



APPENDIX 1:
Elephants - a special case



Elephants crossing fence, Zimbabwe. F. Osborn, WCS

Introduction

The papers in this section are case studies of crop loss to elephants and other species. They highlight the usefulness of intensive research into crop loss from the perspective of the pest species. These studies also highlight the need for comparable data collection protocols. Once the conflict situation has been identified and quantified, interventions aimed at reducing the conflict can be implemented.

In the first paper, Hoare presents the IUCN taskforce paper on human/elephant conflict and their efforts to standardise data collection protocol. This system will aid efforts to compare data by collecting various indices that can be compared between different bio-geographical regions. The methods have been adopted by a number of researchers across Africa and the data are being mapped with an eye toward developing predictive models of conflict sites.

The study by Ilukol examines the ecology and spatial raiding patterns of elephants around Kibale Nation Park in Uganda. Crop preferences are also examined. This detailed study of seasonal movement patterns shows why understanding the basic ecology of the species that raid crops is important for developing interventions.

Experiments with methods to reduce crop loss to elephants were examined in the paper on problem animal control (Osborn & Parker). This overview shows that loss to elephants can be reduced using community-based methods of problem animal control. Various traditional

and experimental methods were tested and results from observation and farmers' perceptions were combined to develop this system to reduce crop loss to wildlife.

The paper by Kamisse & Turkalo gives an example of the problems of crop raiding by elephants and other animals in the rain forest of CAR. This study shows that loss to wildlife has a serious impact on the livelihoods and perceptions of the locals toward the reserve. This theme is also found in Sam *et al* in their study of crop damage by elephants in Ghana. Sam *et al* stresses the pressing need for farmers to address this problem and develop their own tactics to repel elephants.

Towards a Standardized Data Collection Protocol for Human-Elephant Conflict Situations in Africa

Richard Hoare,
Chairman, Human-Elephant Conflict Taskforce,
IUCN African Elephant Specialist Group

Assessing losses due to elephants in general terms

In general terms, known characteristics of elephant damage resulting from a number of well-conducted studies of elephant problems in Africa are:

- Elephants are never the most frequent crop raiding species. Elephant damage is more localized but more severe per raid than that of smaller pest species. Typically a few farms are seriously affected by elephants while many others are often only lightly affected.
- Elephants are only one of a spectrum of agricultural pests that afflict African farmers. Primates, suids, rodents, birds or insects are often the more important taxa of agricultural pests. It is suspected that the level of complaint about elephant damage is often in disproportion (i.e. far greater) to its relative contribution to farming problems.
- Subsistence agriculture is the sector most prone to conflict with elephants. Many agricultural zones where farmers suffer damage by elephants, especially those in semi-arid and arid savanna areas and parts of the rain forest region, are climatically and edaphically unsuitable for subsistence agriculture, even in the absence of pests.
- Socio-economic 'opportunity costs' are borne by rural people living in proximity to elephants. These are important but are difficult to quantify and exist as a result of

‘problem elephants’ being potentially dangerous and difficult to deter. Opportunity costs may outweigh the direct costs of agricultural damage and be a major component of the perceived conflict. Examples of such costs are restriction on people’s movement (especially at night), competition for water sources, loss of sleep or reduced school attendance while guarding crops or property, and employment opportunities being prejudiced. These factors definitely contribute towards peoples’ negative attitude to elephants.

Assessing losses due to elephants in quantitative terms

Elephant problems in any area are thought of as the net result of a number of individual damage incidents occurring over a given period of time (e.g. a season, a year, a period of years). Comparing elephant damage between well-conducted studies is made difficult by the use of different sampling strategies. Three types of sampling approaches have emerged where damage incidents have been quantified on the basis of:

- Method 1: number of “damage events” or elephant incidents reported to an authority.
- Method 2: actual losses to crops due to elephants (measured and quantified by an enumerator or researcher).
- Method 3: perceived losses due to elephants (derived from interviews with farmers).

Method 1

This gives a good general idea of problem elephant activity and thus allows comparisons to be made about the intensity of such activity between areas. There is, however, little distinction between ‘visits’ and ‘raids’ by problem elephants, so there may be an inherent bias. Visits are cases where elephants traverse the field and do little damage; what damage there is may be from trampling only, whereas raids are cases where crops are fed on. Where Method 1 has been actively carried out by a researcher, this logically leads to the descriptive summary sometimes called a “raid frequency index”. Raid frequency indices (RFI) incorporate spatial and temporal dimensions e.g.:

- elephant raids per village per month
- elephant raids per growing season
- elephant raids per household per month
- elephant raids per km² of human settlement per year

Use of a simple RFI avoids the pitfalls of assessing economic damage (e.g. varying crop quality; different assessors) and the statistical problems of comparing different farms (e.g. different acreages; different crop combinations).

Method 2

It is desirable, if possible, not just to record an elephant damage incident but to quantify what was damaged. Method 2 is ideal for assessing the real impact of elephants. Unfortunately it is logistically difficult over the large areas affected by elephants. It has tended to be applied by researchers working in small areas of relatively high elephant challenge.

Very few studies record what proportion of farms or fields in a given area are affected by elephant damage. For a rigorous analysis this information is needed since presenting an overall level of elephant damage which is applicable only to the affected farms is somewhat misleading. The overall level of damage in the whole farming area is what really needs to be quantified. This relies on what can be termed “the proportional availability of different crops”. Proportional availability needs to be assessed so that (i) the total amount of damage in the area can be objectively quantified and an economic loss estimate worked out and (ii) elephant preferences for different crops can be critically evaluated. The compiling of data on proportional availability is a demanding and very time-consuming job, which can only be done by a full-time researcher in a relatively small site. A number of well quantified (“actual loss”) studies assessing damage to farms in relatively small study areas across Africa have revealed a range of levels of crop damage generally between limits of 5% and 10%.

Method 3

Perceived losses are those obtained from interviews with farmers who supply details of damage events and estimate their own losses. This method is good for investigations where it is particularly important to assess either (1) the species mix of animal pests affecting farms and the distribution of damage or (2) attitudes of affected people (i.e. the method of choice if the research is orientated towards a ‘sociological’ approach). With this method, the frequency and severity of damage is less accurately evaluated because of the loss of detail in peoples’ memory over time and the tendency to exaggerate losses from damage incidents to any outside interviewer. Examples of the Method 3 type of study are:

- Interviews in 218 villages across seven provinces of Gabon
- Interviews in five villages around Shimba Hills National Reserve, Kenya
- Interviews with 1396 people living adjacent to seven protected areas in Tanzania.

Standardised data protocol for human-elephant conflict sites

Valid comparisons about levels of human-elephant conflict both within and across different bio-geographical regions of Africa can only be made if a standardized system is employed that guarantees the consistency and quality of data.

Primary data

The present study proposes using a combination of the three sampling methods above to obtain the primary data from fairly large areas of conflict. This involves reporting of the incident to a trained and paid enumerator who then visits the site of the incident and interviews the affected person as soon as possible after the occurrence of the problem. The enumerator makes his own assessment of the incident but asks the affected person (complainant) to provide him with retrospective extra details about the incident.

This approach yields good distribution and frequency information, allows adequate severity assessment and also provides for some of the ‘social dimension’ of elephant problems to be included. The practical advantages of this approach are that it involves local people, provides employment and does not rely only on the complainant. It has the disadvantage that enumerators have to be trained and engaged in paid employment, which requires some administration of finance and personnel. For the returns, however, it is a relatively inexpensive and simple scheme to set up and run.

Secondary data and analysis

A hierarchy of data collection and analysis is involved in this protocol. The second level involves a researcher who trains enumerators according to a recommended format or ‘training package’ and condenses data from their reports into an annual summary for the conflict zone in which they were deployed. Annual reports are designed to show the distribution, frequency and severity of elephant damage and consist of:

- (i) spreadsheet summaries of incidents (to act as a permanent record)
- (ii) graphical illustrations of these spreadsheet summaries (to make large amounts of numerical data in spreadsheets easy to understand)
- (iii) scoring of damage incidents and ranking of problems according to area (to assist in making management decisions on elephants).

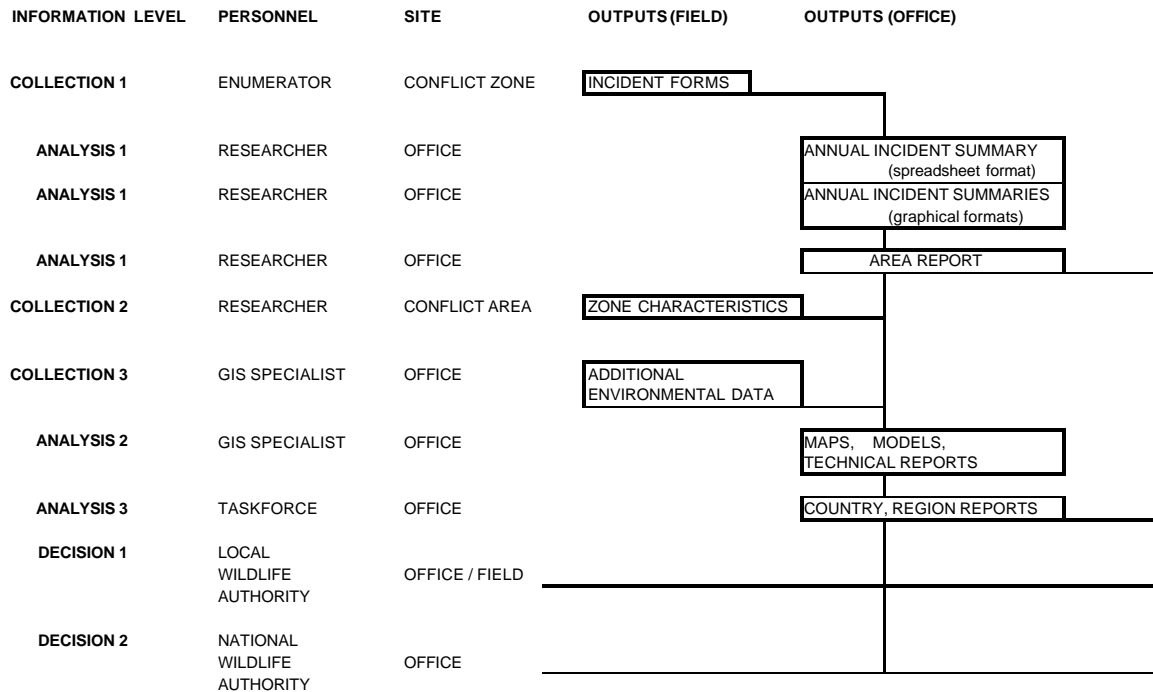
Annual reports are sufficient for local level management decisions (e.g. where to deploy scouts to scare elephants, how to distribute revenue on the basis of the level of problems, where to plan fencing projects).

Tertiary data and analysis

This level involves the input of additional “site characteristics” data by the researcher. Some of these are drawn from a wider area around the conflict zone referred to as the “conflict area”. The reason for this is so that incident data can be linked to environmental variables in the conflict area and used in research-orientated analyses at a third level, the Geographic Information System (GIS) level. A specialized level of spatial analyses in a larger sample of compared sites should be able to synthesize the findings into more meaningful management recommendations at a national level.

The data protocol is illustrated below in diagrams and tables:

FIGURE SCHEMATIC OF PROPOSED HUMAN ELEPHANT CONFLICT DATA COLLECTION AND ANALYSIS PROTOCOL



A flow chart depicts the hierarchy and linkages in the data collection and analysis protocol (Fig. 1). An elephant damage report form is shown (Form 1). Forms, containing the primary data, are filled in by enumerators after visiting incidents of elephant damage. Each incident is a data record and data records for an area can be summarized in columns and rows of a computer spreadsheet. In the example (Table 1) an annual summary is shown for a 'ward' which is the administrative subdivision of a district in Zimbabwe within which one enumerator is employed. The ward summary incorporates a very simple damage scoring system to quantify the seriousness of incidents (based on adding crop age and quality to damage level). Scores of individual incidents can be summed in the ward to give a damage score for the ward. Finally, wards situated in one district are ranked against each other (Table 2) using different criteria. Management decisions can be prioritized according to the desired rank.

FORM 1. ELEPHANT DAMAGE REPORT FORM

REGION **FORM No.**

DISTRICT

SUBDIVISION

VILLAGE **MAP GRID REFERENCE**.....

ENUMERATOR NAME **DATE OF INCIDENT**

COMPLAINANT(S) NAME(S)

DATE OF COMPLAINT

CROP	DAMAGE TYPE	QUALITY	BEFORE	DAMAGE	AGE	OF	CROP
		(Tick one category)	GOOD	MEDIUM	POOR	(Tick one category)	SEEDLING
CROP 1
CROP 2
CROP 3
CROP 4
CROP 5

DIMENSIONS (Paces) OF TOTAL FIELD WHERE DAMAGE OCCURRED

LENGTH PACES

WIDTH PACES

DIMENSIONS (Paces) OF ACTUAL DAMAGED PORTION OF FIELD

LENGTH PACES

WIDTH PACES

OTHER DAMAGE TICK AND SPECIFY DETAIL

FOOD STORE

WATER SUPPLY

THREAT TO LIFE

HUMAN INJURY

HUMAN DEATH

OTHER SPECIFY

ELEPHANTS INVOLVED	NUMBER	VISUAL ID (Tick)	TRACK ID
GROUP SIZE (TOTAL)
Adult Male
Adult Female
Subadult / Calf

YOUR COMMENTS:

.....

.....

Was This Report Forwarded?

To Whom? Where?

When? How?

Table 1 EXAMPLE OF ANNUAL SUMMARY OF PROBLEM ELEPHANT INCIDENTS IN SPREADSHEET FORMAT WITH DAMAGE SCORES CALCULATED FOR EACH INCIDENT AND SUMMED FOR THE AREA

KEYS

CROP TYPE	CROP AGE	CROP QUALITY	DAMAGE CATEGORY	DAMAGE SCORE	ELEPHANTS INVOLVED	GROUP TYPE
1=MAIZE						
2=COTT			1=<5%			
3=GNUTS			2=6-10%			
4=MILLET			3=11-20%			M=BULL
5=VEG	1=SEEDL	1=POOR	4=21-50%	<5 = LOW		MM=BULLS
6=MASAU	2=INTER	2=MED	5=51-80%	6 - 8 = MED		CC=COWS
7=OTHER	3=MATURE	3=GOOD	6=>80%	>9 = HIGH		MH=MIXED

AGE + QUALITY + DAMAGE = SCORE

DATA EXAMPLE

DATE OF INCIDENT	VILLAGE NAME	MAP REFERENCE	CROP TYPE	CROP AGE	CROP QUALITY	DAMAGE CATEGORY	DAMAGE SCORE	NUMBER ELEPHANT	GROUP TYPE
31-Jan-98	Mufudzi	878064	2	2	2	1	5/L	2	MM
31-Jan-98	Mufudzi	878064	1	2	2	1	5/L	2	MM
31-Jan-98	Mufudzi	878064	1	3	1	1	5/L	3	MM
06-Feb-98	Budzinike	872048	7	3	2	1	6/M	2	MM
06-Feb-98	Budzinike	872048	1	2	3	1	6/M	2	MM
06-Feb-98	Budzinike	872048	1	2	1	1	4/L	2	MM
06-Feb-98	Budzinike	872048	1	3	1	1	5/L	2	MM
06-Feb-98	Budzinike	872048	3	2	2	1	5/L	2	MM
07-Feb-98	Budzinike	875045	2	2	3	1	6/M	2	MM
04-Mar-98	Budzinike	875045	1	3	1	1	5/L	1	M
04-Mar-98	Budzinike	879049	1	3	1	1	5/L	1	M
04-Mar-98	Budzinike	875045	2	3	2	1	6/M	1	M
31-Mar-98	Kayongo	844016	2	3	1	1	5/L	1	M
31-Mar-98	Kayongo	844016	1	3	1	1	5/L	1	M
18-Jun-98	Gamanya		1	2	1	3	6/M	2	MM
18-Jun-98	Gamanya		1	2	1	3	6/M	11	MH
23-Jun-98	Gamanya		1	3	1	4	8/M	6	MH
23-Jun-98	Gamanya		1	3	1	4	8/M	6	MH
23-Aug-98	Kayongo	836012	5	3	1	1	5/L	4	MM
24-Aug-98	Budzinike	883039	5	3	1	1	5/L	6	MM
26-Aug-98	Kayongo	834012	5	3	2	3	8/M	3	MM
26-Aug-98	Kapenyongc	833012	5	3	2	3	8/M	4	MM
26-Aug-98	Kayongo	834012	5	3	2	5	10/H	3	MH
26-Aug-98	Kayongo	833012	5	3	1	3	7/M	2	MM

SCORES

SCORE TOTALS FOR WARD

LOW = 14
 MED = 9
 HIGH = 1

DAMAGE POINTS FOR 1998 IN THIS WARD

144

Table 2: An example of problem elephant activity summarized for one district (Muzarabani District, Zimbabwe in 1998).

WARD	Total Incidents (No.)	Serious Incidents (No.)	Damage Score POINTS	Total Incident RANK	Serious Incident RANK	Damage Score RANK	MEAN RANK
Kapembere*	24	3	144	1	3	1	1
Muringazowa	23	1	103	2	4	2	2
Gutsa	18	4	78	3	2	6	4
Dambakurima	17	1	88	4	4	5	5
Chadereka	15	5	90	5	1	4	3
Chiweshe	14	0	95	6	5	3	6
Hoya	12	0	51	7	5	8	8
Chawarura	12	1	63	7	4	7	7
Hwata	9	1	48	8	4	9	9
Machaya	1	0	5	9	5	10	10
TOTALS	145	16	765				

- for a breakdown of incidents in this ward, see Table 1
- Wards are ranked according to various criteria of problem elephant activity: (i) total number of incidents (ii) number of serious incidents (iii) overall damage score of incidents (see Table 2). A mean of the three ranks is given. Management decisions can be prioritized according to the desired rank

Graphical summaries, which are far more ‘user friendly’ than the above tables and diagrams can be produced from any of the above data. If data is stored in electronic format this is a rapid, simple process. In area reports, common graphical summaries produced are:

- Monthly distribution of problem elephant incidents
- Selection of crops by problem elephants
- Group sizes of problem elephants
- High, moderate and low levels of damage incidents.

If the same geo-referenced incident data are then transferred onto a GIS, detailed distribution maps can be produced. If these data are cross-referenced to a number of attributes, the possibility for numerical and spatial analyses increases considerably.

Acknowledgement

I am indebted to researchers of the Mid-Zambezi Elephant Project in Zimbabwe (Loki Osborn, Guy Parker, Kinso Mariba and Ignatius Masarirevhu) for the raw data on crop damage in Muzarabani district.

Elephant Crop Raiding Patterns in Areas around Kibale National Park (KNP), Uganda

Patrick Ilukol,
IUCN Fort Portal, Uganda

Introduction

Reduction in elephant habitat, and consequent isolation of protected areas maintaining elephants by landscapes dominated with agriculture, are often cited as the ultimate cause of increase in elephant-human conflict (Bell, 1980; Barnes, 1996; Seidensticker, 1984; Sukumar, 1990), yet not much is known about the proximate causes or factors that influence the patterns of elephant crop depredation. Any attempt to manage or control crop damage by elephants should be based on the knowledge of causes or factors that influence crop depredation by elephants (Naughton-Treves, 1998; Santiapillai, 1993). This creates an urgent need to examine the patterns of elephant crop depredation and how these relate to elephant ecology and land-use patterns.

Elephants have been observed to display preference for certain crops (Bell, 1984; Naughton-Treves, 1996; Smith *et al.*, 1995). It was observed that banana, and sweet potatoes were the most preferred crop species by elephants in areas around KNP (Naughton-Treves, 1996). However there is lack of information on whether the abundance and distribution of preferred crop species determine the intensity and patterns of crop depredation. This will be important in predicting spatial patterns and intensity of crop damage, especially in the culturally and ecologically heterogeneous environment surrounding KNP (Naughton-Treves, 1996).

Methods and analyses

Crop depredation was monitored in four administrative areas (Parishes) abutting the park boundary. These locations were chosen on the basis of previous records of elephant crop damage and were then spatially stratified in to North, East, South and West, to examine spatial patterns in crop depredation. Two methods were employed for monitoring crop raiding patterns. The first involved establishing an information system within the administrative areas using the Park Management and Advisory Committees' (PMAC) representatives to collect basic information on the frequency and timing of the raids, the crops damaged, and elephant group size (whenever possible). The second method involved systematic monitoring of the perimeter of the Park boundary in each of these administrative

areas. Monitoring was done once every two weeks, or more frequently when the raids began, in order to confirm elephant incursions into cultivated land.

When incursions were confirmed, the path of the group was traced into cultivated land and all the affected fields counted. The date of the raiding event, name of the village, number of fields raided, distance of each field from the Park boundary, field size, proportion of field with damage, crops damaged and a visual estimate of elephant group size from paths in and out of the fields was recorded. In addition, information about elephant group size for every raiding incident was obtained by interviewing the farmers. Some of fields were then randomly selected for damage assessment. For the selected gardens, field size and the area of seriously damaged portions was estimated using the method of polygons (Casely, 1988).

Elephant path follows were undertaken for some crop raiding groups during studies of forage selection. Diameters of a maximum of two intact boli per elephant dropping were measured to the nearest millimeter to obtain age estimates of the raiders. The composition and presence of crop remnants in elephant dung were recorded for each dung pile encountered to establish the presence of habitual crop raiders.

Land-use was assessed in a 2 by 0.5 kilometer area from the Park boundary into cultivated land using a grid sampling technique. One hundred meter grid squares were superimposed on this area. Twenty percent of the plots were randomly selected for land use assessment. The following land use categories were identified and measured; cultivated land (crop specified), pasture land/grazing land, forest patch, swamp and settlement.

Rainfall records were maintained daily at Kanyanchu and Kanyawara by KNP and Makerere University Biological Field Station (MUBFS) staff respectively during the study period. The monthly rainfall totals given are an average total from these two sites.

A rough index of assessing elephant food quality using the frequency of plant parts eaten was employed during this study. The proportions (from frequency records of feeding) of foliage, stemmy or woody material, and fruits in the diet were estimated. Supporting tissues such as stems, twigs, wood, roots and bark are high in indigestible fiber, while fruits contain stores of soluble carbohydrates, and leaves contain photosynthetic enzymes and are highest in protein and minerals (Bell, 1980; Owen-Smith, 1988). The monthly percentage frequency of foliage and fruits was taken as a food quality index (FQI).

Results

Frequency and quantities of damage to crops

In a period of 13 months, raiding incidences for all study sites pooled occurred during 87 nights. Mean number of fields damaged per raid in a night was about 3.28 ± 0.64 . Mean area of damage per field per raid for the five most commonly damaged crops is given in Table 1. Elephants damaged most of the crops cultivated except tea and coffee. Other crops like groundnuts, Irish potatoes and soybeans were mainly trampled upon as elephants were foraging on other crops. No evidence of direct consumption of any part of these plants was observed during the course of this study.

Table 1: Mean field size and damage for five common crops per raid per night (with 95% Confidence intervals).

Crop	Mean field size in m ²	Mean area of damage in m ²	Mean % of field damaged
Bananas	5,190.81 \pm 2,170.55	1,483.73 \pm 514.29	28.6
Maize	1,463.70 \pm 425.48	561.50 \pm 315.86	38.4
Sweet Potatoes	711.50 \pm 429.58	197.43 \pm 141.44	27.7
Sorghum	935.00 \pm 489.43	199.86 \pm 147.50	21.4
Beans	2,971.55 \pm 1,429	581.00 \pm 388.06	19.6

Group size and behavior of crop raiders

Mean group size of crop raiding elephants was 4.22 ± 0.53 (n = 67 groups). The number of elephants raiding on any one night in KNP varied from 1 to 15 individuals. A group size of 3 elephants was the most commonly observed pattern.

For the eight crop raiding groups that were followed the spoor of infants and juveniles below five years of age was not encountered. This implies that family groups rarely raid crops in Kibale. Evidence of habitual raiding was observed from follows of crop raiding groups. All the groups followed from the fields had crops in their dung, an indication that they were previously involved in raiding. Four of the elephant groups were followed from crop field to the forest and back into crop fields, travelling a distance of 1.6 - 3.0 kilometers in a day and concentrating their foraging activity within two kilometers of the Park boundary. Of the four groups that were followed back into the fields, one group (consisting of a sub-adult of 13 years and an adult of 22 years) visited crop fields for more than three nights in a row.

Of the eight groups followed all, except two, included at least one adult above 20 years of age. The latter groups consisted of sub adults with ages ranging from >5 - 12 years old. One group of sub adults was observed to raid for more than two nights in a row.

Temporal patterns in crop damage and forage quality

Monthly raiding frequency pooled for all the study sites was negatively correlated with rainfall of the first preceding month ($r = -0.56$, $p < 0.05$, $d.f. = 11$). However there was no significant difference between mean raiding frequency for dry months (mean = 7.5) and rainy months (mean = 6) ($t = 0.548$, $d.f. = 10$, $p = 0.298$). There was no significant correlation between the intensity of raiding on the banana crop with rainfall in either the current month or the first and second preceding months ($r_s = -0.175, -0.372, -0.49$; $d.f. = 9$; $P < 0.1$ respectively). For the maize crop, which is seasonally available, there was a significant negative correlation with rainfall of the current month ($r_s = -0.61$, $d.f. = 9$, $p < 0.05$). The mean FQI recorded during the study period was 62%. There was no significant difference between the FQI for wet and dry months ($T = 2.1$, $d.f. = 11$, $P = 0.06$), with the mean being 65.7% and 58.6% for dry and wet months respectively. There was no significant correlation between the frequency of raids and FQI for the current months ($r_s = 0.036$, $df = 13$, $p > 0.05$).

Spatial patterns in crop damage and land-use

Crop depredation took place in all study sites during the period of study. The northern and western areas were raided during the period from January to May, whereas the eastern and southern parishes experienced raiding during June to November. The occurrence of elephant raids in the four study sites falls within the general observation of park-wide timing of elephant raids.

The average number of nights in which raids occurred in each of the study sites was significantly different ($X^2 = 17.83$, $d.f. = 3$, $p < 0.01$). However when the average number of nights in which raiding occurred in each study site is corrected for Park boundary perimeter, the difference is non significant ($X^2 = 6.13$, $d.f. = 3$, $p > 0.05$). Within each study site elephant crop raiding patterns were spatially localized to certain spots (villages); sometimes there was foraging concentrated on specific farms, before animals shifted to other fields. Most incidences of raiding took place within 0.5 km (90%) from the Park boundary for data pooled from all study sites.

Land use studies within 500 meters from the boundary reveal that a diversity of crops are grown around KNP. The principal crops grown include bananas, maize, Irish and sweet potatoes, sorghum, beans and groundnuts. Coffee and tea are grown to a limited extent. The proportions of crops grown at different sites in a 0.5 kilometer perimeter around the study sites did not influence crop raiding patterns. There was no significant correlation between proportion of land under each land-use category (cultivation, forest, swamp and pastureland) in the three study sites ($w = 0.063$ $p > 0.05$, Kendall's coefficient of concordance). Proportions of various crops cultivated in a single season differed significantly for the three study sites ($X^2 = 1.554$, $d.f. = 7$, $p > 0.05$, Kendall's coefficient of concordance). Similarly, the proportion of various crops raided in the four sites were not significantly correlated ($X^2 = 4.844$, $d.f. = 7$, $p < 0.05$, Kendall's coefficient of concordance). However, there was a significant positive correlation between proportion of each crop raided and proportion of land under the respective crop (Table 2), implying that elephants had no preferences for particular crops but raided according to crop availability.

Table 2: Correlation between relative percent of land cultivated with maize, bananas, legumes, cassava, sorghum, sweet potatoes, Irish potatoes, and other crops, and the relative percent of these specific crops raided.

Study site	τ (Kendall's Tau)	N	Probability
Busiriba	0.794	8	< 0.05
Kahangi	0.722	8	< 0.05
Kiko	0.036	8	> 0.05

Discussion

The level of elephant-human conflict in Kibale is moderate compared to that observed in most parts of Africa and Asia (Bhima, 1998; Ngunjiri, 1995). The mean percentage damage per raid per field ranged from 19.6%, to 38.4% for bean and maize fields respectively. This is relatively moderate when compared with mean percent field damage reported in southern Ghana and around the Liwonde National Park in Malawi. Mean percent damage per field of crop incurred in southern Ghana ranged from 43%, 68% and 76% for bananas, maize and yam respectively (Barnes, 1995). In the Liwonde National Park, Malawi, the mean percent area damaged per field varied from 2.3% to 22.3% (Bhima, 1998). There were no human deaths or human injury reported as caused by elephants over the entire Park during the study period, as reported in other elephant-human conflict sites in Africa (Ngunjiri, 1995; Tschamber, 1995). The relatively moderate level of elephant conflict is due to the medium elephant density and the low numbers of males. There is also an abundance of forage within the Park which reduces pressure to forage in fields.

Findings from this study accord with observations elsewhere (Sukumar, 1988; Sukumar, 1990; Hoare, 1995; Bhima, 1998), where male elephants, either singly, or in groups, are primarily responsible for most damage to crops. Single adult bulls (>25 years old) were a frequently observed group size in Southern India and Gabon (Sukumar, 1989; Lahm, 1996), yet this was rarely the case in this study, or the observations in areas adjacent to the Liwonde National Park, Malawi (Bhima, 1998), where males between the 12-25 years of age were commonly noted to raid. The high frequency of young bulls recorded raiding is related to the lack of adult bulls above the age of 25.

The group size observed in KNP is similar to that observed in Malawi (Bhima, 1998). Mean group size of raiding elephant in Liwonde, Malawi was 7.64 ± 4.02 . The most frequent group size of elephants raiding in Liwonde was 3 individuals. These observations however contrast with the findings from India, where the number of elephants raiding each night varied between 1 to 25, whilst single elephants were more frequently observed to raid. There are two possible explanations for the former grouping pattern (Sukumar, 1989):

1. Adult bulls >25 years of age are lacking in both KNP and Liwonde (Bhima, 1998), and young inexperienced bulls, invariably need the company of one or more younger bulls to raid successfully. Sukumar (1989) in India has made a similar observation. He noticed that young elephants between 15-20 years always came in groups of 4 when entering fields to crop raid whereas solitarily raiding bulls were usually >25 years old.
2. Secondly, crops are abundantly available in fields abutting the boundaries of KNP and cooperation rather than competition is a pre-requisite for obtaining crop forage (Sukumar, 1988).

Documented observations on the temporal patterns of elephant crop depredation indicate that most crop damage occurs during the rainy season with a peak towards the end of the rains (Bell, 1984; Sukumar, 1986; Barnes, 1995; Hoare, 1995; Smith *et al.*, 1995; Lahm, 1996). Elephant crop raiding peaks often co-occur with peaks in the flowering or ripening of crops. These often coincide with the decline in quality or nutritive value of natural forage (Sukumar, 1990). Accordingly, crop damage has been regarded as an optimal foraging strategy geared towards maximizing nutrient intake in a period of scarcity (Bell, 1984; Sukumar, 1989). In KNP elephant crop damage was sporadic. If food quality and nutritional stress were triggers for crop raiding in KNP, an inverse correlation would be expected between FQI and the frequency of raids. This was however not the case, an indication that nutritional stress does

not trigger elephant crop raiding in KNP. However its occurrence at low to moderate levels throughout the year maintains a sporadic pattern of crop damage.

The lack of a clear-cut seasonality in raiding could be related to the presence of perennial crops, low to moderate FQI, or to the limited scale in spatial sampling. Crop depreddations by elephants in Kibale tend to occur throughout the year with raids spatially distributed in the northern half of the Park. The sampling scale used in this study is likely to have been insufficient to capture seasonal patterns.

Wildlife species have preferences for certain cultivated crops (Bell, 1984; Naughton-Treves, 1996), and areas with a concentration of such highly preferred crops often experience intense depredation (Bell, 1984). In areas surrounding KNP, the percentage contribution of the various crops to cultivated land varied spatially. At each site, crop category damaged was in proportion to availability. This observation is supported by the observation made by Parker and Graham (1989). They stated that elephants have catholic diets and that there is no human food plant that African elephants do not eat. It is apparent from this study that the relative ratios of food crops grown do not influence spatial variation in raiding intensity.

Although crop raiding incidences were recorded in all the parishes during the study period, there was an apparent localization of raiding incidents at village level as observed by Naughton-Treves (1996). This pattern has been observed elsewhere in Africa (Bell, 1984; Smith *et al.*, 1995; Lahm, 1996). Three scenarios explain such localized crop raiding patterns. These include the location of certain sites along bull ranges, elephant migration routes and historic foraging areas (Bell, 1984; Sukumar, 1989; Sukumar, 1990; Santiapillai, 1993; Hoare, 1995).

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Elephant Crop Raiding in the Dzanga-Sangha Reserve

Amis Kamisse⁶ and Andrea K Turkalo⁷
WCS, Central African Republic

Introduction

Situated in south western Central African Republic (CAR), the area of the Dzanga-Ndoki National Park and Special Forest Reserve has long been known as a region abundant in forest wildlife. Forest elephant (*Loxodonta africana cyclotis*) and other mammal species such as bongo (*Tragelaphus euryceros*), sitatunga (*Tragelaphus spekei*), giant forest hog (*Hylochoerus meinertzhageni*), red river hog (*Potamochoerus porcus*), forest buffalo (*Syncerus caffer nanus*), western lowland gorilla (*Gorilla gorilla gorilla*), as well as monkey and duiker species, occur in high densities. In 1981 the Central African government recognised this faunal and floral diversity by creating a forest elephant and bongo sanctuary, and formally ending hunting in the area.

In 1988 further protection was afforded when the government designated two areas of the sanctuary as national parks: the Dzanga Ndoki National Park, consisting of the Dzanga sector in the north (495 km²) and the Ndoki sector in the south (725 km²). Serving as a buffer zone to these two national park sectors, the Dzanga-Sangha Special Dense Forest Reserve comprises 3359 km². The national park and reserve are administered collaboratively by the Central African Ministry of Environment, Water, Forests, Hunting and Fishing and the World Wildlife Fund. This collaborative project includes conservation, and rural development, as well as ecotourism and environmental education sectors.

⁶ Sociologist GTZ B.P. 1053 Bangui, Central African Republic

⁷ Associate Conservation Scientist, Wildlife Conservation Society, c/o B.P. 1053 Bangui, Central African Republic

This area of the extreme south western CAR was originally inhabited by three ethnic groups: the Aka Pygmies, whose survival depended on hunting and gathering, and the Ngoundi and Sangha-Sangha, both Bantu groups, whose livelihood focused upon fishing. Before the 1970s these three ethnic groups dominated this sparsely populated area, with access being limited by navigation of the Sangha River. Beginning in the early 1970s this situation changed dramatically with the establishment of large scale logging in the area by the company Slovenia Bois. The logging opened up the region by establishing road access to the area to the north, and served as an economic magnet attracting a mixture of ethnic groups from other parts of the country. This resulted not only in a population increase but now enabled easy access to a previously isolated area, drastically changing the lifestyles of its original inhabitants. People were drawn to the area not only by the economic possibilities offered by employment at the sawmill but other activities such as diamond mining, agriculture and hunting.

Forest elephant densities have always been high in this area of the CAR and are estimated to be amongst the highest in the Central Africa region: $>1/\text{km}^2$ (Carroll 1989, Blom et al. Pers. com.). The Dzanga Bai, located in the heart of the Dzanga sector of the Dzanga-Ndoki National Park, has been continually monitored for the last ten years. Estimates of 3000+ elephants frequent the clearing, with an additional 1000+ present in the area which is contiguous with the Republic of the Congo to the south and the Republic of Cameroon to the west (Turkalo 1995, 1996).

At present the human population of the DSSFR is estimated to be about 4500 or 2.5 inhabitants/ km^2 . The biggest village in the area is Bayanga with an estimated population of 3000, and the smaller villages are Lindjombo, Babongo, Moussapoula, Kunda Papaye, and Yobe. Given the high elephant densities and low human population density crop raiding had never been a major problem in the area. When people and elephants did come into conflict hunting was usually the solution, discouraging continued crop predation by large mammals.

With the establishment of the Dzanga-Sangha Project in 1989, the fauna, particularly the elephant population, was afforded protection in the hope of developing an ecotourism industry, thus enhancing the economic situation of the local people. With this increased protection elephants, which had previously been hunted, began to feel no fear of human populated areas, particularly in the area of Bayanga where the conservation project was based.

Within the last ten years, with a human population increase leading to increased agriculture, elephants are slowly becoming a liability in the minds of the local inhabitants.

Since the inception of a conservation project in the area the situation of human-elephant conflict has never formally been addressed, although the local inhabitants have complained about elephant damage in the hope of receiving compensation. In the past the project addressed the problem by trying to discourage elephants from the fields by firing blanks, but this action has a limited and temporary effect. In 1992 an administrative order was issued for the culling of two elephants which failed when the assigned hunter tried killing an elephant near the village of Moussapoula. The elephant escaped and the project was accused of using blanks. Many believed that the elephant was a Bangombe pygmy who are reputed to possess unusual transformation powers (Fay 1993).

Agricultural background

Due to dense forest vegetation most agricultural activity in the Dzanga Sangha Dense Forest Reserve occurs along the main north-south axis road connecting Lidjombo in the far south to villages north of Bayanga. Cultivation is found on the road edge in the vicinity of villages with the areas between villages left uncultivated. The only exception is the road between the villages of Bayanga and Moussapoula, which is cultivated along approximately 4 kilometres of road edge, with mostly cassava and coffee fields. The management plan of the Dzanga-Sangha project stipulates the limitation of agriculture to within 100 metres of the road. In a few areas this rule has not been observed, i.e. Yandoumbe, but in most areas it has occurred naturally without enforcement because of the difficulty in clearing thick forest vegetation. The estimated surface area of the reserve under cultivation is less than 2% of the total land surface area. The same fields are cultivated on average for a period of several years and then abandoned for a few years because of soil infertility. Cultivation is then resumed.

Agricultural activity in the area consists mostly of subsistence farming. Cultivated crops include cassava (*Manihot esculens*), both sweet and bitter varieties: the bitter variety is the preferred carbohydrate source and the leaves are also eaten. Ground cassava tuber (bitter variety) is the one crop which is sold commercially by village women throughout the area. Corn is also cultivated for food consumption and is also used in the manufacture of an indigenous alcoholic drink, *mbako*. Peanuts are cultivated to a lesser extent than cassava and corn and are also imported from other areas of the country to meet local consumption needs.

This area was once one of the largest robusta coffee producing areas of the CAR. It still retains an impressive acreage of coffee trees but, due to the vagaries in the world price for robusta (lowland) coffee, groves often go neglected for several seasons because of poor prices. Coco yams, bananas and papayas are also cultivated but are rarely found being sold in the market, being consumed by the cultivator's household. Other food products consist of wild foods derived from the forest. These non-cultivated foods are generally collected in the forest by the Aka Pygmies and sold to the Bantus, who either consume them or sell them in the market. The main forest product is the koko leaf (*Gnetum africana*) which forms a staple food product in the local diet, and which generates income for both the Aka and Bantu in the area.

Precipitation in this area of CAR averages 1200 mm per year. The yearly weather pattern consists of two dry seasons: an extended dry season from December to March and a shorter one occurring in July to August. Interspersed between these two dry seasons are two wet seasons: a long wet season occurring in September through November with the shorter wet season taking place in April through June. With such a favourable climatic condition of abundant rain agricultural activity is a year-round occupation. Cassava is planted all year around and takes approximately two years to produce mature tubers. Corn and peanuts are planted twice a year in May and September (sometimes with a third crop in December). Coffee beans are harvested between the months of November and December (Table 1).

Table 1: Principal Crops Cultivated in the Dzanga-Sangha Reserve

Crop	Cultivation Period	Harvest
Cassava	All year	All year
Corn	May, September, December	
Peanuts	May, September, December	
Coffee	Non-seasonal	November-December

Methods

In March of 1999 Amis Kamisse, a sociologist working in the rural development sector of the GTZ portion of the WWF project, started collecting information on crop damage and raiding. The information was collected using a modified questionnaire developed by IUCN. The original form was in English with a translation into French developed for use in the Dzanga-Sangha Reserve.

During this period (March to November 1999) Kamisse requested that villagers in the Reserve inform him of any crop damage they incurred, at which time he would try to visit the area to inspect the damage and complete a questionnaire.

Results

A total of five questionnaires were completed during the period covering 1st March to 30th November 1999. Four of these questionnaires were collected during the month of March and one questionnaire was collected in July. In all cases mature cassava (bitter) was damaged by elephants. Coffee trees were also damaged on two occasions. In only one of the questionnaires were other crops recorded as being damaged; corn and peanuts in an area of cassava were damaged (Table 2).

In the case of cassava damage, the elephants uproot the entire plant but generally do not eat the tuber: they prefer the sweet variety when they find it. Coffee trees are not consumed but are usually pushed over by the elephants as they travel through coffee plantations. Elephants consume both the stalks and ears of corn. Peanuts are uprooted and eaten during crop raiding.

Because no direct observations were made while crops were being raided, due either to nocturnal activity or no humans being present, the number of individual elephants causing the damage was estimated based on the measurements of rear footprints found in the field. In all cases inventoried the raiding was done by a group; the minimum number of individuals being two, and the maximum four.

Table 2: Elephant Crop Damage

Crop	Location	Date	Maturity stage¹	Degree of damage²	Size of elephant group
Cassava	Moussapoula	March 12	3	2	3
Coffee	Moussapoula	March 12	1	4	3
Cassava	Moussapoula	March 12	3	2	2
Cassava	Moussapoula	March 12	3	2	3
Coffee	Moussapoula	March 12	1	4	3
Cassava	Moussapoula	March 16	3	2	3
Corn	Bayanga	July 27	1	2	4 (approx.)
Cassava	Bayanga	July 27	1	2	4 (approx.)
Peanuts	Bayanga	July 27	1	2	4 (approx.)

¹Maturity stages: 1 = immature, 2 = intermediate, 3 = mature

²Degree of damage: 1 = very high, 2 = high, 3 = medium, 4 = low, 5 = very low

Discussion

Current sample size

There was a low response to the questionnaire for several reasons.

1. Elephants occur in high densities in this region but this, combined with low human population density, makes up an ideal scenario for low rates of crop raiding.
2. Since the inception of the WWF conservation project the problem of crop raiding has never been formerly addressed, with the exception of an attempted administrative cull in 1993 which failed. Because of this history the local people feel that the project is reluctant to accept complaints about crop damage. When informed that the project was now interested in collecting information, without mention of compensation, villagers were reluctant to make the effort to inform the project of damage, especially in areas far from the project headquarters in Bayanga.
3. A third reason for not informing the project about crop raiding is that in certain areas villagers have found their own solutions to elephant damage which includes poaching. In one village where this is the case poaching is a lucrative industry.

Traditional deterrence

The most effective deterrence to elephant damage is the grouping of fields along the main road. As mentioned before, this is stipulated in the management plan of the park and occurs naturally because of thick forest vegetation. Fields, however, are not generally guarded on a 24 hour basis, being tended only during the daylight hours. Therefore most of the raiding takes place at night.

Another traditional elephant deterrence observed is the erection of “fences” around fields. These fences consist of a string mounted around the cultivated area with various objects such as cans, discarded plastic bags, etc. suspended from the string, the perception being that the motion of the objects frightens the elephants from the area. Some of the objects such as milk tin lids make a noise when moved by the wind, which is also thought to deter elephants. Whether this is an effective means of deterring elephants from fields is doubtful.

A further deterrence is the burning of Chinese bamboo near the fields. The closed cavities in the bamboo stems “explode” when burned. This frightens the elephants away, but only for short periods of time.

Other pests

As in all areas of Africa elephants are always perceived as the main crop raider where present. In the area of Bayanga primates as well as rodents are also considered pests. Monkey species, and particularly the crested mangabey (*Cercocebus galeritus agilis*) eat bitter cassava in the fields, and also as the tubers are being soaked in water to remove poisons prior to consumption. Other foodstocks destroyed by mangabeys in this area include papayas, corn and peanuts. Three rodent species are also noted for crop damage. They include cane rats (*Thryonomys sp.*), giant rats (*Cricetomys emini*) and porcupines (*Hystrix sp.*). All of these species damage cassava fields as well as corn and peanut fields.

Recommendations

With the continuing influx of human population into this area, elephant crop raiding will become a more prominent problem and one that will have to be addressed if elephants are to be effectively protected in this region. At present the inhabitants of the Reserve perceive the elephants as agricultural pests and not as a natural resource.

An integrated approach toward problem animal management

Loki Osborne & Guy Parker
The Mid Zambesi Elephant Project, Zimbabwe

Summary

Crop damage by elephants has a major impact on the livelihoods of rural farmers in communal lands of Zimbabwe where elephants are common. In the mid Zambezi Valley, Rural District Councils are tasked with managing this conflict by employing control units and conducting disturbance shooting in an effort to reduce crop loss. Farmers attempt to limit loss using traditional methods. Due to a lack of resources and the ineffectiveness of any single method, farmers lose considerable food and cash crops to elephants every year. To address these issues with Problem Animal Control (PAC), the Mid Zambezi Elephant Project (MZEP) has developed a two-stage integrated approach to increase the livelihood security of farmers. The first aspect builds on experimental crop protection schemes that can be administered by farmers. The second aims to reorganise crops currently grown and to introduce a cash crop that is unpalatable to wildlife.

Background

Conflict between humans and elephants is a growing concern across Africa where the rangeland of the elephant is being rapidly converted to farmland. Crop damage in the communal lands of Zimbabwe is particularly severe: elephants have been responsible for up to 75% of all crop damage in some districts (WWF, 1996). In some CAMPFIRE (Communal Areas Management Programme for Indigenous Resources) districts, crop damage by wildlife is perceived as the major problem facing farmers and threatens to undermine the whole programme (Van der Wittenboren 1999). A direct link has been made between crop damage and the levels of poaching and wounding of animals in the mid-Zambezi (CIRAD, 1997).

MZEP was established in 1997 to examine the ecology of elephants in the Muzarabani and Guruve districts and, in collaboration with the Zambezi Society, identified seasonal inter-district movement of elephants. Based upon this research, MZEP is developing a corridor for elephants between the two districts. The project has also designed and established a crop damage reporting scheme and implemented community-based methods to reduce the impact of wildlife crop damage on rural farmers.

Study area

The Zambezi valley is dominated by *mopane-terminalia* woodland, with dense riverine thicket of mixed species along the major rivers. Most farming is small-scale dry land cultivation and the main wet season crops include maize, ground nuts and cotton. These rain-fed crops are planted in November and harvested between April and June. Agriculture is concentrated on wide bands of alluvial soil bordering the major rivers, and in isolated settlements within the dry forest. Agricultural activities are expanding rapidly due to the profitability of cotton and the associated clearance of new land, and the resettlement of people from other parts of the country.

Elephants move extensively through the communal lands, making use of dense thickets as temporary refuges. The elephant population of the three districts (Guruve, Muzarabani and Magoe district in Mozambique), estimated at approximately 3000 individuals (Davies 1999), is contiguous and as such needs to be managed as a common resource (MZEP and ZamSoc, 2000).

Study Villages

Five villages were selected that experienced high levels of crop loss to elephants, based on information gathered by the MZEP reporting scheme. Museruka village was used as a study site for testing an integrated approach toward PAC. Crop damage incidents and traditional methods of PAC were monitored in Chombe, Gonono, Chadope and Bwazi villages as a comparison to tests in Museruka.

Problems with current responses to crop raiding

Crop damage is a widespread and common problem in the mid-Zambezi region. There are a number of factors that compound the effects of crop loss upon rural farmers besides the direct impact on their livelihood. These are described below in brief.

Problem Animal Control

Farmers generally perceive the control of 'problem elephants' as the responsibility of the council central units. Crop damage is at its height during the wet season when the majority of crops are grown (December-April), and the PAC units do not have the human or financial resources to attend to most incidents. The most common PAC method used is disturbance shooting, firing shots over the raiding animal's head, but this becomes ineffective over time and often an animal has to be shot. Communal farmers commonly resort to their own methods to defend their fields by burning fires, beating drums and throwing stones, but these also become less effective as the season progresses.

Vigilance and co-operation between farmers

Elephants enter fields that are poorly defended and crop loss is correlated to a farmers' vigilance (Osborn, 1998). We found that farmers did not regularly defend their fields during the night when most raiding occurs. Lahm (1996) found that 36% of farmers in Gabon, whose crops were destroyed by elephants, did nothing to deter them. Being aware of the presence of elephants is therefore a key component toward improving the effectiveness of PAC.

Agriculture organisation

The majority of crop raiding incidents involve elephants eating mature food crops which are highly nutritious and palatable to elephants. In Guruve district 73% of damage incidents were to food crops, including maize, sorghum and groundnuts (MZEP, 2001). In many communities maize and sorghum crops are grown in newly cleared fields abutting the forest.

These crops are particularly vulnerable to elephant damage as they grow over two meters tall and conceal elephants as they enter the fields.

Project strategy

The project aimed to improve the livelihood security of communal land farmers in wildlife conflict areas, first through the development of an effective PAC methodology, and second through the establishment of wildlife resistant crops. To overcome the problem of elephants habituating to any single method, we used a combination of methods and ensured that all farmers took part in PAC activities. To address the issue of vulnerable crops, MZEP reorganised food crops and introduced chillies as a cash crop; chillies are unpalatable to mammals. The methods are separated into two approaches, the first deals with PAC and the second addresses the introduction of a new growing plan.

Farmer-based PAC

Meetings were conducted throughout the year and all farmers in the affected areas discussed the problem and formulated plans for PAC. Central to these discussions was encouraging farmers to acknowledge that they have to take responsibility for their own crop protection and that co-operation between farmers is essential for deterring elephants.

The PAC methods were divided into three categories. First, vigilance methods were designed to alert the farmers to approaching elephants and increase the chance of farmers spotting elephants as they approached the fields. Second, passive systems were designed to impede a crop raiding elephant's passage into the field using simple physical barriers and deterrents. These were established at the onset of the rains and required no attention other than maintenance. Third, active PAC methods were developed to be used by farmers to chase crop raiding elephants; they included chilli-based chemical deterrents and noisemakers.

Vigilance methods

- **Buffer Zones:** Farmers were asked to clear a five metre wide buffer zone around their fields (or in some cases along the edge of the whole village) to increase sightings of advancing elephants.
- **Watchtowers:** Farmers with fields on the forest boundary built watchtowers at approximately half-kilometre intervals to increase their vigilance capacity.
- **Whistles** were distributed to farmers along the boundary so they could alert other farmers when elephants were approaching the fields.

- **Fires** were kept burning all night in areas where elephants came regularly. These fires were also used to burn the pepper dung (see below).
- **Cowbells** were placed at 30m intervals along a string fence (see below) to alert farmers when elephants came to the fields.

Passive methods

- **String fences:** Farmers cut three metre poles and placed them at 30 metre intervals along the buffer zone. Bailing twine was strung between them and squares of burlap were tied at 5 metre intervals along the string.
- **Grease and hot pepper oil** were mixed together and applied to the string. As elephants made contact with the string, the grease caused irritation to their skin.

Active methods

- **Pepper dung:** Elephant dung was mixed with ground chillies by the farmers then dried in the sun. These bricks were burned in fires along the field boundaries to create a noxious smoke.
- **Whips** made of bark were made by the farmers that, when used properly, made a loud 'crack' similar to a gunshot.
- **Fire crackers** were used by farmers to chase elephants from the fields by throwing them above the animals.
- **Pepper spray** was used on occasions when the elephants did not respond to bangers (Osborn 2000).

PAC evaluation

The passive deterrents on their own were effective at keeping elephants out of the fields. A number of incidents occurred where elephants entered the buffer zone, contacted the fence, and turned away back to the bush. The cowbells played a crucial role in alerting the farmers to the elephants, and farmers agreed this was a key element to improving PAC. Making fires and co-ordinating vigilance efforts also reduced fear among farmers and improved efficiency by allowing some farmers to sleep while others patrolled. The active methods implemented by farmers were more successful at chasing elephants from the fields than traditional methods. Combinations of active and passive PAC methods used in Museruka were effective at reducing overall crop loss and this village experienced very little damage during the 2001 season. The other villages, where traditional PAC methods were used, suffered losses similar

to previous years. A full quantitative assessment of the methods and results of this study are available from MZEP.

Crops

Chilli peppers contain capsaicin, the chemical which makes them hot, and as such are generally unpalatable to mammals. MZEP introduced chillies to farmers in Museruka as a wildlife resistant cash crop. The chillies were planted at the edges of the fields, forming a buffer of low growing crops in a 10-20m wide strip. Food crops, such as maize and sorghum, were planted away from the edges of the fields and therefore were less accessible to crop raiding elephants.

Crop evaluation

While the buffer crops did not restrict the movement of elephants into fields they were not attractive to raiding elephants. Chillies were found to be less palatable to mammals than maize, sorghum and cotton and were also more resistant to trampling damage by wildlife. As a cash crop, chillies have a market value that is double that of cotton (per kg) and the input costs are similar. Therefore, they have real potential as a competitive cash crop. Over half the farmers of Museruka reorganised their crops in the manner we suggested. The overall damage to food crops was lower than in other villages, but it is difficult to assess the actual benefit of this method. It is however a logical way of protecting the most vulnerable crops.

Conclusions

The methods presented are effective, cheap and can be implemented by rural farmers. They are designed to be used in combination with each other to reduce the impact of crop raiding elephants and provide an alternative cash crop. Developing an efficient and affordable community-based system of PAC not only allows farmers to protect their own crops, but also reduces the management pressures upon the RDCs.

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Crop Damage by Elephants in the Red Volta Area During the 1997 Harvesting Season

Moses Kofi Sam⁸, Charles AK Haziel⁹ and RFW Barnes¹⁰

Introduction

In the northern savannahs of Ghana elephants (*Loxodonta africana africana*) are found in Mole National Park, Upper West Region and the Red Volta valley. The first study of the latter was made by Jamieson (1972), who noted that there were about 25 in the valley of Red Volta/White Volta/Morago rivers. No further surveys were undertaken until that of Sam (1994) in response to complaints of crop damage. Two years later Sam *et al.* (1996) made a survey of the elephants of north eastern Ghana and northern Togo.

Sam *et al.* (1996) learnt that crop raiding by elephants was a serious problem for the rural population in the Red Volta valley. The local people claim that crop raiding had increased during the preceding five years. Sam *et al.* (1996) deduced that this was as a consequence of events over the border in Togo. In 1990-92 there was a period of civil disturbance in Togo. The opposition targeted the national parks and reserves as symbols of the government and urged the populace to invade the protected areas. The rural people did so, and killed most animals. The elephants that survived fled into Burkina Faso, Benin and Ghana.

⁸ Wildlife Division of Forestry Commission, Box M.239, Accra - Ghana

⁹ Wildlife Division of Forestry Commission, Box M.239, Accra - Ghana

¹⁰ Univ. of California at San Diego, Dept. of Biology 0116, La Jolla, California 92093-0116, USA

Sam *et al.* (1996) mentioned that the most severe crop damage period was around harvest time, i.e. between September and December. Therefore we undertook the study described here during the 1996 harvest period. The goal was to understand the crop raiding phenomenon so that effective deterrence methods could be employed. Specifically, we were to:

1. determine the distribution of elephants within the forest reserve and cultivated lands outside the forest reserve;
2. determine the distribution and extent of crop raiding;
3. identify the individuals, social groups, or age-sex classes responsible for crop raiding;
4. determine the efficacy of the usual method employed by Wildlife Division (WD), to drive away elephants, i.e. firing shots in the air;
5. test the efficacy of capsicum pepper spray, and formulate a means of deploying it under local conditions.

(This paper will deal with objectives 2 and 3 only.)

Description of study area

The study area is located in the Upper East Region of Ghana, between long. 0° 24' and 0° 46' W and lat. 10° 33' and 11° N. The Red Volta is the main river running southwards from Burkina Faso, through the middle of the area to its confluence with the White Volta river. Its banks are lined with forest reserves. It falls in the Guinea savannah zone with very low numbers of animal species. The area falls under two major edaphic zones - savannah ochrosols to the west of the river and groundwater laterites to the east. These types of soils are poorly drained and two of the poorest soils in Ghana (Boateng, 1970). According to Sam *et al.* (1996) soil fertility is on the decline.

The average annual rainfall is below 1,000mm with one wet season, from May to November. The temperature in the dry season is about 39° C. Sam *et al.* (1996) reported a downward trend and irregular fluctuations in the rains. They also reported higher temperatures for the last three decades in north eastern Ghana.

Agriculture is the mainstay of the local economy. The average land holding is 2.12 ha per family-compound. Human population density is about 118 per sq. km (Sam *et al.* 1996).

Methods

In each village a volunteer was given the task of recording all incidents of crop raiding. Afflicted farmers were asked to report to the registrar the following details: date of raid, location of farm, crops damaged, and estimate of damage.

Later we went to the village and visited each damaged farm. The name of the farmer, the crop types, the type of damage, and the GPS reading were noted. Ideally one should measure the damage for every field, but time was limited. Therefore out of every five damaged farms, one was selected at random and measured. The following records were made: number of fields in the farm; for each field that had been damaged, the size of the field itself was measured using a tape measure or a road runner. The number of damaged stems were then counted.

Each time a clear hind footprint of an elephant was found in a field, it was measured with a tape measure. There is a strong relationship between age and the length of the hind footprint (Western *et al.*, 1983; Lee and Moss, 1995). One can also obtain a rough estimate of the age of an elephant from measuring the circumference of the dung boli (Jachmann and Bell, 1984).

Results

Severity of crop damage

We were not able to count the total number of fields for each village. Hence, though we know roughly how many fields were damaged, we do not know how many were spared, and thus cannot calculate the percentage of fields that were damaged in the area.

A total of 133 farms that had been damaged were examined. The number of damaged stems was counted in 27 fields; the percentage of stems that were damaged ranged from 0.1% to 100%. The median was 8.6%. In other words, half the fields suffered less than 10% damage. Three-quarters of the fields suffered less than 30% damage (Fig. 1). Five fields (i.e. about a fifth of the sample) suffered very high rates: more than 70% damage (Fig. 1). Only two fields experienced medium damage (between 30% and 70% of the stems damaged (Fig.1). Therefore these limited data suggest that if elephants visit a farmer's field, then it is most likely to be lightly damaged. But there remains a 20% risk that it will be very badly damaged.

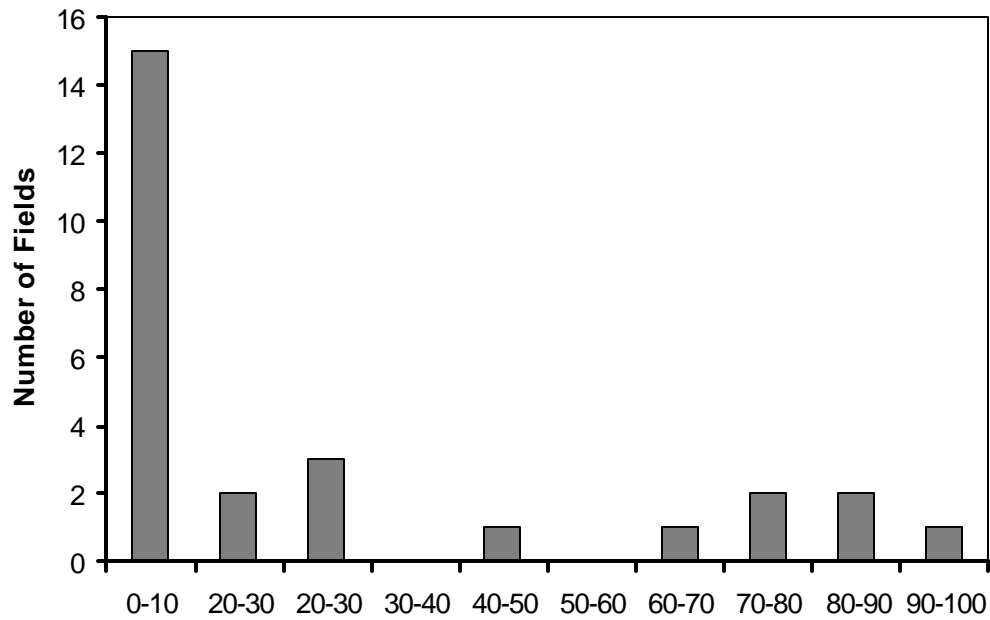


Figure 1: The frequency distribution of crop damage (n=27 fields).

Table 1: Comparison of damage between the East and West sides of the River Volta. The median percent damaged and its range are shown.

Category	Median	Range	N
East	7.5	0.1 - 85.3	20
West	13.0	0.2 - 100.0	7

Table 2: Comparison of damage between villages. The median percent damage and its range are shown.

Village	Median	Range	N
Tilli	5.9	0.9 - 74.6	6
Kusanaba	4.7	0.1 - 14.6	6
Widenaba	1.9	0.5 - 80.0	5
Others	21.5	0.2 - 100	10

Table 3: Comparison of damage between crop types. The median per cent damage and its range are shown.

Crop Type	Median	Range	N
Guinea corn	4.1	0.1 - 100	10
Rice	22.5	9.8 - 74.6	6
Others	0.5	0.5 - 80.0	11

In each of the above tables, the range is so great that there will be no significant differences in damage rates between east and west, or between villages, or between crop types.

Distribution of crop damage

The spatial distribution of fields raided by elephants is shown in Fig. 2. Not all raids were reported to us, and we were not able to visit all the raided farms. Nevertheless, Fig. 2 probably gives a reasonable picture of the distribution of raiding activity.

Most raided farms were on the east side of the river, with the villages of Widenaba, Tilli, Shiega, and Kusanaba being the most affected. Sekoti and Kongo (Nangodi) were the worst affected villages of the west side. The concentrations of crop raiding incidents correspond to the high elephant densities on transects 2E, 3E, 7E, 5W and 6W.

Elephant footprint and dung measurements

In the fields we found 22 footprints that were clear enough to measure. Two of these were 19cm, and represent very young infants. Ten were between 20cm and 29cm, representing calves aged between about one and six years old.

Twenty-three dung boli were measured in the fields. Ten of these were <30cm in circumference, and therefore represent calves less than three years old (see Table 4 in Jachmann and Bell, 1984). Another six were between 30 and 39cm, representing animals between about three and six years old.

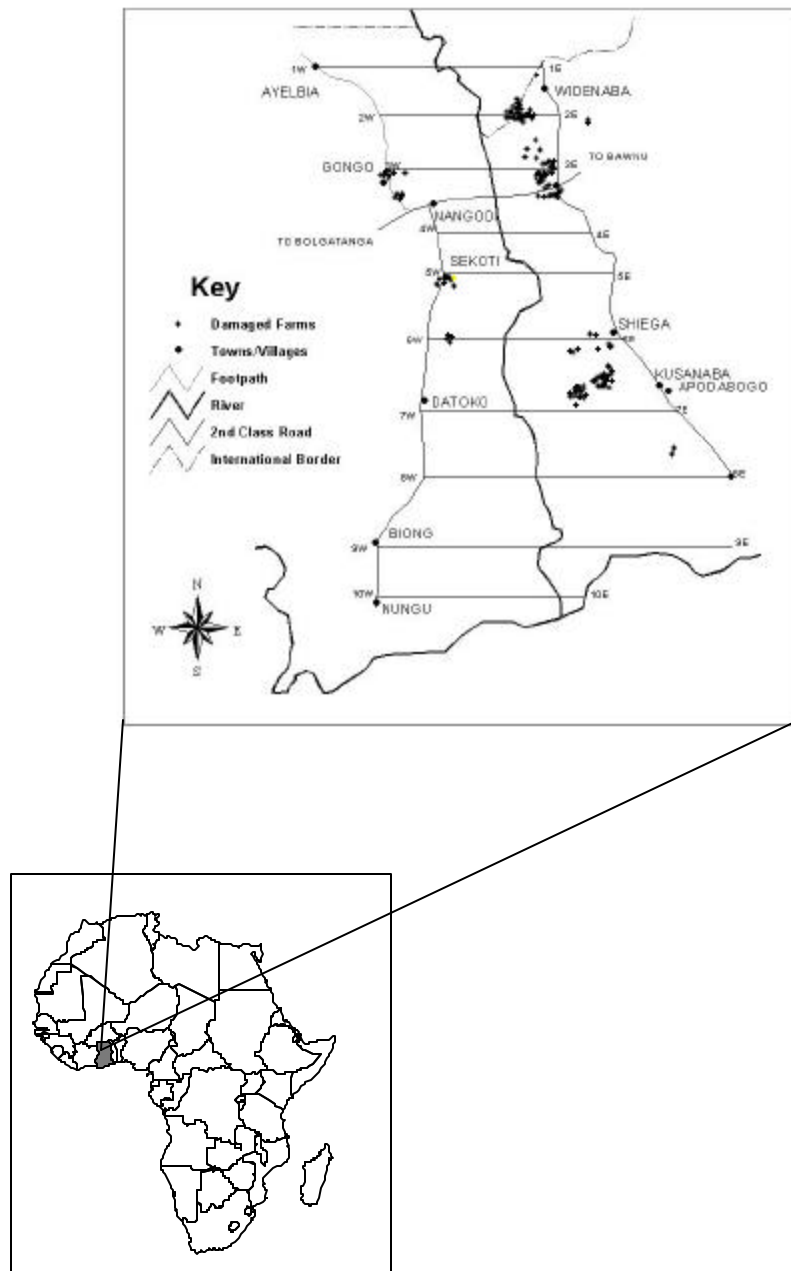


Figure 2: The spatial distribution of reported crop raiding incidents.

There is of course considerable variation in growth rates between the elephants in Ghana and those in the countries where the growth curves were calculated. Therefore the growth curves in Jachmann and Bell (1984) can give only a very rough indication of the ages of the animals in the Red Volta Valley. The main point to be made through the footprint and dung measurement data is that we found signs of many very young elephants in the fields. Both the footprint and the dung boli measurement show that families with very young elephants participate in crop raiding.

Discussion

Intensity of crop damage

Damage was light (less than 10% of the stems damaged) for most raided fields. But damage was severe in about a quarter of the fields that were raided: they lost 70% or more of their crop. Only a small number of fields suffered intermediate levels of loss. This is a peculiar distribution; one might have expected a sort of bell curve, with most farmers suffering about the average, a few suffering less, and a similar number suffering more. The sample size is too small to give a clear picture, but the bimodal distribution suggests two types of behaviour. The left hand part of the histogram (Fig. 1) may represent elephants that cause incidental damage while simply passing through on their way to some other place (“collateral damage” in military parlance). The right hand part of the histogram may represent groups that decided to stop and feed in that particular spot.

Ramachandran and Eastman (1997) have classified Upper East Region as having “very high vulnerability” to food insecurity. This is the most severe of their four classes of food security. In this very poor area the people live on the brink of food shortage even when there are no elephants. To suffer losses from elephants as well is an especially cruel burden.

The cost to the farmers living near elephants is very great. Even 10% of the standing crop must be a grievous loss to a subsistence farmer, while 70% or more can barely be imagined. One farmer told us how he arrived early one morning to harvest, only to see a group of elephants feeding in his field and said “I wept”. His field was almost completely destroyed.

It is not just the loss which is painful; there is also the fear of loss. For example, we saw that farmers in Kusanaba and other villages started to bring in the harvest earlier than usual, because they feared that if they did not do so, the elephants would get it first. This means that the quality of the harvest was sub-optimal because the grain had not fully ripened. But there is more to it than that. Even if a family was able to bring in the harvest safely, all through the

growing season was the fear that any night the elephants might strike and rob the family of the fruits of its labours. This fear, year after year, must make a big difference to the quality of life.

Deterrence tactics

Deterrence falls into two categories: strategic and tactical. Strategic methods are those which aim to deny part of the landscape to elephants. They include electric fencing (see Hoare, 1995 for a description of different arrangements). Fencing the entire forest reserve boundary would require high capital cost of constructing over 150km of fence, and regular patrolling and maintenance. Furthermore, long fences enclosing small areas have a high perimeter to area ratio and are very cost-inefficient. Fencing the elephants into the reserves would restrict their range especially during the dry season. The option recommended for this area is one that will enclose fields to keep out elephants. Hence it is crucial that the villagers see it as their fence from the very beginning. If the fences are seen as belonging to the government or some other organisation, which is therefore responsible for its maintenance, there is a higher probability of it failing. Sam (1998) estimated the cost of establishing a pilot 2km experimental electric fence and maintaining it for the first year in the Red Volta Valley at US\$3,278/km. While this is lower than one in Tsavo NP (US\$10,800) it is higher than Hoare (1992) reported in Zimbabwe (US\$500-1,500).

It has been estimated that in its 10th and 20th years, the cost of the fence would have fallen to US\$54/ha and \$44/ha respectively. According to Sam (1998) a 2km fence around a rice field in the Red Volta Valley would be economically worthwhile in the first year, while a Guinea cornfield would break even. However, a millet field would break even in the second year.

Tactical methods are those which aim to drive elephants away, or to discourage them from approaching the fields. They include the traditional methods such as banging drums, lighting fires, firing shots etc. They also include newer methods such as capsicum spray (red pepper). Shooting crop-raiders falls into this category. The goal should be to change elephants' perception of crop raiding as a low or risk-free activity. If one could frighten family groups enough, so they learn that approaching cultivation puts their calves at risk, then a large sector of the elephant population would refrain from crop raiding.

The first step must be for the villagers to do more to protect their crops. One suggestion is for the men in each village to organise themselves, and take turns to watch their fields during the

late growing season. However, this is not a risk-free undertaking for the farmers, because a large elephant can be invisible at 10 metres in a mature stand of Guinea corn, even in daylight. Note, however, that if elephants are harassed or associate certain places with risk, they will become more aggressive when they do come into contact with people. Thus if these tactics are successful, one might have fewer, but more aggressive, elephants indulging in crop raiding. Second, the WD could organise two or three teams on the east side, and one on the west. Each team would station itself in a central village. When villagers heard elephants approaching their fields, they could send a runner (possibly on a bicycle) to summon one of these teams.

The tactical methods of deterrence can start immediately. Fence construction may take a couple of years. In combination, electric fences and organised deterrent tactics should make a large reduction to crop raiding and thereby improve the lot of the valley people.

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