RESEARCH

Risk of crop raiding by elephants around the Kakum Conservation Area, Ghana

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Abstract

Crop raiding by elephants is becoming a serious management problem around many protected areas in West Africa as forests shrink and human populations expand. We describe a case study of the Kakum Conservation Area in Ghana's forest zone. We monitored 203 farms to explain why some suffered huge crop losses from elephants while close neighbours remained unscathed. Less than a third of the farms in the most vulnerable farmland were raided by elephants. Elephants were attracted to larger farms and those with many types of crops. Isolated farms were more vulnerable than those in clusters. A farmer could dramatically reduce risk by moving away from the park boundary, joining other farmers in a cluster, limiting farm size and growing fewer kinds of crops.

Résumé

Les dégâts causés par les éléphants aux récoltes deviennent un problème de gestion grave autour de nombreuses aires protégées en Afrique de l'Ouest, étant donné que les forêts se réduisent et que la population humaine s'accroît. Nous décrivons une étude de cas de l'Aire de Conservation de Kakum, dans la région forestière du Ghana. Nous avons suivi 203 fermes pour tenter d'expliquer pourquoi certaines subissaient de lourdes pertes à cause des éléphants alors que de proches voisins restaient indemnes. Les éléphants ne s'attaquaient qu'à moins d'un tiers de fermes dans la partie la plus vulnérable. Ils étaient attirés par les plus grandes fermes, et par celles qui avaient de nombreuses sortes de cultures. Les fermes isolées étaient plus à risques que celles qui étaient groupées. Un fermier pouvait beaucoup réduire les risques en s'éloignant des limites du parc, en se regroupant avec d'autres, en réduisant la taille de son exploitation et en faisant pousser moins de plantes différentes.

Introduction

Wherever agriculturalists and elephants (*Loxodonta* spp. and *Elephas maximus*) share the same landscape there is conflict (e.g. Lahm 1994; Barnes 1996; Naughton-Treves 1998; Hoare 1999; Mubalama 2000; Seneviratne and Rossel 2001; Sitati et al. 2003; Sukumar 2003). Many elephant ranges in the West African forest zone are now surrounded by dense cultivation (Barnes 1999). An example is the Kakum Conservation Area (KCA) in the forest zone of southern Ghana. KCA is Ghana's most successful national park in terms of visitors and public education but the adjacent farmers receive few benefits and suffer grievous losses from marauding elephants (Azika 1992; Dudley et al. 1992; Nchanji 1994; Barnes et al. 1995; Barnes et al. 2003). Elephants are seen by farmers as a major pest species, but from the national point of view they are an asset. The government of Ghana has committed itself to conserving the country's remaining elephants and to resolving the issue of human–elephant conflict (Wildlife Division 2000). Here we present a case study of the human–elephant conflict around Kakum Conservation Area. The lessons from this study will enable managers elsewhere in the West African forest zone to reduce levels of crop damage by elephants.

Crop raiding is a question of risk: what is the probability that a particular farmer will lose crops to elephants during a given growing season? Proximity to the park was clearly an important predictor (Naughton-Treves 1998), but it did not explain why the risk varied so much between farms, with some farmers suffering catastrophic losses while their neighbours escaped completely. Elsewhere it had been shown that certain crops were preferred by elephants (Naughton-Treves 1998; Chiyo et al. 2005) while larger areas of cultivation were more likely to draw elephants (Sitati et al. 2003). Nchanji (1994) suspected that clusters of farms attracted elephants at Kakum. We speculated that a greater diversity of crop types would increase vulnerability because elephants select a varied diet. We collected data from a large sample of farms to identify the farming patterns and the combinations of variables that, after accounting for distance from the park boundary, determine the risk of crop loss for individual farms.

Methods

Study area

The Kakum Conservation Area lies in the moist evergreen zone defined by Hall and Swaine (1981). Kakum and Assin Attandanso Forest Reserves were demarcated in 1925/26 and 1935/36 respectively (Kpelle 1993). They cover 366 km^2 and now form the Kakum Conservation Area, which is managed as a national park. The mean annual rainfall during the 1990s was 1223 mm with peak rainfall in May–June and October–November.

The area is a fragment of the lowland forest that formerly covered south-western Ghana. Elephants once ranged throughout this area but were gradually restricted as the intensity of human disturbance increased during the 20th century (Barnes et al. 1995). Eggert et al. (2003) estimated their numbers at 225 (95% CI from 173 to 308).

KCA is completely surrounded by a human-dominated landscape consisting of a mixture of cultivation, farmbush, patches of secondary forest, and swampland. Farmbush consists of the regrowth that follows cultivation: forb regrowth, thicket and early secondary forest (Ahn 1961). Both commercial and subsistence farming are practised. Cash crops are cocoa, oil palm, coffee, citrus and coconut (Agyare 1995). The subsistence farming system is rain-fed mixed cropping on a shifting cultivation basis, or rotational agriculture (Agyare 1995). The main food crops are cassava (*Manihot utilissima)*, maize (*Zea mays*), plantain (*Musa paradisiaca*), cocoyam (*Xanthosoma* spp.), yam (*Dioscorea* spp.), and vegetables such as okra (also known as okro) (*Abelmoschus esculentus*), tomato (*Lycopersicon esculentum*), peppers (*Capsicum* spp.), beans, eggplant (garden egg, aubergine) (*Solanum melongena*) and watermelon (*Citrullus lanatus*). Rice (*Oryza sativa*) is grown only around the north-east.

A farmer might have several farms in different places or separated by patches of farmbush. Many farms are several kilometres from the farmer's house. The median farm size was 0.3 hectares in 2001 and 2002, and subsistence cultivation covered less than 10% of the land adjacent to the park.

Data collection and analysis

The time required to walk to each farm precluded a large random sample of farms. Instead, 10 study sites were randomly distributed around the KCA periphery (fig. 1); each site was 1 km^2. Each farm on the site was identified, and a local villager was employed to work part-time as a monitor on each site. The monitors were trained to record all incursions by elephants into the site and record which farms were affected. Each incursion onto a farm, whether damage was caused by trampling as the elephant passed across the farm or by feeding, was recorded as one incident. The work of the farm monitors was checked at random intervals.

Data on crop-raiding incidents were collected from August 2000 to September 2002. Here we summarize the numbers of raided farms in both 2001 and 2002 and analyse in detail the data collected from the 2001 crop-growing season (April to August). We describe the number of crop damage incidents only; the damage caused per raid will be discussed in a separate paper.

Survey teams mapped each farm during the growing season. Most farms were mixed, that is, the different crop types were intermingled. The abundance of each crop staple (maize, cassava, cocoyam and rice) was estimated with random quadrats, and the percentage area of that crop was multiplied by the area of the farm to give the effective area (in square metres) covered by that crop. The data for field sizes and coverage of staple crops were normalized by square root transformations.

The number of raids recorded in each farm was typical count data: raids were not normally distributed and the data consisted of integers, positive numbers, and many zeroes. Therefore log-linear models with Poisson errors were fitted by maximum likelihood (McCullagh and Nelder 1989; Crawley 1994) to express the number of raids as a function of farming variables. The models had the form:

$$Y = \exp[\ a + b.x\ ]$$

$$Y = \exp[\ a + b_1.x_1 \ldots + b_n x_n\ ]$$

for one or n independent variables respectively, where Y was the number of raids during the growing season and x or x_i were independent variables. The significance of each variable was evaluated by comparing the change in deviance with χ^2 when that variable was added to the model (Crawley 1994). The exponent of the regression coefficient (i.e. e^b) measures the change in risk for an additional unit of the independent variable. Thus if the independent variable increases by z units, risk will change by $(e^b)^z$ (Selvin 2004).

For a few farms data were missing for some variables, thus reducing the sample size for analyses that included those variables.

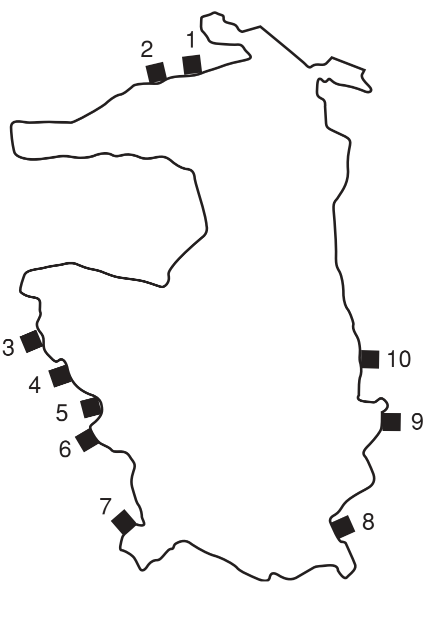

Figure 1. Outline map of the Kakum Conservation Area showing the location of the 10 study sites.

Results

Number of raided farms

In 2001 we monitored 213 farms in the 10 study sites for the whole year. Of these, 55 farms (26%) suffered one or more crop-raiding incidents by elephants, and 120 incidents were recorded. In the following year we monitored 179 farms in the same 10 study sites until the end of September. Again, 55 farms (31%) suffered one or more incidents, and 92 incidents were recorded. There was no difference between years in the frequency distribution of incidents (G-test comparing frequencies of 0,1,2,3 and > 3 raids, $G = 4.84$, $df = 4$, NS), and the combined data are shown in table 1. In both years most affected farms suffered only one or two incidents. One farm suffered 12 incidents during the course of 2001, 5 of which occurred during the growing season.

Incidents in the 2001 growing season

The most important single predictors of incidents in the 2001 growing season were farm size, distance to the park boundary, and number of food crops (table 2). Isolated farms—those far from the nearest neighbour—were at significantly greater risk of being raided (table 2). The number of incidents experienced by a neighbouring farm had no effect upon risk.

Table 1. Frequency distribution of crop-raiding incidents on farms, 2001 and 2002

No. of incidents	Frequency (no. farms) 2001	Frequency (no. farms) 2002	Combined frequency
0	158	122	280
1	31	34	65
2	11	16	27
3	4	3	7
4	1	3	4
5	4	0	4
6	2	0	2
7	1	1	2
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	1	0	1
13	0	0	0
14	0	0	0
Total	213	179	392

Table 2. The effect of farming variables on the number of raids in the 2001 growing season. The second column shows the reduction in deviance in number of raids when each variable was added alone to the null log-linear model (n = 203 farms). The residual deviance of the null model was 241.49. For plantain and the crops listed following it, the variables were entered as indicator variables (i.e. present/absent)

Variable added to null model	Change in deviance	Regression coefficient b	e^b	p
√Farm size	36.11	0.020	1.020	<0.001
Distance to park boundary*	35.51	–0.003	0.997	<0.001
Number of food crops	32.10	0.508	1.661	<0.001
Distance to nearest farm*	14.20	0.007	1.007	<0.001
Raids on nearest farm*	1.05	0.182	1.200	NS
√Maize	30.65	0.020	1.020	<0.001
√Cassava	20.83	0.022	1.022	<0.001
√Cocoyam	3.85	0.014	1.014	<0.05
√Rice	0.08	–0.004	0.996	NS
Plantain	9.28	0.811	2.250	<0.01
Watermelon	5.70	1.104	3.016	<0.05
Okra (okro)	4.22	0.870	2.387	<0.05
Tomato	3.90	0.687	1.988	<0.05
Pepper	3.52	0.677	1.968	<0.10
Beans	3.44	0.991	2.694	<0.10
Yam (all varieties)	2.01	0.580	1.786	NS
Eggplant (garden egg)	1.69	0.748	2.113	NS

* *n = 198*
NS – not significant

Maize was the crop that had the greatest attraction for elephants (table 2); next were cassava and plantain. Watermelon, okra, tomato and cocoyam were significant at $p < 0.05$. Pepper and beans exerted a weak effect ($p < 0.10$).

A multivariate model was built by adding variables one at a time and retaining those that gave a significant reduction in deviance at each stage. This gave a model where farm size, distance to the boundary, and number of crops were the major predictors of the number of incidents (table 3a). Each of the independent variables was significant at $p < 0.001$. Once one had accounted for the number of crops, each of the smaller crops (plantain, watermelon, okra, etc.) made no significant contribution to the model. In other words, it is the diversity of crops, not the particular small crop, that attracts elephants.

Risk could also be expressed in terms of proximity to the park and each of the major crops: maize, cassava or cocoyam (table 3b). In each case the independent variables were significant at $p < 0.001$, except for $\sqrt{CO}$ ($p < 0.05$). A similar model with rice returned a coefficient for $\sqrt{RI}$ that was not significant.

Models with greater predictive power for each crop included the number of crops (N) (table 3c). In each case the independent variables were significant at $p < 0.001$, except for $\sqrt{CA}$ ($p < 0.01$) and $\sqrt{CO}$ ($p < 0.20$).

The risk of crop raiding decreased with increasing distance from the park boundary. A farmer adjacent to the boundary could reduce risk by 75% simply by reducing the number of crops on the farm from six to two (fig. 2). The farmer could reduce risk even further by planting two crops and moving 1 km away.

Discussion

General

Farmers living around protected areas frequently suffer depredations from a variety of animals that may cause more damage than

Table 3. The models that best describe the relationship between the number of crop-raiding incidents and farming variables. In these equations, S is farm size (m^2), x_b the distance to the boundary (m), N the number of crops, MA maize (m^2), CA cassava (m^2), and CO cocoyam (m^2)

a) Number of incidents per month, Y, as a function of farming variables:

$$Y = \exp[-2.32 + 0.015\sqrt{S} - 0.0025x_b + 0.32N]$$
$$(\chi^2 = 77.82,\ df = 3,\ p < 0.001)$$

b) Number of incidents per month, Y, as a function of proximity to the park and each of the major crops:

$$Y = \exp -0.66 - 0.0028x_b + 0.016\sqrt{MA}]$$
$$(\chi^2 = 58.17,\ df = 2,\ p < 0.001)$$
$$Y = \exp[-0.82 - 0.0030x_b + 0.019\sqrt{CA}]$$
$$(\chi^2 = 52.36,\ df = 2,\ p < 0.001)$$
$$Y = \exp[0.029 - 0.0033x_b + 0.016\sqrt{CO}]$$
$$(\chi^2 = 40.64,\ df = 2,\ p < 0.001)$$

c) Number of incidents per month, Y, in 2001 as a function of the number of crops and each of the major crops:

$$Y = \exp[-1.87 - 0.0025x_b + 0.015\sqrt{MA} + 0.34N]$$
$$(\chi^2 = 72.99,\ df = 3,\ p < 0.001)$$
$$Y = \exp[-1.95 - 0.0026x_b + 0.015\sqrt{CA} + 0.36N]$$
$$(\chi^2 = 67.15,\ df = 3,\ p < 0.001)$$
$$Y = \exp[-1.40 - 0.003x_b + 0.0097\sqrt{CO} + 0.41N]$$
$$(\chi^2 = 61.30,\ df = 3,\ p < 0.001)$$

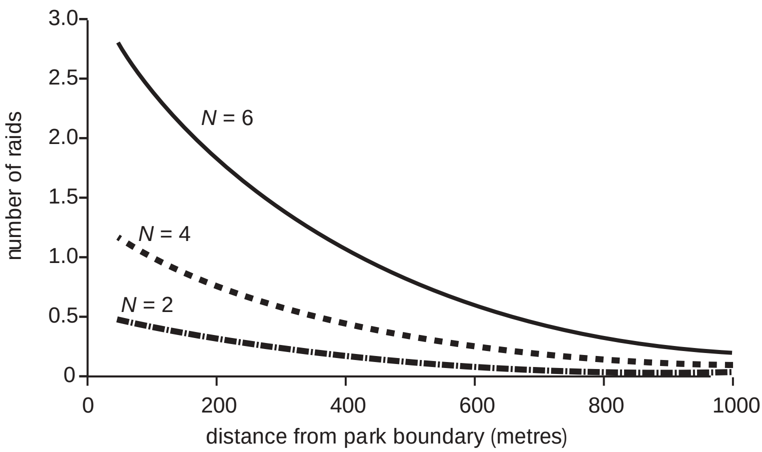

Figure 2. The risk of raiding in relation to proximity to the park and number of crops (N) during the 2001 growing season, estimated from $Y = \exp[-1.45 - 0.0028x_b + 0.44N]$, ($\chi^2 = 59.51$, $df = 2$, $p < 0.001$)

elephants (Dudley et al. 1992; Lahm 1994; Naughton-Treves 1998). But around KCA it was elephants that stirred passions, and their raiding became a sensitive political issue. Nevertheless, the situation may have been exacerbated by exaggerated reports of crop damage that gave local politicians the impression that the situation was much worse than it really was. Our data show that two-thirds of the farms in the most vulnerable farmland—within 1 km of the park boundary—were not damaged at all in the 2001 and 2002 growing seasons. Nevertheless, they were at risk, and one cannot quantify farmers' dread that they might awake one morning to find their fields devastated (Sam et al. 1997).

Raiding and the farming landscape

Four farming variables had a major influence upon a farm's risk of suffering raids by elephants: distance to boundary, area under cultivation, number of crops planted on the farm, and degree of the farm's isolation. Farms adjacent to the park boundary were obviously most at risk, reflecting the common problem of human–wildlife conflict on the boundaries of protected areas in Ghana and elsewhere (Naughton-Treves 1997, 1998; Seneviratne and Rossel 2001; Adjewodah et al. 2005; Sam et al. 2005). The important point is the rate of change in risk with distance from the boundary. In fact, a farmer could dramatically reduce losses by moving just a short distance from the boundary (fig. 2).

Sitati et al. (2003) and Sam et al. (2005) found that area under cultivation was a significant predictor of crop-raiding intensity, and our data showed that larger farms were indeed more attractive to elephants.

The third important variable influencing risk was the number of food crops grown on the farm (table 2 and fig. 2): six crops instead of two greatly increased the probability of a raid by elephants. Sam et al. (2005) showed that farms around Bia National Park, also in southern Ghana, suffered more raids when they planted four or five crops instead of two or three. Elephants have evolved as catholic feeders (Sukumar 2003), and so they are more likely to be attracted to fields with a diversity of crops.

In contrast to Nchanji's (1994) prediction, isolated farms were more vulnerable than those in clusters. There is probably more human activity around clusters of farms where farmers can share the burden of guarding, while isolated ones are more likely to be left unwatched for long periods.

Maize was the crop bringing the greatest risk for farmers; next were cassava and plantain (table 2). This is similar to the pattern that Sam et al. (2005) recorded at Bia. Banana was elephants' preferred crop around Kibale National Park in Uganda (Naughton-Treves 1998) but maize suffered the greatest percentage of damage (Chiyo et al. 2005). Across Gabon banana was the most frequently damaged crop: elephants were attracted first to the bananas and afterwards they turned to other crops (Lahm 1994).

Most of the farmers around KCA believed that pepper was a deterrent because elephants did not eat it. However, pepper was associated with greater risk (table 2). This is probably because most of the farmers that grew pepper also cultivated a mixture of other vegetables such as tomatoes and okra, and it was the diversity of crops that attracted the elephants.

Each of the variables in table 2 influenced risk, but it is the combination that is important. This explains why farms in the same area can differ greatly in the losses they suffer. A small farm with two crops is less likely to attract elephants than a large one with six crops, especially if one of those is maize. At a given distance from the park boundary a farmer can cut risk significantly by growing fewer crops, limiting farm size, reducing the amount of maize, and joining with other farmers in a cluster. A modest farm will produce a smaller harvest, but that will be balanced by the reduced risk of loss.

Crop raiding by elephants is a growing problem across West Africa as forests shrink in the face of expanding human pressure. Between 2000 and 2005 the rural population of the West African countries between Guinea-Bissau and Benin (i.e. those with forest, excluding Nigeria) increased by 2.7 million, and they are predicted to grow by a further 2.3 million during the next five years (United Nations 2004). Crop raiding is a problem that will get worse across the region unless it is addressed now. In the long term, the problem must be addressed by land-use planning around protected areas (Barnes 2002; Boafo et al. 2004; Chiyo et al. 2005). But that will take time, and meanwhile something must be done to reduce immediately the suffering of farming communities. This case study emphasizes that there is much that wildlife managers can do outside protected areas to reduce the risk to farmers. The variables that influenced elephant behaviour at Kakum are unlikely to be site specific but will apply elsewhere in the forest zone. As a first step, park managers should persuade farmers to adopt the practices described above to reduce the risk of attracting elephants. Nevertheless there will always be some elephants that wander into the farmland, and then managers should repel them with the methods of Osborn and Parker (2002).

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