

**Spatio-temporal patterns of human-wildlife conflicts at
different scales in the north Western Ghats biodiversity
hotspot, India**

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Contents

Acknowledgements	3	
Executive Summary	4	
Chapter 1	Patterns of change in human-wildlife conflicts at broader temporal scale in north Western Ghats	6
Chapter 2	Socio-ecological aspects of a unique gaur (<i>Bos gaurus</i>) - human conflict at finer spatio-temporal scale	26

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Executive summary

Human-wildlife conflicts occur within the context of dynamic socio-ecological systems. Understanding these conflicts at relatively broader spatial and temporal scales gives an insight into the conflict scenarios across larger area and changes in their spread and intensity over a broad period of time. This knowledge can give robust inputs in policy making for the region on the issue. On the other hand, understanding these conflicts at relatively smaller spatio-temporal scale may prove useful in mitigation of conflicts for local management agencies such as Forest Department. We tried to understand spread and intensity of human-wildlife conflicts, especially gaur-human conflict, at different spatio-temporal scales and their socio-economic-environmental predictors.

I, through a structured questionnaire based interview survey, studied changes in patterns of in human-wildlife conflicts in the north Western Ghats of India, a region with high biological diversity which appeared to show significant ecological changes over past couple of decades. The study showed that while geographical extent of conflict categories remained almost the same, their intensities changed significantly over thirty years. The significant rise in crop depredation by implicated species was not closely associated with the change in relative abundance of the correspondent species. However, decline in livestock depredation inflicted by large carnivore species appeared to be influenced by the decline in relative abundance of those species. This study suggests that the management agencies need to put more emphasis on reducing losses due to crop depredation. It also raises a concern regarding the decline in large carnivore abundance in the region.

The northern part of the Western Ghats biodiversity hotspot in India has been witnessing the genesis and build-up of conflicts with elephants and gaur (*Bos gaurus*) since last couple of decades. Gaur, known for its shy nature, nowhere across its distribution except this region, has been reported as a crop raider here. We studied the spread and intensity of gaur-human conflict at relatively fine spatio-temporal scale i.e. at household and village level over four cropping seasons. The key informant surveys were carried out in and around Radhanagari Wildlife Sanctuary (350 km²) in the region. Cropfields of 250 households from eight villages were monitored for seventeen months. Farmers had to bear significant losses due to crop damages inflicted by wild animals and highest were by gaur. Much of the crop losses were in the cropfields located in proximity with the forested area. The gradual increase in crop losses from wet to dry seasons, peak of crop depredation losses during mid-season and preference

for leguminous crops among cultivated crop species indicate the preference for nutritious food as one of driving factor for gaur to raid the crops. Significantly greater perceived losses than the observed losses may be attributed to the greater dependency of the people on the agriculture as a source of livelihood. Though, the social taboo on gaur hunting minimises the direct threat to the species from humans, the threat to the livelihood of local people due to crop losses may negatively impact the conservation efforts in the region and makes it imperative to address the issue before it goes beyond the tolerance level of local communities.

Chapter 1. Patterns of change in human-wildlife conflicts at broader temporal scale in north Western Ghats

Introduction

Human dominated landscapes offer spatially concentrated, predictable and reliable food sources which often lead to human-wildlife conflict (Baruch-Mordo et al., 2013). In India, densely populated human landscapes and wildlife habitats often overlap and the resultant crunch of space and resources adversely affect both humans and wildlife (Madhusudan and Mishra, 2003). Though, these principles of conflict have remained the same, its intensity has changed to a great extent over last century in India (e.g. human-elephant conflict in India) (Madhusudan M. D. and Sankaran, 2010). While there have been studies to understand the present situation of human-wildlife conflict in different ecosystems in India (Saberwal et al., 1994; Mishra, 1997; Madhusudan, 2003; Treves and Karanth, 2003; Bagchi and Mishra, 2006; Karanth et al., 2006; Athreya et al., 2011; Gubbi, 2012; Suryawanshi et al., 2013), fewer are aimed at understanding changes in the spread and intensity of conflict at a broader temporal scale. An understanding of the changing scenario of human-wildlife interactions in a region can help in better conflict management. Though it is difficult to obtain information on conflict in the past through field based methods, structured interviews with knowledgeable key informants can provide valuable information on the occurrence and abundance of large mammal species in the past (Pillay et al., 2011).

The northern Western Ghats located in the states of Maharashtra and Goa (14.9 - 20.4°N, 73.0 - 73.8° E), popularly known as Sahyadri, has been witnessing some of the unique conflict situations in recent decades. Gaur (*Bos gaurus*), known for its shy nature, has been raiding the crops in this region, with few such reports from other parts of its distribution. Also, while there were almost no reports of Asian elephant (*Elephas maximus*) movement in the region in the last century, elephants and resultant property damage by them have been frequently reported from the southern part of the region in the last decade.

In this context of genesis and build of unusual conflicts in the region over last couple of decades, we assessed the spread and intensity of human-wildlife conflict in north Western Ghats in the past (30 years back) and at present (2010), through structured interviews with knowledgeable elderly key informants. We also estimated the past and present encounter rates of such species, along with other focal species, as a proxy for their relative abundance.

The influence of changes in abundance of these species over time on changes in losses inflicted by them was examined.

Study area

The Western Ghats mountain chain, a biodiversity hotspot, runs almost parallel to the west coast India from 7° N to 21° N. It harbours about 5,000 flowering plant species, of which 1700 species are endemic to the region (including Sri Lanka) (Myers et al., 2000). The northern part of the Western Ghats located within the states of Maharashtra and Goa are popularly known as Sahyadri, and extend over an area of about 52,000 km². The Sahyadri region mainly receives rain from south-west monsoon from June to September each year with an average annual rainfall of 3000 - 5000 mm. The annual rainfall decreases rapidly to the east of Sahyadri range to 500 - 600 mm (Gadgil and Malhotra, 1982). The main forest types in this region are southern tropical semi-evergreen and west coast semi evergreen forests, southern tropical moist mixed deciduous forests and west coast tropical evergreen forests (Champion and Seth, 1968).

At present, in terms of ownership, the forests are broadly divided into government owned forests (Protected Areas and Territorial Forests), private forests and community forests, with a major proportion of the forests under the ownership of the state government. These forests are now restricted to the remote hilly terrains of the Sahyadri region. In many places they have been fragmented due to conversion of forest lands for cultivation, mines and developmental activities such as hydro-electric power projects, dams and roads. A recent study on land use changes in the region reports the decline in dense forests and increase in water bodies from 1985 to 2005 (Panigrahy et al., 2010). Majority of the private forests lie on the western part of the Sahyadri mountain range and most of them are highly degraded (personal observation). Most of the community managed forests are sacred groves and located on the central and western side of the Sahyadri mountain range. Though the forests and wildlife in the region have been severely affected by historical unsustainable exploitation, the remaining forests continue to harbour rare and endangered wildlife species.

Methods

Across 49 forest ranges of the north Western Ghats, 320 questionnaire based interviews were conducted in 172 villages. In each sampled village, person/s with sound knowledge of the village, surrounding forests and wildlife in the last three decades were interviewed, and

information on incidents of crop depredation, livestock depredation and attack on humans by wild large mammals was collected. The perceived spread of the implicated species across the Sahyadri region was assessed for the year 2010 (present) and 1980 (past). The average proportion of households affected in a village due to crop raiding, livestock depredation and human attacks by each of the selected wildlife species in last three years was recorded. The responses were ranked as absent (where affected households in the village were 0), rare (1 – 20 % households affected), common (20 – 50% households affected) and intense (affected households > 50%). Similarly, information on encounters with focal wildlife species at present (2010) and in the past (1980) were recorded, depending on the forest range where the resource persons had spent time earlier, or from 1980 to the present. The details of this method are described in Pillay et al., 2011.

Analysis

The damage inflicted by each implicated wildlife species for the present and the past was estimated for the forest ranges where crop depredation, livestock depredation or attacks on humans by the corresponding species had been reported. The degree of conflict was ranked as 0 (absent), 0.2 (rare), 0.5 (common) and 1 (intense), based on the proportion of households affected in a village as perceived by the key informants. The conflict level of each implicated wildlife species for each forest range was calculated by averaging the ranks given by the key informants. The intensity of each conflict form (crop raiding, attack on humans and livestock depredation) for each forest range was estimated as a product of proportion of implicated species inflicting losses in each range and average proportion of human population affected by the losses inflicted by correspondent species.

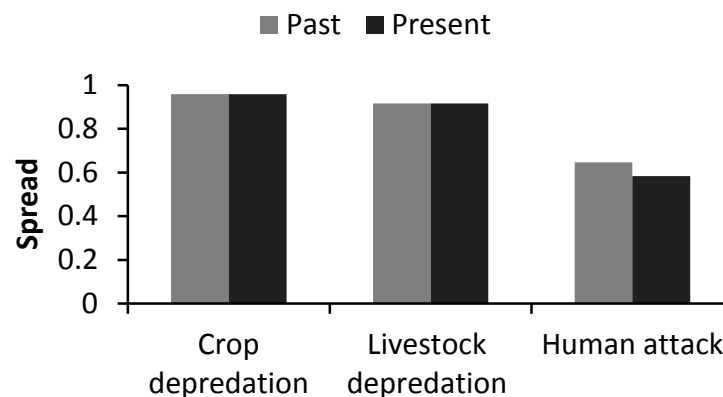
The difference in intensities of losses inflicted by each wildlife species and conflict categories between past and present were assessed using paired t test. The influence of change in encounter rates on the change in intensity of loss was assessed using linear regression (Zar, 1999; Crawley, 2012). Statistical analyses were carried out using R statistical and programming environment (R Development Core Team, 2014).

Results

Three kinds of human-wildlife conflict were reported in the Sahyadri region - crop depredation, livestock depredation and attacks on humans (henceforth human attacks). Crop and livestock depredation incidents in recent years occurred in more than 90% of the forest

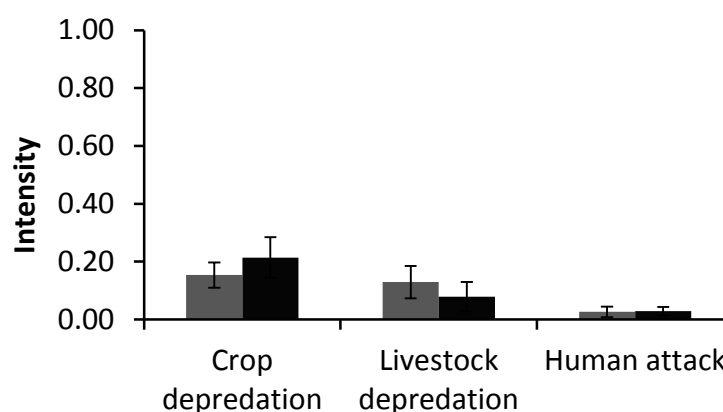
ranges, and human attacks in around 60% of the forest ranges (Figure 1). The overall spread of crop depredation and livestock depredation showed negligible change over thirty years. However, human attacks were more widespread in past than at present (Figure 1).

Figure 1. Proportion of forest ranges with occurrence of human-wildlife conflict forms: Crop depredation, Livestock depredation and attacks on humans (N=49)



Though the extent of crop depredation has not changed, its intensity has increased significantly within its spread. The intensity of livestock depredation shows a decline, while the average intensity of human attacks has remained almost unchanged over the three decades (Paired t test – Livestock depredation: $t = -6.9274$, $df = 40$, $p < 0.005$; Crop depredation: $t = 7.4616$, $df = 45$, $p < 0.005$; Human attacks: $t = 0.4548$, $df = 22$, $p = 0.6537$; Figure 2).

Figure 2. Average intensity of conflict forms across the corresponding forest ranges of occurrence



Crop depredation

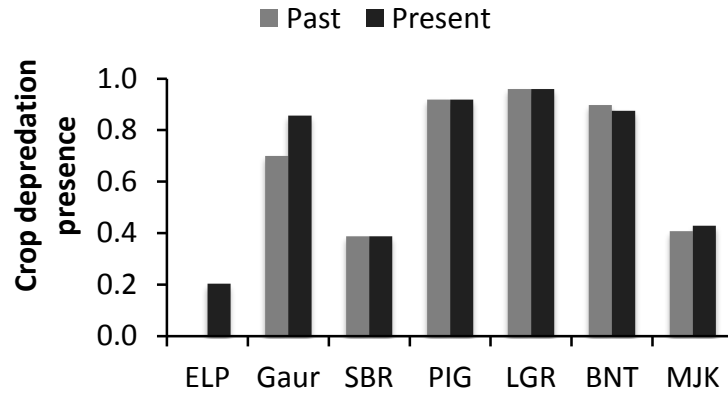
Seven wild large mammal species were reportedly inflicted crop damage in the region: elephant, gaur, wild pig (*Sus scrofa*), muntjac (*Muntiacus muntjak*), sambar (*Rusa unicolor*), hanuman langur (*Semnopithecus entellus*) and bonnet macaque (*Macaca radiata*). Crop depredation by gaur, wild pig and both primate species, hanuman langur and bonnet macaque was reported in more than 85% forest ranges in the Sahyadri region, while that by sambar and muntjac was perceived in 40% of the forest ranges. Perceived spread of crop depredation by gaur has increased from 70% to 90% of forest ranges over thirty years. Crop depredation by elephants was absent thirty years back and it has recently spread in 27% of the forest ranges in the region. Crop depredation by wild pig, sambar, muntjac, hanuman langur and bonnet macaque, however, had a negligible increase over the thirty years (Figure 3a).

Within the area of perceived spread of losses inflicted by each of the seven focal species, gaur and wild pig were perceived as affecting more than 40% of the households, followed by elephant and the two primate species - hanuman langur and bonnet macaque, with losses to approximately 30% of the households. Muntjac and sambar had affected 10% and 4% families respectively. The perceived intensity of crop depredation by gaur and hanuman langur showed a significant increase over thirty years (Paired *t* test- Gaur: $t = 10.31$, $p < 0.005$; Hanuman langur: $t = 3.3578$, $p < 0.005$; for both species: $df = 48$). The perceived crop depredation intensity of wild pig, sambar, muntjac, hanuman langur and bonnet macaque showed a negligible increase (Paired *t* test for these species: $p > 0.005$, $df = 48$, Figure 3b). The crop depredation by elephant was reported only in recent times, and was absent thirty years ago.

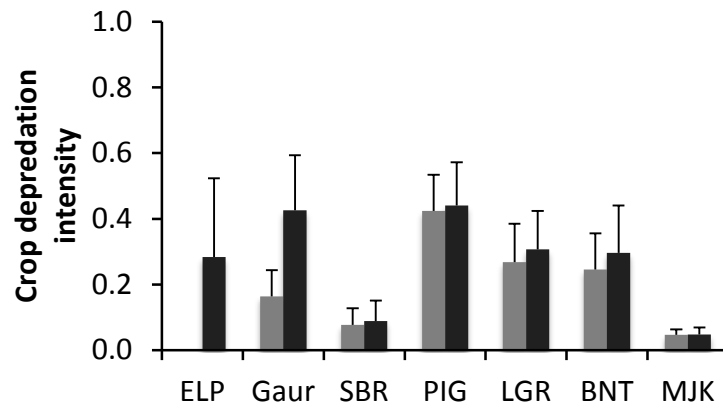
Figure 3. Spread and intensity of crop depredation over time

(ELP: Elephant, SBR: Sambar, LGR: Hanuman langur, BNT: Bonnet macaque, MJK: Muntjac; X axis – Wildlife species; N=49)

a. Proportion of perceived spread of crop depredation over time



b. Average perceived intensity of crop depredation within its spread



Change in encounter rates over thirty years, a proxy to relative abundance, of gaur and hanuman langur did not appear to influence the significant change in gaur and langur crop depredation intensities respectively (Table 1).

Livestock depredation

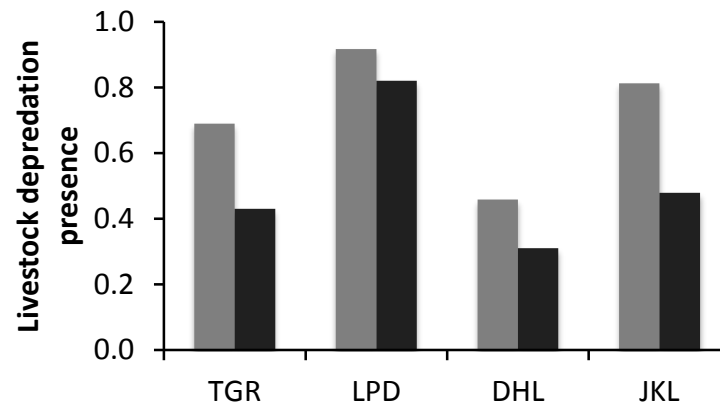
Among four implicated wild carnivore species, leopard was perceived as the wildlife species inflicting losses to livestock in the largest area (90% of the forest ranges) in recent period; followed by tiger (*Panthera tigris*, 60%), jackal (*Canis aureus indicus*, 48%) and dhole or Asiatic wild dog (*Cuon alpinus*, 33%). The spread of livestock depredation by all the four implicated wild species were similar in the past. Over thirty years, the perceived spread of livestock depredation by jackal declined over 30% of the forest ranges, that by tiger and dhole declined in their respective spread in approximately 20% of the forest ranges, and the perceived spread of livestock depredation by leopard remained almost unchanged over thirty years (Figure 4a).

Within their respective geographical spread of livestock depredation, leopard inflicted losses to the highest proportion of (20%) the households. This was followed by jackal (10%), tiger (10%) and dhole (6%). A similar trend was observed in perceived livestock depredation intensity of the past (1980). Over thirty years, intensity of livestock depredation by tiger, leopard, dhole and jackal had declined significantly (Paired t test- Tiger: $t = -4.282$, $p < 0.005$; Leopard: $t = -2.8828$, $p = 0.006$; Dhole: $t = -2.7951$, $p = 0.007$; Jackal: $t = -6.2375$, $p < 0.005$, for all species: $df = 48$; Figure 4b).

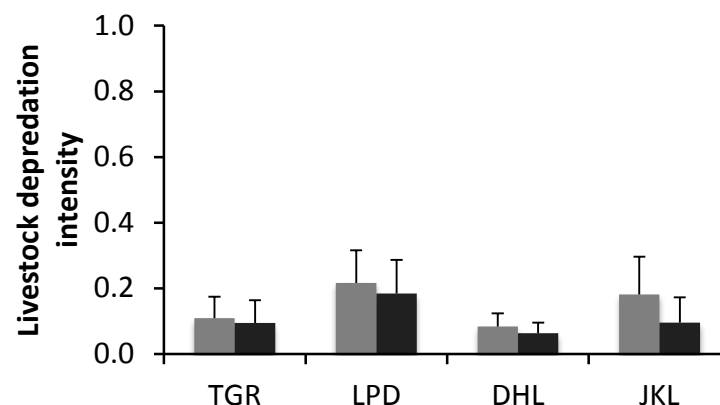
Figure 4. Spread and intensity of livestock depredation over time

(TGR: Tiger, LPD: Leopard, DHL: Dhole, JKL: Jackal, X axis- Wildlife species)

a. Proportion of perceived spread of livestock depredation



b. Average perceived intensity of livestock depredation within its spread



Among these focal species, decline in livestock depredation by tiger, leopard and dhole over thirty years showed a significant influence of change in their encounter rates (Table 1).

Table 1. Linear regression results of change in livestock depredation against change in encounter rate of correspondent species over thirty years (df = 47)

Conflict form	Wildlife species	Predictor variable	Adjusted R ²	Estimate (standard error)	<i>p</i>
Crop depredation	Gaur	Change in encounter rate	0.013	0.12 (0.09)	0.201
		Intercept		0.23 (0.03)	<0.005
	Hanuman langur	Change in encounter rate	0.0003	0.13 (0.13)	0.31
		Intercept		0.04 (0.01)	<0.005
Livestock depredation	Dhole	Intercept	0.11	-0.01 (0.01)	0.32
		Change in encounter rate		0.07 (0.02)	<0.005
Livestock depredation	Jackal	Intercept	0.028	-0.07 (0.03)	0.008
		Change in encounter rate		0.08 (0.05)	0.13
Livestock depredation	Leopard	Intercept	0.11	-0.03 (0.01)	0.03
		Change in encounter rate		0.10 (0.04)	0.01
Livestock depredation	Tiger	Intercept	0.21	-0.02 (0.01)	0.06
		Change in encounter rate		0.10 (0.03)	<0.005

Attacks on humans

Among the implicated species, gaur was perceived as the wild species that inflicted most widespread incidents in recent period (45% of forest ranges). This was followed by sloth bear (*Melursus ursinus*, 30%), leopard (19%), elephant (13%) and tiger (4%). The perceived spread of human attack incidences by wildlife species in the past showed that human injuries

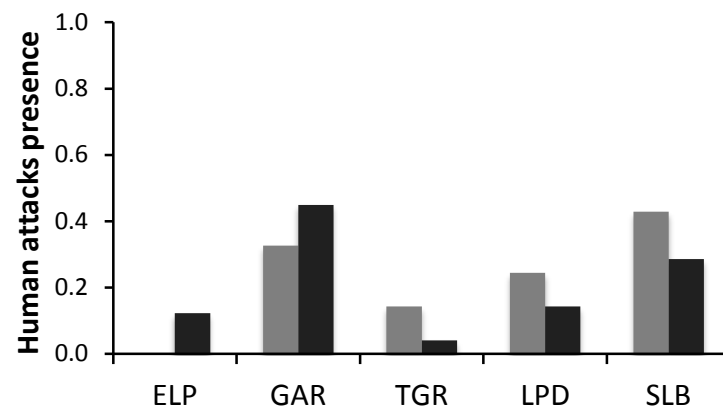
inflicted by sloth bear were spread in greater area (41%) followed by gaur (33%), leopard (25%) and tiger (15%). Over thirty years, the perceived spread of human attack incidents by carnivore species - leopard and tiger and omnivore- sloth bear showed decrease whereas it showed increase with herbivore species - gaur and elephant (Figure 5a).

Within their range of human attacks, sloth bear and gaur were perceived as species inflicting injuries to 8% households followed by elephant (7.5%), tiger (5%) and leopard (4%). In the past also, sloth bear was perceived as the wild species inflicting relatively greater human injuries. It affected 10% of the households within the forest ranges of its spread followed by gaur (7%), leopard (5%) and tiger (4%). Among the implicated species, perceived human attack intensity did not show significant change over thirty years (Paired *t* test- All implicated species: $p > 0.005$, $df = 48$; Figure 5 b).

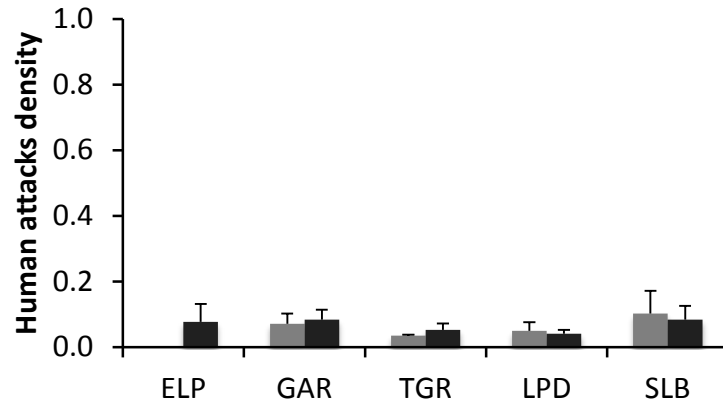
Figure 5. Spread and intensity of attacks on humans over time

(TGR: Tiger, LPD: Leopard, DHL: Dhole, JKL: Jackal, SLB: Sloth bear; X axis- Wildlife species; N=49; X axis – Wildlife species)

a. Proportion of perceived spread of attacks on human



b. Average perceived intensity of attacks on human within its spread



Discussion

Increase in crop depredation by gaur has been reported as one of the serious emerging conflicts in the region. Local respondents attributed this to rise in the abundance of the species, and decline in food due to loss of grasslands. According to them, taboo on gaur hunting and decline in predator (tiger) population in the region have caused the increase in the abundance of the species, whereas decline in forest fires has caused shrubs to encroach in the grasslands, resulting in the decline in food availability in the wild. However, a recent study on land use change in the region shows negligible change in the grasslands (Panigrahy et al., 2010). Therefore, at a broader spatial scale, the argument on declining grasslands does not seem to be valid. Also, our analyses show that the rise in perceived crop depredation by gaur does not appear to be closely related with the change in relative abundance of the species.

Some forest ranges in southern part of the region have been witnessing crop depredation by elephants in recent times. This is clearly due to recent movement of elephants into the study region from adjacent forests located in the state of Karnataka. The reasons behind their movement into these areas are still not very clear. However, elephant presence in the forests of Maharashtra is, though rare, not new (Kulkarni et al., 2008). Except elephants, the study reports no significant change in intensity of human attacks incidents. The genesis and sharp increase in attacks on humans by elephants can be attributed to the recent and unusual movements of elephants in southern part of the region.

People reported overall decline in the geographical extent and intensity of livestock depredation over thirty years. According to them, decline in abundance of the implicated species has reduced the extent and intensity of livestock depredation. Our study also found

that the populations of the focal carnivore species (dhole, jackal, leopard and tiger) showed a decline in their relative abundance, hence supporting the argument that decline in abundance of large carnivore species can be one of the factors that has caused the decline in livestock depredation.

Conclusions

The Sahyadri region appears to be witnessing unusual changes in human-wildlife conflict over last thirty years. For instance, significant levels of crop depredation by gaur in the region which is not reported in any other region so far. This is an alarming sign, as the animal is widespread in the region and the increase in crop depredation may turn into negative attitude of local people whose subsistence is mostly dependent on the agriculture. Also, crop depredation by elephants and attacks on humans by them in the southern part of the region in recent times has become an issue of serious concern for the Forest Department and local residents. Though, sharp decline in livestock depredation by some of the implicated wildlife species appears as a positive sign from social point of view, it also seems to be an outcome of decline in abundance of those species in the region. In a nutshell, this study suggests that management agencies need to put greater efforts in reducing losses inflicted by large herbivore species, especially elephant and gaur. It also gives an alarming signal on the decline of large carnivore species.

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Introduction

Wildlife-human conflict, including the loss of crops to large herbivores and loss of livestock to large carnivores, is one of the serious challenges for wildlife conservation across the world (Hill, 2004; Riley et al., 2013). Some mammal species that have large body size such as elephants, wild cattle or wild cats require greater absolute amounts of food (Eisenberg, 1983). These requirements can be met by traversing bigger home range and/or choosing area of abundant or more nutritious resources (Riley et al., 2013). The large home range of large mammals dramatically increases the likelihood of human-animal interaction. These animals may come in contact with humans during daily foraging and territorial movements which many times turn into conflict (Madhusudan and Karanth, 2002; Madhusudan and Mishra, 2003). In densely populated countries like India, it is very difficult to remove the human settlements in and around the habitats of large mammal species as a means of reducing conflict. These factors make conflict with large mammals a serious and complex issue.

We decided to address this issue as Forest Officials and local media expressed concern over genesis and build-up of an unusual issue of crop damage inflicted by gaur (*Bos gaurus*) in the northern part of Western Ghats biodiversity hotspot (locally known as Sahyadris) in India. Gaur is known for its shy nature and tends to avoid human contact. Therefore, across its distribution there were very few reports of crop damages inflicted by gaur (Bokil, 1999; Choudhury, 2002, 2004; Madhusudan, 2003; Distefano, 2005; Gubbi, 2012). In this context, this was a unique situation where damages inflicted by gaur to the crops were reportedly more than other usual crop raiding animals in the region such as wild pig and macaques.

Given that a household was the fundamental unit of production in the rural landscapes covered under this study, we strived to understand conflict between people and wildlife as a risk factor affecting production at the household level. Losses inflicted by wildlife species can affect both food security and cash income of households directly, which may, in turn, influence their attitudes towards wildlife. Where conflict goes unaddressed, attitudes of local communities have sometimes turned negative and led to reprisal against wildlife and conservation (Madhusudan and Mishra, 2003). Therefore, it is important to understand the nature of losses incurred by households; their causes and impact of these losses on households (Manfredo and Dayer, 2004). We tried to address these issues in this study

through assessments of spread and intensity of income losses of households due to wildlife species in the study region.

In this article, we address the change in spread and intensity of property damages incurred by gaur and some other focal wild animal species over the period of thirty years in study region, the perceptions of local communities towards this issue, the present scenario of property damage inflicted by wildlife species and the relation between observed losses and perceived damages. Finally, we synthesize different possible ways as perceived by local communities to reduce the damages inflicted by wild animals.

Study area

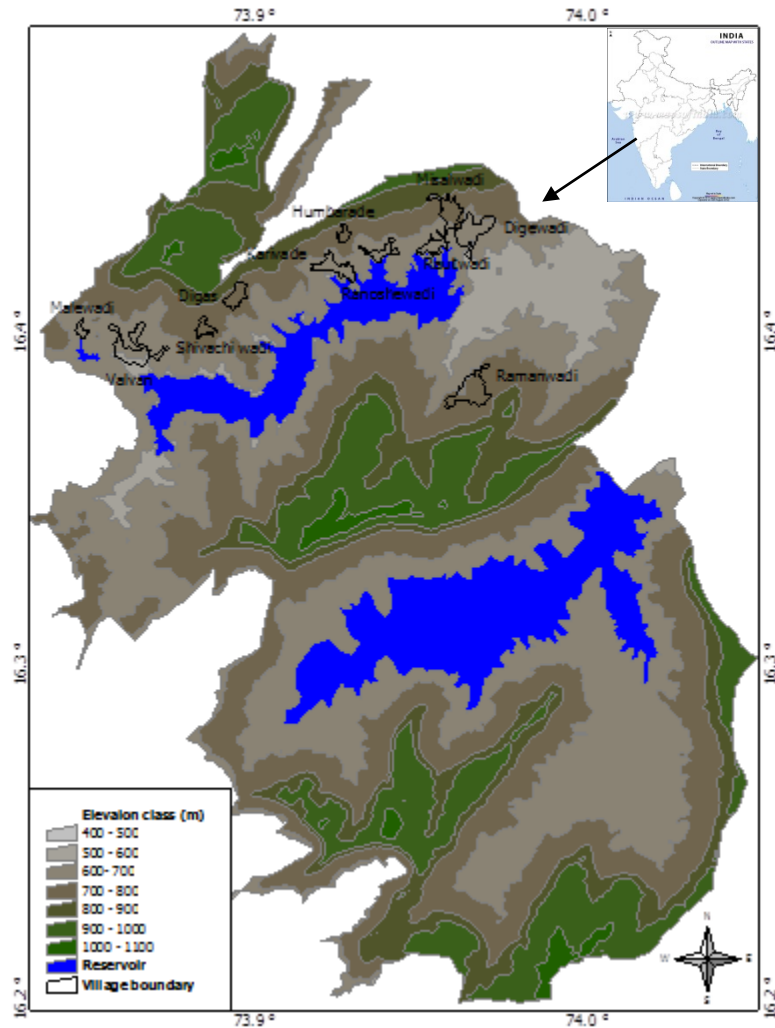
Radhanagari Wildlife Sanctuary (WLS)

Radhanagari WLS (16° 10' N to 16° 30' N, 73° 52' E to 74° 5' E), located in the northern Western Ghats of India, is the first Wildlife Sanctuary of the Maharashtra state and was notified in 1958. Maharaja of Kolhapur Province maintained part of the Sanctuary as a game reserve which was declared as Dajipur Gaur Sanctuary in 1958. It was later declared as Radhanagari Wildlife Sanctuary in September 1985 with an area of 351.16 km². The mean annual rainfall ranges between 2500 mm and 5000 mm. Two dams have been constructed on the rivers Bhogavati and Dudhganga. These two reservoirs and their surrounding forests constitute prime habitat for the wildlife of this sanctuary (Salunke and Sirdesai, 2001). The main forest types are Southern tropical semi-evergreen and west coast semi evergreen forests, Southern tropical moist mixed deciduous forests and West coast tropical evergreen forests (Champion and Seth, 1968). Within the sanctuary, 47 species of mammals, 59 species of reptiles, 20 species of amphibians, 264 species of birds and 66 species of butterflies have been reported (Salunke and Sirdesai, 2001).

Around 55 villages are located in and around the Radhanagari WLS. Some villages, located inside the Sanctuary area, were rehabilitated by the Irrigation Department during the dam construction on Dudhganga in 1980s. It has been reported that, the upper hill terraces were mainly habituated by a Shepard community called Gavli dhanagar till 1985. Their main occupation was livestock rearing. The livestock grazing was prohibited within this area after its declaration as Wildlife Sanctuary. As a consequence they left this area with their livestock and settled down in semiarid plains of peninsular India (Gadgil and Malhotra, 1982; Gadgil and Guha, 1993). Agriculture and livestock rearing are major occupations of the communities

residing in this area. Much of the young men population has been migrated towards the industrial towns and cities in search of employment. Along with agriculture and livestock rearing, money provided by these individuals to their families also forms an important source of livelihood to the people residing in this area.

Figure 1. Map of Radhanagari WLS with study villages in polygons with black outline



Methods

Temporal changes over thirty years

As a part of the landscape level survey on human-wildlife conflict, across the Sahyadri landscape, a questionnaire based interview study was conducted in 172 villages across 49 Forest Ranges in the states of Goa and Maharashtra. In each of the sampled village, person/s with sound knowledge of the village, surrounding forests and wildlife in last three decades were interviewed. The information was collected on the incidents of crop raiding, livestock depredation and attack on human by wildlife species in the village. The average proportion of

households affected in a village due to crop raiding by each of the selected species in last three years was recorded. The responses were ranked as absent (where, affected households in the village were 0), rare ($1\% < \text{Affected households} < 20\%$), common ($20\% < \text{Affected households} < 50\%$) and intense ($\text{Affected households} > 50\%$). We used data from four forest ranges – Radhanagari Wildlife, Dajipur Wildlife, Radhanagari Territorial and Gaganbawada Territorial to assess the temporal change in spread and intensity of property damage inflicted by focal wildlife species over thirty years.

Perceived and observed losses

A key informant survey was carried out in randomly selected 18 villages located in and around Radhanagari WLS to assess the local perceptions on human-wildlife conflict. In each sampled village, information was collected pertaining to the losses incurred by villagers inflicted by wildlife and the economic situation of respective village. This was done through semi-structured interviews with the group of elderly people having sound knowledge of their village. During the interviews, precautions were taken that there will be minimum three members in a group to be interviewed, the group members belong to the same village and have fair information about their village and surrounding area.

Based on village level key informant survey, five villages were selected for the assessment of spatio-temporal variation in human-wildlife conflict along the gradient of perceived losses. All 189 households residing in these selected villages were monitored for 17 months during July 2008 to November 2009. In addition to these villages, three more villages, practicing only monsoon cultivation, with 64 households were monitored from June 2009 to November 2009. The monitoring period was distributed across all three seasons of the year: monsoon (June to October), winter (November to February) and summer (March to May). A local research assistant was appointed for each village and trained to collect data pertaining to losses due to conflict and socio-economic status of each household.

The cultivated area within the administrative boundary of each monitored village was under the private ownership, much of it being owned by the households residing in the same village. The households usually own more than one piece of land of varying area, in different locations within the village boundary. Each such piece of land under the ownership of a single household was considered as a cropfield. The total area of cropfields under cultivation in a particular season belonging to a household was considered as the crop area of that household of that season. The total crop area of the households was calculated as the

summation of crop areas of each season during monitoring period. The information pertaining to crops and losses due to crop raiding was collected at cropfield level. The cropfield was considered as a unit for recording the conflict incidents. The number of forays by large wild animals within one night on same cropfield could not be differentiated and were considered as one crop raiding incident. The crop area loss and produce loss inflicted by wild animals were recorded after each of crop raiding incident through actual loss measurement in the field. Animals foraging in the crop field were not seen throughout the monitoring period. The identification of damage causing animal was done through tracks and feces observed at the crop raided site. As all five field assistant were farmers, they were proved to be unanimous in the measurement of crop damage.

Among the wildlife species, losses by large mammal species (> 2kg) were considered for the loss measurement. The losses by rodents, though might significant, were not recorded. The crop area damage was measured in local unit gunta (100 m²) as farmers and field assistant were more familiar with this unit. Later, this was converted into hectare. Simultaneously, the produce loss was estimated on the basis of the extent of damage of the crop within the damaged area and its chances of recovery. The monetary loss was estimated based on the produce loss multiplied by its local market price. The perceived losses by households were recorded after each conflict incident through interaction with the affected household. The information pertaining to socio-economic status of each household and the previous year's losses at household level were recorded through the questionnaire based interviews.

Analysis

Perceived changes over thirty years

Perceived crop depredation intensity inflicted by each implicated wildlife species for present and past was estimated for the four forest ranges where crop depredation by correspondent species had been reported. The degree of conflict was ranked as 0 (absent), 0.2 (rare), 0.5 (common) and 1 (intense), based on the proportion of households affected in a village as perceived by the key informants. The conflict level of each implicated wildlife species for each forest range was calculated by averaging the ranks given by the key informants.

Perceived losses across villages

The Perceived losses inflicted by each focal wildlife species were calculated as sum of proportion of losses incurred by each crop species in the surveyed villages. This was done on

the basis of raiding incidents per month, relative perceived damage and proportion of the area under the crop species. Perceived loss for each village was calculated by summing up of all perceived losses for all crop species in that village.

Evaluated losses

The losses inflicted by wild animals were measured and calculated in terms of area damaged, produce loss and monetary loss. The monetary losses were calculated from the produce losses measured in the field by multiplying them by local market price of that produce. We assessed the role of proximity of vegetation and human settlement to cropfields using linear multiple regressions. The proximity variables were derived using the Arc GIS software. The statistical analyses were carried out using the R software (R Development Core Team, 2014).

Results

Socio-economic details of households

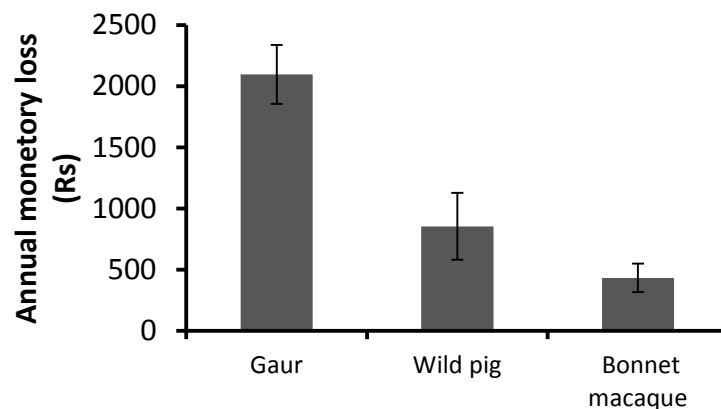
Among the 253 households, agriculture was the only source of livelihood for 30% households whereas 72% households were dependent on agriculture and livestock for their living. The 26% households were serving in other sectors in nearby industrial towns or big cities. The landless households (4.3% of the monitored households) were either involved in agriculture on a land taken on lease from other or in livestock rearing or working as daily wage labours in agricultural fields and private forests in konkan region. All households had own house but none of the households in these villages had car. The electricity had reached in 94% of the households but only 22% had television and 28% households had telephone.

The average landholding of each household was 0.58 ha; and it was ranging from 0.4 to 4 ha. Three cropping seasons in a year were observed: kharip (June-October; Monsoon), rabi (November-February; Winter) and summer (March-May). All cultivated crops were seasonal except perennial sugarcane crop species (*Saccharum* sp.). The kharip season crops were paddy (*Oryza sativa*) and ragi (*Eleusine coracana*); rabi season crops were beans (*Lablab purpureus*), groundnut (*Arachis hypogaea*), and wheat (*Triticum aestivum*); and the only summer crop was groundnut. Excluding some landless households, all households cultivated crops during kharip season. As water availability for crops during the dry season was scarce, only 17% households grew rabi season crops and 15% grew summer season crops.

Losses inflicted by gaur

Gaur was perceived by local communities as a large mammal species inflicting losses to the greater proportion of households (Mean loss index (0-100): gaur = 30.2, wild pig = 11.9, Bonnet macaque = 3.1, chi square = 25.37, df = 2, $p < 0.001$) and also, proportion of the affected households (gaur= 31.2%, wild pig = 4.7%, Bonnet macaque =1.2%) and among the affected households, the average annual monetary losses inflicted by gaur were significantly greater than wild pig and macaque (Figure 2; chi square = 1327, df = 2, $p<0.001$).

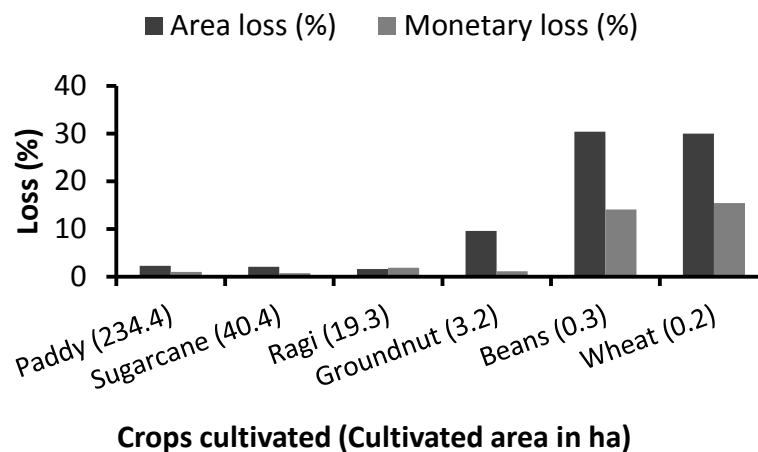
Figure 2. Monetary losses incurred by affected households due to crop raiding inflicted by wildlife species



Losses incurred by crops

Paddy was widely cultivated crop species in the region, followed by sugarcane, ragi and groundnut. Though, beans, wheat and green gram were observed to be cultivated in very small proportion (<1% of the total cultivated land); they faced greater losses per unit area of their cultivation compare to the other crops (Figure 3).

Figure 3. Area and monetary loss incurred by cultivated crops due to crop raiding



Influence of forest, reservoir and human settlements proximity to crop fields

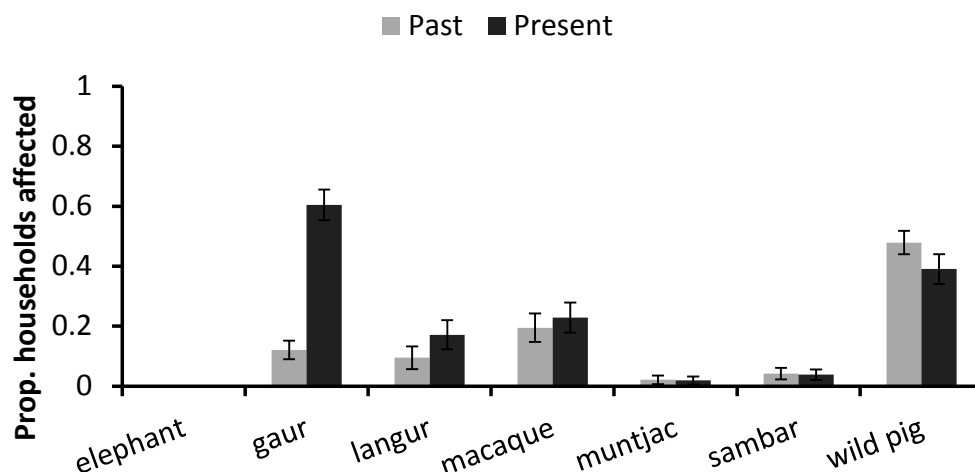
Proximity of cropfields to forest showed negative relationship with the crop area damaged by the gaur (Intercept =1.261, adjusted R^2 = 0.013, estimate= -2.14×10^{-3} , p = 0.0002, df = 1265). However, the crop area loss across the crop fields was indifferent to the proximity of human settlements distance (p = 0.269).

Losses over different time scale

Over thirty years

Across the study villages, gaur perceived as affecting more than 60% households followed by wild pig (30%) and primate species - hanuman langur and bonnet macaque with losses to approximately 20% households in recent period. Sambar and muntjac had affected 4% and 2% families respectively (Figure 3). The crop depredation by elephant was absent in recent period as well as thirty years back. The perceived intensity of gaur crop depredation increased fivefold over thirty years. The perceived crop depredation intensity of hanuman langur and bonnet macaque had increase, though negligible, over thirty years. Crop depredation by wild pig showed decrease in perceived crop depredation. Sambar and muntjac were perceived as wildlife species which inflict negligible crop losses in the past as well as in the present (Figure 4).

Figure 4. Change in conflict intensity inflicted by wildlife species over thirty years



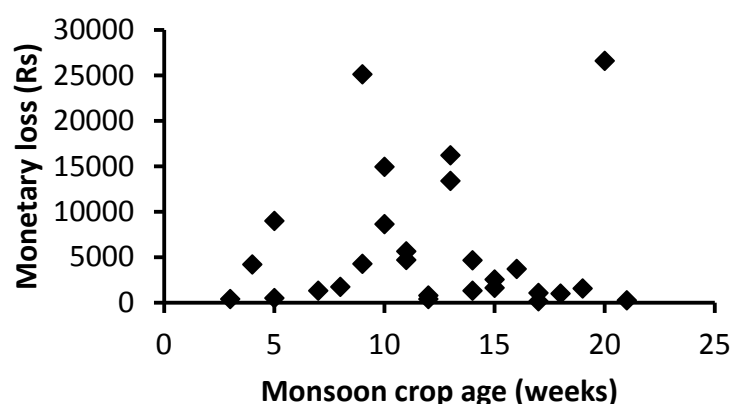
Across seasons

Summer crops incurred much greater monetary losses per hectare of the cultivated land (Summer = 1274 rupees/ha; Monsoon = 612 rupees/ha; Winter = 520 rupees/ha). However, losses incurred by monsoon crops were much widespread and the average monetary loss of affected households doing monsoon cultivation (29.5%) was higher in relation with the winter and summer seasons (Affected households: Monsoon= 29.5%, Winter = 4.9%, Summer = 6.5%; Monetary loss per affected household: Monsoon= Rs 2000, Winter = 658, Summer = Rs 1094).

Across weeks

As higher number of conflict incidences occurred in monsoon and also, greater proportion of households incurred losses due to gaur crop raiding in monsoon. We looked at the within season variation in crop depredation by gaur during monsoon season. It appeared that crops incurred relatively higher losses in the middle of cropping season than in the beginning or at the end of cropping season (Fig. 5).

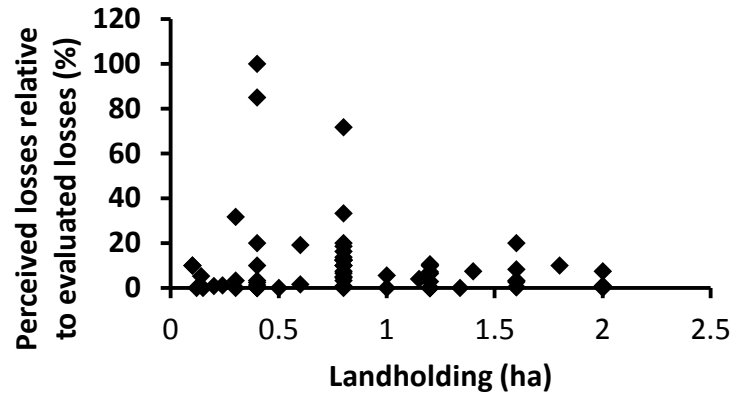
Figure 5. Monetary losses incurred by households cultivating monsoon crops across the weeks



Perceived vs evaluated losses

People perceived that among cultivated crops paddy incurred much higher losses, followed by ragi and sugarcane. With very few exceptions, households perceived their crop losses due to wildlife greater than the evaluated losses in the field. The households, with small landholding, appeared as they perceive their losses much higher than those of with relatively larger landholding (Fig. 6).

Figure 6. Perceived losses of households in relation to the landholding



Discussion

Agriculture and livestock rearing form major part of the income of households in the region. The households involved in agriculture have much low landholding (0.58 ha) compare to average landholding in India which is 1.23 ha (Department of Agriculture and Cooperation, 2011). Around 85% of the households can only cultivate their land in monsoon as no irrigation facility is available. This situation has made majority of the households to live marginal life. Around 75% households still can't afford television or telephone which indicates the low financial status of the households. Therefore, the losses incurred by households, though appeared as low in proportion, affect their livelihood badly. The greater perceived losses indicate that the losses inflicted by the households make much higher impact on their livings. The income from agriculture to the households is critical for the livings of these households and therefore, many households those were facing crop losses due to gaur, have given up the agriculture in the region and have preferred to work as daily wage laborers in nearby towns and cities.

Ecology

Change over thirty years

Local people perceived that wild pig was most destructive species thirty years back. A study in Koyana WLS in the north Western Ghats, situated at around 150km from study region, also reports wild pig as wildlife species inflicting higher losses to crops (Bokil, 1999). But over thirty years, the crop damage inflicted by gaur appears to have surpassed the wild pig. The reasons behind this would be declaration of wild pig as vermin and Forest Department allowed killing of the wild pig few years ago. Also, wild pig has reportedly been hunted in the area for meat, though it is illegal, in this region whereas gaur doesn't have such hunting

threat as it is regarded as sacred cow. This might be one the few reasons behind increase in crop depredation by gaur in relation to the wild pig.

Why gaur inflicts losses in north Western Ghats?

- Preference for more nutritious food

The studies have shown that gaur is grazer as well as browser and consumes wide range of plants. It is known as a forest species but also prefers open habitats for foraging (Schaller, 1967; Prater, 1971) and it prefers green grass over browse (Chetri, 2003, 2006; Gad and Shyama, 2009). Studies have attributed temporal variation in crop raiding to the changes in crop and natural forage quality (Chiyo et al., 2005). The variation in losses across seasons and within season also indicates that nutritive value of the cultivated crops might have been one of the important driving factors for gaur crop depredation. The summer crops are concentrated in much smaller area. As much of the forest vegetation is of deciduous type, the summer crops, being relatively more nutritious and concentrated in smaller area, might have been greater attraction to gaur. Also, the losses to seasonal crops were higher during mid-months of the season. This may be attributed to the size and nutrition value of the crops. During initial period, the crop height is small which may not give enough food to gaur. When crop attains enough size to eat, the spread and intensity of crop losses were higher. Again, at the end of season, the spread and intensity of crop losses showed decline. This may be attributed to the decline in nutrition value of crop at the end of the season i.e. after flowering and fruiting of crop. The greater preference for relatively more nutritious leguminous crops by gaur also supports the arguments in various studies that nutritive value of the crops plays an important role in crop depredation (Sukumar, 1990; Madhusudan and Mishra, 2003; Riley et al., 2013).

- Lower predation pressure?

It appeared that greater proximity to the forest vegetation makes cropfields more vulnerable for the crop raiding which was expected. However, considering the shy nature of the gaur, it was also expected that gaur would raid crop mostly away from human settlements. However, the crop damage didn't show significant variation across the proximity distances from the human settlements. This indicates the lower predation pressure on gaur in the region. But also, a fact needs to be considered that almost all the incidents happened during the night when human activities were very low. The crop depredation locations were also indifferent in relation to the distance from nearest large water bodies. The potential explanation could be,

as much of the incidents happened during wet period, the water during that period is mostly available inside the forest and it may not come to the reservoir outside the Forest areas from the water.

Some studies have shown the positive relationship between the increase in population of animal species and the amount of damage (Hofman-Kamińska and Kowalczyk, 2012). The local residents and officials in the region perceive that gaur abundance has been increased over the period of time in the region. The management plan of the Radhanagari Wildlife Sanctuary specifies the increase in number of individuals from 340 in the year 1994 to 510 in 2001. Our survey at landscape level survey also reveals the decline in tiger, a major predator of gaur, and increase in gaur abundance over thirty years. As the landscape of fear concept postulates, prey animals have ability to learn and differentiate the safety level of their habitats (Laundré et al., 2010). It seems the gaur in this area experiences, lower predator presence and no direct threat of hunting from humans. These factors could have resulted into the lower predation risk for the gaur which might have helped to come out of psychological fear of humans and predators at some extent and would have been resulted into their foraging into the agricultural lands.

Some major demographic changes have happened in the 20th century also need to be considered. The dam was constructed on Bhogawati river in this region by 1935 and people doing settled agriculture had to move to the upper hill terraces in the region. The reservoir occupied major portion of the forest area and also the newly moved people had cut some areas of forests for cultivation. In 1985, the area was declared as Wildlife sanctuary and with the regulations people had to give up livestock grazing inside the Protected Area. The resident communities such as Gavli-dhangar, who traditionally been involved in livestock rearing as their main source of livelihood, had to move outside the area to find the new areas for their livestock to graze. So, the decline in forest area, increase in human activities and cultivated area but decline in livestock grazing and fire are few prominent changes took place in the region in the last century. These changes might have led to the decline in food availability and quality inside the protected area, decline in predator populations such as tiger and resultantly low predation pressure on gaur. However, as no data present to support, these arguments are purely speculative at present.

Conservation implications

Tropics support greater diversity of bovids (Traill et al., 2012). However, in recent period the large scale deforestation and fragmentation have resulted into the range contraction and local extinction of many species with large home range (Pillay et al., 2011). The north Western Ghats has also been facing high threats of habitat fragmentation and range contraction of some of the large mammal species (Johnsingh et al., 2010). High body mass, high home range and greater food requirement may pose threat of population decline or local extinction of bovids. This situation demands conservation efforts designed in accordance with local situation (Traill et al., 2012). Gaur, in north Western Ghats, is regarded as the sacred cow therefore hunting gaur is social taboo on in the region since long time. This seems to have been helpful conservation of the species in the region. However, increasing crop raiding by the animal might result into negative attitudes towards the animal (Gillingham and Lee, 1999, 2003). In the study region, the effect of crop raiding is such that many villagers have given up the farming in their cropfields. However, it is very important to design conservation measures that will stimulate participation of local people into conservation initiatives and build up positive attitude towards wildlife.

Protection measures for the crops are important steps to mitigate the human-wildlife conflict; however these measures should be looked from the local people's point of view as well (Hill and Wallace, 2012). The villagers living in this area are migrated from the valley. However, the land they have been using since then not under their ownership and Forest Department claims the ownership on their land. Therefore, the villagers have a sense of insecurity and they are not really willing to take risk and invest money in protection measures such as strong fencing as they feel that Forest Department may ask them to vacate the land and move outside. Also, much of the young men population has migrated to the big cities for employment and guarding the crops during night for residential population especially women and elderly people is quite difficult.

During our study, local people were referring to the decline in open grassy areas inside the Protected Area as the major reason for crop depredation by gaur and recommended that the grasslands need to be restored. There is no global evidence on effect of shrub encroachment on grasslands and resultantly on herbivory (Eldridge et al., 2011). Therefore, this speculation needs to be evaluated with appropriate study. However, in the presence of very low predator abundance, it is highly likely that gaur would still prefer to graze the fertilizer supplemented and so highly nutritious crop species over the natural grasslands. Therefore, it would be more appropriate to suggest that more efforts need to be taken on habitat conservation in addition

with the crop protection measures in such a way that it will maintain the healthy ecosystem which resultantly would help reduce the crop depredation in the region.

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