Patterns of crop raiding by wild ungulates and elephants in Ramnagar Forest Division, Uttarakhand

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Abstract: Crop raiding is a major form of human–wildlife conflict that not only affects livelihoods of farmers living close to forest areas but also jeopardizes the objective of wildlife conservation. In this study, we report patterns associated with crop raiding based on periodic field inspections of 95 crop fields spread across 16 villages in India. Average raided area of the field was highest in seedling stage (21%). Fields closer to the forest edge incurred higher damage in the seedling (22%) and mature stages (7%) than fields farther from the forest edge, although this was not statistically significant. Guarding was found to be ineffective in decreasing crop raiding, with no statistical difference in the mean area of damage between guarded and unguarded fields. Cheetal (*Axis axis*), sambar (*Rusa unicolor*), nilgai (*Boselaphus tragocamelus*), and wild pig (*Sus scrofa*) were the main raiders in fields close to the forest edge whereas nilgai and wild pig were chief raiders in fields farther from the forest edge. Results of this study suggest that in the study area, wild pig and nilgai are more problematic species than elephants (*Elephas maximus*), which are reported to cause the most damage in other landscapes.

Key words: Crop raiding, elephant, human–wildlife conflict, Ramnagar Forest Division, wild ungulates

CROP RAIDING IS a major form of human–wildlife conflict, and its mitigation has become crucial to realize long-term wildlife conservation. It can be defined as wild animals moving from their natural habitat into agricultural land to feed on the crops that humans grow for their own consumption and trade (Sillero-Zubiri and Laurenson 2001). Such a conflict negatively affects both wildlife as well as local farmers. Economic loss due to crop damage is just one aspect of the consequences faced by farmers. Investment in terms of money and time is required to protect their crops. Moreover, a loss not only occurs because of damage to edible crops; wildlife also damage non-palatable crops in the process of raiding. Elephants (*Elephas maximus*) cause damage to infrastructure and inflict injuries to humans (Madhusudan 2003). While local residents have limited ability to bear the direct costs of these conflicts, such adverse situations for farmers decrease their tolerance toward wildlife, and their attitude increasingly becomes hostile, which leads to retaliation attacks, injuries, and killing of wildlife (Conover and Decker 1991).

Most research on spatial and temporal patterns of crop raiding has been on elephants and primates (Sukumar 1990, Hoare 1999, Hill 2000, Gubbi 2012). A few studies have focused on the behavioral ecology of the raiding species (Osborn 2004, Hill and Wallace 2012) and the attitudes and perception of people toward the conflict situation (Conover and Decker 1991, Gadd 2005, Wang et al. 2006, Marchal and Hill 2009).

Earlier studies have investigated the correlates of spatial patterns of crop raiding. Linkie et al. (2007) reported significantly higher amount of crop damage closer to the forest by wild pigs (*Sus scrofa*) and pig-tailed macaques (*Macaca nemestrina*). Households closer to protected areas were at higher risk of crop damage by wild herbivores (Sam et al. 2005, Gubbi 2012, Karanth et al. 2012). However,

Figure 1. Rice crop damaged by elephant (*Elephas maximus*) in Ramnagar Forest Division. (*Photo by Harendra Singh Bargali*)

Hoare (1999) and Sitati et al. (2003) found no such association in the case of crop raiding by elephants.

Interventions to mitigate such a conflict situation become necessary for wildlife conservation as well as to protect livelihoods of farmers. Linkie et al. (2007) also found that guarding intensity did not have any influence on crop damage whereas Karanth et al. (2012) found crop damage to decrease with increasing guarding intensity. Studies that have looked into the socio-economic aspects of crop raiding have reported ineffectiveness of compensation schemes to mitigate conflict situations (Madhusudan 2003, Gubbi 2012, Karanth et al. 2012, Karanth et al. 2013). Compensation schemes can only be made more effective when the amount of money given to the farmer is sufficient and timely. Moreover, physical interventions such as fencing require detailed knowledge of spatial and temporal patterns of the problem, especially in developing countries where resources are often limited and their allocation needs to be well planned.

Villages present in Ramnagar Forest Division (RFD) of India have been experiencing loss in income due to crop damage by wild ungulates and elephants for many years (R. Bisht, farmer, personal communication). The objective of this study was to quantify the crop loss due to raiding by wild ungulates and elephants and also look for patterns associated with crop raiding. We tested 2 hypotheses for the research: 1) crop loss should be higher in fields closer to forest edge than fields far from the edge, and 2) unguarded fields should experience higher crop loss than fields that are actively guarded by farmers.

Methods

Study area

Ramnagar Forest Division is located in Uttarakhand, India (N29°33'-29°13', E79°06'-79°32') on the eastern boundary of Corbett Tiger Reserve. The RFD is comprised of 5 forest ranges: Kosi, Kota, Dechauri, Fatehpur, and Kaladhungi. The vegetation is dense mixed forest dominated by Sal (*Shorea robusta*).

Figure 2. Sugarcane crop damaged by elephant (*Elephas maximus*) in Ramnagar Forest Division. (*Photo by Harendra Singh Bargali*)

Table 1. Percent area affected and percent fields raided, Ramnagar Forest Division, Uttarakhand, India, January 15 to April 15, 2015. Note: 95% confidence intervals appear in parentheses next to means.

Stage	Area affected (%; *n* = 95)	Farms raided (%; *n* = 95)
Seedling	21 (15–27)	64
Immature	15 (10–22)	40
Mature	6 (3–9)	33

Fauna includes tiger (*Panthera tigris*), leopard (*Panthera pardus*), elephant, nilgai (*Boselaphus tragocamelus*), cheetal (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus muntjac*), wild pig, and many other species of mammals, reptiles, and birds found in the Himalayan biogeographic region.

Human settlements are widely scattered in the RFD. The dominant source of livelihood in the region is agriculture and daily wage labor activities, such as government sponsored construction of roads, buildings, and fences. Major crops grown in the farmlands are paddy (*Oryza sativa*), wheat (*Triticum aestivum*), sugarcane (*Saccharum officinarum*), maize (*Zea mays*), and vegetables. Crop raiding by wild herbivores and livestock depredation are the 2 major forms of human–wildlife conflicts reported in the division (Figures 1 and 2).

Sampling design

We conducted periodic inspections in crop fields of 16 villages. Inside each of these villages, we pre-selected fields for subsequent periodic inspections. Criteria used for selection was the difference in proximity of the field to the forest edge, and we ensured that each of the selected fields was at a different distance from the forest edge. Sampling units were individual cultivated fields (with only 1 crop species in 1 field) within the administrative boundary of 3 ranges (Kosi, Kota, and Dechauri) of RFD. A total of 95 fields were selected for repeated periodic field inspections. Of these, 75 fields cultivated wheat and the other fields were of barley (*Hordeum vulgare*), barseem (*Trifolium alexandrinum*), ginger (*Zingiber officinale*), gram (*Cicer arietinum*), lentil (*Lens culinaris*), mustard (*Brassica rapa*), onion (*Allium cepa*), pea (*Pisum sativum*), and potato (*Solanum tuberosum*).

Data collection and analyses

We made field inspections January 15 to April 15, 2015. We categorized growth of wheat crop into 3 stages, namely; seedling, immature, and mature. In seedling stage, the germinated plant is a few cm in height with a delicate stem and leaf. In immature stage, the plant has a fully differentiated stem and leaf and begins formation of fruit. A plant is categorized in the mature stage when it has reached its maximum attainable height and ripening of fruit begins. Each field was visited 3 times with a period of 1 month in 3 different stages of the wheat crop. When evidence of crop raiding was found in a field, information about crop species, age of crop, dimensions of the entire field and the raided portion, property damage (if any), wildlife species involved, and geographical coordinates were recorded. The area of the field and damaged portions were measured through pacing. The average pace size of the on-field researcher was 0.66 m. The dimensions of the field and damaged area were converted to meters by multiplying paces by 0.66. Raiding species involved in damage in the period between 2 field inspection visits were determined by asking the owners of the fields and then verified by looking for animal signs in the field and asking the owners of the neighboring field. Approximate distance of fields to the nearest forest edge was measured using Google Earth™ image dated April 23, 2014. The collected data were analyzed using IBM SPSS Statistics for Windows, Version 20.0 (Armonk, NY, USA).

Results

Crop damage

The number of fields raided by wild ungulates and elephants was found to be highest in the seedling stage ($n = 95$, 64%) and lowest in the mature stage ($n = 95$, 33%; Table 1). The average
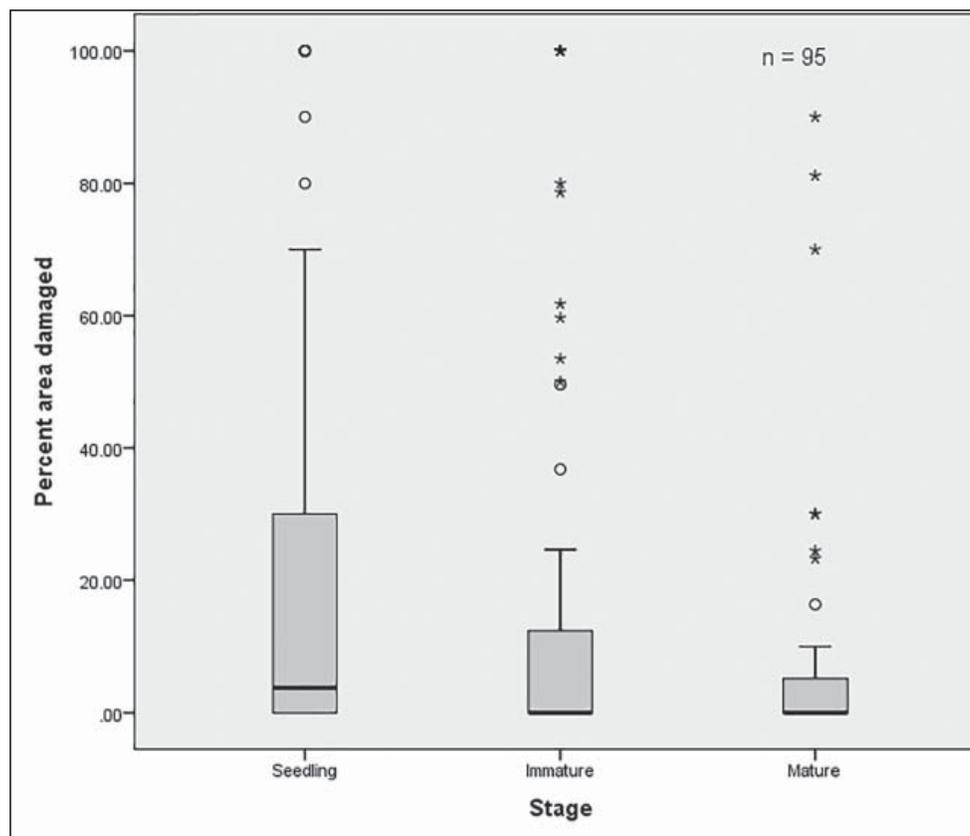

Figure 3. Area damaged during different crop stages, Ramnagar Forest Division, Uttarakhand, India, January 15 to April 15, 2015. Circles represent outliers and stars represent extreme outliers. Bold line in center of boxes represent the median value. (Extreme outliers are data points that are more extreme than Q1 - 3 * IQR or Q3 + 3 * IQR. Mild outliers are data points that are more extreme than Q1 - 1.5 * IQR or Q3 + 1.5 * IQR, but are not extreme outliers. Q = Quartile. IQR = Interquartile Range.)

Table 2. Percent area damaged in farms close and farther from forest edge in different crop stages, Ramnagar Forest Division, Uttarakhand, India, January 15 to April 15, 2015. Note: 95% confidence intervals appear in parentheses next to means.

Stage	Close to forest edge (<200 m; n = 64)	Far from forest edge (>200 m; n = 31)
Seedling	22 (14–30)	17 (6–28)
Immature	15 (7–22)	19 (6–30)
Mature	7 (3–12)	2 (0.2–4)

Table 3. Unpaired t-tests for percent damages between farms close and far from the forest edge in different crop stages ($P \leq 0.05$), Ramnagar Forest Division, Uttarakhand, India, January 15 to April 15, 2015.

Stage	t	df
Seedling	-0.489	93
Immature	0.479	93
Mature	-1.977	93

Table 4. Number of farms that reported different species as crop raiders in seedling or immature crop stages.

	Seedling stage		Immature stage	
Species	Farms close to forest edge (<200 m; n = 64)	Farms far from forest edge (>200 m; n = 31)	Farms close to forest edge (<200 m; n = 64)	Farms far from forest edge (>200 m; n = 31)
Cheetal	14	2	4	4
Wild pig	14	6	3	8
Sambar	14	3	9	1
Elephant	2	2	3	1
Nilgai	10	7	7	4
Barking deer	2	0	3	0

Table 5. Area affected in guarded and unguarded farms in different crop stages, Ramnagar Forest Division, Uttarakhand, India, January 15 to April 15, 2015. Note: 95% confidence intervals appear in parentheses next to means.

Stage	Area affected (%)	
	Guarding present (n = 80)	Guarding absent (n = 15)
Seedling	19 (13–26)	28 (8–51)
Immature	17 (10–24)	10 (0–25)
Mature	6 (3–9)	5 (3–16)

Table 6. Unpaired t-tests for percent damages between unguarded and guarded farms ($P \leq 0.05$), Ramnagar Forest Division, Uttarakhand, India, January 15 to April 15, 2015.

Stage	t	df
Seedling	-0.942	93
Immature	0.715	93
Mature	0.194	93

area of field damaged was also highest in the seedling stage (n = 95, 21%) and lowest in the mature stage (n = 95, 6%; Table 1, Figure 3).

Crop raiding in fields close and far from the forest edge

Except for the immature stage of the crops, fields closer (<200 m) to the forest edge averaged higher amounts of area damaged than fields >200 m from forest the edge (Table 2). In the immature stage, fields farther from the forest edge experienced a higher amount of area damaged than the fields closer to the forest edge. We arcsine transformed the data as it was in the form of proportions and conducted an independent sample t-test to compare percent area affected in fields close and far from the forest edge in 3 stages of the wheat crop (Gotelli and Ellison 2004). However, no significant difference was found between 2 types of fields in any of the stages of the crop (Table 3).
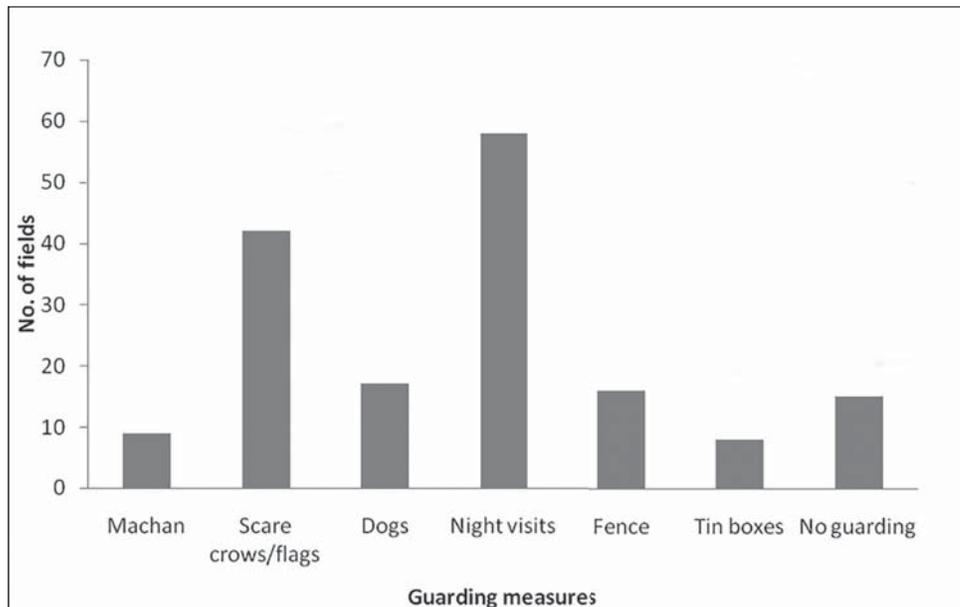
Figure 4. Popularity of guarding measures (*n* = 95), Ramnagar Forest Division, Uttarakhand, India, January 15 to April 15, 2015.

Involvement of different species in crop raiding

During the seedling stage of the crops, fields closer to the forest edge (*n* = 64) were mostly raided by nilgai (16%), wild pig (22%), sambar (22%), and cheetal (22%; Table 4). However, fields far from the forest edge (*n* = 31) were chiefly raided by nilgai (23%) and wild pig (20%).

In the immature stage of the crops, fields close to the forest edge (*n* = 64) experienced the highest amount of raiding by sambar (14%) and nilgai (11%), and fields far from the forest edge (*n* = 31) were chiefly raided by wild pig (26%; Table 3).

To look at the difference in the involvement of different species in fields close and far from the forest edge in the seedling and immature stage of the wheat crop, we conducted a chi-square test for independence between wild pig and other raiding species. The χ^2 value of the immature stage contingency table was multiplied by N-1/N as one of the cells of the table had expected the value of <5 (Campbell 2007). No significant difference was found in species involvement in fields close to and far from the forest edge in the seedling stage, χ^2 (1, *n* = 76) = 0.185, *P* > 0.05. However, in the immature stage, results suggest that as compared to other raiders, wild pigs are more likely to cause damage in fields that are far from the forest edge, χ^2*N-1/N (1, *n* = 47) = 7.04, *P* < 0.05.

Guarding measures

Different guarding measures employed by farmers in the study area are machans, scarecrows/flags, dogs, night visits, fencing, tin box, and crackers. Machans are temporary night shelters in fields usually made of wood where farmers stay during the night to guard their crops. Tin boxes are hung in the field so that they make loud metallic noise in windy weather. Crackers are locally available fireworks that make a loud noise when fired. Night visits (61%) and scarecrows/flags (44%) were found to be the most popular guarding techniques (*n* = 95; Figure 4). However, a few fields (16%) did not employ any of the guarding measures to protect their crops from being raided by wild ungulates and elephants.

In the seedling stage, less amount of area was affected by raiding (*n* = 95, 19.1%) in fields where ≥1 guarding measure was employed as compared to fields where no guarding measure was employed (*n* = 95, 28%; Table 5). However, in the other 2 stages of the crop, fields that were not guarded had a lesser amount of area affected than the guarded fields.

Because we collected data in the form of proportions, we arcsine transformed it and conducted an independent sample *t*-test to compare percent area affected in guarded and unguarded fields in the 3 stages of the wheat crop. However, no significant difference was

found between guarded and unguarded fields in any of the stages (Table 6).

Discussion

Results of the study suggest a substantial amount of crop damage in villages of RFD. In the sampled fields, the area of the field damaged by raiding was highest in the seedling stage and lowest in the mature stage. Such a pattern could be a result of the higher amount of attention by farmers in guarding their crops when crops are mature, although we did not measure guarding effort at any stage of the wheat crop. The amount of area damaged by raiding can be translated to an equal amount of economic loss by assuming that damaged areas have zero yield. Madhusudan (2003) reported an average economic loss of 11% due to crop raiding to each household, which is comparable to the findings of this study (14%). Karanth et al. (2013), in their study from 3 protected areas in India, found that 80% of households around the protected areas reported crop damage. Results from our study report a lower incidence of crop raiding in RFD (i.e., 32% to 64%).

High variance in area damaged can be attributed to the difference in raiding species, the location of the field with respect to the forest edge, the difference in the intensity of guarding, and different crop species. High variance in damage across fields also suggests a variable impact on different farmers. The government-run compensation scheme in the region is the main tool to mitigate the conflict situation. However, delay in compensation and inadequate compensation amount does not help in the protection of livelihood of farmers (R. Bisht, farmer, personal communication). Therefore, we recommend that protocols should be developed to identify farmers who have been suffering due to excessive crop damage, and that these farmers need to be compensated on a priority basis when the resources are limited at the hands of government or non-government organizations.

We expected that fields closer to the forest edge should be raided more than the fields far from the forest edge. Gubbi (2012), in a study from Nagarhole National Park, India, reported that most of the crop raiding happened in fields located 1–5 km from the boundary of the national park. The data from the sampled fields in RFD also showed that fields closer to the forest edge bear more damage than fields far off in the seedling and mature stage, although the difference was not statistically significant.

We found that when fields had seedling-stage crops, the fields close to the forest edge were raided more by cheetal, sambar, wild pig, and nilgai whereas fields far from the forest edge were raided chiefly by nilgai and wild pig. A similar pattern was observed in the immature stage. This shows that crop raiding by wild pig and nilgai is ubiquitous. Elephants were found to be a minor contributor to the crop damage. This result is important from a conservation standpoint as it shows that, unlike other landscapes where elephants are reported to be a chief raider, in RFD elephants are involved in far fewer crop raiding cases as compared to other herbivore species (Madhusudan 2003, Gubbi 2012, Karanth et al. 2013). Therefore, management interventions in RFD should focus more on wild pig and nilgai.

Guarding of fields was not found to decrease crop raiding. Such a result should be interpreted with caution because only the numbers of guarding measures were recorded in this study and not the intensity of guarding. The intensity of guarding might be a more important determinant in decreasing crop raiding. Therefore, a detailed field experiment is suggested to assess the effectiveness of different guarding measures on crop damage. Of all the guarding measures employed by farmers, night visits and flags were found to be the most popular. The popularity of these guarding measures may or may not be based on their effectiveness. Cost effectiveness and ease of implementation are also important variables that might influence the popularity of a guarding measure. Crackers are not only expensive but also pose health hazards in terms of loss of hearing. Fences and machans are expensive to make and maintain. People sleeping in machans to guard their crops must face adverse weather conditions and diseases such as malaria.

Crops once raided by wild ungulates in initial stages tend to regain their vigor in subsequent stages (personal observation, March 15, 2015). This means that crop yield in raided areas might be >0. Therefore, for more precise quantification of damage, a field experiment

should be designed to measure the yield from a damaged area that was raided in initial stages of the crop growth.

Another limitation of the study is attribution of damage to particular raiding species. Because we made monthly inspections and asked farmers about the raiding species, in most of the cases, >1 species was reported to be the raider. Therefore, we cannot attribute damage in a field to a particular species. This presents a problem in terms of how much damage different raiding species cause in fields, though it did not bias the measurement of the amount of damage.

This study also shows a cost-effective way of quantifying crop damage because periodic inspections of fields does not require many people in the field. A more popular method of interviewing farmers may not be as reliable to quantify the crop loss and to study the spatial and temporal patterns of it because farmers may tend to overestimate the losses (Cannell and Henson 1974). Moreover, such tools rely on the memory of the respondents, which might be erroneous.

Management implications

We found a high amount of crop damage with high variance. We recommend that changes should be made in compensation mechanisms so that farmers experiencing higher crop raiding can be identified and compensated on a priority basis. To identify regions in RFD where crop raiding is more severe, a long-term study with a higher sample size should be undertaken by the forest department that in turn might help them devise strategies to protect farmlands from wildlife.

Acknowledgments

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