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Full Length Research Paper

Wildlife crop depredation in the Luangwa Valley, eastern Zambia

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Wildlife crop raiding was assessed in six chiefdoms of the Luangwa Valley, eastern Zambia between 2004 and 2008 to establish nature and extent of wildlife crop degredation and examine the impact of existing mitigation measures being implemented to deter wildlife crop raiding. Crop damage assessments, involving crop quality, stage of growth and proportion of crop damage, were conducted using six trained field enumerators. Structured questionnaires were administered randomly to local farmers that were inflicted by wildlife crop raiders to elucidate on-farm deterrence measures. Eleven species of wildlife were identified as 'problem animals': African elephant (*Loxodonta africana*), Hippopotamus (*Hippopotamus amphibius*), Bushpig (*Potamochoerus larvatus*), Yellow baboon *(Papio cynocephalus)*, Porcupine (*Hystrix africaeaustralis*), African civet (*Civetta civetta*), Roan antelope (*Hippotragus equinus*), Lesser kudu (*Tragelaphus strepsiceros*), Eland (*Taurotragus oryx*), Cape buffalo (*Syncerus caffer*) and Warthog (*Phacochoerus africanus*). Results showed that African elephant caused the most damage, 67.82 and 98.41% of total wet and dry farming crop raiding incidences respectively, which occurred at crop maturity between February and April. Maize (*Zea mays*) and cotton (*Gossypium hirsutum*) were the most affected crops by problem animals, associated with 71.38 and 42.86% of the total crop raids in wet and dry farming seasons respectively. Frequency and extent of damages depended on deterrence measure applied on the crop fields. Of the six chiefdoms, in Malama chiefdom where solar powered electric fences and *Capsicum* fences were implemented, there were few and less intensive incursions. Based on the findings, we suggest development of capacity for local farmers in effective wildlife crop mitigation measures, particularly against African elephants. Future research would require determining uptake by local farmers and efficacy of novel counter-measures.

Key words: Wildlife crop raiding, conservation, Luangwa Valley.

INTRODUCTION

Human-wildlife conflict (HWC) can be defined by a complex mix of characteristics, which include instances of crop raiding, wildlife-livestock disease transmission, livestock depredation, destruction of property by wildlife, killing of wildlife by people who experience or perceive actual or potential wildlife threats to themselves, family members or their property (Madden, 2006). Human-elephant conflict (HEC) is a specific HWC that involves humans and elephants. It occurs where competition for resources and landscapes between humans and elephants results in actual or perceived damage to humans, wildlife or property (Balmford et al., 2001; Lamarque et al., 2009). Human-elephant conflict is broadly defined by African Elephant Specialist Group (AfESG) of the World Conservation Union/Species Specialist Group (IUCN/SSC) as "any human-elephant interaction which results in negative effects on human social, economic or cultural life, on elephant conservation or on the environment" (Hoare, 2001).

Human-wildlife conflicts are widespread in one form or another in all parts of the world and involve several animal species (Lamarque et al., 2009). In Africa, several

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large herbivores, reptiles and mammalian carnivores are considered as threats to humans. Increasing human-elephant interactions resulting in conflicts is one of the eminent challenges facing wildlife conservation in sub-Saharan Africa (Balmford et al., 2001; Sitati et al., 2003). The interactions lead to emerging conflicts, *inter alia*; crop raiding, damage to infrastructure (e.g. houses, food stores, fences and other barriers), occasional injuries and demise of people on one hand. On the other hand, habitat loss to wildlife and retaliatory killing of wildlife by inflicted people take place. Zambia, with over 30% of its landmass under protected area system, experiences numerous cases of HWC. Typically, HEC reports are heightened in 'hotspots' of African elephant rangelands of Luangwa Valley, Zambezi, Kafue and Sumbu eco-systems, where crop raiding incidences are high. This study was motivated by the high widespread incidences of wildlife crop raiding in the Luangwa Valley. Such incidences and extensive wildlife crop damage cause food insecurity among the affected impoverished households (Lewis, 2007). Food deprivation, which consistitutes food insecurity, disrupts active and health life (FAO, 2008) and has potential of eroding local support for biodiversity conservation (Gadd, 2005). In Zambia and Luangwa Valley in particular, there is no formal compensation scheme to cushion losses caused by wildlife, although wildlife crop raiding in the Luangwa Valley has a long history. Dalal-Crayton and Child (2003) highlighted that by 1930's, crop raiding by African elephants was already a considerable problem to subsistence farmers in the Luangwa Valley.

Despite the long history of crop raiding in the Luangwa Valley, there has not been a study that combines physical (nature and extent) and social (counter-measures) dimensions of HWC in the Luangwa Valley. We therefore, considered that high incidences of wildlife crop raiding in the Luangwa Valley was indicative of wildlife hotspots, in '*refugia*' areas, surrounded by human settlements as postulated by Naughton-Treves (1998) and Wittemyer et al. (2008). With diminishing wildlife habitats caused by human encroachment, wildlife crop raiding was postulated to increase and to play a significant role in the decline of wildlife populations, particularly the African elephant (Hoare, 1999a). Lewis and Phiri (1998) contended that the threat of wildlife population depletion was exacerbated by food shortages which coerce rural populace to engage in illegal killing of wild animals. Therefore, knowledge of crop depredation patterns is important for planning, implementing and monitoring of crop raiding interventions.

Mitigation against wildlife crop raiding requires a detailed understanding of underlying factors, patterns and processes associated with crop raiding incidences (Sitati et al., 2005). The associated factors, patterns and processes should therefore, be linked to efficacy of deterrence mechanisms farmers employ to protect their crops. Effectiveness, being output oriented, has connotation of a measure of productivity in utilizing the undertaking's resources and bearing long term profitability (Reilly and Reilly, 2003). Consequently, the objective of this study was to elucidate the nature and extent of wildlife crop depredation in the Luangwa Valley and determine the efficacy of key counter-measures applied in mitigating wildlife crop raiding in the Luangwa Valley. We hypothesised that the nature and extent of crop depredation by African elephants and other wild animals, coupled with key counter-measures were associated with crop raiding occurrences in the Luangwa Valley, Zambia.

MATERIALS AND METHODS

Study site location and description

Crop depredation was assessed in six chiefdoms (Jumbe, Kakumbi, Malama, Mnkhanya, Msoro and Nsefu) of Kunda people, adjacent to South Luangwa National Park in the Luangwa Valley, eastern Zambia. The study area, encompassing six chiefdoms, were Lupande Game Management Area (4, 840 km^2) in Luangwa Valley, eastern Zambia, located at 12°57'00"S to 13°49'05"S and 31°32'00"E to 32°23'23"E (Figure 1), and was one of the crop raiding 'hotspots'.

Human demography and socio-economic characteristics

The estimated human population in Lupande Game Management Area was 47,376 people (CSO, 2003). The people of the Luangwa Valley co-existed with wildlife for a long time as evidenced by animal and plant fossils, forming "footprints" of human-wildlife interactions. Another anthropogenic evidence of Luangwa Valley people's interactions with wildlife was through their culture, demonstrated by songs and dances, dressing and to some extent culinary habits. Agriculture was the mainstay of the people in the Luangwa Valley, as a source of revenue and food as subsistence farmers (Dalal-Clayton and Child, 2003), supported by acrisols, lithosol-cambisols and fluvial-vertisols (Astle et al., 1969). Crops were mostly cultivated in mono-specific stands and crop varieties included maize (*Zea mays*), cotton (*Gossypium hirsutum*), millet (*Eleusine* sp.), sorghum (*Sorghum vulgare*), beans (*Phaseolus vulgaris*), pumpkin (*Curcubita maxima*) and sweet potato (*Ipomoea batatas*). Crop production was constrained by firstly, crop raiding by wild animals, causing food insecurity (Lewis and Phiri, 1998; Simasiku et al., 2008) and secondly, by climate variability in the Luangwa Valley reflected by above 60% drought occurrence (Gilvear et al., 2000). Other economic activities in the Luangwa Valley were photographic tourism and safari hunting .

'Problem animal' population sizes

According to McIntyre (2004), the Luangwa Valley was one of the areas in Africa with high species diversity and large population sizes of wild fauna. Simukonda (2008) estimated population sizes of selected species in Lupande Game Management Area as follows: African elephant (2, 107), Yellow baboon (424), Cape buffalo (6, 221), Lesser kudu (83), Warthog (244) and Roan antelope (42). Other 'problem animals' such as Bushpig, Porcupine, African civet and Eland were not surveyed and as such their population estimates were not available. In case of African elephant, Luangwa Valley supported 72% (n=18 634 ± 3 592) of Zambia's elephant population (CITES, 2010). As animals compete

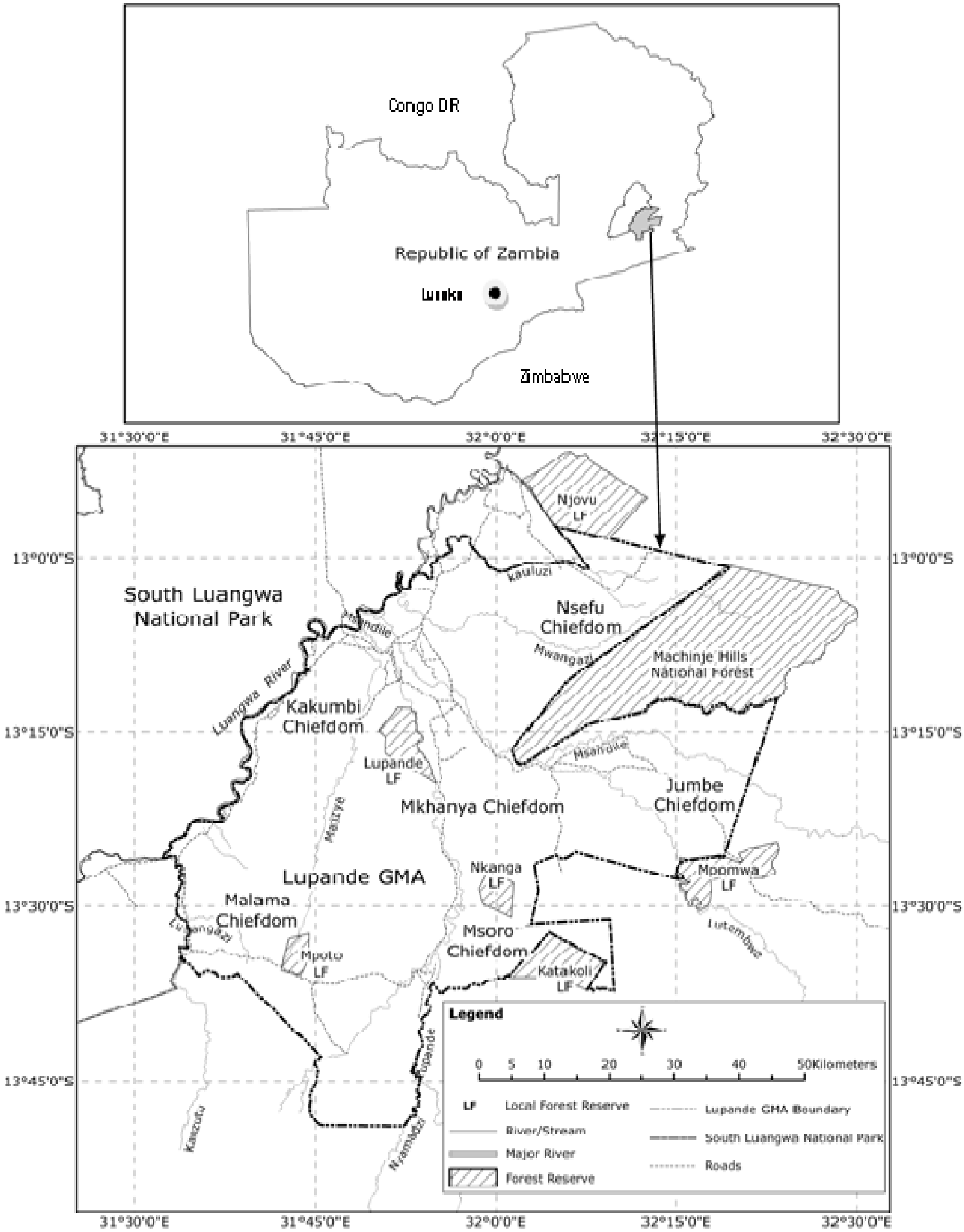

Figure 1. Location of Lupande game management area in Luangwa Valley, eastern Zambia.

for food and space, the large African elephant population size resulted in increased crop raiding (Balfour et al., 2007). Luangwa River together with its tributaries, ox-bow lakes and lagoons which were utilized for dry season cultivation also were a prime habitat for

Hippopotami, whose population increased in the last 30 years and is currently estimated at 6, 318 with density of 33 km per river stretch (Chansa et al., 2011).

Vegetation communities

Phiri (1994) and Smith (1998) characterised vegetation types of the Luangwa Valley, as being predominantly Miombo woodland on the plateau and a mosaic of vegetation types on the valley floor constituting Miombo-Mopani, *Acacia-Combretum*, *Faidherbia-Combretum*, Mopani and riparian woodlands. There were also patches of palm communities. These vegetation communities occupied 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).

Climate

There were 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 was 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, were noted in the northern sector of the Luangwa Valley. For this study, total rainfall (mm) and rain-days between 2004 and 2008 wet seasons were obtained from three metrological weather stations at Mfuwe, Chinzombo and Tafika, situated within Lupande Game Management Area. Rainfall data was used to validate relationship between wildlife crop raiding and amount of rainfall. We assumed that amount of rainfall influenced rain-fed crop husbandry and accordingly attracted wildlife crop raiders to crops under cultivation.

The mean daily maximum temperatures ranged from 32 to 36°C in the hot season. The minimum mean temperature in the cold season (June to July) was 15°C and maximum mean temperature in hot season (October) was 36°C in the valley floor. On the escarpment and surrounding areas it was colder and less arid than on the valley floor (Archer, 1971).

Assessing crop damages

Crop damage data was recorded during 2004 to 2008 farming seasons on a form modified after Hoare (1999b). Farming season was defined as the period between November and May for rain-fed crops (wet season farming) and June to October for dry gardening crops (dry season farming). Farmers were sensitised on crop damage reporting requirements, through extension programmes, prior to and during the farming seasons. Each farmer who suffered crop invasion within the study area reported to the respective field enumerators. The farmer accompanied the enumerator(s) to the affected field(s) for crop damage assessments. In the study area, crop damage assessments were conducted within 72 h of damage by six trained field enumerators. Each crop type was categorized by variety and quality which was further classified as good, medium or poor as determined by vigour and stage of growth (seedling, intermediate or mature) at the time of damage.

The damaged portion and the total area dimensions of crop fields were estimated by graduated paces, which were converted to metric measurements (Chiyo et al., 2005). Damaged areas were compared with the unscathed crop field areas for validation of crop quality and stage of growth. In instances where the responsible animals for the damage were not seen, damage 'culprit' animals were identified by examination of foot prints, dung droppings, crop remnants and animal feeding habits as suggested by Kagoro-Rugunda (2004). Some of the damage was assessed some hours after the damage had been caused, and as such species responsible for the damage were not traced. In such instances, farmers provided subjective information on description of animals seen in groups or solitary, colour and their relative body sizes. This study focused on crop depredation itself but future assessment will use on-farm technology of remote cameras to study in detail the relationship between crop damage and characteristics of individuals perpetuating crop raiding in Luangwa Valley.

Counter-measures

Structured questionnaires, to investigate effectiveness of counter-measures implemented by respective local farmers, were administered to 311 randomly selected respondents representing 56% of inflicted farmers in the periods between 2004 and 2008. For comparative purposes, local farmers growing similar varieties in proximity (≤ 1 km) but had their crop fields undamaged, were interviewed to elucidate counter-measures employed during the same farming season when the neighbouring farms were raided. Protocols proposed by Bradburn et al. (2004) were used, stressing pre-testing, use of choice of answers in menu and disclosure of confidentiality of responses.

Statistical analyses

Minitab statistical software package version 14 was used in the analysis (Minitab, 2004). The measurements of total amount of rainfall and number of rain-days between 2004 and 2008 were pooled by their monthly means and contrasted with the mean crop raiding incidences in the same period. Correlations were made between mean crop raiding incidences and the mean total rainfall as well as mean rain-days using Spearman's Rank Higher Order Correlation (SROC), following normalization of data by arcs in transformation (Fowler et al., 2006). Combined scores were obtained by adding respective scores derived from the crop growth stage, quality and proportion of damage for each crop field to determine severity of damage (Hill et al., 2002; Malima et al., 2005). Crop growth stage; seedling, intermediate or mature was allotted one, two and three points respectively. Crop condition in terms of whether the crop was in poor, medium or good status, was respectively given one, two or three points. Percentage of the damage was assigned one of six points, based on; ≤ 5%, 5.1 to 10.9%, 11 to 20.9%, 21 to 50.9%, 51 to 80% or >80% as one, two, three, four, five or six. Though being a relative term, percentage was useful because from local farmers' perspective, perception of severity of crop damage was linked to the spatial proportion of crop field(s) damaged. Additive combined scores were apportioned as low (≤ 5 points), medium (6 to 8 points) or high (≥ 9 points) damage classes. Using the severity categories, wildlife crop raiders and crop types were further ranked by nominal ranking technique, whereby ranks were allocated by order or frequencies.

Analysis of effectiveness of counter-measures was allotted "1" if crop damage took place or "0" if the field was unscathed. Each counter-measure was coded with a unique numerical number. The counter-measures were tested for their effectiveness along with ten other independent variables such as farm sizes, vegetation types around crop fields, elevation and distance to rivers, major roads, forests and parks, by use of stepwise binary logistic regression techniques as described by Guisan et al. (2002) and Nicholls (1989). However, for purpose of this paper, we limited our focus to counter-measures only. Variable selection was conducted in iterations of "Forward Stepwise Selection''. Each independent variable was added alone to the null log-linear model. Succeeding iterations were made to improve the building of the statistical model. Only variables having the maximum likelihood estimator that would

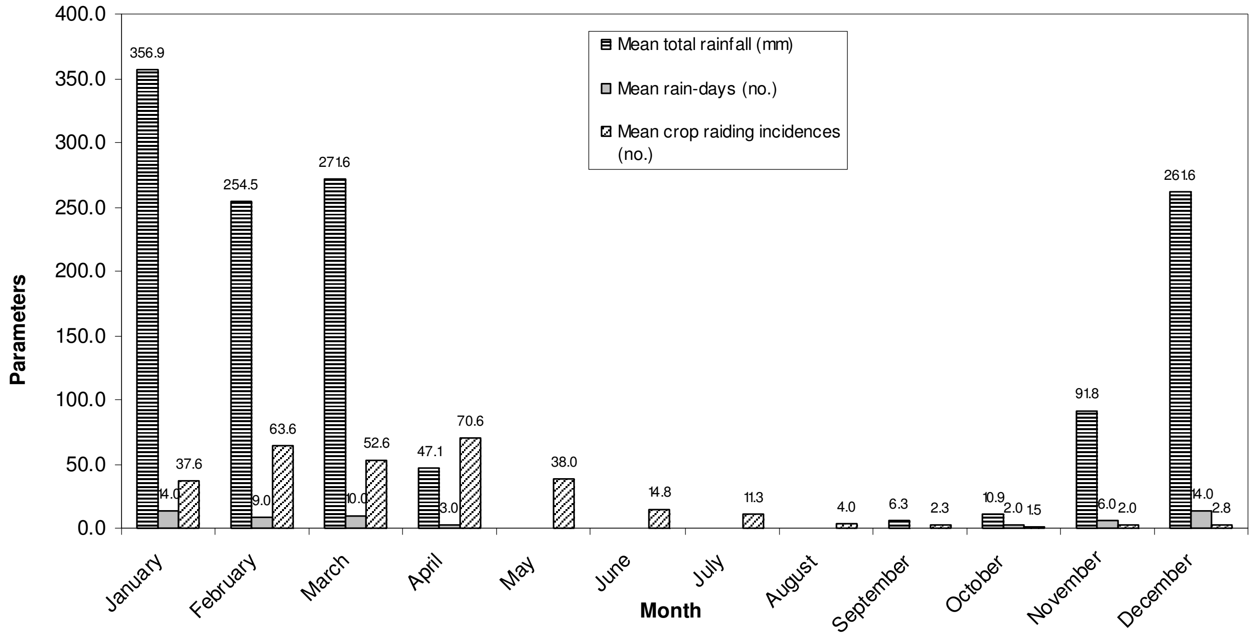

Figure 2. Wildlife crop raiding and rainfall pattern of Luangwa Valley, Zambia, 2004 to 2008.

improve the model were selected. Thus, the choice for model building was based on a set of parameters for which the log-likelihood was highest (Crawley, 1994). At the end of each iteration, change in deviance resulting from the addition of a variable to the model was determined. Transformation in the risk for any additional unit of the independent variable was quantified by the exponent of the regression coefficient, e^b (Selvin, 2004). The model specifications took the general forms based on Nicholls (1989) as:

$y_i = exp\ [a + b_1X_1]$; and

$y_i = exp\ [a + b_1X_1 \ldots\ldots + b_nX_n]$;

Where y_i represents predicted response (damaged or unscathed), *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 model.

RESULTS

Correlates of mean wildlife crop raiding incidences and mean total rainfall or mean rain-days

Crop raiding in the Luangwa Valley depicted a bimodal frequency in February and April during the wet season (Figure 2). The pinnacle of the crop raiding occurred during the transition period from wet to dry season, which coincided with crop maturity. Test of the relationship between mean crop raiding incidences and the mean total rainfall precipitation as well as mean rain-days, showed weak positive correlation between mean crop raiding incidences and mean total rainfall ($r^2 = 0.189$; $p \leq 0.557$), and mean crop raiding incidences and mean rain-days ($r^2 = 0.366$; $p \leq 0.242$) .

Characteristics of wildlife crop damage

African elephants caused 72.35% (n=1 073) of the total crop raiding incidences, totalling 1, 483 incidences on 1, 251 crop fields between 2004 and 2008 (Table 1). In Table 1, the 1, 483 crop damage incidences were represented by sum of high, medium and low severity incidences and figures in brackets represented dry season occurrences. Other wildlife species that contributed to crop damage in descending order were; Hippopotamus, Bushipig and Yellow baboon. African elephant, Hippopotamus, Bushpig, Yellow baboon and other species damaged 70.82, 15.03, 9.43, 3.68 and 1.04% respectively, of the total number of crop fields invaded by wildlife crop raiders. On the affected crop fields, African elephant, Hippopotamus, Bushpig, Yellow baboon and others were associated with 72.35, 13.49, 9.64, 3.24 and 1.28% respectively, of the total number of crop damage incidences.

Crop damage varied between seasons (wet or dry) and animal species. The rainy season had the highest crop fields (n=1 125, 89.93%) damaged. Damage by African elephants occurred mainly at night, with 81.23 %, 63.99 % of the total invasions during wet and dry farming seasons respectively. In some cases the same individuals (African elephants) occasioned damage on more than one site (range=1, 4; median=1) within a 24 h period of incursion. African elephants and Bushpigs

Table 1. Crops damage by wildlife during wet farming season and dry farming season (dry season parameters in parentheses) in the Luangwa Valley, Zambia, 2004 to 2008.

Parameter	Wildlife crop raiders						
	Elephant	Hippopotamus	Bushpig	Baboon	Others	Total	Rank
No. affected crop fields	763(124)	188(-)	115(2)	46(-)	13(-)	1125(126)	-
% Damage (Mean ±Standard error)	22.19±1.12 (31.65±3.02)	11.69±1.40 (-)	11.36±1.88 (75.00±2.50)	8.02±2.45(-)	15.86±1.42 (-)	-	-
% Night invasions	81.23(63.99)	100.00(100.00)	100.00(100.00)	100.00(-)	9.12(-)	-	-
High Severity incidences	353(41)	21(3)	27(9)	6(1)	8(1)	415(55)	-
Medium Severity incidences	531(78)	146(5)	82(17)	36(4)	7(2)	802(106)	-
Low Severity incidences	56(14)	24(1)	5(3)	1(-)	1(-)	87(18)	-
Maize	318(34)	141	106	38	5	608(34)	1(2)
Cotton	176(20)	7	2	4	6	195(20)	2(3)
Rice	150	14	1	0	1	166(0)	3(-)
Groundnuts	27(1)	18	3(1)	3	1	52(2)	4(7)
Sorghum	27(3)	2	1	0	0	30(3)	6(6)
Cassava	14(9)	0	2	0	0	16(9)	7(5)
Bananas	10(16)	0	0	0	0	10(16)	8(4)
Others	41(41)	6	0(1)	1	0	48(42)	5(1)
Total	763(124)	188	115(2)	46	13	1125(126)	-
Rank by Species	1(1)	2	3(2)	4	4	-	-

caused greater crop damage (mean±standard error) (31.65±3.02 and 75.00±2.50% respectively) in dry season than in wet season (22.19±1.12 and 11.36±1.88% respectively). During the wet farming season, Hippopotami were second ranking marauders and considerably invaded crops along the riparian zones at night. Bushpigs raided crop fields at night and mostly in wet farming season. Yellow baboons and other day-time opportunistic raiders ate a few of cultivars (n=5) in wet farming season. Maize (*Z. mays*) and cotton (*G. hirsutum*) were the most predated crop types by all recorded problem animals. In addition, other crop types devoured included: rice (*Oryza sativa*), groundnuts (*Arachis hypogaea*), sorghum (*Sorghum vulgare*) and cassava (*Manihot esculenta*). During the dry season, however, predated crops included: bananas (*Musa* spp.), sweet potatoes (*I. batatas*), cassava (*M. esculenta*), tomatoes (*Lycopersicon esculentum*) and sugarcanes (*Saccharum officinarum*). Bananas were unscathed by all other species except African elephants throughout farming seasons.

Spatial perspective of wildlife crop raiding

Kakumbi chiefdom experienced the highest number of fields invaded (n=558, 44.60%) (Table 2). Kakumbi, Jumbe and Nsefu chiefdoms had more crop raiding incidences than Msoro chiefdom but the latter had proportionally larger areas damaged (27.87±1.26 and 33.52±2.36%) by African elephants in both wet and dry farming seasons respectively. Msoro chiefdom had the greatest severity rating by the number of fields. Malama chiefdom had the lowest number of crop fields invaded (n=44, 3.52%), but with highest proportional crop field damage (22.78±1.35%) by African elephants. In proportional terms, more damage by African elephants and other problem animals occurred in dry farming season than in wet season, involving a variety crops but on only 10.07% of crop fields.

Effect of counter-measures against African elephants

Main counter-measures against African elephants were solar powered electric fences, chilli (*Capsicum*) fences and traditional measures. Traditional measures included use of guard huts;

noise creation to scare animals away; wood fires creation in chosen parts of crop field boundaries particularly in known gateways of the African elephants; use of trajectories including stones, metal bars and wood pieces; and occasionally use of decoy foods, with chilli seeds embedded in them. Counter-measures implemented significantly influenced crop incursions incidences (Equation 1). A unit of increase in different counter-measures resulted in large differences in the outcomes of the response variable. By changing counter-measures the chance of invasion reduced or increased by as much as ten times; thus, $e^b = 10.237$, where regression coefficient b was 2.326:

$$Y = \exp [2.326 (CM) - 5.885] \qquad (1)$$

Log-likelihood = -36.527; G = 7.890; df = 1; p = 0.005

Factors influencing adoption of counter-measures

Availability of knowledge and logistics (materials) to mitigate crop raiding was the major motivation factor determining the adoption of a particular counter-measure for majority of respondents (n=65, 52.85%; n=14, 40.00%; n=40, 75.47%) against African elephants, Bushpigs and Yellow baboons respectively (Table 3). Other factors such as habituation by target wild animals, human risks involved in the safeguarding of crops and the non-lethal approaches to mitigating crop raiding were secondary considerations to access to and affordability of knowledge and materials.

DISCUSSION

Importance of correlates between wildlife crop raiding incidences and rainfall

Like many aspects of wildlife crop raiding, information on correlates between crop raiding incidences and rainfall was a critical input to the planning of mitigation measures and subsequent control of wildlife crop raiding. Information of this nature if communicated to the local farmers by the extension services of Wildlife Agency and adopted, would assist in reducing the number of wildlife crop raiding incidences by serving as an early warning mechanism.

Temporal and spatial patterns of wildlife crop raiding

Temporal patterns of wildlife crop raiding had connotation of both seasonality and diurnal perspectives. Much of the damage happened in the transitional period between typically wet and dry seasons across landscapes, when crops mature and natural forage quality in natural environment declined as also observed by Chiyo et al. (2005) and Jackson et al. (2008). However, a number of crops were also damaged at their tender stage of growth by February. Crop damage by wildlife could be attributed to a number of reasons. For instance, Rode et al. (2006) urged that wildlife, particularly African elephants, were attracted by mineral concentrations such as sodium in crops. African elephants were also known to be non-selective to food types (Poole, 1996) and, therefore, consumed a wide variety of crops.

Hippopotami grazed at night along aquatic environments of the Luangwa Valley, requiring large areas of forage often exceeding 5 ha within 2 to 5 km of the watercourses to maintain good body condition (Chansa et al., 2011). Therefore, crop fields situated along grazing belt were vulnerable to Hippopotami invasions. In the dry season, smaller crop fields (≤4,782.00 ± 342.00 m^2) were sufficiently protected by use of wood pole fences compared to the wet season larger crop fields (≥8,614.00 ± 1,184.00 m^2), thereby excluding Hippopotami intrusions. Bushpigs, in addition to being nocturnal herbivores, were also cryptic crop invaders. They also evaded physical barriers such as fences, due to their ability to excavate trenches below the fences. Yellow baboons attacked crop fields in day-time, with their speed, ability to climb, strength and powerful jaws, they were considered aggressive to humans (Sillero-Zubiri and Switzer, 2001), which reduced effectiveness of the traditional deterrence methods. Most other wildlife crop raiders were mainly opportunistic and attacked crop fields mostly during the day. It is for these and other different reasons that we suggested that nature and timing of the attacks of fields by wildlife crop raiders be understood by local farmers and wildlife managers in order for the knowledge to be applied in crop raiding control efforts.

Efficacy of counter-measures in place

Some aspects of problem animal behaviour made it difficult to implement traditional counter-measures, which were a major and prevalent counter-measure in the Luangwa Valley. As a result, traditional counter-measures became increasingly ineffective. However, traditional methods such as guarding and chasing raiding African elephants away could yield effective results, if organized and varied (Osborn, 2002). Clustering of settlements and crop fields by local farmers of Luangwa Valley through collective action was an eminent approach to protect crops against wildlife crop raiding. Enhancement of collective action would be based on the growth of social capital, which needed constant nurturing among local farmers (Nyirenda et al., 2010), whereby transaction costs of implementing mitigation measures by individual farmers would be reduced.

Besides traditional counter-measures, an array of other counter-measures were employed in Luangwa Valley and

Table 2. Crops damage during wet farming season and dry farming season (dry season parameters in parentheses) in the Luangwa Valley, Zambia, 2004 to 2008, presented by Area.

Parameter	Chiefdoms						
	Jumbe	Kakumbi	Malama	Mnkhanya	Msoro	Nsefu	Overall
No. affected crop fields	219(27)	512(46)	39(5)	60(12)	87(13)	208(23)	1125(126)
% Damage by elephants (Mean±Standard error)	21.01±1.51 (32.30±2.74)	19.14±1.12 (29.46±1.54)	22.78±1.35 (16.63±3.13)	18.91±1.66. (19.96±1.67)	27.87±1.26 (33.52±2.36)	20.45±2.06 (34.25±3.86)	22.19±1.12 (31.65±3.02)
% Damage by other animal species than elephants (Mean±Standard error)	12.64±2.23 (77.47±2.58)	15.37±1.09 (67.14±1.00)	11.25±2.48 (41.85±2.46)	8.92±1.11 (-)	16.91±3.62 (83.66±1.53)	14.22±2.68 (64.52±1.84)	12.98±2.13 (75.00±2.50)
% Night invasions	66.89	81.42	49.21	68.94	82.67	79.40	71.42
High Severity incidences	78(7)	55(5)	39(3)	25(4)	191(10)	51(2)	439(31)
Medium Severity incidences	188(23)	96(6)	73(5)	42(2)	361(26)	81(5)	841(67)
Low Severity incidences	30(4)	9(1)	7(1)	14(2)	16(5)	14(2)	90(15)
Maize	185(5)	76(7)	33(2)	64(4)	209(6)	41(10)	608(34)
Cotton	35(2)	30(4)	21(2)	12(2)	64(6)	33(4)	195(20)
Others	53(7)	76(13)	12(4)	34(5)	117(16)	30(27)	322(72)

Table 3. Factors influencing perception by local farmers in the Luangwa Valley, Zambia, 2008.

Factors	Elephant		Bushpig		Baboon	
	n	%	n	%	n	%
Habituation	11	8.94	10	28.57	7	13.21
Human risks	15	12.20	8	22.86	0	0.00
Knowledge and logistics	65	52.85	14	40.00	40	75.47
Non-lethal	31	25.20	2	5.71	5	9.43
Others	1	0.81	1	2.86	1	1.89
Total	123	100	35	100	53	100

included: disturbances (e.g. blasting way problem animals by firing blanks), experimental (e.g. use of chilli bombs and chilli guns), physical barriers (e.g. live fences, solar and chilli fences) and killing of problem animals. Nevertheless, Balakrishnan and Ndhlovu (1992) accentuated that control shooting of problem African elephants had marginal effect in reducing crop damage in the Luangwa Valley. Though not effective, at least in long term, blasting away and killing problem animals were performed mostly for public relations purposes to maintain local community conservation support. However, due to high conservation status of wild animals such as African elephants, greater protection for them than others was required by local

Wildlife Agency and international community. Therefore, non-lethal methods were preferred and promoted in Worldwide Fund for Nature Conservation (WWF) supported heartlands (Muruthi, 2005). Perhaps the greatest challenge faced by a myriad of non-lethal mitigation interventions was that they became ineffective due to habituation by wildlife species across time and space (Osborn and Rasmussen, 1996; O'Connell-Rodwell et al., 2000).

Whereas Nsefu, Jumbe and Mnkhanya chiefdoms increasingly experimented with chilli fencing methods to deter African elephants, Msoro chiefdom applied rudimenttary traditional counter-measures. High proportional crop field damage in Msoro chiefdom was probably due to longer residence of wild animals in unprotected crop fields. Failure to adopt novel mitigation interventions by local farmers in Msoro chiefdom made their crops susceptible to wild animals, particularly the African elephants. In Malama chiefdom, bordering South Luangwa National Park, where solar powered electric fences and chilli fencing were utilized, wildlife crop damage invasions minimized despite high concentrations of wildlife. Dalal-Crayton and Child (2003) supported this phenomenon and stated that solar powered electric fences were the most effective methods for crop raiding control in Malama chiefdom. Nonetheless, due to expenses involved in establishing and maintaining solar electric fences as also described by De Boer and Ntumi (2001) in Mozambique, alternative counter-measures using 'chilli guns' to repel marauding African elephants were exploited in the Luangwa Valley. Use of chilli guns was an improved hybrid disturbance counter-measure aimed at scaring away raiding African elephants and involved use of dried powdered chilli seeds, mixed with dry gun powder, fired in wind direction against marauding African elephants. It was assumed that the pungent smells from *Capsicum* substances would repel African elephants.

Simultaneous use of several counter-measures was recommended for mitigating wildlife crop raiding (Balfour et al., 2007; Lamarque et al., 2009; Sitati and Walpole, 2006). Though combined methods of deterrence were likely to be more effective than single methods (Jackson et al., 2008), innovative and effective single counter-measures that could be used in combination with others required developing against African elephant and other key problem animals such as Hippopotami, Bushpigs and Yellow baboons. Future attempts on the mitigations could focus on enhancing traditional methods by exploring indigenous knowledge systems and their evolution in addressing crop raiding. Therefore, it was recommended that non-traditional counter-measures serve as complimentary methods to traditional counter-measures.

The need to manage wildlife crop raiding

Given that only few wildlife crop raiding incidences resulted in low severity, the impact of wildlife crop raids on the affected impoverished community was great. As human population and agricultural activities increased in areas surrounding protected areas (Wittemyer et al., 2008), so would extent and intensity of crop raiding in Luangwa Valley. Considering that costs outweigh the benefits associated with living with wildlife, local communities' livelihoods needed sustaining to encourage participation by local communities in natural resource conservation (Jones and Murphree, 2004). We assumed that impacts of crop raiding would likely influence local farmers' response to wildlife conservation. Through ensuing perception, tolerance levels for wildlife by rural communities could reduce due to depressing experiences with wildlife (Lamarque et al., 2009; Naughton-Treves et al., 2004). Therefore, local farmers' capability to deal with crop raids would require enhancing. Performance payment that award rural communities, particularly local farmers who individually suffer crop damage, for living with wildlife (Nyhus et al., 2005) could be developed in line with benefit sharing.

Conclusion

Wildlife crop depredation was a serious challenge to both local farmers and wildlife managers. African elephants, Hippopotami, Bushpigs and Yellow baboons caused much of the crop damage, affecting a variety of crops in Luangwa Valley. Crop losses by wild animals occurred in both wet and dry farming seasons, with peaks in February and April. High intensity and great extent of damage risked reducing support for conservation among affected local farmers.

In the six chiefdoms of Luangwa Valley, areas with relatively more effective counter-measures such as solar powered electric fences and chilli fences than other methods were spared from crop raiding. Knowledge of a particular counter-measure, access and availability of materials for implementation of mitigation measures motivated local farmers and determined what type of counter-measures were implemented in Luangwa Valley. Habituation by wildlife to various counter-measures also posed difficulties in development and implementation of counter-measures.

However, specific knowledge of temporal and spatial elements particularly for planning purposes coupled with implementation of enhanced new counter-measures, could prevent much of wildlife crop depredation. Since African elephants are responsible for majority of wildlife crop damage, focusing mitigation measures on them would be critical, thereby also protecting African elephants from retribution killing.

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