-h}); precipitation status whether not raining, drizzling (trace) or heavily raining; visibility whether day light, twilight (dusk, evening, nightfall or sunset), moon light or dark. All trials were conducted in windward direction whereby *C. oleoresin* aerosols were discharged towards elephants and away from the local hunters to maximise on impacts of the aerosols on target elephants while minimising impact of aerosols on local hunters and their assistants. Characteristics of invading elephants were noted as number in a group, relative sizes, colour, breeding and bachelor herds. Multiple invasions and lapsing periods inbetween present and previous raids were also recorded. Distances (in metres) from local hunters to elephants at the time of firing with *C. oleoresin* guns were estimated. Numbers of firings made before any reaction by target elephants were noted. Time between firing by local hunters and reaction by the target elephants, attributed to *C. oleoresin* effects other than the mere sound of the guns were also noted. Nature of reaction formed response variables, whether elephants turned and moved away from the crop fields, charged towards the hunters or ignored the firings. Estimated intervals between the firings, if more than once, before any reaction were observed and recorded. Where no reactions were made by target elephants, other measures taken by local hunters were recorded.

Incidences of failure of use of *C. oleoresin* gun to discharge aerosols, and limitations encountered and steps taken to resolve them were noted. The physical features where the firings were conducted and where elephants were situated at the time of firings were also noted to enable subsequent verifications. Other countermeasures such as clapping and shouting were excluded or avoided during the experiment.

Analyses

Minitab statistical software was utilised in the analyses. In building multivariate regression models, response data was allotted "1" if elephants responded to *C. oleoresin* aerosols by turning and moving away from crop fields under incursion or "0" if they either charged towards the local hunters or ignored the effects of *C. oleoresin* aerosols. Similarly, other categorical data which related to weather parameters were apportioned unique numbers corresponding to applicable category of data. For instance, parameters associated with rains were given as 1 where there were no rains, 2 where there were drizzles, and 3 where there were heavy rains during the trials. Further, data were transformed by arcs of transformation (*Asinh*) and natural logarithms in accordance with Fowler et al. (2006). Stepwise binary logistic regression techniques were applied as described by Gausan et al. (2002) and Nicholls (1989) based on the categorical nature of data for response variables. Variable selection was conducted in iterations of "forward stepwise selection'', whereby independent variables were included in the models if succeeding iterations enhanced them. Only variables contributing maximum likelihood estimator for the resultant models were selected (Crawley, 1994). At the end of individual iterations,

Table 1. Multivariate regression model of crop raiding elephant response to gun propelled chilli *C. oleoresin* aerosols as a function of environmental independent variables in the Luangwa Valley, Zambia, during 2012 crop farming seasons.

Parameter	Change in deviance	Regression coefficient b	e^b	Pcal	Pstd.	Rank
Rains	22.750	-1.450	0.234	0.003***	<0.05	1
Asinh (number of elephants in an invading group)	24.644	0.919	2.507	0.037***	<0.05	2
Log(time between intervals of firings)	25.082	-1.664	0.189	0.037	>0.05	3
Asihn (period from last time of raid)	25.705	-0.438	0.645	0.078	>0.05	4
Log (number of firings made before elephants react)	26.162	-1.490	0.225	0.134	>0.05	5
Wind speed (vigour)	26.741	0.525	1.690	0.320	>0.05	6
Visibility	26.828	0.262	1.299	0.349	>0.05	7
Log (distance from the hunter to invading elephants)	27.085	-1.556	0.211	0.563	>0.05	8
Asinh (number of repeat invasions)	27.131	-0.247	0.781	0.615	>0.05	9

Legend: *** - statistically significant; e^b - exponent of the regression coefficient; Pcal – calculated; P-value; Pstd -set allowable p-value.

changes in deviance resulting from addition of variables to models were determined. Transformations in the risk for additional units of the independent variables were quantified by the exponent of the regression coefficients, e^b (Selvin, 2004). The model specifications took the general form based on Equations 1 by Nicholls (1989) as:

$$y_i = \exp(a + b_1X_1 \ldots\ldots + b_nX_n) \qquad (1)$$

Where y_i represents predicted response (turning and moving away from crop fields under incursion upon trials or resisting effects of *C. oleoresin* aerosols by either charging towards the local hunters or ignoring *C. oleoresin* aerosols trials), *a* and $b_1 - b_n$ being intercept and slope parameters respectively for one or *n* independent variables (X_1-X_n). A *G*-test was used to test the significance of association of the frequencies in response variable as function of the selected variables into the models.

RESULTS

Performance of *C. oleoresin* guns was influenced by two factors of nine key potential factors in Luangwa Valley, Zambia: rain conditions and elephant head size (Tables 1 and 2). Responses by elephants to *C. oleoresin* aerosols were significantly associated with precipitation levels, whether dry, drizzling or heavily raining. Of the total 73 trials conducted, 41 were conducted in dry weather conditions, 24 during drizzles and 8 during heavy rains. In all trials (n = 41) conducted in dry environment, elephants retreated from the crop fields. In 62.5% (n = 5) of trials conducted during heavy rains, elephants resisted *C. oleoresin* and continued with crop field invasions. During the heavy rains, no additional interventions were made until trials were repeated upon subsidence of rains. In all trials conducted during light drizzles except in one, elephants turned away and left crop fields. The single elephant that resisted *C. oleoresin* aerosols was a marauding bull.

In terms of elephant herd size, the smaller the group the harder it was to disperse them from crop fields. The mean elephant herd size was 6.99 ± 0.77 elephants, median 5.00 elephants with a range of 1.00 elephant to 30 elephants (Table 2). Elephants' responses to *C. oleoresin* aerosols neither depended on time between firings by local hunters, period from last time of raid, number of firings made, wind (strength), visibility, distance between the local hunters and invading elephants nor the number of repeat invasions (Table 2). There was no gun failure experienced during trials.

DISCUSSION

Chilli *Capsicum oleoresin* guns trials

The concept of usage of *C. oleoresin* aerosols hinges on reducing residence time of invading elephants in crop fields or any other place of invasion. Though, use of *C. oleoresin* aerosols was in the past claimed to be effective under controlled environments (Osborn, 2002), application of *C. oleoresin* aerosols by use of guns requires "special" skills by the users. The special skills, however, can be acquired locally within traditional settings. Internalising skills probably reduces associated transaction costs such as community mobilisation. This particular innovation takes advantage of fusion of local and modern knowledge by the players such as local communities and wildlife managers. For such innovations to be successful, they require creation of flexible linkages among the players (Innes and Booher, 1999). Further, institutional and voluntary individual self-organisation in participating stakeholders is crucial (Folke et al., 2005), which may take the form of instituting and implementing local rules and regulations on use of mitigation tools to reduce risk of abuse. The trials in Luangwa Valley revealed that usage of *C. oleoresin* aerosols in rainy conditions poses practical difficulties. First, the users have to protect themselves and the guns in use from rains. Secondly, though chilli as substance is insoluble in wet conditions, it is susceptible to washing away by precipitation. Under such conditions, therefore, even when *C. Oleoresin* loads have been in contact with sensitive mucous membranes of the nose, mouth and eyes, and trunk receptors of the

Table 2. Environmental independent variables as determinants of marauding elephants responses to chilli *C. oleoresin* aerosol trials in the Luangwa Valley, Zambia, during 2012 crop farming seasons.

Parameter	Constituencies	Mean±SE	Median	Range (min;max)	χ^2	p-value
Rains	No rain	-	-	-	22.750	0.003***
	Drizzle	-	-	-		
	Heavy rains	-	-	-		
Number of elephants in an invading group	-	6.99± 0.77	5.00	1.00; 30.00	24.644	0.037***
Time between intervals of firings(in minutes)	-	9.15±1.51	5.00	1.00;90.00	25.082	0.037
Period from last time of raid (in days)	-	4.08± 0.85	1.00	0.00; 30.00	25.705	0.078
Number of firings made before elephants react	-	2.81± 0.33	2.00	1.00;12.00	26.162	0.134
Wind speed (vigour)	Calm	-	-	-	26.741	0.308
	Little winds	-	-	-		
	Strong wind	-	-	-		
Visibility	Day light	-	-	-	26.828	0.349
	Twilight	-	-	-		
	Moon light	-	-	-		
	Dark (night)	-	-	-		
Distance from the hunter to invading elephants (in meters)	-	41.33±1.46	40.00	12.00;70.00	27.085	0.563
Number of repeat invasions	-	1.44± 0.15	2.00	0.00; 4.00	27.131	0.615

elephants, prevailing rains would wash away the substance. When *C. oleoresin* is washed away on contact with elephants' sensitive mucous membranes, it looses its effectiveness. Performance of *C. oleoresin* aerosols has hitherto been linked to wind direction (Hoare, 2012). Therefore, users of *C. oleoresin* guns in the field require positioning themselves in upward wind direction to effectively deploy *C. oleoresin* aerosols. This practice is also convenient to the local hunters as they minimised backlash of *C. oleoresin* aerosols to themselves. Further, firing distance is considered based on a number of factors such as visibility but for as long as the local hunters could clearly identify elephants and their essential parts such as mouths, eyes and nose.

In the Luangwa Valley trials, trajectory distances for *C. oleoresin* aerosols between local hunters and target elephants varied between 12 and 70 m, which were within the recommended 75 m by Osborn (2002). However, the challenge is if wind direction changes in the course of implementation of the method. Thus, such a change in wind direction calls for attentiveness by the users so that new appropriate positions can be adopted in time. Accordingly, marauding elephants that took more than 5.00 min of interval of firings were those that probably did not get the right dosage of *C. oleoresin* on contact and were slowly moving away from the local hunter yet did not completely leave invasion site prior to follow up firings. It was not clear how much of the *C. oleoresin*, in percentage terms, discharged by local hunters reached and stimulated the target elephants into expression of avoidance. When *C. oleoresin* loads are increased by making more than one firings, chances of effective contacts of *C. Oleoresin* with sensitive elephants parts probably increase, especially where marksmanship skills are rudimentary. On contact with *C. oleoresin* aerosols, elephants react by displaying response behaviour. There have been no known long-term negative impacts on humans, elephants, crops, insects and other environmental components as a result of *C. Oleoresin* aerosols application in the Luangwa Valley, Zambia. As already indicated, the immediate effects on the unprotected humans are body irritations resulting from sound and aerosols contact. On contact with aerosols, elephants are provoked.

The response behaviour by elephants to provocation is influenced by the population size of the marauding elephants. We attribute response behaviour of elephant groups to vocal communication strategies and social behaviour (Estes, 1991; Stuart and Stuart, 1988). Elephants are known to poses high communicative abilities, embedded in multiple facades that include vocalisation, body posture, locomotion pattern, and matriarch leadership. Therefore, these behavioural facades may plausibly explain why solitary bulls may appear to resist *C. oleoresin* discharges. Period from last time of raids and number of repeat invasions were linked to proper identification of individuals and habituation syndrome. Though, appropriate measures were taken to make use of a combination of physical and visual observations in this study, future individual identification should be made by advance technologies such as use of telemetric or satellite tagging methods in order to reduce human physical errors (Jackson et al., 2008).

From the findings, it is demonstrated that *C. Oleoresin* discharge by use of guns is not a panacea by itself to elephant habituation (n = 50, 67.57%) though, momentarily effective to rid off elephants from crop field incursions. Elephant habituation has been persistent and widespread across many mitigation mechanisms (Lamarque et al., 2009; O'connell-Rodwell et al., 2000; Osborn and Rasmussen, 1996) and as such many researchers, conservationists and practitioners recommend use of a combination of counter-measures (Balfour et al., 2007; Hoare, 2001a; Lamarque et al., 2009).

Relevance of transformative approaches to human elephant conflicts

Engaging local hunters in elephant deterrent methods is one of innovative CBCM, especially in a landscape where traditional counter-measures are more prevalent than other counter-measures. Traditional counter-measures include use of guard huts, used by local farmers to watch over their crop fields; creation of noise to scare animals away; creation of wood fires in chosen parts of crop field boundaries particularly in known gateways of the elephants; use of trajectories including stones, metal bars and wood pieces. Local hunters, volunteering on the HEC management programme, support biodiversity conservation by employing such non-lethal methods. Therefore, conservation psychology can also play a critical role in improving local community participation (Saunders et al., 2006). The use of *C. Oleoresin* guns by local hunters is cost effective farm-based mitigation as it largely uses local materials that are readily available and accessible to local communities. As earlier stated, involvement of local hunters in protecting their own fields reduces transaction costs, while increasing the chances for uptake of the technologies by wider groupings in the local communities due to lower capital investment and levels of expertise than most other counter-measures (Graham and Ochieng, 2008). *C. Oleoresin* guns technologies comprehensively integrate local knowledge and practices, which permit environmental sustainability through permeation by use of local structures such as clans, family ties and other social units with high resilience, thereby socially legitimising them by local communities and wildlife managers.

Local hunters' participation in the HEC counter-measures by use of *C. oleoresin* guns was premised on the tenets of decentralisation and subsidiarity of community based natural resource management (Child, 2009). These tenets promote devolutionary processes which require facilitation roles for local communities' innovations and freedom to construct local resource regime through robust governance systems and capacity development (Marks, 2009). Transforming local hunters into conservationists hinges on provision of tangible benefits to local hunters (Gibson and Marks, 1995) such as protection of their crop fields. Therefore, such stakeholder participation needs integration of empowerment, equity, trust and learning (Reed, 2008).

CONCLUSION

Farm-based mitigation methods perform variedly (Sitati and Walpole, 2006) and may be influenced by a number of factors associated with technology and mediating environmental parameters. Effectiveness of *C. oleoresin* aerosols by use of guns in Luangwa Valley was influenced by rain conditions and elephant head size. Further, usage of *C. oleoresin* guns can be enhanced by provision of appropriate training to users, with specific technical application protocols. While involvement of local communities in conservation innovations such as *C. Oleoresin* guns is commendable especially for enforcing prevalent and non-lethal traditional counter-measures, the onus on controlling and monitoring of proper use of the tools lies on Wildlife Agency in the case of state managed protected areas and private landowners, including local communities in the case of privately managed lands. Proper usage of CBCM tools is likely to attract conservation support by local communities through sustainable crop protection, consequential food and livelihood security.

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REFERENCES

Archer DR (1971). Rainfall. In: Davies DH (ed.). *Zambia in Maps*. University of London Press, London, pp.1-20.

Andelt WF, Baker DL, Burnham KP (1992). Relative preference of captive cow elk for repellent treated diets. J. Wildl. Manage. 56:164-173.

Balakrishnan M, Ndholvu DE (1992). Wildlife utilization and local people: a case study of upper Lupande Game Management Area, Zambia. Environ. Conserv. 19(2):135-144.

Balfour D, Dublin HT, Fennessy J, Gibson D, Niskanen L, Whyte IJ (eds.). (2007). Review of options for managing the impacts of locally overabundant African elephants. The World Conservation Union, Gland.

Becker M, McRobb R, Watson F, Droge E, Kanyembo B, Murdoch J, Kakumbi C (2013). Evaluating wire-snare poaching trends and the impacts of by-catch on elephants and large carnivores. Biol. Conserv. 158: 26-36.

Central Statistical Office (2012). Zambia 2010 Census of population and housing: population summary report. Central Statistical Office, Lusaka.

Child B (2009). Recent innovations in conservation. In: Suich H, Child B, Spenceley A (eds.). Evolution and innovation in wildlife conservation: parks and game ranches to transfrontier conservation areas. Earthscan, London.

Chiyo PI, Cochrane EP, Naughton L, Basuta GI (2005). Temporal patterns of crop raiding by elephants: a response to changes in forage quality or crop availability? Afr. J. Ecol. 43:48-55.

Chomba C, Senzota R, Chabwela H, Mwitwa J, Nyirenda V (2012). Pattern of human-wildlife conflicts in Zambia: causes, consequences and management responses. J. Ecol. Nat. Environ. 4(12):303-313.

Crawley MJ (1994). GLIM for ecologists. Blackwell Scientific Publications, Oxford.

Dalal-Clayton B, Child B (2003). Lessons from Luangwa: the story of the Luangwa Integrated Resource Development Project, Zambia. International Institute for Environment and Development, London. (Wildlife and Development Series p.13).

Estes RD (1991). The behaviour guide to African mammals, including hoofed mammals, carnivores and primates. University of California Press, California.

Folke C, Hahn T, Olsson P, Norberg J (2005). Adaptive governance of social-ecological system. Ann. Rev. Environ. Resour. 30:441-473.

Fowler J, Cohen L, Jarvis P (2006). Practical statistics for field biology. 2^{nd} Ed. John Wiley & Sons Ltd., England.

Gadd ME (2005). Conservation outside of parks: attitudes of local people in Laikipia, Kenya. Environ. Conserv. 32(1):50-63.

Gausan A, Edwards TC, Hastie T (2002). Generalized linear and generalized additive models in studies of species distributions: setting the scene. Ecol. Model. 157:89-100.

Gibson CC, Marks SA (1995). Transforming rural hunters into conservationists: an assessment of community-based wildlife management programs in Africa. World Dev. 23(6):941-957.

Gilvear D, Winterbottom S, Sichingabula H (2000). Character of channel platform change and meander development: Luangwa River, Zambia. Earth Surf. Proc. Land. 25(4):421-436.

Graham MD, Ochieng T (2008). Uptake and performance of farm-based measures for reducing crop raiding by elephants (Loxodonta africana) among smallholder farms in Laikipia District, Kenya. Oryx 42(1):76-82.

Guldemond R, van Aarde R (2008). A meta-analysis of the impact of African Elephants on Savanna Vegetation. J. Wildl. Manage. 72(4):892-899.

Hoare R (2012). Lessons from 15 years of human-elephant conflict mitigation: management considerations involving biological, physical and governance issues in Africa. Pachyderm 51:60-74.

Hoare RE (2001a). A decision support system for managing human-elephant conflict situation in Africa. The World Conservation Union, Nairobi.

Hoare RE (2001b). Management implications for new research on problem elephant. Pachyderm, 30:44-48.

Hunt CL (1985). Descriptions of five promising determinant and repellent products for use with bears. Grizzly Bear Recovery Coordinator, Missoula, Montana. (United States Fish and Wildlife Service Report p.3).

Innes JE, Booher DE (1999). Consensus building and complex adaptive systems. J. Amr. Plann. Assoc. 65(4):412-423.

Jackson TP, Mosojane S, Ferreira SM, van Aarde RJ (2008). Solutions for elephant (Loxodonta africana) crop raiding in northern Botswana: moving away from symptomatic approaches. Oryx 42(1):1-9.

King LE, Douglas-Hamilton I, Vollrath F (2011). Beehive fences as effective deterrents for crop-raiding elephants: field trials in northern Kenya. Afr. J. Ecol. 49:431-439.

Lamarque F, Anderson J, Fergusson R, Lagrange M, Osei-Owusu Y, Bakker L (2009). Human-wildlife conflict in Africa: causes, consequences and management strategies. FAO, Rome.

Marks SA (2009). Rural people and wildlife in Zambia's Central Luangwa Valley: Precautionary advice from a long-term study. In: Baldus RD (eds.). A practical summary of experiences after three decades of community-based wildlife conservation in Africa: what are the lessons learnt? FAO and CIC, Budapest, (CIC Technical Series Publication No. 5). pp. 52-71.

McIntyre C (2004). Zambia: the Bradt travel guide. Third edition. Chalfont, Bradt, St Peter.

Muruthi P (2005). Human wildlife conflict: lessons learned from African Wildlife Foundation's African heartlands. Africa Wildlife Foundation, Nairobi.

Naughton-Treves L, Grossberg R, Treves A (2003). Paying for tolerance: the impact of depletion and compensation payments on rural citizen's attitudes toward wolves. Conserv. Biol. 17(6):1500-1511.

Naughton-Treves L (1998). Predicting patterns of crop damage by wildlife around Kibale National Park, Uganda. Conserv. Biol. 12(1):156-168.

Nicholls AO (1989). How to make biological surveys go further with generalized linear models. Biol. Conserv. 50:51-75.

Nyirenda VR, Myburgh WJ, Reilly BK (2012). Predicting environmental factors influencing crop raiding by African elephants *Loxodonta africana* in the Luangwa Valley, eastern Zambia. Afr. J. Environ. Sci. Technol. 6(10):391-400.

Nyirenda VR, Chansa WC, Myburgh WJ, Reilly BK (2011). Wildlife crop depredation in the Luangwa Valley, eastern Zambia. J. Ecol. Nat. Environ. 3(15):481-491.

Osborn FV (2002). Chilli *Capsicum Oleoresin* as an elephant repellent: field trials in the communal lands of Zimbabwe. J. Wildl. Manage. 66(3):674-677.

Osborn FV, Rasmussen LEL (1996). Evidence for the effectiveness of an *Oleoresin capsicum* aerosol as a repellent against wild elephant in Zimbabwe. Pachyderm, 21:55-64.

O'Connell-Rodwell CE, Rodwell T, Rice M, Hart LA (2000). Living with the modern conservation paradigm: can agricultural communities co-exist with elephant? A five – year case study in East Caprivi, Namibia. Biol. Conserv. 93:381-391.

Poole J (1996). The African Elephant. In: Kangwana K (ed.). Studying Elephant. African Wildlife Foundation, Nairobi, (Technical Handbook No. 7). pp.1-8.

Phiri PSM (1994). The relevance of plant taxonomic information for the conservation of the low altitude Luangwa Valley ecosystem. In: Seyani JH and Chikuni AC (eds.). Proceedings of the XIIIth Plenary Meeting AETFAT, pp.903-910.

Reed MS (2008). Stakeholder participation for environmental management: a literature review. Biol. Conserv. 141:2417-2431.

Saunders CD, Brook AT, Myers Jr. OE (2006). Using psychology to save biodiversity and human well-being. Conserv. Biol. 20(3):702-705.

Selvin S (2004). Statistical analysis of epidemiological data, 3^{rd} ed. Oxford University Press, New York.

Simukonda C (2012). Wet season survey of the African elephant and other large herbivores in selected areas of the Luangwa Valley, 2011. Zambia Wildlife Authority, Chilanga.

Simukonda C (2008). National-wide large mammal surveys and population estimates. New Horizon Printing Press, Lusaka.

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

Smith P (1998). A reconnaissance survey of the vegetation of the North Luangwa National Park, Zambia. Bothalia 28(2): 197-211.

Stuart CT, Stuart MD (1988). Field guide to the mammals of Southern Africa. Struik Publishers, Cape Town.