

## Patterns of Crop Raiding by Asian Elephants in a Human-Dominated Landscape in Southeastern Sri Lanka

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### Introduction

Human-elephant conflict (HEC) describes occurrences of crop raiding, infrastructural damage and disturbance of daily activities of people due to elephants, which can result in injury or death of people and elephants (Hoare 2000). Sri Lanka currently holds roughly 10% of the global wild Asian elephant population (Santiapillai & Jackson 1990) and supports the highest elephant density in Asia (Fernando *et al.* 2005). Ensuring the survival of elephants in the wild is nationally important due to the elephant being considered a socio-cultural and religious icon, an umbrella-species and one of the most financially valuable species in terms of tourism (Santiapillai & Wijeyamohan 2004). HEC is the primary threat to the survival of elephants in Sri Lanka (Fernando *et al.* 2005). The present levels of high conflict contribute to developing negative attitudes towards elephants, particularly where they exist outside protected areas (Fernando *et al.* 2005). Therefore, the chief challenge to their conservation is the reduction of the present level of conflict.

The main management strategy in Sri Lanka to conserve elephants and mitigate HEC is to confine elephants within protected areas. This has been pursued by 'driving' resident elephants outside protected areas, and translocating "problem animals" from conflict areas, into national parks, around which electric fences are erected (Fernando 1997). However, these strategies have been ineffective in mitigating HEC or conserving elephants (Fernando 1997). Therefore new, strategies based on scientific information need to be developed and implemented.

Crop raiding by elephants is a complex problem that may vary enormously from one area to the next (Hoare

2001). Also every field site has specific characteristics and it is unlikely that any single mitigatory method will work in all situations (Osborn & Parker 2003). Therefore, mitigation of crop raiding requires an understanding of the temporal patterns of crop utilization by elephants, and the factors influencing them (Naughton-Treves 1998). However such studies have been limited in Sri Lanka and elsewhere within Asian elephant range. We studied the utilization of crops by wild Asian elephants for a period of one year in southeastern Sri Lanka with the objective of describing and explaining the basic patterns of crop raiding in the region.

### Methodology

The study was carried out in the South East Dry Zone (SEDZ) of Sri Lanka from June 2005 to May 2006. This region is characterized by intense agricultural activity as well as a number of large protected areas. Crop raiding was monitored in four localities abutting the Yala-Lunugamvehera National Park complex, namely Kotiyagala, Okkampitiya, Gonaganara and Mattala (Fig. 1). The climate was subtropical monsoonal with three distinct seasons. The rainfall occurred primarily during the Northeast monsoon from September to December and a lesser amount in March and April from inter-monsoonal rains. The dry season extended from May to mid September, with the maximum drought occurring in August and early September. The average annual precipitation ranged from 1000 to 2000 mm. Natural vegetation of the region was dominated by dry mixed evergreen forest and thorn scrub. Individual based small-scale agriculture was the major livelihood of the people in the region. Irrigated paddy farming, and permanent and shifting cultivation ("chena") of other crops were the predominant agriculture types in the area.



**Figure 1.** Map of the study area and study localities.

Crop deprecations by elephants were monitored following a standardized data collection protocol (Hoare 1999) and modified to avoid the problem of exaggeration by farmers (Tcamba 1996; Hedges *et al.* 2005). The collected data included date, location, characteristics of damage and the size class, sex and social grouping of elephants involved. See Campos-Arceiz *et al.* (2009) for more details on the data collection protocol.

Statistical analyses were conducted using different types of linear models in R, a language and environment for statistical computing. Initially we fitted a full model including the response variable of interest and all independent variables. The effect of each factor was later tested applying a Likelihood Ratio Test (LRT) of reduced models (missing the variable tested) over the full model. Factors were considered significant at  $P$  values lower than 0.05.

## Results

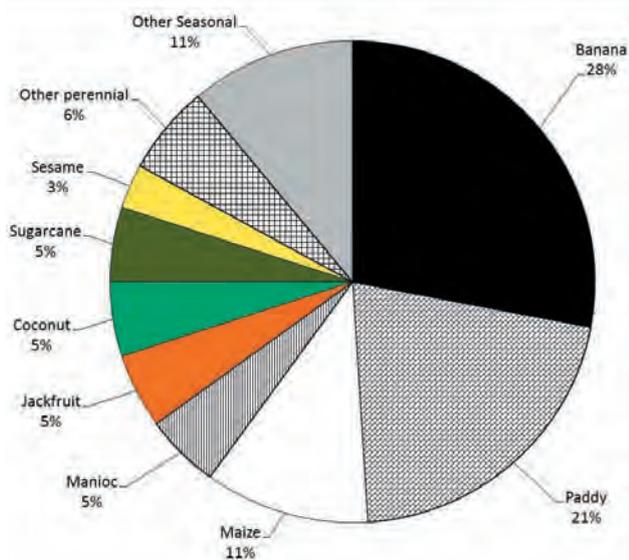
In all, 383 separate crop damage incidents were recorded in the four sampling areas. Of all the incidents, 39%, 29%, 19% and 13% occurred in Okkampitiya, Kotiyagala, Mattala and Gonaganara respectively. The frequency of occurrence of crop damage per km<sup>2</sup> for each locality was 3.5, 2.1, 1.8

and 1.3, corresponding to Okkampitiya, Kotiyagala, Mattala and Gonaganara areas respectively.

During the study, 25 species of crops were identified and all suffered damage from elephants to some extent. Four species of crop (chili, peanut, onion, sesame) were subject to damage by trampling only. Of all incidents, 17.5% related to damage of more than one type of crops, corresponding to 16.4%, 38.8%, 9.0% and 35.8% in Okkampitiya, Kotiyagala, Mattala and Gonaganara areas respectively. Of all reported incidents in 95% damage was due to consumption and the rest by trampling (Fig. 2).



**Figure 2.** Elephant footprints in the paddy field.



**Figure 3.** Proportion of raiding incidents by elephants related to different types of crops.

Raiding of banana, paddy and maize was responsible for 28%, 21% and 11% of incidents respectively. Thirteen crop species were included in the category of “other seasonal crops” and contributed to 11% of all incidents. Perennial crops manioc, jackfruit, coconut and sugarcane contributed equally with 5% of incidents each. “Other perennial crops” included 4 species (drumsticks, mango, papaya, teak), which contributed to 6% of the raiding incidents (Fig. 3).

Raiding of banana, paddy, maize, manioc and coconut occurred in the entire study area but in varying proportions at different locations. In Kotiyagala and Okkampitiya, banana, paddy, maize and manioc contributed to over two thirds (83.1% and 69.6% respectively) of the incidents (Fig. 3). In Gonaganara and Mattala they contributed to about half the incidents (40.7% and 53.0% respectively). In Okkampitiya, banana raiding was responsible for 45.3% of incidents. In Kotiyagala, paddy damage consisted of 39.7% of incidents. Sugarcane raiding incidents mainly occurred in Gonaganara consisting of 25.6% of incidents. Sesame damage occurred only in Mattala with 19.3% of incidents. Jackfruit raiding was not reported from Mattala (Fig. 4).

Elephants damaged crops in all growth stages from planting to harvest, but in different proportions. In all the areas together, 75% of raiding incidents were associated with mature crops. Damage to intermediate and early stage crops corresponded to 15% and 10% of raiding incidents respectively.

The range of raiding incidents occurring per month across all areas was 0 to 20 cases (Fig. 5). The mean

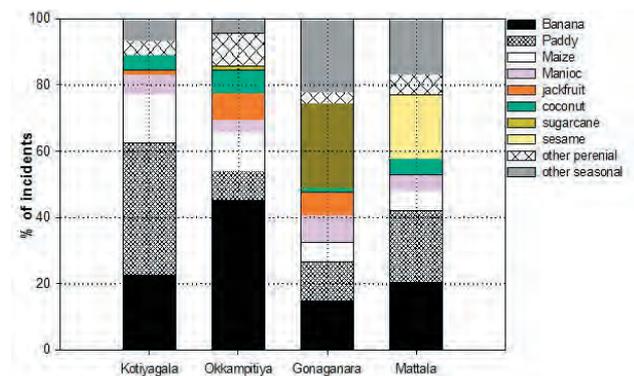
value of crop raiding incidents per month and area was 4.08, 9.25, 8.00 and 12.58 for Gonaganara, Kotiyagala, Mattala and Okkampitiya respectively. The differences in the monthly number of crop raiding incidents between areas were statistically significant ( $df = 39; P < 0.0001$ ).

Elephants raided crops throughout the year with two peaks of damage, one occurring during the dry season (Aug-Sep) and the other in the rainy season (Jan-Feb) (Fig. 6). The frequency of raiding incidents in the rainy season was higher than in the dry season. There was a highly significant difference in the frequency of occurrence in raiding incidents between different months of the year ( $df = 28; P < 0.001$ ).

Male elephants were responsible for 88 % of all incidents. The proportion of female family groups involved in crop damage incidents was very low. Male elephant(s) raided crops throughout the year and at all times in higher frequency than female groups (Fig.6) Female groups did not contribute to crop damage throughout the year. The frequency of female group raiding crops was higher in the post rainy season (Jan-Mar) when compared to other times of the year.

## Discussion

In our study area in southeastern Sri Lanka, the annual level of crop raiding was 2.2 incidents per  $km^2$ . Sukumar (1990) reported 603 - 955 ‘days’ of raiding in one year, in a study area of 45.45  $km^2$  with 12 villages in South India. Although the number of raiding incidents were not reported, even taking one incident per ‘day’ of raiding, the mean number of raids in south India amounts to 17.15/ $km^2$ . The actual number of incidents is likely to be much higher. When compared to Sukumar (1990), very low frequencies of crop raiding incidents were observed in southeast Sri Lanka. The level of crop raiding by African elephants in Tanzania reported by Malima *et al.* (2005) was 4.1

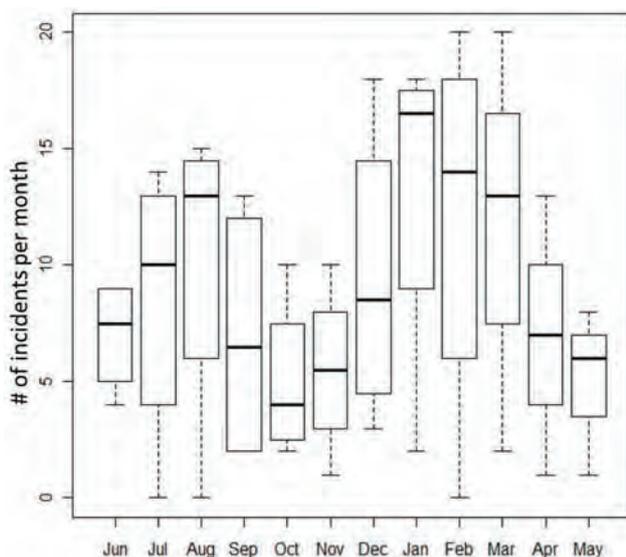


**Figure 4.** Proportion of raiding incidents related to types of crops in different study locations.

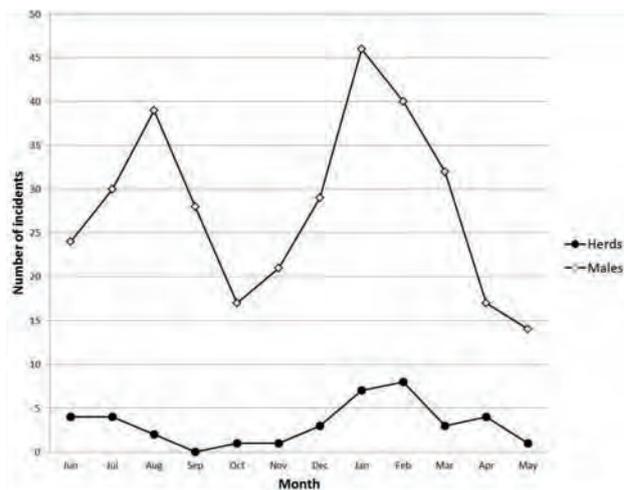
incidents per km<sup>2</sup> (1239 raiding incidents in study area of 300 km<sup>2</sup>) per year in 38 villages in the eastern part of the Selous Game Reserve in Tanzania. Therefore, although still almost double, the frequency of crop raiding incidents reported from Tanzania was more similar to that from this study than to that reported from South India.

The occurrence of crop damage was dissimilar across the study localities and the average number of incidents was significantly different between localities. The number of crop raiding incidents per km<sup>2</sup> in Okkampitiya was higher and Mattala was lower than the total mean number of incidents. Variations in raiding frequency may be caused by differences in intensity of crop protection methods, crop availability and type of cultivated crops, elephant density in the surrounding area, and quality and availability of wild forage. However, there were no obvious major differences in elephant densities and availability of wild forage between the four study localities. Therefore the reason for the difference in overall frequency of crop raiding incidents between areas may have been due to crop related factors.

All 25 species of crops cultivated in the study area were damaged by elephants. Therefore crop damage by elephants was widespread. Fernando *et al.* (2005) reported 24 crop species as consumed by elephants in Kahalle in Northwest Sri Lanka. Kahalla also being in the dry zone of Sri Lanka a similar number of crops as in this study can be expected to be cultivated there. Campos-Arceiz *et al.* (2009) described damage in at least 30 different crops in SE Sri Lanka. Therefore, it can be assumed that most cultivated crops are consumed by elephants across the dry zone of Sri



**Figure 5.** Distribution of the number of monthly crop raiding incidents occurring across the study area.



**Figure 6.** Monthly variation of different elephant groups involved in crop damage.

Lanka. Thus the degree of overlap between the food choice of elephants and people is very high.

Banana (Fig. 7) had the highest damage among crops in the study area. This may be due to a number of facts. Banana was available throughout the year hence sustained greater cumulative damage than seasonal crops. To a raiding elephant, it was easier to gather than other perennial crops because it grew in dense stands. Elephants consumed the entire plant, which required little effort in processing because of its succulent nature. Unlike other perennial crops such as coconut, jack and mango, banana was cultivated far from settlements. Therefore the risk to elephants in raiding banana was comparatively low.

Three types of crops, banana, paddy and maize contributed to the majority (60%) of damage incidents. These were also the most common crops available in the area. In Kotiyagala, elephant damage to paddy was more than twice compared to other localities. This was probably due to the practice of rain-fed paddy cultivation inside the forest during the rainy season in Kotiyagala but not in the other areas. Banana damage in Okkampitiya was more than twice as in other areas, probably due to differences in extents of the banana plantations and somewhat lower levels of deterrent measures.

Raiding of maize in different areas occurred corresponding to its abundance, with more raiding incidents in Kotiyagala and Okkampitiya than Gonaganara and Mattala. The less abundant crops such as manioc, jackfruit (Fig. 8) and coconut were raided less frequently. Therefore raiding of a particular crop seemed to be related to its abundance. Damage to “other perennial crops” was comparatively high in Okkampitiya area due to damage to cultivated teak



**Figure 7.** Damaged banana trees.

plants in home gardens. Damage to the category “other seasonal crops” was comparatively high in Gonaganara area due to incidents of seasonal vegetable raiding. The raiding of some crop species such as jackfruit, sesame and sugarcane, were recorded only in some areas due to their occurrence only in the particular area.

The palatability and nutrient content of crops at any given growing stage is higher when compared to wild forage (Sukumar 1989). Due to this reason elephants may raid crops in all stages of growth from planting up to harvest. Three fourths of the crops raided by elephants in the study area were in the mature stage. Therefore we found that they raided mature crops more than the other growth stages. This may be because the crop material that can be consumed per unit time feeding is higher when crops are mature. In addition, the nutritional value of crops increases when they mature. Most raiding incidents of perennial crops occurred in the mature stage of growth, possibly due to the greater abundance of mature stage plantations.

Natural fodder decreases in availability and quality in the dry season. Therefore the differential in availability and quality between crops and natural fodder increases greatly in the dry season. If elephants raid crops mainly because of nutritional differences between natural fodder and cultivated crops, or insufficiency of natural fodder, occurrence of crop damage during the dry season should be higher. However, we found comparatively higher crop raiding in the rainy season.

Many of the cultivated crop fields in the dry season were located in close proximity to human settlements and were protected by farmers more energetically due to the high market price of agricultural products during the dry season. Therefore raiding crops may

have higher risk for elephants during this time, which may be an alternative explanation for the lower crop raiding in the dry season.

Most seasonal crops matured during the post rainy season. Though rainfall was low during this time, wild forage was abundant. Therefore the greater availability of nutritive mature crops, rather than any shortage in wild forage, better explains the greater damage in this season. This corresponds with the peaks of damage described for other study sites in Asia (Sukumar 1990; Campos-Arceiz *et al.* 2009) and Africa (Bhima 1998). Therefore we conclude that raiding by elephants may not be driven by deficiency of natural fodder but by availability and preference of crops.

Most of the raiding incidents in the study area were caused by males. Thus, most ‘problem elephants’ in this region are males. Our results are consistent with previous studies (Fernando *et al.* 2005; Campos-Arceiz *et al.* 2009), in southern India (Sukumar 1989), northern India (Williams *et al.* 2001), and in African savanna (Bhima 1998), where males were noted to raid much more than female groups. These results suggest different behavioral strategies between adult males and female-led herds, with males more ready to assume the risks of crop raiding than females in a “high risk-high gain” behavior related to their reproductive strategies (Sukumar & Gadgil 1988). The fact that female herds managed to obtain their required resources without frequently feeding on crops further strengthens the view that crops are not a necessary component of the diet of elephants in the SEDZ of Sri Lanka.

Our findings suggest that reducing accessibility of elephants to crops should be the main approach to human-elephant conflict mitigation. Methods such as crop guarding, elephant barriers and land-use



**Figure 8.** Jackfruit tree uprooted by elephants.

planning to minimize edges etc. are likely to be more effective than actions such as habitat enrichment and supplementary feeding.

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