Determining correlates of Human-elephant conflict reports within fringe villages of Kaziranga National Park, Assam

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ABSTRACT

Human-elephant conflict (HEC) is a key example of the growing competition between people and wildlife for space and resources throughout Africa and Asia. This study explores the correlates of reported HEC incidents within 20 villages between 0 and 10 km from the boundary of Kaziranga National Park, Assam. I find a highly significant negative association between proportions of forest cover and reported houses damaged, based upon which I recommend Joint Forest Management as an alternative income generation activity. Furthermore, my analyses show that mitigation techniques are mainly used out of tradition rather than effectiveness, indicating that there is much scope for trying further low-cost, active deterrence methods. My study also shows that HEC does not lessen with increasing distance from the park boundary, indicating that additional research must be carried out on a larger spatial scale to encompass the elephant's entire range. I detect intense respect towards elephants by local people, which is of considerable importance to their conservation. Overall, although HEC is a definite issue within this region, I conclude that is not as high as in other areas of Assam.

INTRODUCTION

As the human population encroaches upon natural habitat, animals find themselves increasingly in competition with people for space and resources (Pimm *et al*. 1995; Balmford *et al*. 2001). Large herbivores and carnivores are particularly affected by this conflict and are either critically endangered or rapidly declining as a result of it (Woodroffe & Gindsberg, 1998). Human-elephant conflict (HEC) is a key example of such an interaction. It describes occurrences of elephant crop raiding, infrastructural damage (Fig. 1) and disturbance of daily activities, which can result in injury or death of people and elephants alike (Hoare, 2000). HEC arises in rural areas of Africa and Asia, posing equally significant problems to local communities, elephants and wildlife managers (Sitati *et al*. 2003).

Fig. 1. House damage caused by raiding elephants.

For the dwindling populations of the Asian elephant (*Elephas maximus*), HEC is a progressively serious issue. Compared to 300,000 to 600,000 African elephants (*Loxodonta Africana*), there are only 44,000 Asian elephants distributed across 13 nations (India, Bangladesh, Malaysia, Sri Lanka, Bhutan, Indonesia, Laos, Nepal, Thailand, Burma, Cambodia, China and Vietnam; Asian Nature Conservation Foundation, 2006). Within India, an estimated 23,900 to 32,400 individuals make up a series of small populations ranging over 200,000 km² of fragmented landscape (Kempf & Santiapillai, 2005; Asian Nature Conservation Foundation, 2006). Assam is considered a fundamental conservation area for the Asian elephant (LahiriChoudhury, 1980; Santiapillai & Jackson, 1990; Choudhury, 1991, 1999; Bist, 2002; Talukdar *et al.* 2004). Specifically, it gives refuge to approximately 20% of India's elephant population, thus exceeding the number of individuals found in any other South East Asian country (Talukdar & Barman, 2004; Asian Nature Conservation Foundation, 2006). However, the elephant's natural habitat in Assam is rapidly diminishing because of increased land clearance for cultivation and industrial use (Talukdar *et al.* 2006). Indeed, forest cover in Golaghat region has decreased by 85% between 1977 and 2004 due to such developmental activities (Talulkdar *et al*. 2007). Human encroachment has forced elephants to forage in non-protected areas, thus augmenting the likelihood of disturbing local people (Talukdar *et al.*

2006). The increased opportunity for human-elephant interactions has resulted in many elephants being killed both accidentally (i.e. by road accidents or electrocution) and purposely (i.e. through poisoning), causing the population in Golaghat to decline from 500 individuals in 1973 to between 160 and 190 in 2006 (Talukdar *et al.* 2007).

To secure the survival of the Asian elephant, it is critical that we obtain a more comprehensive understanding of their raiding patterns. So far, several definite trends in HEC have been identified. Elephant disturbance usually takes place between dusk and dawn and it is strongly seasonal, corresponding with crop harvesting periods (Hoare 1999, 2000; Sukumar, 2003; Osborn & Hill, 2005). Moreover, conflict is usually highest closer to protected areas that act as elephant refuges (Naughton-Treves *et al.* 1998; Hoare, 2000). Studies carried out near Manas National Park (MNP) and in Golaghat district of Assam confirm these tendencies (Lakhar *et al.* 2007; Talukdar *et al.* 2007). Elephant raiding was found to peak during specific times of year when rice paddy (*Oryza sativa)* becomes more palatable and nourishing as it approaches harvesting (Sukumar, 1990). Specifically, this takes place between June and August (for *aahu* paddy) and October to November (for *xali* paddy) (Lakhar *et al.* 2007). The difference between these local rice types is that *xali* is cultivated in shallow-water, while *aahu* requires deeper water levels (J. Boruah, Aaranyak, pers. comm.). The distance at which villages were located from the park also influenced HEC intensity, with decreasing conflict incidents as the distance from the forest boundary increases (Lakhar *et al.* 2007). Based on this information it could be possible to predict the seasons and areas of high intensity elephant disturbance.

HEC is a complex problem, which cannot be mitigated through reliance on a single mitigation technique (Sitati & Walpole, 2006). Each field site requires specific deterrence strategies. Moreover, an extensive range of mitigation techniques has shown to be more effective in driving away raiders compared to the use of only a few, as it reduces the possibility of habituation (Hoare, 2001; Parker & Osborn, 2003). The practices employed by farmers in Assam to deter elephants are also wide ranging. Close to MNP, these generally consist in the use of active traditional deterrents such as shouting, drum beating, bursting firecrackers, shining torch lights, and setting fire to raw jute or tires fixed at the end of bamboo sticks, known as "*bolem*" (Fig. 1A; Lahkar *et al.* 2007).

Fig. 2A. Villager holding a *bolem,* which is set on fire during elephant deterrence

2B. *Tangis* is used for keeping watch over rice fields.

Usually, farmers guard their crops on their own, however during peak raiding season two to three neighbouring farmers form groups and construct "*tangis*" as look-out points (temporary tree houses; Fig. 1B; Lahkar *et al.* 2007). Additionally, forest department officials may aid in mitigating human-elephant conflict by firing shots in the air as well as using domestic elephants to drive away crop raiders (Lahkar *et al.* 2007). In areas of high conflict, certain villages near MNP have recently begun cultivating alternative crops to those preferred by elephants, such as patchouli (*Pogostemon cablin*), jetrofa (*Jetrofa* curcas) and *Citrus* spp. (Lahkar *et al.* 2007).

The cost of conserving large animals, like elephants, is often born excessively by farmers living closest to wildlife (Nyhus *et al.* 2005). Recognition of this imbalance has led to the idea of compensation schemes, which in addition to spreading the economic loss should also increase lenience towards wildlife and support for conservation amongst local people (Nyhus *et al.* 2005). Although theoretically attractive, there is little empirical evidence supporting the success of such programmes (Nyhus *et al.* 2005). The compensation system for elephant damage in Assam is generally regarded by farmers as unsatisfactory due to its "lengthy and faulty procedure" (Lahkar *et al.* 2007). At present, the budget provided from Government Central Assistance is "too meagre" to cover cultivators' outstanding claims (M. C. Malakar, Chief Wildlife Warden, Assam, pers. comm.). For this reason, only human deaths resulting from elephant conflict are immediately compensated with Rs. 40,000 – approximately £500. Further claims of crop loss, property damage and injuries are recorded with the hope of reimbursement over the following years (M. C. Malakar, pers. comm.).

This study aims to elucidate correlates for HEC incidents across villages on the fringes of Kaziranga National Park (KNP), Assam, by integrating GIS data on land-use and elephant movement patterns collected by Aaranyak: A Society for Biodiversity Conservation in North East India (NGO) with local information on crop loss and house damage obtained through interviews. Specifically I ascertain whether variables exist to account for discrepancies in intensity within the surveyed area. Additionally, this study analyses local mitigation techniques as well as attitudes towards HEC with a view to suggesting further non-lethal methods of control and possible alternate sources of income. I use the results of my report to recommend future strategies and further research to ameliorate HEC mitigation within this region.

STUDY AREA

The study area comprises 20 villages in Bokakhat circle, Golaghat district, Assam (26° 42' – 26° 33' N, 93° 26' - 93° 41' E; Fig. 3A and B). It covers 32904 ha of which 83.3% is cultivated land and 4.1% forest cover (Agricultural Department, Bokakhat subdivision, 2006). 45.8% of this area is flood prone, while 4.9% is affected by drought (Agricultural Department, Bokakhat subdivision, 2006). Average rainfall within Golaghat district is between 2005-2300 mm and average temperature in winter season is 8°c rising up to 37 °c in summer. Relative humidity is 60-95% (Agricultural Department, Golaghat District, 2006). Kaziranga National Park (KNP; 26° 30' – 26° 45' N, 93° 08' - 93° 36' E) is found adjacent to Bokakhat circle and is one of the principal habitats for Asian elephants within this region (Supplementary Information I; Eastern Assam Wildlife Division, Bokakhat, 2007).

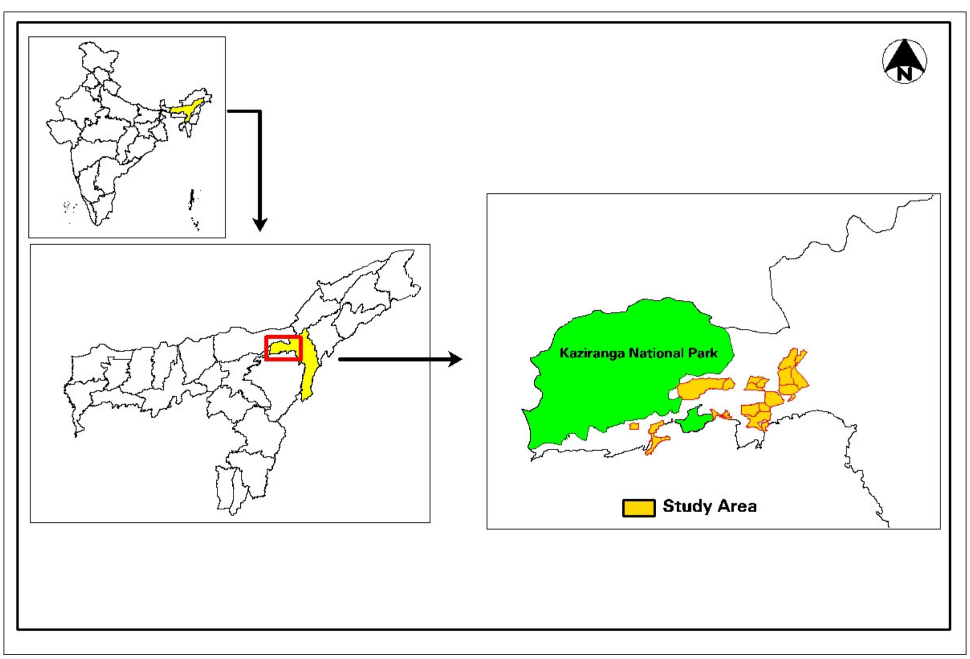

Fig. 3A. The study area is located within Bokakhat circle, Golaghat district, Assam, India

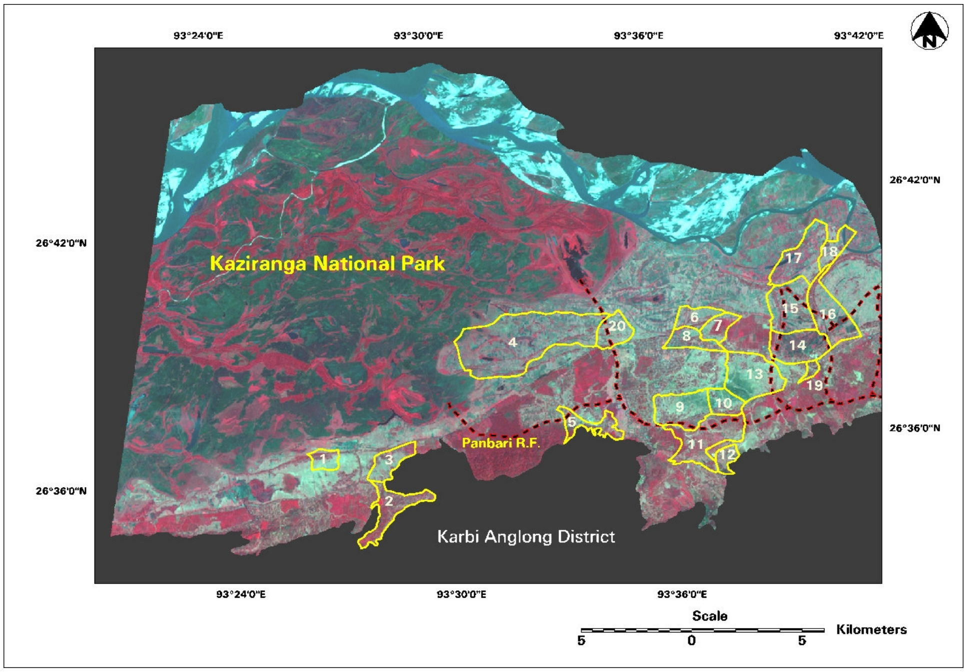

Fig. 3B. Satellite imagery of the study area. It comprises twenty villages (Table S1), whose perimeters are marked in yellow. Red and black tracks represent elephant corridors.

Movement of Elephant Herds

Elephant movement patterns in Golaghat district were determined by Aaranyak (Talukdar *et al.* 2006, 2007). Direct data was obtained by following elephant herds and assessing habitat use, while indirect information was collected from local people, experts and forest guards. Three distinct elephant herds have been identified to move between key habitats in Nambor Reserve Forest (RF) and KNP approximately 3 times a year (Talukdar *et al.* 2007; Fig. 4). The herd recorded closest to my study site comprises 40-50 individuals, and resides in the Deopahar area as well as close to Numaligarth Refinery. The other two herds in this district are of similar sizes and reside closer to Nambor RF.

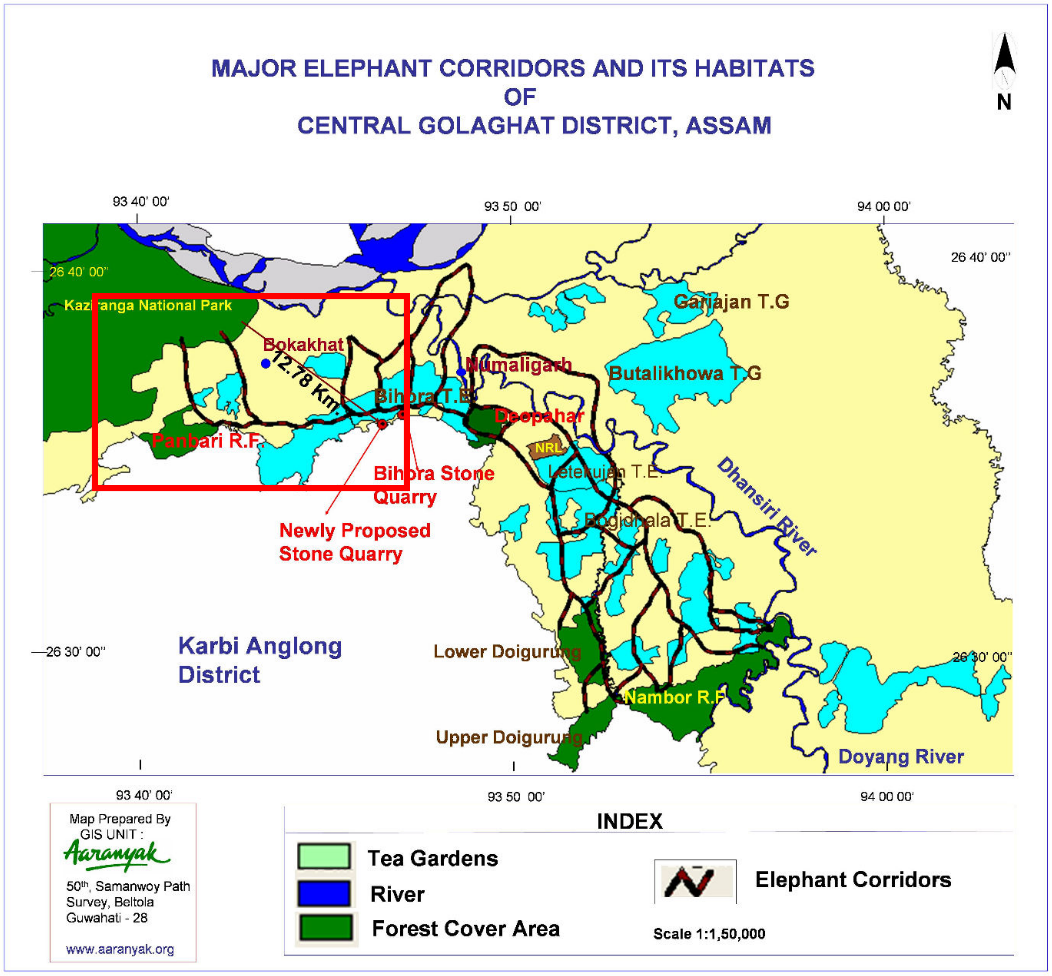

Fig. 4. Major elephant corridors and habitats of central Golaghat district, Assam. Figure from Talukdar *et al*. 2007. Red box indicates my study area.

METHODS

Questionnaire Survey

Information on the intensity of Human-elephant conflict (HEC) and on variables which could be used to predict it was collected from 20 villages throughout June 2007. In order to select my study villages, all villages in Bokhakat circle were stratified according to aerial distance from KNP. Approximate distances were provided by a local journalist, Mr. Uttam Saika. Specifically, four villages at 0-2km, four at 2-4 km, three at 4-6 km, five at 6-8 km and four at 8-10 km from the park were randomly sampled. I chose to stratify by distance since previous studies on HEC showed a relationship with distance from park boundary (Naughton-Treves *et al.* 1998; Hoare 2000; Lakhar *et al.* 2007). The latitude and longitude points for each sampled village were recorded using a Global Position System (GPS) receiver.

To determine correlates for variation in HEC throughout Bokakhat circle, I collected the following information from each village on: (a) agricultural practices (i.e. crop types, harvesting periods), (b) loss to animal depredation (i.e. types of raiding species and rankings of problem wildlife, timing of increased depredation, proportion of crop loss and house damage), (c) mitigation techniques (i.e. order of use) and compensation, (d) characteristics of HEC and attitudes towards it (i.e. change in HEC over time, responsibility for controlling it, further suggestions for its mitigation, perception of threat from elephants).

The above information was collected by semi-structured interviews with both open-ended and structured questions (Milner-Gulland and Rowcliffe, 2007; Supplementary Information II). This interview method was used in order to obtain both quantitative and qualitative data on variation in HEC. When I asked informants to rank certain responses not every response category was mentioned in each village. Furthermore, categories could be ranked the same if so perceived. Interviews were carried out with village leaders and their families through the help of translators. I chose these as my key informants in order to obtain reliable information at the village-level, thus enabling HEC to be analysed on a larger spatial scale. Before collecting data, a pilot study was carried out with the headman of a village which not part of my sample, so as to assess the feasibility of my questions and acquire a notion for the types of answers I would obtain. I was able to assess how long my questionnaire would take as well as add further questions that would be of interest.

Land-use pattern analysis

Satellite data from IRS (Indian Resource Satellite) 1D/LISS III bearing 112/53 (Path/Row) was employed to visualise the land-use patterns in Bokakhat circle. The date of the satellite pass was 16th March 2004. Using ERDAS Imagine v. 8.5, the satellite image was georeferenced into the latitude/longitude coordinate system by Aaranyak (Talukdar *et al.* 2006). Principal landscape element types were digitised and GPS points for each village were superimposed. Proportion of land-use patterns were calculated for each village using ERDAS Imagine v. 8.5.

Data analysis

Data were managed and coded with Microsoft Excel and analysed using R v. 2.4.0 (R Development Core Team, 2006). The response variables for this study were: average proportion of crop loss per year and proportion of house damage over the last 12 months. I was unable to collect information regarding crop loss over the preceding year, as there had been a severe drought causing low agricultural produce. Thus it would have not been sufficiently representative. Explanatory variables are given in Table 1. I represented my all proportion data as counts out of 100 for my statistical analyses.

Non-parametric, chi square tests were carried out to analyse differences in response variables between villages. Spearman's rank correlation was used to test for associations between spatial explanatory variables. I determined significant differences between ranked data by comparing the mean and standard error rankings for each category. Generalised linear models (GLMs) with Poisson or quasipoisson errors were employed for univariate analyses (Crawley, 2007). I carried out multivariate analyses to determine whether any interactions existed between explanatory variables which could influence either indices of HEC. My saturated models included the three terms that explained the highest amount of variation (r^2) within the univariate analyses of my response variables. The models were simplified by deleting non-significant terms and I checked for changes in model fit using a chi-squared goodness-of-fit test. Significance was determined for all analyses at $p=0.05$.

Table 1. Explanatory variables analysed in relation to proportion of crop loss and houses damaged.

Type	Name
Spatial	Distance from park boundary (km)
Spatial	Length of corridor within village (km)
Spatial	Village area (km^2)
Spatial	Proportion of cropland (km^2)
Spatial	Proportion of agriplantation (km^2)
Spatial	Proportion of forested land (km^2)
Spatial	Proportion of water-logged land (km^2)
Village characteristics	Village size (number of households)
Village characteristics	Literacy level (%)
Village characteristics	Dependency on agriculture (% households that are cultivators)
Village characteristics	Type of rice grown
HEC characteristics	Type of herd
HEC characteristics	Point of origin of herd
HEC characteristics	Timing of visit
HEC characteristics	Frequency of visits during periods of highest intensity
HEC characteristics	Were neighbours notified?
HEC characteristics	Was the Forest Department called?
HEC characteristics	Did the Forest Department arrive right away?
HEC characteristics	Was the torchlight used first?
HEC characteristics	Were *tangis* (lookout points) used?
HEC characteristics	Was damage recorded?
HEC characteristics	Did they receive compensation?
HEC characteristics	Do elephants have a right to enter their cultivated land?
HEC characteristics	Are elephants ranked as the most dangerous threat?
HEC characteristics	Was the forest department reported to be responsible for controlling HEC?

RESULTS

Crop loss

Of the 20 villages sampled, 17 were subject to annual crop loss by wild animals (Fig. 5). I found animal depredation was an important issue, as half reported it as their only cause for crop loss.

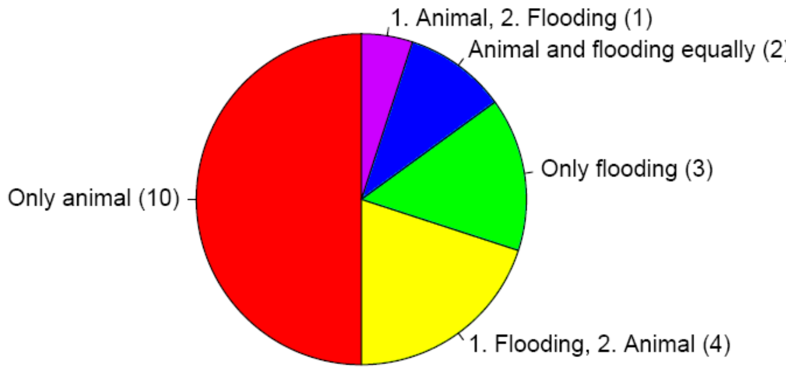

Fig. 5. Causes of crop loss within the sampled villages (1=most important). The number in brackets represents the total respondents in each category.

All respondents reported that rice paddy was the principal crop consumed by wild animals in this region. Every village surveyed grew *xali,* while *boro* was grown in six villages, and *aahu* in four. Like *aahu, boro* is harvested during monsoon season, however it requires a higher water level than *aahu* to grow. Overall, within villages affected by depredation, the average annual reported loss of rice paddy to animals ranged from 5 to 75%, with a mean of 28.12 $\pm$ 12.81% (*n*=17). Indeed, there is a significant difference in proportion of crops loss between villages (X^2 = 244.41, d.f. =16, p=***).

Respondents reported seven principal raiding species: Asian elephants, Asiatic wild buffalo (*Bubalus arnee*), Greater one-horned rhinoceros (*Rhinoceros unicornus*), Hog deer (*Axis porcinus*), Rhesus macaque (*Macaca mulatta)* and Rose-ringed parakeet (*Psittacula krameri*). The number of villages in which each species were reported varied significantly; with elephants being mentioned more often than other species (Fig. 6; Table S1). The annual loss specifically attributed to elephants ranged from 2 to 50% with a mean of 17.12 $\pm$ 6.95 % (n=17). This differed significantly between villages (X^2 = 220.81, d.f. =16, p=***; Fig. 7). Moreover, elephant depredation explained 54.69% of the variance between villages in total crop loss (GLM with quasipoisson errors; B= 1.03 ± 1.01; t=4.20, d.f. =15, p=***).

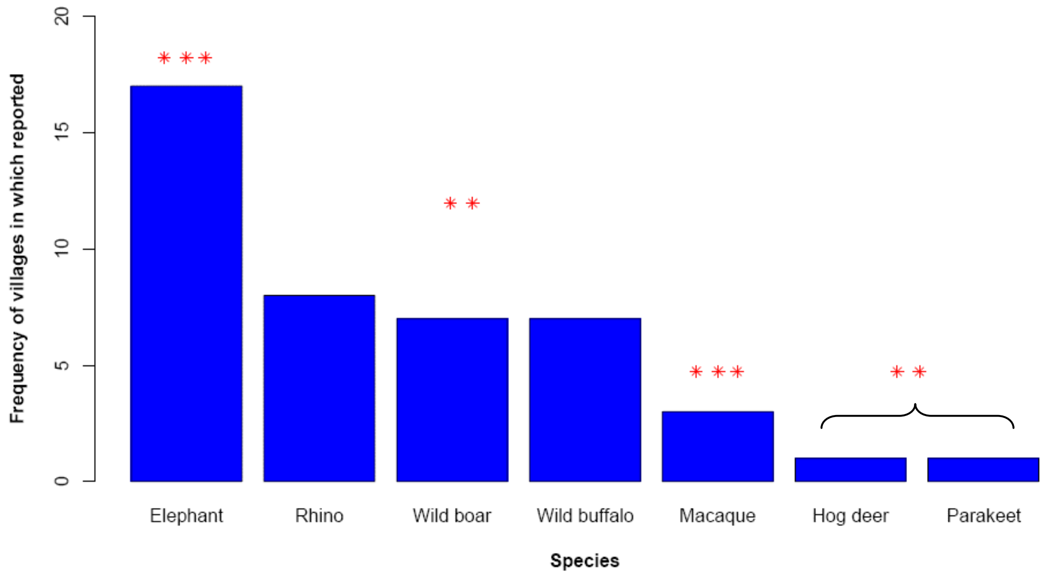

Fig. 6. Frequency of villages in which each raiding species is reported. Stars represent significant differences between collapsed categories (GLM with Poisson errors for interactions between reports of depredation for each species; minimum adequate model simplified from the original in which each species was represented separately; "**"for p<0.01 and "***" for p<0.001).

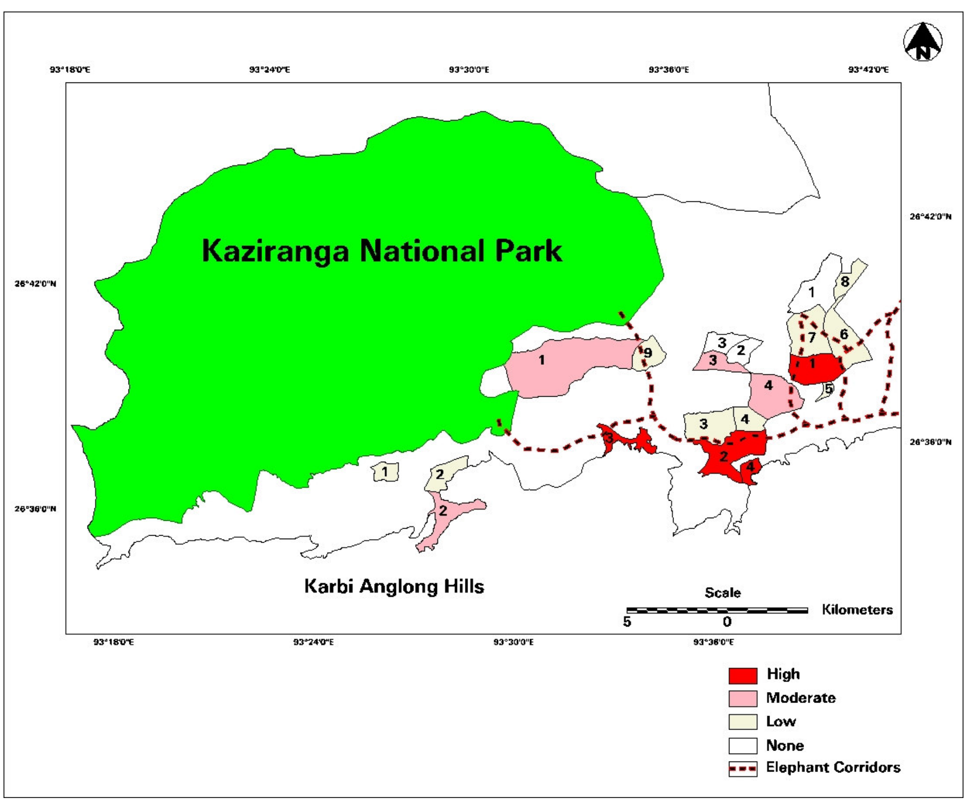

Fig. 7. Elephant crop-depredation varies in intensity within villages on the fringes of KNP (Low= between 1-10%, Moderate=between 10-20% and High=over 20% crop loss). See Table S2 for corresponding HEC intensity village ID.

I found that the proportion of damage reported varied amongst species (Fig. 8). Elephants were responsible for most crop loss, followed by Wild boar, whose damage levels are not significantly different. However, while elephants depredate at high intensity mainly over just a few months of the year (Fig. 9; Table S3), the damage caused by Wild boars is reported to be lower, but continuous. Periods of frequent depredation were mostly reported to occur during the post-monsoon months of October to December, which coincides with the harvesting of *xali*. The months during which *aahu* and *boro* rice varieties are harvested (June – July) were also mentioned slightly more often as periods of increased raiding frequency, however the frequency of reports is not significantly different from winter and pre-monsoons months.

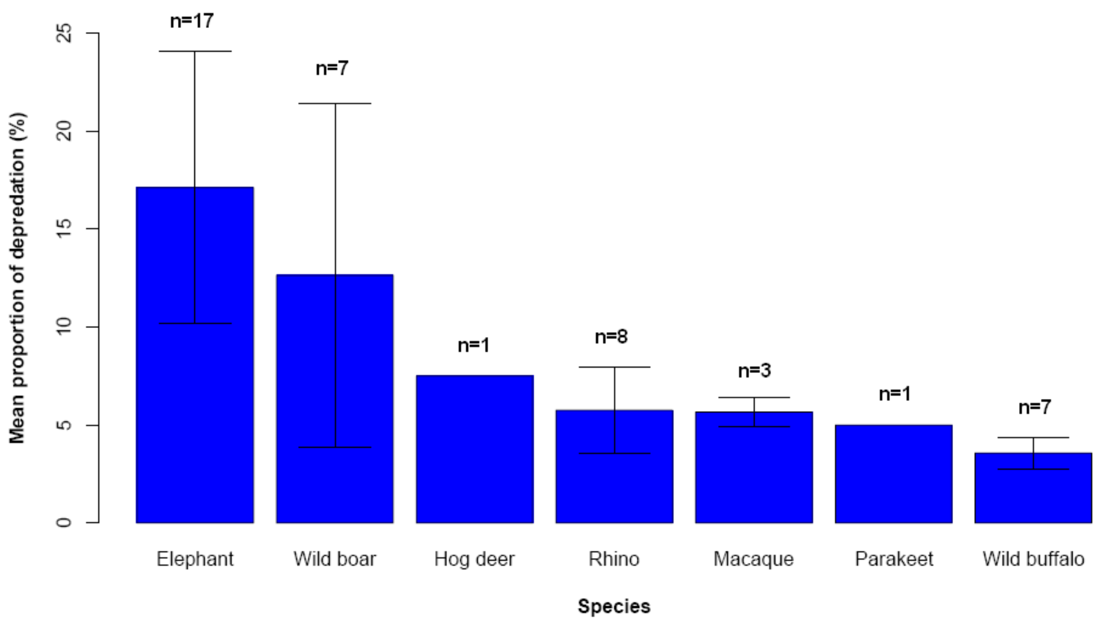

Fig. 8. Mean proportion of depredation caused by each species. Error bars represent the standard error of the mean, "n" indicates the total number of respondents who mentioned the particular category.

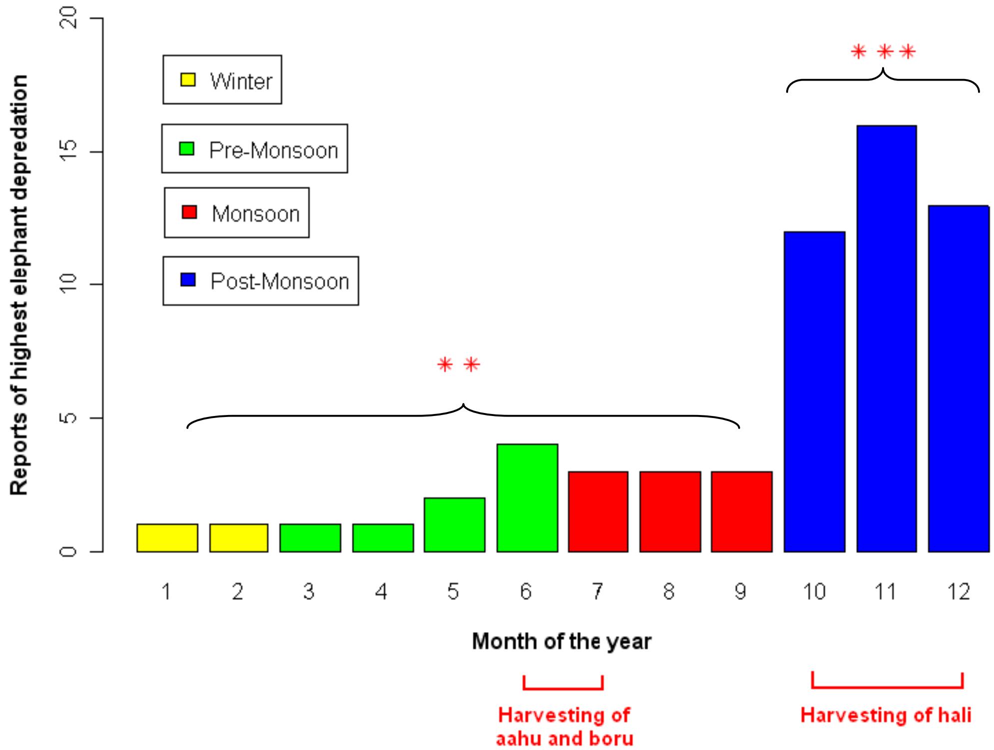

Fig. 9. There are more reports of highest elephant depredation during the monsoon period compared to all preceding months grouped together. Stars represent significant differences between collapsed categories (GLM with Poisson errors for the association between month of the year and reports of highest elephant depredation; minimum adequate model simplified from the original in which each month was represented separately; "**"= p<0.01 and "***"=p<0.001).

House damage

The proportion of house damage over the past 12 months within villages affected by elephant depredation varied from none to 17%, with a mean of 4.18$\pm$ 0.66% (*n*=17). The difference between them is significant (X^2 = 86.31, d.f. =16, p =***.). There is a slight positive correlation between proportion of reported houses damaged and crop loss (Spearman's rank correlation; rho=0.525, d.f. =16, p=*; Fig. 10).

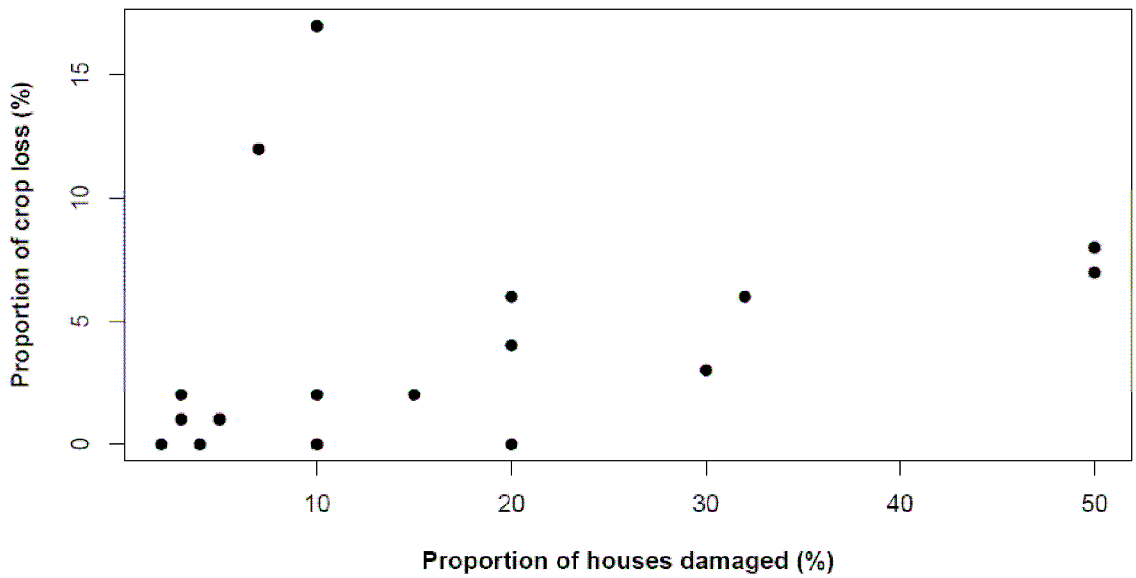

Fig. 10. There is a positive correlation between crop loss and houses damaged (GLM with quasipoisson errors; *B*= 1.05 $\pm$ 0.04, t=1.180, d.f.= 15, p=n.s., r^2=8.02%).

Spatial correlates of HEC

Spatial variables (Table 2) for each village were analysed to determine differences amongst villages as well as relationships between explanatory variables. I analysed differences in land-use patterns between villages since water, shade and nutritious cropland are known to influence elephant movement (Sukumar, 2003). Correlations between spatial variables are listed in Table S4.

Table 2. Spatial correlates measured for each village.

Spatial variables	**Mean ± S.E. (n=20)**
Aerial distance from park boundary (km)	5.32 ± 0.25
Length of elephant corridor (km)	0.68 ± 0.03
Village area (km^2)	2.98 ± 0.18
Cropland area (km^2)	1.13 ± 0.06
Agriplantation (km^2)	0.97 ± 0.02
Forested area (km^2)	0.22 ± 0.001
Water-logged land area (km^2)	0.48 ± 0.001

There are no significant relationships between reported crop loss and the spatial correlates listed above (Table S5). The only variable to which house damage is significantly associated in a negative relationship is the proportion of forested area per village (Fig. 11). Moreover, proportion of forest cover has a strong influence on extent of house damage, as it explains 49.32% of the variance.

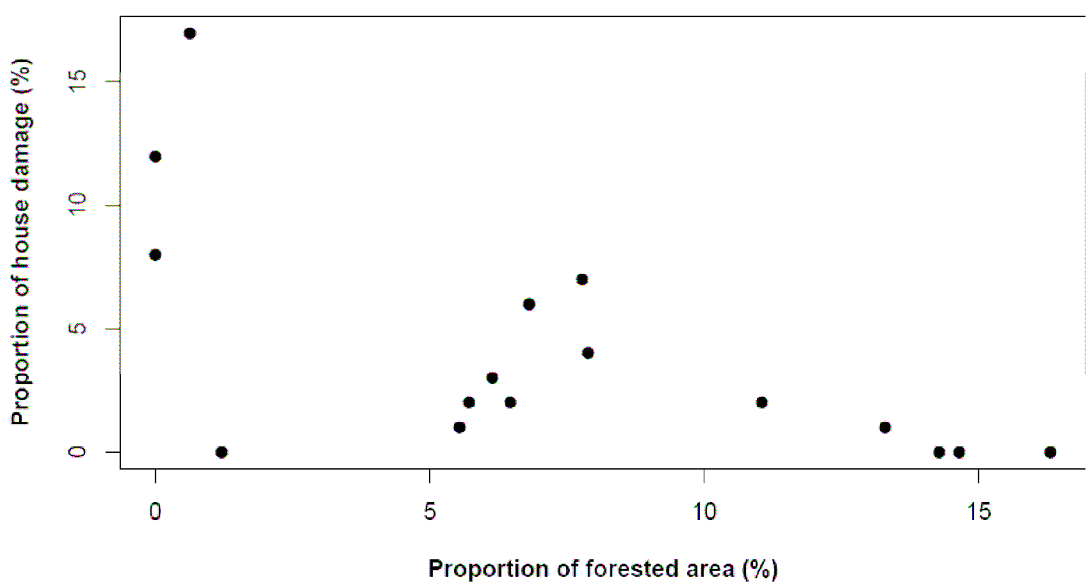

Fig. 11. There is a negative correlation between house damage and forest cover (GLM with quasipoisson errors; *B*=-0.84 ± 1.04, =-3.87, d.f. =15, p=**, r^2=49.32%).

Village correlates of HEC

There is no correlation between any of the village-level characteristics (Table 3; Table S6). Since it has previously been shown that villages that are habituated to farming amidst elephants are also less quick to blame elephants for crop depredations (Fernando *et al.* 2005), I looked at the relationship between elephant damage and age of village in my study area, however found no correlation (Table S7). I also did not find any associations between other village characteristics and the response variables.

Table 3. Village characteristic variables.

Village characteristics	**Mean ± S.E. (n=20)**
Size (number of households)	324 ± 1769.5
Age (years)	136.30 ± 299.81
Literacy level (%)	58.25 ± 13.17
Dependency on agriculture (%)	69.6 ± 17.32

General characteristics of HEC

Most villages reported that elephants raided in groups during night time and during months of increased frequency this mainly occurred every day. I find no significant trend in the origin of raiding herds (Fig. 12). All respondents reported they knew elephants were raiding since they witnessed the occurrence directly. Usually, they reported first hearing elephant movement and feeding, which would alert them of their presence. Moreover, respondents are warned by a particular smell emitted from the animals. When elephants broke into houses, the informants said that the main reason was to reach rice stores. All village households are informed when elephants are raiding. However, in only two cases were neighbouring villages also alerted (Fig. 12). Of 17 respondents, most said they called Forest Department when elephants started to raid (Fig. 12). When the Forest Department was notified, 12 respondents out of 15 mentioned that forest guards came immediately to help drive elephants away (Fig. 12). Overall, although there are distinct patterns in most of the above characteristics, I find nothing to support the hypothesis that villages that do not display these trends were affected by a significantly different level of HEC (Table S8).

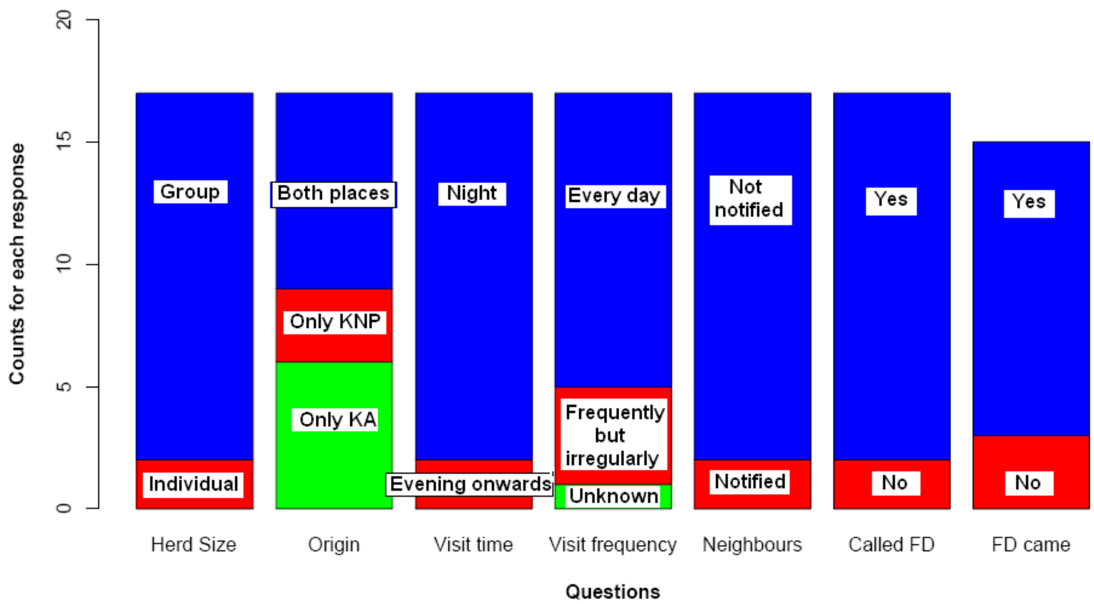

Fig. 12. Responses to questions regarding the behaviour of raiding individuals. Each section of the columns represents different types of responses for each question.

HEC mitigation

All respondents reported using active deterrence methods that involve scarring animals with either bright lights (i.e. *bolem,* torchlight, oil lamp) or loud sounds (i.e. shouting, sound bomb and drumming). Additionally, nine informants mentioned that they constructed *tangis* during harvest season, from which they guarded their fields at night. This was always carried out in groups. *Bolem,* torchlight, shouting and sound bombs are widely used throughout my study area, followed by the construction of seasonal *tangis.* Drumming and oil lamps are used the least, perhaps because the more popular techniques are usually employed first (Fig. 13; Table S9).

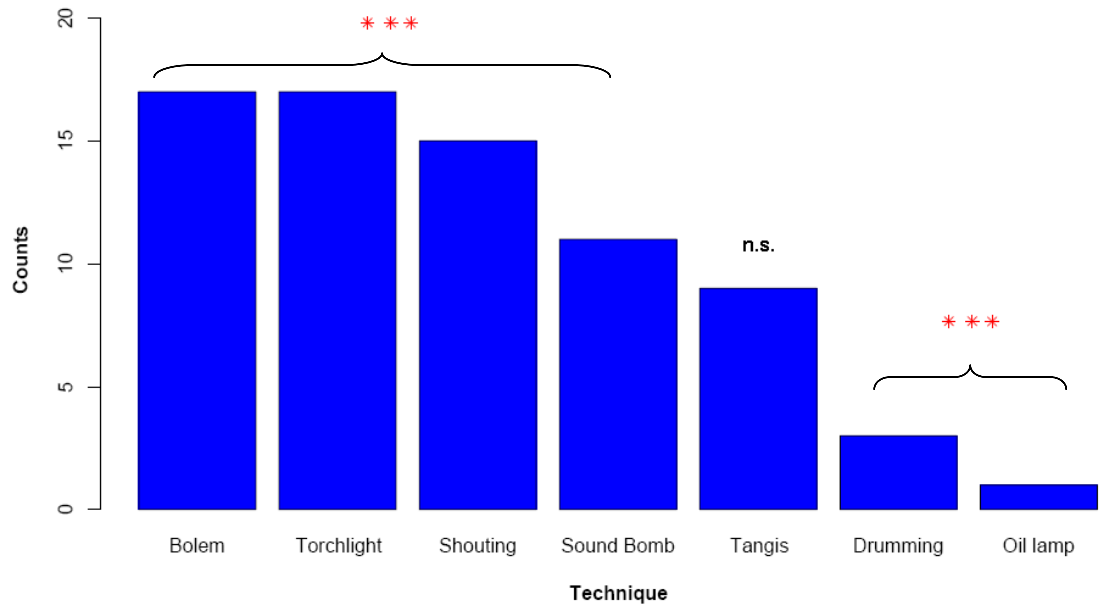

Fig. 13. Extent to which each technique is used throughout the study area. Stars represent significant differences between collapse categories (GLM with Poisson errors for the association between mitigation technique and order of use; minimum adequate model simplified from the original in which all techniques were represented separately; "***" for $p<0.001$, "n.s."for $p>0.05$).

Specifically, torchlight is used first above of all other practices, followed by shouting, and then *bolem* (Fig. 14). Shouting is such an important practice that five respondents even said they shout continuously throughout their efforts to deter raiding elephants. Oil lamps, sound bombs and drumming are used as a last resort, perhaps because they are more expensive than other deterrence methods. Although torchlights are mainly used first in driving the elephants away, I found that there was no reduction in crop loss or house damage if they were instead used later on (Table S10). Whether or not villages constructed *tangis* to aid in guarding their fields also did not affect HEC levels (Table S10).

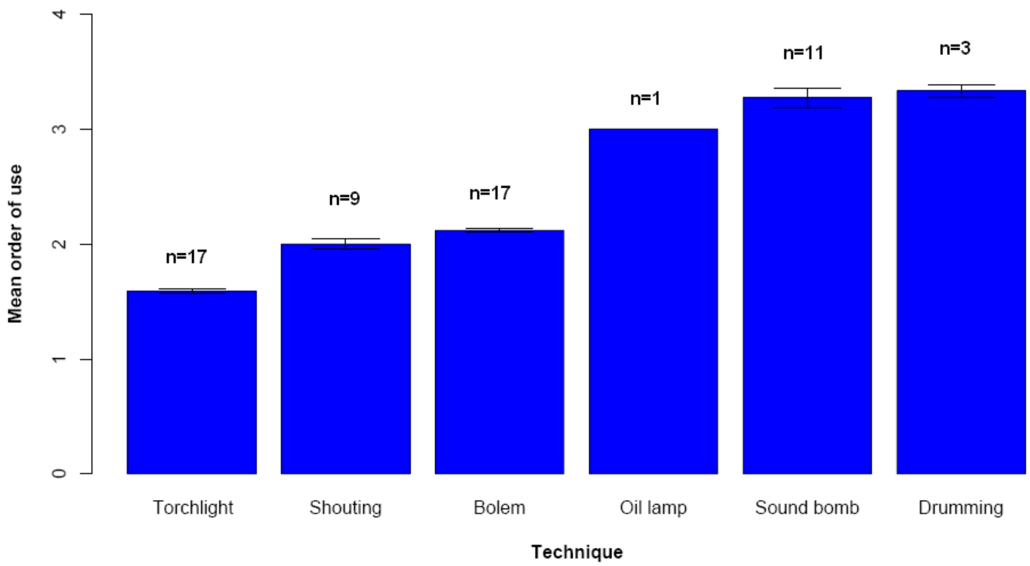

Fig. 14. Mean order in which mitigation techniques are used during elephant depredation. Error bars represent the standard error of the mean, "n" indicates the total number of respondents who mentioned the particular category.

HEC compensation and attitudes

Almost all villages stated that they recorded the extent of elephant damage in at Forest Department Offices in Bokakhat (Fig. 15). One respondent said his village did not record loss because there would be "no benefit in doing so", another because "they had no idea they could receive any". Another informant reported that his village only recorded house damage, since "crop loss was never compensated". Of those who reported their loss, the majority did not receive reimbursement (Fig. 15). A few villages, however, were compensated for injuries. One respondent reported that their village did receive compensation also for house damage; however this was from the Civil Administration rather than the Forest Department. Respondents from all villages within the study area reported that they received no benefit from having elephants nearby, and that instead, they represented a detriment to their agricultural production. Nevertheless, most strongly agreed that elephants had a right to pass through their area (Fig. 15), mainly out of their respect for the Hindu deity, Ganesha, which is represented as man with an elephant head. The only respondent who disagreed did so because he believed that elephants should "stay in the jungle". Three were unsure about whether elephants had the right to cross their land on account of the extent of damage which they cause. When asked whether there had been any change in HEC over the past 10 years, informants principally reported that it had either stayed the same or increased (Fig. 15). Interestingly, three respondents said that HEC had decreased, which could suggest a change in elephant home range since two of these are from villages that are located next to one another (Village ID 14-15).

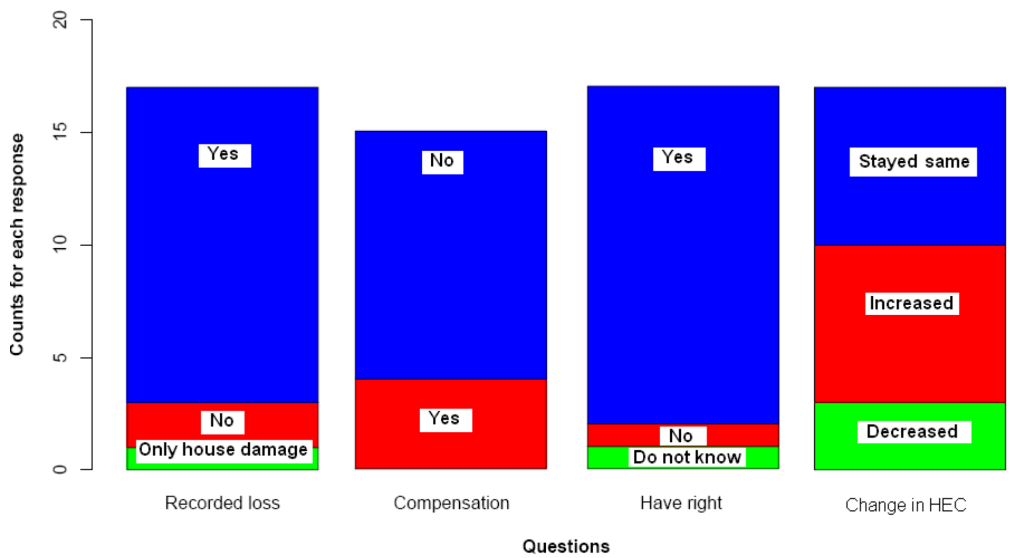

Fig. 15. Responses to questions regarding how elephant damage compensation is managed as well as perceptions of elephant depredation. Each section of the columns represents different types of responses for each question.

Out of the above responses, the only significant association with HEC indices that I found was between those who were compensated for their loss and the extent of reported crop loss (r^2= 59.77%; Table S10). Whether one was compensated or not explained 59.77% of the variation in crop loss between villages. Specifically, respondents whose villages were not compensated for the damage loose a significantly lesser amount of their crops to elephants per year (mean= 9.27 $\pm$ 2.01%, *n*=11) than those who are compensated (mean=33 $\pm$ 19.5%, *n*=4). This suggests that although the compensation scheme is generally unsatisfactory, those that are more heavily affected by HEC do receive some aid.

In order to determine to what extent respondent's considered elephants a danger to their personal safety, I asked them to rank various types of threat (Fig. 16). I found that road accidents were more of an issue than elephant damage. Moreover, elephant-related accidents were not a significantly higher threat than agricultural injuries or damage provoked by flooding. I found no association between extent of elephant damage and whether elephants were reported as the most important threat (Table S10).

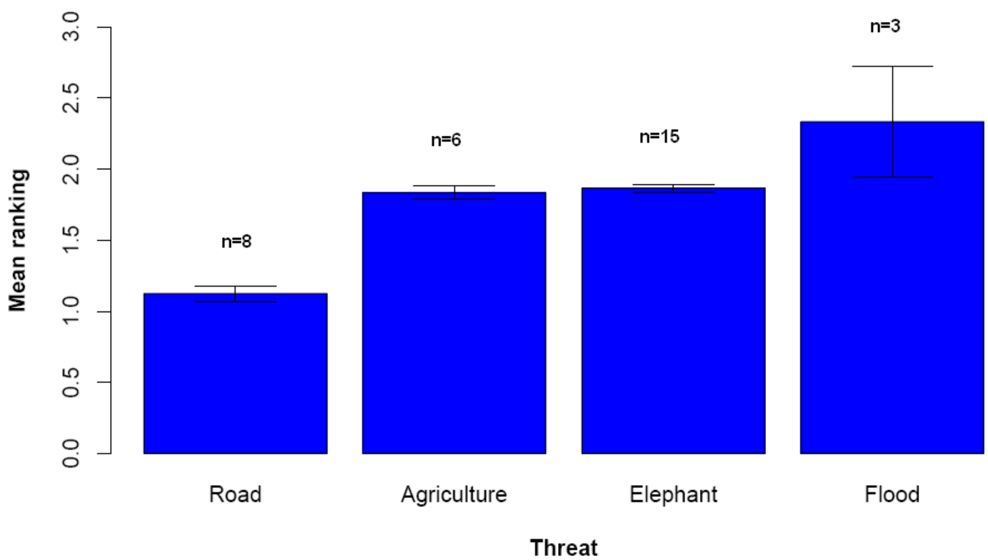

Fig. 16. Comparing mean ranking for threat types (1=most dangerous). Error bars represent the standard error of the mean, "n" indicates the total number of respondents who mentioned the particular category.

There is a clear difference in the extent to which the Forest department (FD) are held responsible for controlling HEC compared to other suggested parties (Fig. 17). The FD is perceived as accountable for dealing with this issue because elephants are generally considered by local people as the "forest department's animals" (Lakhar *et al.* 2007). Interestingly, I find no correlation between placing the responsibility on the FD and reported intensity of elephant damage, demonstrating that it is not because they have higher losses that they blame the forest officials for unsatisfactory levels of patrolling (Table S7). Other suggestions for responsible bodies include: the general public, the government, the villagers themselves and the United Liberation Front of Assam (ULFA), who was said to "hide in forest areas, therefore pushing out the elephants from their natural habitat". One respondent also suggested the illegal loggers should take responsibility for the degrading natural habitat.

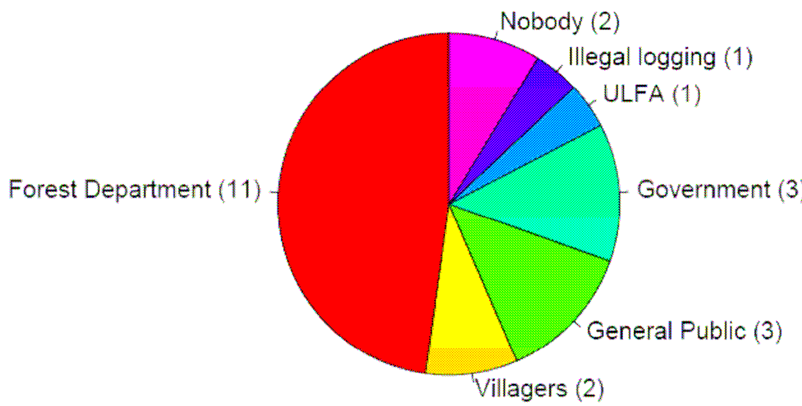

Fig. 17. Respondent views on who should be responsible for controlling HEC. Informants often mentioned more than one responsible party.

When respondents were asked if they had any suggestions to improve HEC mitigation in their village, ten ideas were put forward (Fig. 18). However, no idea was mentioned significantly more times compared to others. Of the suggestions put forward, five respondents reported that they thought it would help if the FD could increase patrolling in their area, reiterating their idea of elephants being "forest department animals". Interesting ideas for mitigation include selling kerosene at a subsided price for lighting *bolem*, creating fences using teagardens, digging trenches, using electric fencing, shining large halogen lights on rice paddy and providing villages with more deterrence equipment. Five respondents said that in order for long-term mitigation, there is need to "improve elephant habitat".

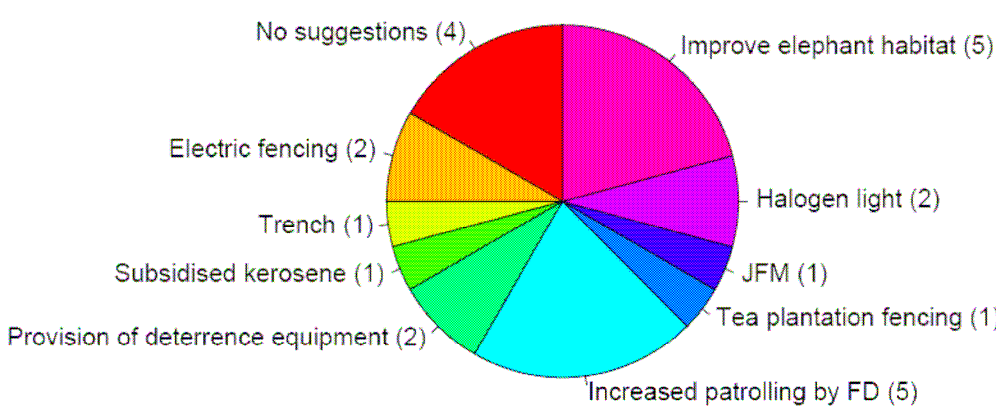

Fig. 18. Respondent suggestions for how HEC mitigation could be improved. Informants often mentioned more than one suggestion.

Multivariate analysis

I modelled reported crop loss as a function of proportion of forested land, whether villagers were compensated and whether they believed elephants had a right to cross their agricultural land in a saturated model. Through model simplication, I found no interactions between these terms. The minimum adequate model only included compensation as its explanatory term. For my multivariate analysis of reported house damage, I incorporated proportion of forested area, origin of the herd and whether the villagers used a torchlight first as my explanatory variables within a saturated model. Again, there were no interactions between terms, and my minimum adequate model comprised of only the proportion of forested land as its explanatory variable. The above results indicate that there are no other factors influencing the significant associations between the proportions of reported crop loss with compensation, and reported house damage with forested area.

DISCUSSION

Spatial correlates of HEC

My analyses confirm that Human-elephant conflict (HEC) represents a definite issue within the fringe villages of Kaziranga National Park (KNP). Not only were elephants reported to cause damage in 17 out of 20 sampled villages, but they also brought about the highest amount of crop loss compared to other depredating species. Moreover, my study confirms the widespread characteristics of both seasonal and nocturnal raiding across Africa and Asia. Similarly to Hoare *et al.* (1999), but in contrast to most studies on HEC around protected areas (PAs; Naughton-Treves *et al.* 1998; Hoare, 2000; Lakhar *et al.* 2007), I discovered that discrepancies in crop loss and house damage did not decrease with greater distance from the park boundary. Elephant home ranges are on average 150 km² (Sukumar, 2003), hence the scale of my study area (between 0 – 10 km from KNP) may be too small to detect any differences in HEC intensity. Alternatively, problem elephants in this region may not originate directly from KNP. Rather, HEC could occur while elephants migrate from KNP to Nambor Reserve

Forest (RF) using established, forested corridors that are adjacent to human settlements. In order to accurately establish the provenance and habitat use patterns of depredating herds it would be necessary to tag individuals and follow them over extended time-periods.

Elephant raiding patterns are known to be notoriously unpredictable (Naughton-Treves, 1998). Indeed, of all the spatial variables measured for this study, the only relationship which I found is between proportions of house damage and forested area. Specifically, a higher proportion of house damage is reported in villages with lower forest cover, corroborating the positive association between extents of transformed land and level of problem elephant activity (Sukumar, 1991). As the elephant's natural habitat decreases, HEC could take place if individuals continue to treat encroached land as part of their home range (Sukumar, 2003). Moreover, reductions in forest cover will result in decreases in palatable browse species, thus potentially attracting elephants to nutritious grain stores (Sukumar, 2003). To ascertain whether there is a definite association between degraded forest and HEC incidents, a more detailed vegetation analysis is required. Through such a study it would be possible to make recommendations regarding which browse species could be re-planted in order to aid in satisfying the elephant's nutritional requirements.

Interestingly, the proportion of reported crop loss is not significantly related to any of the spatial variables within this study. This may be because village-level crop loss is harder to quantify than house damage, which could result in slightly inaccurate measures. Furthermore, there is an inherent bias in reported crop loss as affected individuals are likely to increase their deficits (Nyhus *et al.* 2005). House damage, on the other hand, may be harder to falsify, as this information is generally well known within small villages. In order to reduce this issue, future studies could involve monthly questionnaire surveys to determine average crop loss over shorter time periods (Milner-Gulland and Rowcliffe, 2007).

Evaluating mitigation techniques

The mitigation techniques employed by farmers in Bokakhat circle are similar to the short term, active deterrence methods used for controlling HEC throughout Africa and Asia (O'Connell-Rodwell *et al.* 2000; Osborn & Parker, 2003; Sukumar *et al.* 2003; Osborn & Hill, 2005). Both shouting and using fire in order to scare elephants away are traditional techniques, practiced for centuries (Osborn & Parker, 2003). Interestingly, although within Bokakhat circle, using torchlight is the most widespread and important type of deterrence method, I found no evidence to suggest that it was more effective than other techniques. This indicates that farmers may use this technique mainly out of tradition rather than efficiency. Hence, I would recommend that further, simple, active deterrence strategies be tried out in this region. This has proven to be an especially useful strategy where government support for HEC is lacking (Osborn & Parker, 2003). It is well known that Chillies (*Capsicum* spp.) have been effective in discouraging African elephants from raiding crops (Parker & Osborn, 2006; Sitati & Walpole, 2006). Although previous trials with Chillies have been unsuccessful in Assam (B. Talukdar, Aaranyak, pers. comm.), I would suggest testing these again on a larger scale. Specifically, the use of "pepper dung" should be re-evaluated (Osborn & Anstey, 2002). This practice entails mixing elephant dung with ground chillies and drying them in the sun. These are then burnt along field boundaries in order to create a noxious smoke (Osborn & Anstey, 2002). An increase in guarding also has shown to be especially beneficial in reducing HEC as it provides early warning to farmers (Sitati & Walpole, 2003). Organised guarding does not currently take place in the study villages, and it may be that a more organised approach may improve mitigation. My study did not show a relationship between the use of lookout points (*tangis*) and HEC, indicating that they may not be well positioned. Further studies could be carried out in this region to determine where best to construct these posts.

Respondents suggested a wide range of potential mitigation strategies in order to improve HEC within their region. Three of these short-term possibilities are passive methods of deterrence, such as putting in place electric fencing, digging trenches around their land, and creating "tea plantation fencing". Electric fencing is technically effective

(Taylor, 1999), however the materials, installation and maintenance costs are impractical for large-scale applications in developing countries (Osborn & Parker 2003). The use of trenches to prevent individuals traversing cropland is not a better option, since calves often fall inside and become stranded from their mothers (A. Swargowari., Indian Forest Service, pers. comm.). The idea of using tea plantation as natural fencing could act as a buffer zone by putting more distance between the forest and agricultural land. Respondents suggested that both the forest department and local NGOs should provide them with equipment for deterrence. Specifically, they asked for a halogen light to shine on their fields in order to deter potential raiders. This may not be an effective strategy since the elephants are likely to become habituated (Sitati & Walpole, 2006). However, there is scope for NGOs providing equipment for elephant deterrence since, in 2006, Aaranyak supplied villages in Golaghat district with a jeep, searchlights, crackers and kerosene oil for burning *bolem* amongst other items. To determine whether NGO support can reduce raiding incidents as well as improve attitudes towards HEC it would be beneficial to assess the situation of these villages after a few years.

Reimbursing the loss

A further interesting relationship, which my study reveals, is the association between reported crop loss and compensation. Although the compensation system in Assam is not particularly well regarded, I find that villages that have been compensated are affected by higher crop loss. Interestingly, most of these report having received reimbursement for injuries rather than actually for their agricultural produce. However, since higher crop loss should also correspond to more human-elephant interactions there is still a link between these two factors. Mitigating HEC through compensation schemes is an important method for aiding subsistence farmers, however when government funds are lacking, such a system is difficult to run.

Since I have found forest cover to be negatively correlated with reports of house damage, a potential source of revenue for villages with low forest cover could be practicing Joint Forest Management (JFM; Malhotra *et al.* 2004). The principal aim of JFM is to promote active participation and collaboration between communities and forest officials in protecting and managing forests. Not only can this strategy improve elephant habitat, but it could also aid communities in generating income from the forest by harvesting certain plants in a sustainable manner. Specifically, the forest department aids villagers during the initial stages of JFM by providing seeds for long rotational timber species such as *Tectona grandis, Gmelina arborea* and *Michelia champaca*, which can only be harvested after 50-60 years (A. Swargowari., pers. comm.). During this period, villagers are able to make use of short rotational non-timber forest products, such as bamboo (*Bambusa* spp.) and fig trees (*Ficus hispida*) for fodder, and local medicinal plants like *Cinchona ledgeriana, Aegeles marmelos,* and *Plantago ovata*, since these are suitable for growth in elephant habitat (Malhotra *et al.* 2007). The main issue with JFM is that is it hard to convince villagers to accept this strategy, as it would involve changing their traditional way of life (Malhotra *et al.* 2004).

Attitudes towards HEC

Similarly to most studies on HEC (Osborn & Hill, 2005), I found that within Bokakhat circle it was common to bestow the responsibility of controlling HEC upon Forest Department guards. In order to improve HEC mitigation, it has been suggested that there is need to decentralise the responsibility for controlling elephant damage to the farmers (Osborn & Parker, 2003). However, this shift can only take place if substantial local strategies exist to combat the issue (Osborn & Parker, 2003). In contrasts with most studies on HEC (Osborn & Hill, 2005). I find that is that local people believe elephants "have a right" to pass through their agricultural land. As previously mentioned, this may be due primarily to their respect for the Hindu god Ganesha. Their reverence is demonstrated by the fact that none of the villages that reported elephant depredation stated that elephants were harmed or killed during conflict incidents. This feeling of respect is extremely important for the conservation of the Asian elephant, and should be encouraged by local researchers within this area.

Interestingly, I find that elephants are not considered as severe a threat to personal safety compared to road or agricultural accidents. This could suggest that, within my study area, HEC is not as serious an issue as in other parts of Assam. To support this hypothesis, there is evidence that out of the three herds that have been recorded moving within Golaghat district, those causing most damage are located closer to Nambor RF (Talukdar *et al.* 2007). Furthermore, reports of HEC within the fringe villages of Manas National Park (MNP) are considerably higher (Lakhar *et al.* 2007). While the average proportions of reported crop raiding and house damage in Bokakhat circle were 17.12% and 4.18% respectively, those caused by herds between 0 to 6 km from the boundary of MNP were approximately 60% and 40% (Lakhar *et al.* 2007). To further substantiate the intensity of man-elephant interactions within Bokakhat circle a more extensive study should be carried out comprising a greater sample at varying distances from the park.

Concluding remarks

Overall, this study contributes to Aaranyak's ongoing analysis of HEC patterns within Golaghat district. I highlight the negative association between proportion of reported house damage and forest cover, thus providing an incentive for further analyses concerning the elephant's preferred food types. This relationship also leads on to recommending Joint Forest Management as an alternative income generation activity. Furthermore, my analyses show that the principal mitigation techniques within this region are not used because of their efficiency but mainly out of tradition, indicating that there is much scope for trying out simple, low-cost active deterrence methods such as burning "pepper dung" or increased guarding. Lastly, I demonstrate that, on the whole, HEC intensity within Bokakhat circle is not as high as other areas of Assam. This should be taken into consideration when proposing site-specific mitigation strategies.

A weakness of this study is that it has been carried out on too small a spatial scale to detect differences in intensity throughout the whole of the elephant's range. Thus, it would be advisable for future studies to administer questionnaire surveys on villages distributed between the two principal elephant habitats of KNP and Nambor RF. Moreover, to determine more specifically the origin of raiding herds as well as their movement patterns, it would be ideal to tag individuals. Additional research on this topic should try to reduce the bias which reports of crop loss may be subject to by carrying out surveys within shorter time intervals. Lastly, it would be interesting to continue to assess the local people's attitude to HEC, which could give an indication of the effectiveness of new mitigation techniques and livelihood strategies. Human-elephant conflict in Assam has taken place since the advent of agriculture, and will carry on if our burgeoning human population continues to encroach upon natural habitat. For the conservation of the Asian elephant it is imperative that researchers continue investigating correlates of elephant damage so as to improve present relations as well as prevent conflict from occurring in the future.

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SUPPLEMENTARY INFORMATION

I. Information on Kaziranga National Park.

Kaziranga National Park was inscribed in the list of World Natural Heritage Sites in 1985. It has had an important influence on the 74 villages within Bokakhat circle since it became a Reserve Forest in 1908. It comprises 430 km² south of the Brahmaputra River, in which alluvial inundated grasslands and tropical wet evergreen and semievergreen forests (Hajra & Jain, 1978) harbour a diverse range of species, including the endangered One-horned rhinoceros (*Rhinoceros unicornus*), Asian elephant (*Elephas maximus*), Bengal Tiger (Panthera tigris), Swamp deer (*Cervus duvaucelii*), Wild buffalo (*Bubalus arnee*), Hoolock gibbon (*Hoolock leuconedys*), Gangetic dolphin (*Platanista gangetica*), Bengal florican (*Housbaropsis bengalensis*) and the Great Indian Hornbill (*Buceros bicornis;* Eastern Assam Wildlife Division, Bokakhat, 2007).

II. Questionnaire on Agricultural Production

NB. I chose to describe only the most pertinent responses in this report; 1 *bigha* = 0.137 ha =13.7 km².

General

1) How many households in this village?

2) What are the ethnic groups living in this village?

3) How long has this village been here?

4) In general, what is the education level of this village?
- What educational institute is in this village?
- What is the literacy level?

5) What are the main professions of this village? How many people in each profession?

6) What is the number of types of houses in this village?
- Bamboo houses
- Assam-type houses (stone and concrete with tin roofs)
- High-rise RCC (rock, concrete and cement).

7) How long does it take you to reach Bokakhat?

8) What mode of transport do you use?

9) How many people have Mobile phones?

Cultivated crops

10) What is the total cultivated area of this village?

11) What crops/vegetables/fruit are cultivated in this village? How many *bigha* each?

12) How much land does each household own?

13) Is the same area of land always cultivated or do you move your crops around?

14) Do you follow certain agricultural practices at specific times of the year?

15) How much do these different crops contribute to the village income? List for each crop-type.

- All
- Distinct percentage (ask which percentage)
- None

16) What are the reasons for crop-loss? Please rank.

17) How many *bigha* of crops have you lost over past 12 months? and for each crop-type?

18) What is the average crop-loss per year?

19) How many households have been affected by crop loss over the past 12 months?

20) During which months does most loss occur? Does this vary between crops?

21) Are roughly the same amount of crops lost every year? If not, why?

- Yes
- No
- Don't know

22) Compared to 10 years ago has the crop-loss pattern changed?

- Increased
- Decreased
- Same

Animal depredation

23) If animal depredation has been mentioned, do you know by which animals the crops are depredated? How many *bigha* of crop-loss attributed to each animal over past 12 months? Rank by importance.

24) How do you know that it is that specific animal?

- Signs – if so, which ones?
- Direct observation
- Don't know

25) Does animal depredation vary throughout the year? When is it greater? Do different animals depredate more at different times?

26) During months of increased frequency, how often does raiding take place in a month?

27) Compared to 10 years ago, have you seen any changes in the crop-raiding pattern of animals?

28) Do you reserve any part of your crops especially for animals?

If elephants are mentioned

---

29) Do villagers usually see the elephants grazing on crops?

- Yes
- No
- Sometimes
- Don't know

30) Can you show me where the raids have taken place? Is there an area which is usually raided?

31) What is usually the composition of raiding groups?

- Tusker – adult with tusks, usually part of herd.
- Makhna – adult lone male, without tusks.
- Entire herd

32) When does this usually take place?

- Morning
- Afternoon
- Night

33) If this is not witnessed, what signs are attributed to elephant depredation?

- Droppings
- Crops damaged in a certain way
- Debarkation.
  Elephants were known to be nearby
- Don't know

34) Have you ever noticed crop raiding to take place more frequently following a certain type of weather?

35) How many injuries have elephants caused to members of this village over past 12 months? Minor (scratch, sprain) or major (bone fracture, head injury).

36) Were they \ accidental encounters or were elephants provoked when trying to drive away?

37) How many properties damaged over past 12 months? - what type? Residential houses, grocery shops? Which area of village (use GPS)?

38) How many human/elephant casualties over past 12 months? Where?

39) Compared to 10 years ago has the number and type of HEC incidents changed?

40) Who should be responsible for preventing these incidents?

41) Have you received any compensation?

42) Do you record your crop-loss in the forest department?

43) What are the elephant-deterrence methods practiced in this village?
(list of methods practiced in the area, Rank by most used).

44) Has the village always used these methods?

45) Are these carried out alone or in a group?

46) Are other members in the village informed when an elephant is raiding or are only those whose crops are being eaten involved?

47) Do you inform other villages when this is taking place?

48) Do you know what other types of mitigation techniques are used by other villages?

49) Any suggestions about how it could be possible to further reduce elephant depredation?

50) Would you consider trying out growing alternative crops, that are less palatable to elephants, to reduce HEC?

Attitudes towards HEC

51) In general, what are the benefits of living in this particular area? Any other costs apart from animal depredation?

52) Any benefits of having elephants nearby? Any costs apart from crop depredation?

53) Do you think elephants have a right to be here? If not, why not

- Strongly agree
- Agree
- Netural
- Disagree
- Strongly disagree

54) Please rank which threats are more important to your personal safety:
Road accidents

- Elephants
- Agricultural accidents
- Natural calamities (forest fire or flood)

III. Statistical results

N.B. Significance levels are represented by: "n.s." for $p>0.1$, "." for $p<0.1$, "*" for $p<0.05$, "**" for $p<0.01$ and "***" for $p<0.001$.

Table S1. GLM with Poisson errors for interactions between reports of depredation for each species (minimum adequate model).

Explanatory factor levels	**z-value**	**d.f.**	**p-value**
Intercept (Elephant)	11.682	3	***
Rhino, Wild boar and Wild buffalo	-2.604	3	**
Macaque	-3.790	3	***
Hog deer and Parakeet	-2.770	3	**

Table S2. Village ID for Fig. 2B and 5.

ID	Name	HEC intensity	HEC intensity village ID
1	Lukhurakhonia	Low	1
2	Panbari N.C.	Medium	2
3	Geleka Mikic	Low	2
4	Dipholupathar	Medium	1
5	Borbhetta	High	3
6	Kumaraniati	None	3
7	Ikorajangrant	None	2
8	Basagaon	Medium	3
9	Jugigaon	Low	3
10	Daffaloda Gaon	Low	4
11	Naharjan T.E.	High	2
12	Naharjan Gaon	High	4
13	Gormur	Medium	4
14	Rajabari	High	1
15	Khotialhuli	Low	7
16	Nepalikhuti	Low	6
17	Juganiati	None	1
18	Paranganiati No.1	Low	8
19	Lokhowjan Gaon	Low	5
20	Agaratoli	Low	9

Table S3. GLM with Poisson errors for the association between month of the year and reports of highest elephant depredation (minimum adequate model).

Explanatory factor levels	**z-value**	**d.f.**	**p-value**
Intercept (Months 1-9)	3.257	10	**
Months 10-12	6.730	10	***

Table S4. Spearman's rank correlations between spatial variables. Significant associations are bolded and italicised.

Variable a	Variable b	rho	p-value
Village area	Cropland	0.24	n.s.
Village area	Agriplantation	0.08	n.s.
Village area	Forest	-0.004	.
Village area	Water body	-0.43	n.s.
Village area	Distance from KNP	-0.19	n.s.
Village area	***Corridor length***	***0.73***	**
Cropland	Agriplantation	0.02	n.s.
Cropland	***Forest***	***-0.55***	*
Cropland	Water body	-0.33	n.s.
Cropland	Distance from KNP	0.06	n.s.
Cropland	Corridor length	0.02	n.s.
Agriplantation	Forest	-0.04	n.s.
Agriplantation	Water body	-0.2	n.s.
Agriplantation	Distance from KNP	0.13	n.s.
Agriplantation	Corridor length	-0.02	n.s.
Forest	Water body	0.37	n.s.
Forest	Distance from KNP	-0.40	.
Forest	Corridor length	0.01	n.s.
Water body	Distance from KNP	-0.13	n.s.
Water body	Corridor length	-0.41	.
Distance from KNP	Corridor length	0.18	n.s.

Table S5. GLMs with quasipoisson errors for the associations between response variables and spatial variables (*B* and S.E are in log scale). Significant associations are bolded and italicised.

Response	Explanatory	*B*	S.E.	t-value	d.f.	p-value	r^2
Crop loss	Distance from park	0.04	0.07	0.64	15	n.s.	2.86
Crop loss	Length of Corridor	-0.07	0.23	-0.31	15	n.s.	0.71
Crop loss	Village area	-0.01	0.08	-0.11	15	n.s.	0.09
Crop loss	Crop land	0.01	0.02	0.44	15	n.s.	1.42
Crop loss	Agriplantation	-0.01	0.021	-0.42	15	n.s.	1.24
Crop loss	Forest	-0.07	0.04	-1.55	15	n.s.	14.99
Crop loss	Water body	-0.01	0.02	-0.44	15	n.s.	1.51
House damage	Distance from park	0.14	0.09	1.53	15	n.s.	14.43
House damage	Length of Corridor	-0.35	0.32	-1.11	15	n.s.	8.14
House damage	Village area	-0.14	0.14	-0.99	15	n.s.	7.41
House damage	Crop land	0.04	0.02	1.88	15	n.s.	25.03
House damage	Agriplantation	-0.04	0.02	-1.60	15	n.s.	13.19
House damage	***Forest***	***-0.17***	***0.04***	***-3.87***	***15***	**	***49.32***
House damage	Teagarden	0.14	0.42	0.33	15	n.s.	0.71
House damage	Water body	-0.01	0.02	-0.26	15	n.s.	0.48

Table S6. Spearman's rank correlations between village characteristics.

Variable a	Variable b	rho	p-value
Literacy	Agricultural dependency	0.05	n.s.
Literacy	Size	-0.34	n.s.
Literacy	Age	-0.29	n.s.
Agricultural dependency	Size	-0.1	n.s.
Agricultural dependency	Age	-0.05	n.s.
Size	Age	0.25	n.s.

Table S7. GLMs with quasipoisson errors for the associations between response variables and village characteristics (*B* and S.E are in log scale).

Response	Explanatory	B	S.E.	t-value	d.f.	p-value	r^2
Crop loss	Village age	0.0009	0.002	0.50	15	n.s.	1.69
Crop loss	Village size	0	0	0.10	15	n.s.	0.07
Crop loss	Literacy	-0.002	0.01	-0.19	15	n.s.	0.26
Crop loss	Agricultural dependency	-0.90	0.81	-1.11	15	n.s.	8.26
Crop loss	Intercept (hali)	NA	NA	12.45	14	***	
	Hali and aahu	NA	NA	-0.93	14	n.s.	
	Hali and boru	NA	NA	-1.34	14	n.s.	14.86
House damage	Village age	0.001	0.002	0.51	15	n.s.	1.67
House damage	Village size	-0.0009	0.001	-0.88	15	n.s.	4.72
House damage	Literacy	-0.02	0.01	-1.93	15	.	21.42
House damage	Agricultural dependency	0.180	1.13	0.16	15	n.s.	0.17
House damage	Intercept (hali)	NA	NA	5.49	14	***	
	Hali and aahu	NA	NA	-1.23	14	n.s.	
	Hali and boru	NA	NA	-0.88	14	n.s.	16.3

Table S8. GLMs with quasipoisson errors for the associations between response variables and characteristics of HEC incidents.

Response	Explanatory factor levels	t-value	d.f.	p-value	r^2
Crop loss	Intercept (Group)	12.88	15	***	
Crop loss	Single	-0.69	15	n.s.	3.79
Crop loss	Intercept (Both KA and KNP)	8.90	14	***	
Crop loss	Only KA	0.10	14	n.s.	
Crop loss	Only KNP	-0.51	14	n.s.	2.67
Crop loss	Intercept (Evening visits)	5.87	15	***	
Crop loss	Night	-0.73	15	n.s.	3.59
Crop loss	Intercept (Everyday)	11.95	14	***	
Crop loss	Frequently	-0.92	14	n.s.	6.52
Crop loss	Intercept (Neighbours not notified)	10.2	15	***	
Crop loss	Notified	0.46	15	n.s.	1.41
Crop loss	Intercept (Did not call FD)	6.78	15	***	
Crop loss	Called FD	-1.03	15	n.s.	6.03
Crop loss	Intercept (Did not come right away)	4.55	14	***	
Crop loss	Came right away	0.43	14	n.s.	1.58
House damage	Intercept (Group)	5.53	15	***	
House damage	Single	-0.83	15	n.s.	6.07
House damage	Intercept (Both KA and KNP)	3.15	14	**	
	Only KA	1.88	14	.	
House damage	Only KNP	-1.16	14	n.s.	33.57
House damage	Intercept (Evening visits)	1.87	15	.	0
House damage	Night	-0.10	15	n.s.	0.07
House damage	Intercept (Everyday)	3.53	14	**	0
House damage	Frequently	0.69	14	n.s.	3.07
House damage	Intercept (Neighbours not notified)	4.98	15	***	0
House damage	Notified	-0.66	15	n.s.	3.04
House damage	Intercept (Did not call FD)	1.88	15	.	0
House damage	Called FD	-0.10	15	n.s.	0.07
House damage	Intercept (Did not come right away)	0.96	14	n.s.	0
House damage	Came right away	0.72	14	n.s.	4.41

Table S9. GLM with Poisson errors for the association between mitigation technique and order of use (minimum adequate model).

Explanatory factor levels	**z-value**	**d.f.**	**p-value**
Intercept (*Bolem,* Torchlight, Shouting and Sound bomb)	20.976	4	***
Tangis	-1.429	4	n.s.
Drumming and Oil lamp	-3.902	4	***

Table S10. GLMs with quasipoisson errors for the associations between response variables and HEC mitigation, compensation and attitudes towards it.

Response	Explanatory factor levels	t-value	d.f.	p-value	r^2
Crop loss	Intercept (Not torch first)	10.14	15	***	
Crop loss	Torch first	-1.02	15	n.s.	7.05
Crop loss	Intercept (Did not use *tangis*)	6.29	15	***	
Crop loss	Used *tangis*	1.87	15	n.s.	21.20
Crop loss	***Intercept (No compensation)***	***10.31***	***13***	***	
Crop loss	***Compensation***	***4.41***	***13***	***	***59.77***
Crop loss	Intercept (Only house damage recorded)	0.10	14	n.s.	
Crop loss	Do not record loss	1.04	14	n.s.	
Crop loss	Record loss	0.73	14	n.s.	12.22
Crop loss	Intercept (Do not have right)	1.53	14	n.s.	
	Unsure	1.28	14	n.s.	
Crop loss	Have right	0.49	14	n.s.	35.95
Crop loss	Intercept (Not ranked as 1st threat)	9.36	15	***	
Crop loss	Ranked as 1st threat	1.11	15	n.s.	7.39
Crop loss	Intercept (FD not responsible)	9.27	15	***	
Crop loss	FD responsible	-0.60	15	n.s.	2.52
House damage	Intercept (Not torch first)	7.58	15	***	
House damage	Torch first	-2.67	15	*	36.32
House damage	Intercept (Did not use *tangis*)	2.44	15	*	
House damage	Used *tangis*	0.85	15	n.s.	4.94
House damage	Intercept (No compensation)	1.96	13	.	
House damage	Compensation	0.97	13	n.s.	9.46
House damage	Intercept (Only house damage recorded)	0	14	n.s.	
House damage	Do not record loss	0.96	14	n.s.	
House damage	Record loss	0.54	14	n.s.	19.90
House damage	Intercept (Do not have right)	3.49	14	**	
House damage	Unsure	-0.81	14	n.s.	
House damage	Have right	-1.62	14	n.s.	17.14
House damage	Intercept (Not ranked as 1st threat)	3.18	15	**	
House damage	Ranked as 1st threat	1.09	15	n.s.	7.07
House damage	Intercept (FD not responsible)	2.50	15	***	
House damage	FD responsible	0.65	15	n.s.	2.82