

An assessment of crop damage and economic loss caused by elephants in Harohalli and Kodihalli ranges of Bannerghatta National Park, Karnataka, India

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The human–elephant conflict, which results in extensive crop damage as well as casualties (both humans and elephants) has significantly increased over the past decade. We studied the patterns of crop raiding and associated economic loss by elephants across two forest ranges of Bannerghatta National Park (BNP), Karnataka, India, namely Kodihalli and Harohalli ranges, from January 2014 to December 2014. We found that 127 villages reported crop raids by elephants during the study period. The incidence of crop raiding in villages ranged from 1 to 59 (mean = 7.17) and was highest in Kodihalli division. Maximum crop raiding incidences were recorded during the rainy season in both the ranges. Elephants with varying proportions raided all cultivated crop species in the study area. Finger millet (*Eleusine coracana*) (65 acres), banana (*Musa paradisia*) (1535 plants) and coconut (*Cocos nucifera*) (140 trees) were the most raided crop species. Crop maturity and crop raiding incidence showed positive correlation for finger millet in the Kodihalli range. In contrast, bananas were damaged throughout the year in the Harohalli range. Other crops such as red gram, paddy, sugarcane and beans were raided less in the sampling areas. In conclusion, this study reveals rising incidence of human–elephant conflicts and significant economic loss as a result of crop damage in the adjoining regions of BNP.

Keywords: Crop damage, elephant–human conflict, economic loss, forest ranges.

ALARMING growth in the human population during the past decades has led to a rise in human settlements around the migratory corridors of wildlife in India and across the world. In particular, growing human settlements have caused fragmentation and significant reduction of elephant habitats as well as encroachment of migratory corridors. All these events have led to restriction of elephants into ever-shrinking islands of habitation and concurrently, have increased contacts with humans^{1–3}. Together, this has resulted in the growing problem of human–elephant conflicts^{4,5}.

Such conflicts result in crop damage, destruction of property along with injuries and casualties to humans and elephants^{6–8}. Crop damage accounts for the major socio-economic loss in both Asia⁹ and Africa^{10,11}. Common causes for crop raiding by elephants include proximity to agricultural land, density of elephant population¹², rainfall patterns¹³, and increase in cultivated area¹⁴ and natural preference of crops by elephants¹⁵.

Bannerghatta National Park (BNP) is a major elephant habitat in Karnataka, India. It is highly fragmented and surrounded by 117 human settlements distributed within 5 km radius from the forest edge with an estimated human population of about 107,082 (ref. 16). The BNP has an elephant population of 148 with a mean density of 1.41/sq. km (ref. 17). The fragmented nature of BNP combined with the relatively high density of elephants and human activities creates a significant risk for human–elephant conflicts. Growing of elephant-preferred crops like banana (*Musa paradisiaca*), paddy (*Oryza sativa*) and finger millet (*Eleusine coracana*) by farmers residing around BNP is the predominant causal factor in such conflict. Crop raiding by elephants is now considered as agricultural pest¹⁸. BNP is highly prone to human–elephant conflict. However, no comprehensive studies have been conducted to assess such conflicts in the region. With growing human settlement and demand for cultivated area, there is a need to investigate such conflicts in detail. In this context, the present study was designed to assess the type and pattern of crops cultivated by the farmers, frequency of crop raiding by the elephants, and annual economic loss incurred due to crop damage in Kodihalli and Harohalli forest ranges of BNP.

BNP is the smallest and highly irregular-shaped National Park in India, with an estimated area of 103 sq. km (ref. 19). It measures 26 km in length from south to north, and ranges between 0.3 and 5 km in width from west to east. BNP lies between 12°34'–12°50'N lat. and 77°31'–77°38'E long.²⁰. The Park is adjoining the Hosur forest, Tamil Nadu in the southeast and the Kanakapura forest, Karnataka in the southwest. These two forest divisions further join the larger forest patch of the Cauvery Wildlife Sanctuary (Figure 1), and then the Nilgiri Biosphere Reserve of the Western Ghats forest at the Nilgiris, extending through Malaimahadeshwara hills, Biligiriranga Swamy Temple Wildlife Sanctuary, Kollegal Forest Division and Sathyamangala forest¹⁹. For ease of administration, BNP is divided into four forest divisions – Harohalli range, Bannerghatta range, Anekal range and Kodihalli range. The landscape of the Park is hilly and rolling with a mean altitude of 865 m, and varies from 700 to 1035 m amsl. This region receives average annual rainfall of 937 mm ranging between 728 and 1352 mm during April to November (eight months). The maximum rainfall (50%) occurs between August and October, while January–March experience dry months with rainfall ranging from 0.3 to 46 mm.

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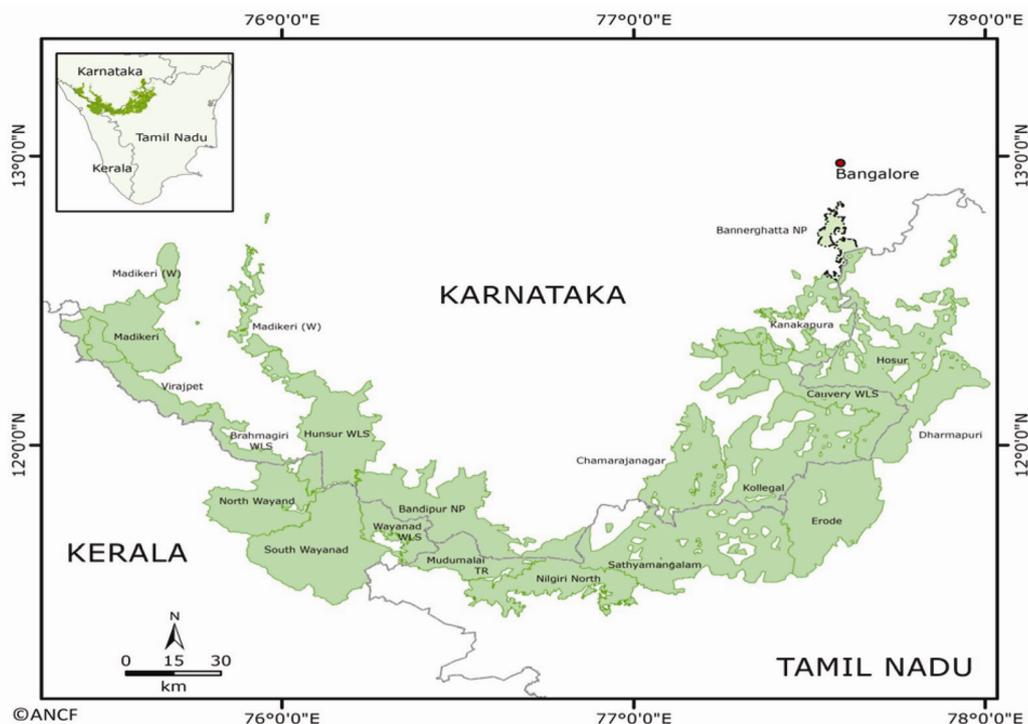


Figure 1. Map showing Bannerghatta National Park, Karnataka along with other adjoining forest divisions.

Table 1. Status of crop-raiding incidents in the affected villages in Kodihalli and Harohalli ranges of Bannerghatta National Park during January–December 2014

No. of incidents	Kodihalli range		Harohalli range	
	No. of villages	Percentage contribution	No. of villages	Percentage contribution
1–10	56	80.00	55	96.46
11–25	11	15.71	02	03.50
26–50	02	02.85	–	–
51–60	01	01.42	–	–

To assess crop damage, we visited the office of the Deputy Conservator of Forest (DCF) and collected data from compensation claims made by farmers from the Harohalli and Kodihalli ranges of BNP for the period of 12 months (January–December) in 2014. The office of DCF records crop damage cases after a joint inspection by the Forest Department personnel with the complainant and representatives of the Village Panchayat Committee. Each recorded case contains data related to crop loss, including type of crop, quantity of loss, area damaged, compensation payment claimed and total land ownership. We validated the information collected from the range office by oral confirmation of affected farmers during the study period. The methodology of data collection and analysis to assess the crop damage and economic loss was performed as described elsewhere^{21,22}.

A total of 911 separate crop-damage incidents were recorded in the Harohalli and Kodihalli ranges, of which

72% (70 villages) of crop-raiding incidences occurred in Kodihalli and 28% (57 villages) in Harohalli range during the study period. Table 1 provides the status of crop-raiding in the affected villages of both the ranges. In the Kodihalli range, highest number (59) of incidents was reported in Kadushivanahalli village, followed by Keralalu Sandra (50) and Kebbere (25). In the Harohalli range, maximum number of incidents was recorded in Yalachavadi (19), followed by Kadushivanahalli (6).

During this study, a total of 12 crop types were identified in the Kodihalli and Harohalli ranges, which were damaged by elephants. In the Kodihalli range, the major crops that were damaged included finger millet (57%), red gram and maize (12% each), coconut (7%) and others (paddy, sugarcane and tomato), 3% of the raiding incident (Figure 2 a). In the Harohalli range, banana (22%) was the most damaged crop followed by maize (21%), coconut and finger millet (20% each). The

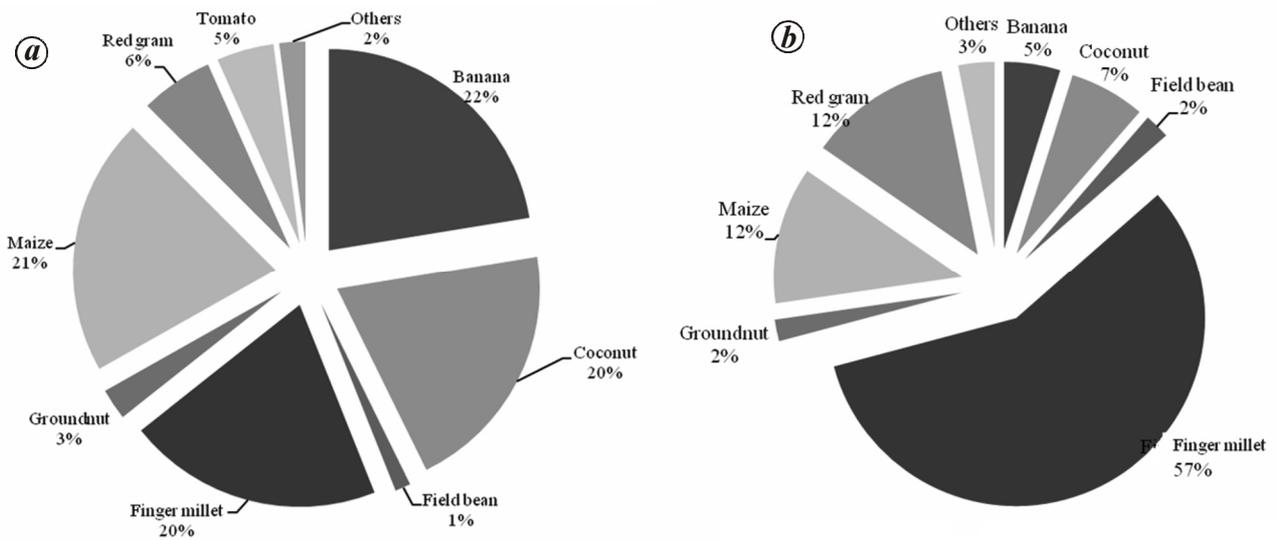


Figure 2. Graphical representation of proportion of elephant-raiding incidents related to different types of crops in (a) Kodihalli range and (b) Harohalli range of BNP.

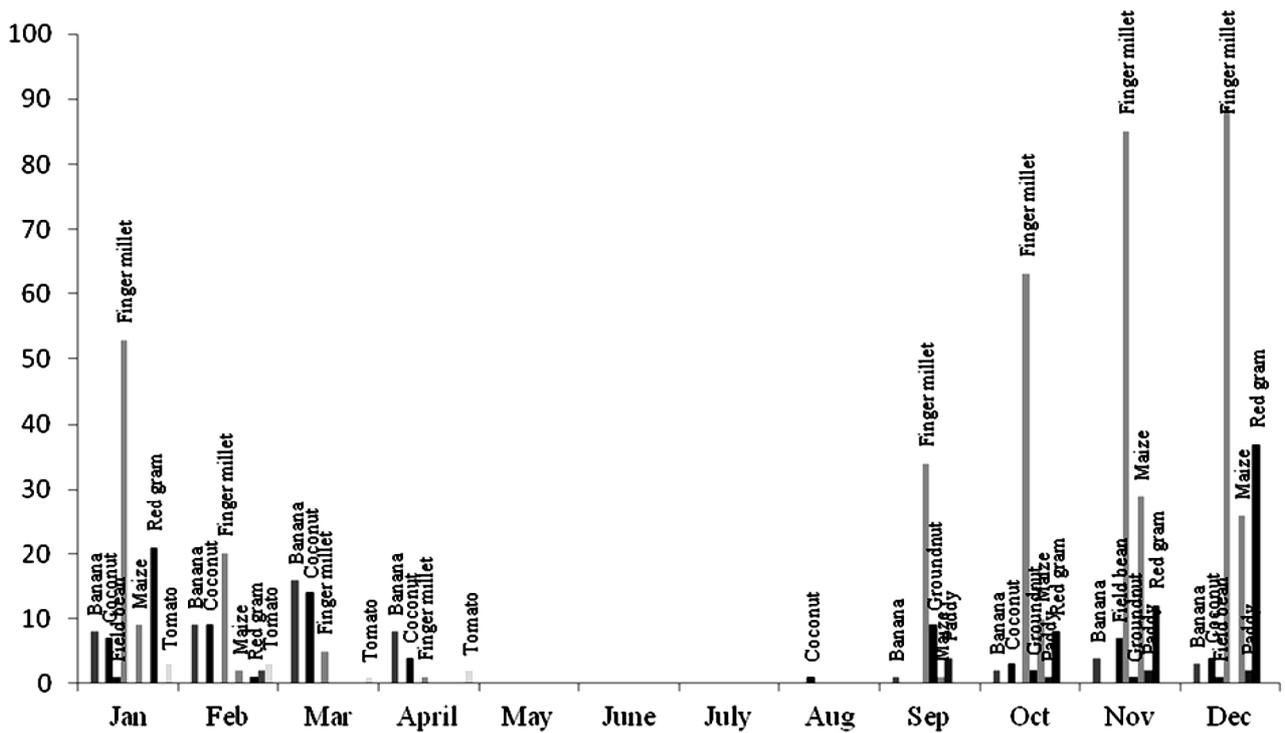


Figure 3. Graphical representation of crop damage in different months during the assessment period in the Kodihalli range.

incidence of crop damage of other crops was minimum (Figure 2 b).

In the Kodihalli range, month-wise pattern of crop damage was distinctly different from that in the Harohalli range (Figure 3). Crop damage incidents occurred from January to April 2014 and then again from September to December 2014, with a maximum during December. No

incidents of crop damage was recorded during May–August 2014. Finger millet was the predominant cultivated crops, therefore cases of crop raiding were also much higher for finger millet compared to other crops in the Kodihalli range.

Figure 4 shows the month-wise crop damage cases for 12 major crops in the Harohalli range. In contrast to the

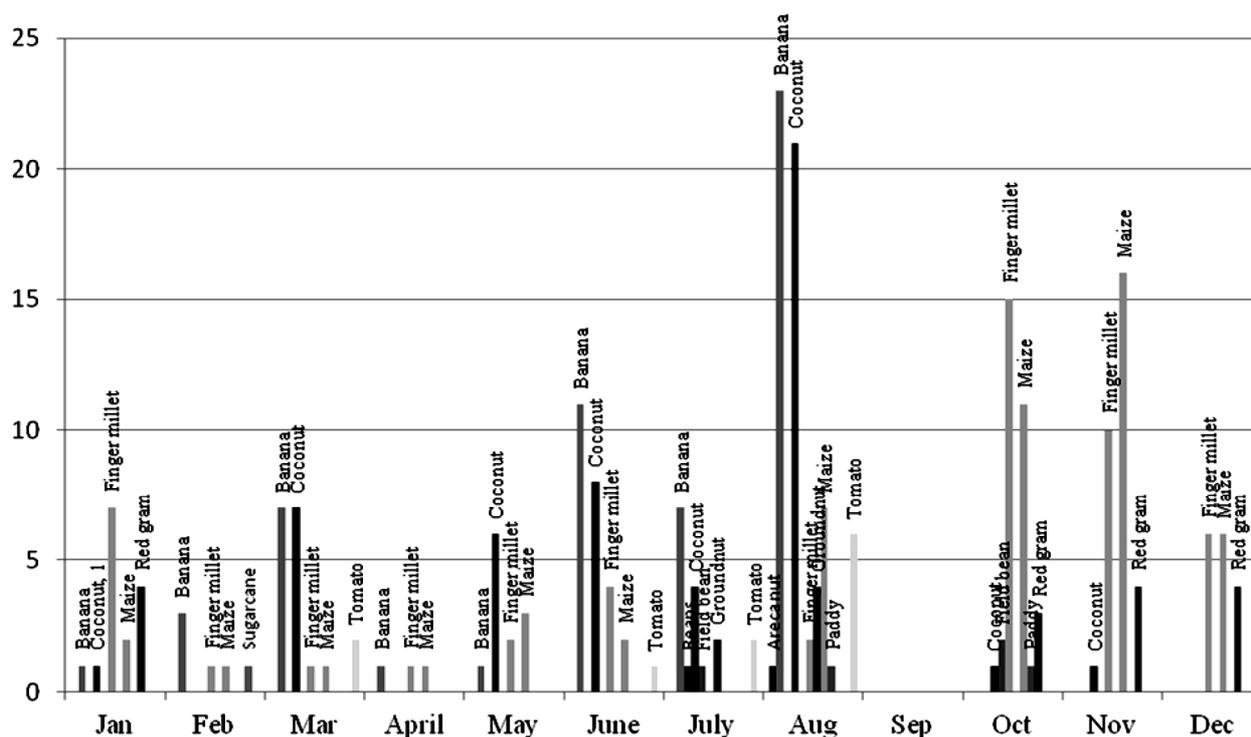


Figure 4. Graphical representation of crop damage in different months during the assessment period in the Harohalli range.

Kodihalli range, crop damage in the Harohalli was reported throughout the year. Banana was raided the most – spanning eight months of the year, followed by finger millet (seven months), coconut (five months), maize (three months) and tomato (two months). Other crops like field bean, groundnut and red gram were damaged the least, for a period of 2–3 months. Banana remained the maximum raided crop in all months, except September–December, when it was surpassed by finger millet. There were a few cases of depredation on tomato from July to August 2014.

Crop-raiding incidences were highest during November and similar trend was observed in both the ranges. Probably, this corresponds to the maturation of finger millet crop in the region. However, there was a higher case of crop damage from September to December in the Kodihalli range, which was not observed in the Harohalli range. Also, the Harohalli range reported greater incidence of crop raiding in the rainy season, which was not the case in the Kodihalli range (Figure 2 a and b).

We also noted that the elephants damaged crops of all the growth phases from planting to harvest. Although we noted varied proportions of crop damage among the cultivated crops, banana and finger millet were the most preferred in both the forest ranges. Table 2 provides an estimate of the economic loss of the main crops damaged in the study area. The overall economic loss for the year 2014 in both the ranges was estimated as Rs 365,075.00. The major contributor to economic loss was banana crop

(Rs 54,400.00) in the Harohalli range followed by finger millet (Rs 111,900.00) in the Kodihalli range. The cultivation of coconut and banana although less in the study area but they incurred more economic loss due to the high economic value of these crops. Field bean, groundnut, paddy and red gram were cultivated to a lesser degree (1–5 acres) and therefore incurred less economic loss (Table 2).

The Indian Wildlife (Protection) Act 1972 under Schedule I and Part I has categorized the Asian elephant (*Elephas maximus*) as an endangered species²³, which is confined to a few regions in the Indian subcontinent. Due to growing anthropogenic activities, the area and quality of elephant habitats have drastically reduced and fragmented, which has forced the elephants to drift beyond their traditional habitats and invade agricultural fields in the forest fringe areas to meet their everyday requirements^{24,25}. During such forays, the elephants damage crops and property. Also, confrontation between humans and elephants becomes inevitable²⁶, which ultimately leads to casualties on both sides. Therefore, the mitigation of elephant–human conflicts has become a major task for ecologists, conservationists, wildlife researchers and forest officials.

In many instances, overindulgence in exploitation of forest resources by humans has contributed to loss of habitat and therefore, rapidly altered the quality of the natural habitat^{27,28}. Shortage of available resources across their home range has forced elephants to forage outside

Table 2. Economic loss of different crops due to elephants in the Kodihalli and Harohalli ranges during January–December 2014

Crop	Scientific name	Harohalli range			Kodihalli range		
		Extent of damage (acres)	Total loss	Total economic loss (rupees)	Extent of damage (acres)	Total loss	Total economic loss (Rs)
Areca nut	<i>Areca catechu</i>	–	04 plants	600.00	–	–	–
Banana	<i>Musa paradisia</i>	–	680 plants	54,400.00	–	855 plants	68,400.00
Beans	<i>Phaseolus vulgaris</i>	4.0	4.0 quintals	4000.00	1.75	2.5 quintals	2500.00
Coconut	<i>Cocos nucifera</i>	–	37 plants	13,500.00	–	103 plants	36,300.00
Field bean	<i>Lab lab purpureus</i>	0.30	1.0 quintals	500.00	2.5	2.0 quintals	1000.00
Finger millet	<i>Eleusine coracana</i>	1.55	8 quintals	4800.00	43.27	186.5 quintals	111,900.00
Groundnut	<i>Arachis hypoea</i>	0.30	2.0 quintals	1000.00	2.5	2.0 quintals	1200.00
Maize	<i>Zea mays</i>	1.1	13.5 quintals	6750.00	04.25	6.35 quintals	3175.00
Paddy	<i>Oryza sativa</i>	1.0	2.5 quintals	2500.00	6.10	13.0 quintals	13,000.00
Red gram	<i>Cajanus cajan</i>	0.30	1 quintal	1500.00	05.45	20 quintals	30,000.00
Sugarcane	<i>Saccaram officinarum</i>	0.20	2 tonnes	1600.00	1.5	3 tonnes	2400.00
Tomato	<i>Lycopersicon esculentum</i>	0.50	5.5 quintals	1650.00	7.25	8.0 quintals	2400.00

the forest blocks, thus finding themselves in human-dominated areas. Crop damage by elephants is the major causal factor for human–elephant conflicts in South India. In this study, crop raiding was assessed in two forest divisions. Incidents of crop damage were not similar across the study areas and the mean number of incidents was remarkably different between the regions. The Kodihalli range witnessed more incidences than the Harohalli range (Figures 3 and 4), which could be attributed to proximity to forest area, greater area under cultivation as well as differences in agricultural patterns. Least crop damage was recorded in the Harohalli range, perhaps mainly due to lesser cultivated area attributed to lack of interest in cultivation caused by more profitable opportunities in a nearby city.

Twelve cultivated crop species were prone to elephant damage in the study area. According to some researchers^{6,15,16}, paddy and ragi were the main crops raided by elephants in the forests of Tamil Nadu and Karnataka. Jayson²⁹ reported that palm, coconut, cocoa, sugarcane, areca nut and paddy were the main crops raided by elephants in Kerala. Campos-Arceiz *et al.*³⁰ reported damage to at least 30 different crops in Sri Lanka. Parker *et al.*³¹ reported similar results of crop raiding during their study on African elephants in Kenya³². In the present study, finger millet, banana, maize and coconut were the main crop species raided by the elephants. In Kodihalli, banana suffered maximum events of elephant raiding. This could be due to ease of access to gather the banana fruit as it grows in dense patches, requires less effort in processing because of its succulent nature and also high palatability compared to other perennial crops³³. Ekanayaka *et al.*³⁴ reported an analogous situation of raiding of banana crops by elephants in southeastern Sri Lanka.

The present study as well as other works suggest that the predominant factor for elephant raiding is proximity of cultivated crops to the elephant natural habitat (forest range). In addition to proximity, palatability and better

taste of cultivated crops compared to wild plants in the forest range are significant factors for repeated elephant raiding in the same region. Cultivated crops are lower in fibre and richer in sugars. Presence of huge rainfed areas near forest ranges resulted in greater cultivation of finger millet, which accounted for more economic loss (Rs 116,700), followed by banana (Rs 122,800) and coconut (Rs 49,800) in the study region.

Elephants raided crops throughout the year in the Harohalli range with two peaks of damage, one reported during the rainy season (August) and the next in the post-monsoon season. The frequency of damage incidents in the post-monsoon season was greater than the other months of a year, because most crops attained maturity during the post-monsoon season in the study region. Seasonality of crop loss by elephants and its relation with cropping patterns have been studied in Africa and Asia^{32,33}.

It is observed that the elephants invade cultivated crops invariably at night, particularly during moonless nights, perhaps to minimize the risk of recognition by farmers. The general consensus is that more tuskers are implicated in crop raiding than herds. According to Sukumar³⁵, bulls are likely to invade farmlands six times more frequently than a female-led herd. Possibly, male elephants might obtain greater benefits (i.e. nutrition) from crop raiding than females³⁶. Sukumar and Gadgil³⁶ presented this as evidence for the high-risk, high-gain strategy. According to Balasubramanian *et al.*⁶, elephants that have lost portions of their home range to agricultural fields become crop raiders; however, none of these authors examined differences among elephants related to this behaviour. Since the risks associated with crop raiding in this area are low, we are unable to conclude whether the male adopted high-risk and high-gain strategy as proposed by others³⁷. Previous studies have linked musth period of male elephants with instances of crop raiding by them. Musth is a periodic condition in bulls characterized by

aggressive behaviour mainly due to high production (40–60 times) of testosterone that lasts for a few weeks to months. In the study area, we noted few instances of crop raiding by bull elephant during musth period; however, it was not a major determinant. It was observed that most of the male elephants in the study area came into musth during winter, while crop-raiding events predominantly occurred in early winter³⁸.

Blockage of elephant corridors due to various anthropogenic activities coupled with cultivation of nutritious crops like finger millet, coconut, banana, red gram and sugarcane along the forest boundary, and availability of water in the human settlements throughout the year inevitably attract more elephant–human conflicts in the Harohalli and Kodihalli ranges. Reducing accessibility of elephants to crops should be the immediate strategy to prevent or mitigate crop-raiding incidents in the study region. This can be achieved by taking short-term and long-term strategic measures. Short-term preventive measures such as erecting watch towers, electric fence and rubble wall in sensitive areas could mitigate crop-raiding incidents. Elephants possess highly developed olfactory senses which could be guiding them to ripened crops. Hence, as recommended by a study in Sri Lanka³⁹, identifying materials that could be sprayed on crops to mask the ripening smell of significant crops like ragi, paddy and maize could be another promising short-term strategy to prevent crop-raiding incidents. Furthermore, constituting an exclusive, well-trained elephant-scaring squad, including both forest watchers and farmers armed sufficiently to protect the crops from elephant raids at night during the high conflict months could be an effective short-term measure. Every year, at beginning of the cropping season, this squad should be trained in various elephant-driving methods such as usage of crackers, sirens and thunder flashes as well as deploying kunkies (trained tame elephants) to chase off wild herds. These short-term methods have been effective in mitigating crop-raiding incidents by elephants in other countries¹⁸. Longer-term solution requires intensive management of elephant corridors and migratory routes in this region. Corridors and movement routes of elephants allow them to use different parts of their home range without intruding into human-use areas. Since corridors appear to be degraded areas between forests, often people are unaware of their importance. Loss of corridors would deny access to seasonal ranges resulting in compression and high densities of elephants, which increase the risk of these animals, coming into direct conflict with humans in their attempts to access other parts of their home range. Therefore, securing elephant corridors and migratory routes could be an effective long-term measure to prevent conflicts in the study region. It is easier to protect an existing corridor than re-establishing a lost one. Prohibiting human activities such as quarrying, sand mining, fuelwood harvesting, non-timber forest produce (NTFP) collection and access road,

including livestock grazing in the Karadikkal–Madeshwara (KM), Karnataka corridor would ensure continuous movement of elephants in these regions. Modern technology like GIS should be used for monitoring elephant movements and safeguarding sensitive corridors.

We found that affected communities are open to new approaches for mitigation of conflict. Therefore, initiating community-based conservation and human–elephant management programmes, insuring crops against damage by elephants, raising awareness among people about the importance of securing corridors through visual educational programmes, and creating a platform for regular communication among the rural people, Forest Department and non-government organizations to review the status of conflicts and formulating timely mitigation measures could greatly help in reducing the human–elephant conflicts in the study region as well as other regions.

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