Conservation and Society 15(4): 474-482, 2017

Article

Conflict to Coexistence: Human – Leopard Interactions in a Plantation Landscape in Anamalai Hills, India

Swati Sidhu, Ganesh Raghunathan, Divya Mudappa, and T. R. Shankar Raman[#]

Nature Conservation Foundation Mysore, Karnataka, India

[#]**Corresponding author. E-mail**: trsr@ncf-india.org

Abstract

When leopards are found in human-dominated landscapes, conflicts may arise due to attacks on people or livestock loss or when people retaliate following real and perceived threats. In the plantation landscape of the Valparai plateau, we studied incidents of injury and loss of life of people and livestock over time (15 – 25 y) and carried out questionnaire surveys in 29 plantation colonies and eight tribal villages to study correlates of livestock depredation, people's perception of leopards, and preferred management options for human – leopard interactions. Leopards were implicated in an average of 1.3 (± 0.4 SE) incidents/year (1990 – 2014) involving humans and 3.6 (± 0.8 SE) incidents/year (1999 – 2014) involving livestock, with no statistically significant increasing trend over time. Most incidents of injury or loss of life involved young children or unattended livestock, and occurred between afternoon and night. At the colony level, livestock depredation was positively related to the number of livestock, but decreased with the distance from protected area and number of residents. Half the respondents reported seeing a leopard in a neutral situation, under conditions that resulted in no harm. All tribal and 52% of estate respondents had neutral perceptions of leopards and most (81.9%, n = 161 respondents) indicated changing their own behaviour as a preferred option to manage negative interactions with leopards, rather than capture or removal of leopards. Perception was unrelated to livestock depredation, but tended to be more negative when human attacks had occurred in a colony. A combination of measures including safety precautions for adults and children at night, better livestock herding and cattle-sheds, and building on people's neutral perception and tolerance can mitigate negative interactions and support continued human – leopard coexistence.

Keywords: large carnivores, *Panthera pardus,* human – wildlife conflict management, human deaths, livestock depredation, tea, coffee, Western Ghats, human ecology

INTRODUCTION

Large predator species are wide-ranging and are known to inhabit human-dominated landscapes. Where people and large predators share space, they often encounter one another, which sometimes results in negative interactions such as livestock depredation, injury or loss of human life, and translocation, hunting or retaliatory killing of predators (Madhusudan and Mishra 2003). In such landscapes, large predators may kill livestock, especially when wild prey densities are low, or when livestock are not properly guarded (Mishra 1997; Mazzolli et al. 2002; Bagchi and Mishra 2006). Some examples include leopards *Panthera pardus* (e.g., Athreya et al. 2016), lions *P. leo* in Africa (Bauer and de Iongh 2005), pumas *Felis concolor* and jaguars *P. onca* in South America (Mazzolli et al. 2002; Zimmermann et al. 2005), snow leopard *Uncia uncia* in the Himalayas (Mishra 1997), and wolves *Canis lupus* and coyotes *C. latrans* in North America (Windberg et al. 1997; Treves et al. 2002). In such incidents, conservation of large carnivores becomes particularly challenging when people lose a major part of their income to these predators, and especially

Access this article online	
Quick Response Code:	Website: www.conservationandsociety.org
	DOI: 10.4103/cs.cs_16_35

if the species involved are endangered (Mishra 1997; Wang and MacDonald 2006).

Frequency of livestock depredation incidents may depend on the relative abundances of predators, wild prey, and livestock. Depredation incidents may decrease when predator densities decrease with increasing human population densities (Newmark et al. 1994; Woodroffe 2000). They may also increase with higher predator density following successful reintroduction or protection (Linnell et al. 2001; Suryawanshi 2013), although evidence supporting this correlation is lacking from other studies (Conner et al. 1998; Knowlton et al. 1999; Landa et al. 1999). Increase in livestock depredation may also result from low wild prey availability or high livestock numbers in a landscape (Bagchi and Mishra 2006). Low wild prey abundance may be caused by hunting for trophies or meat or because of competition for resources with domestic species. Other factors reported to influence conflict are distance to grazing pastures, guarding of livestock, and bad weather (Mazzolli et al. 2002; Wang and Macdonald 2002). There are also socio-economic and political dimensions to conflict between humans and predators as the attitudes and responses of local people often depend on their economic and cultural background (Dickman 2010).

Although the leopard is considered as the most widespread of all large felids, the species now occupies only 25% – 37% of its historical range (Jacobson et al. 2016). Based on its 'threat status' the species has been listed in Appendix I of the Convention for International Trade in Endangered Species of Flora and Fauna (CITES, Simcharoen et al. 2008) and in Schedule I of the Wildlife (Protection) Act of India (WLPA 2003). Translocation is becoming a threat to conservation of the species, as it often leads to an increase in conflict by failing to adequately consider aspects of leopard biology such as territoriality, homing instincts, increase in leopard numbers at the site of release or at the original conflict site due to immigration of new individuals (Athreya 2006; Athreya et al. 2010; Bhattacharjee and Parthasarthy 2013). There is evidence that leopards are capable of living in human-dominated areas with low levels of conflict in the absence of translocation (Athreya and Belsare 2006; Athreya et al. 2016). Further, solutions sought by management and scientists need to consider social norms and cultural ideologies to improve management effectiveness (Manfredo and Dayer 2004).

Here, we studied incidence of human – leopard interactions in the Valparai plateau of the Anamalai Hills, which has experienced loss of human life and livestock depredation due to leopards, and explored the following questions—1) How are the incidences of human deaths and injuries and livestock depredation, distributed across years? 2) What are the economic losses due to livestock depredation? 3) What are the correlates of livestock depredation that influence distribution of these incidents in the study area landscape? 4) What is the perception of local communities towards leopards and their preferred management response towards human – leopard interactions; and which factors determine the perception and response of local communities?

MATERIALS AND METHODS

Study area

We carried out this study in the Valparai plateau (220 sq. km) and surrounding Anamalai Tiger Reserve (958 sq. km, 10°12′ N to 10°35′ N and 76°49′ E to 77°24′ E, Figure 1), which lie in the Anamalai Hills of the Western Ghats, a global biodiversity hotspot (Kumar et al. 2004). It adjoins several protected areas within Tamil Nadu and Kerala in the southern Western Ghats. The plateau, with an altitudinal range between 800 m and 1300 m above sea level, receives a mean annual rainfall of 3500 mm, majority of which falls during the southwest monsoon between June and September. The main mammalian large carnivores in Valparai and surrounding protected areas include leopard, tiger *Panthera tigris*, dhole *Cuon alpinus*, and sloth bear *Melursus ursinus*.

The Valparai region is an undulating plateau that underwent land-use changes in the late 19th and early 20th century from mid-elevation tropical wet evergreen forest into plantations of commercial importance such as tea, coffee, cardamom, and *Eucalyptus* (Mudappa and Raman 2007). At present,

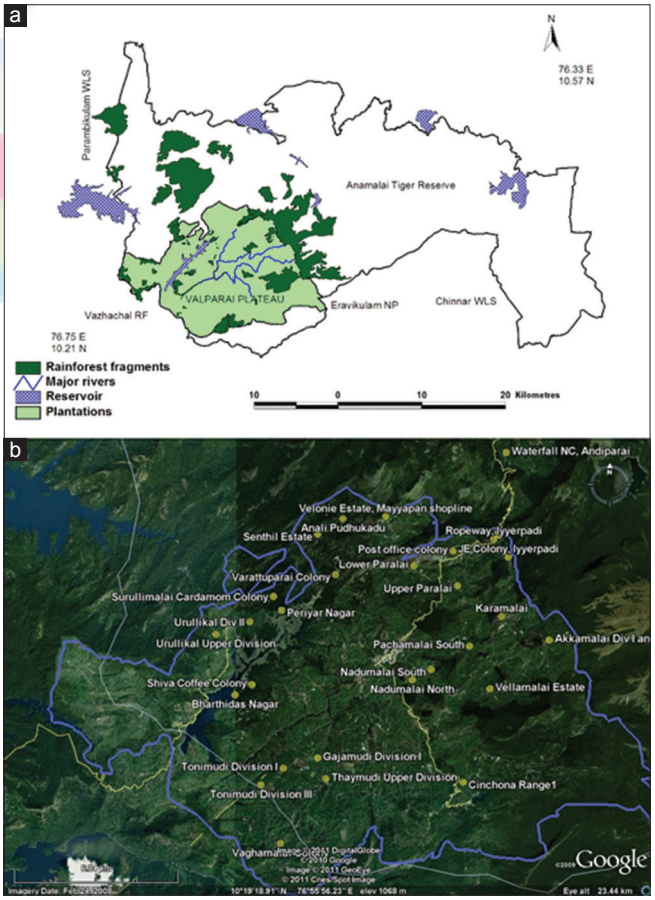

Figure 1

(a) Study area of Valparai plateau in light green and surrounding Anamalai Tiger Reserve in white, with rainforest fragments in dark green, and water bodies in blue (upper panel). (b) Valparai plateau, showing locations of colonies where household surveys were carried out (lower panel, courtesy: Google Earth)

around 75% of the cultivated area on the Valparai plateau is dominated by tea plantations, with the remaining comprising of other forms of land-uses including remnant forest fragments on private land (Mudappa and Raman 2007). Around 71,000 people live in Valparai town and the surrounding estates, in the latter mostly in scattered colonies with line housing for workers. While the estate workers are mostly non-tribal, around the Valparai plateau in the Anamalai Tiger Reserve, there are eight forest villages of people belonging to the Kadar, Muthuvar, and Malai Malasar communities (Chandi 2008).

Data on leopard-related incidents and interactions

From the Tamil Nadu Forest Department (TNFD) records, we compiled data on incidents attributed to large carnivores that resulted in injury or loss of human life, loss of livestock, and compensations paid. The TNFD data on injury and loss of human life were available from 1990 to 2014, while data on loss of livestock were available only from 1999 to 2014. In addition, during November 2010 – January 2011, we carried out interview surveys with the local communities to compile other conflict incidents that were not part of the TNFD record. While TNFD records were verified by the authorities at the time of the incident, incidents reported only in interviews were cross-verified by speaking to other residents in the colony where they occurred. For the purpose of analysis of temporal trends in incidents related to humans or livestock, we restrict our analysis to TNFD records only.

We carried out interview surveys at colony and at household levels. We sampled 29 colonies in eleven estates in the plateau. These were chosen randomly (using a random number generator) from among 40 colonies where incidents of livestock depredation and injury/loss of human life were recorded with the forest department. We also sampled eight tribal settlements in the adjoining protected area. Sampling in estates included 4 – 6 colonies in the four large estates belonging to Bombay Burmah Trading Corporation Ltd., Parry Agro Industries Ltd, Peria Karamalai Tea and Produce Company Ltd., and Tata Coffee Ltd., and one colony per estate in the seven smaller estates belonging to Siva Coffee, Senthil estate, Mahaveer estate, Waterfall estate, Tamil Nadu Tea Plantation Corporation (TANTEA), and Bharatidas Nagar (Figure 1). For interviews with residents, we selected 126 of a total of 3213 households in the estate colonies (including households with and without livestock) and 35 households in the tribal settlements. We visited the randomly selected colonies during evenings (when most families return from estate work) and solicited information on households that had livestock. We then interviewed people from livestock-keeping households based on their availability and willingness to be interviewed.

At the colony level, we gathered data on human and livestock numbers in each colony and identified households that reported monetary loss to predators as a result of livestock injury and death. Surveys at household level identified livelihood sources, contribution of livestock to the household's economy, economic losses to conflict with large predators, personal encounters with leopards. For livestock-keeping households, we gathered information on herding practices, whether herders were appointed for day guarding during grazing, and condition of livestock corral (open or closed). To understand attitudes of local people towards leopards, we asked the household respondents a set of two questions, one related to perception of leopards and another related to their preferred management response towards interactions with leopards. We first asked respondents to indicate the major problems related to livelihood security of their household. If leopards were mentioned as a problem, respondents were asked to indicate the severity of the problem on a scale of 1 to 5 from least to most severe. In case leopards were not mentioned as a problem, we noted the response as neutral with a zero on the 'perception scale', and therefore, define 'neutral' as an absence of negative perception towards leopards for the purpose of this paper. We also noted their preferred management option on a scale by asking which of the following control measures they felt was most appropriate for dealing with human – leopard interactions: 1) change one's own behaviour, 2) be aware and monitor leopard occurrence and movement, 3) chase away the animal with noise, 4) catch and translocate, and 5) lethal control. If the respondent did not think any such measure was necessary, we noted this as neutral or zero on the response scale.

Data analysis

We used 25 years of data on human injuries and deaths, and 16 years data on livestock depredation incidents attributed to large carnivores, to explore the temporal distribution in conflict incidents across years. We analysed the contribution of livestock to the household economy of livestock owners and estimated the perceived economic losses incurred, in terms of the reported value of the animal, as a result of depredation (using an average of other responses for two cases where no reported value was available). To understand the effects of potential factors influencing livestock loss in colonies on the Valparai plateau, we used the Generalised Linear Model (GLM) analysis, with quasi-poisson errors to account for over-dispersion in the data, and a log link function using the R statistical and programming environment (R Core Team 2015, version 3.2.0). During analyses, the number of depredation incidents in a colony, which resulted in injury or loss of livestock was treated as the response variable, while the number of people and the number of livestock in the colony, distance from the colony to the nearest protected area boundary, and distance to nearest forest edge were included as potential explanatory variables.

To test whether an individual's perception of leopards and their preferred management option to interactions with the species were significantly associated with occurrence of the following factors: attacks on humans in the colony, depredation of livestock in the colony, depredation of livestock at household level, or sighting of a leopard (not resulting in a negative

interaction), we used a chi-squared test of independence with Yates' correction for continuity as the two response variables were categorical. We compared perceptions of people who kept livestock with those who did not within the same colony as these households were otherwise similar in environmental attributes such as housing quality, distance to forest or water source, and availability of toilets. We compared the attitudes of people in estate colonies and tribal settlements in terms of their perception of leopards as a problem and their response index towards conflict management. We also quantified the number of respondents who had seen a leopard in their lifetime in Valparai and used the data from the most recent year prior to the interviews (2010) to estimate the number of interactions between people and leopards that did not result in conflict and could be termed as 'neutral'.

RESULTS

Human deaths and injuries

Over a 25-year period (1990 – 2014), there were 32 incidents (involving 32 people) where leopards encountered people resulting in 18 fatalities, and 14 people sustaining injuries. In these incidents, the age of the person was known in 17 cases; this included 10 deaths, of which 9 (90%) were children below 10 years of age, and one was an adult (21 years old). The remaining 7 cases that resulted in injuries involved five children (less than 10 years old) and two adults (age 44, 55 years). The number of incidents averaged 1.28 (± 0.38 SE) per year, with a range of 0 – 8 incidents per year (Figure 2). More incidents involving injuries to humans occurred during 2008 (6 injured) and 2010 (3 injured). There was no statistically significant linear trend of increase over time in the number of incidents of leopard attack on humans (Pearson's $r = 0.36$, $df = 23$, $P = 0.076$) or in the number of human deaths ($r = 0.26$, $df = 23$, $P = 0.208$). Other large carnivores to which attacks on people in the study area were attributed included tiger (1996: 2 incidents, 4 deaths, 1 injury; 2005: 1 incident, 1 person injured) and sloth bear (2007: 2 incidents, 1 death, 1 injury; 2011 – 2015: 2 incidents, 2 people injured).

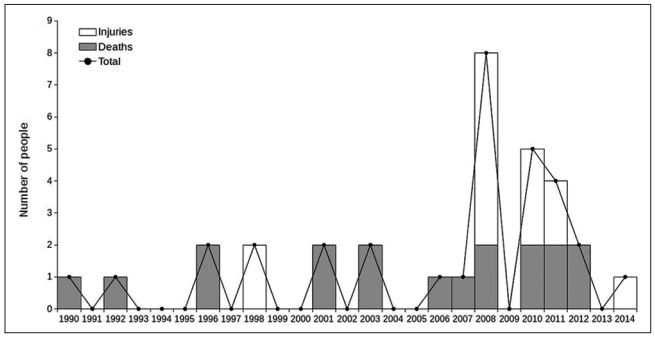

Figure 2
Conflict incidents related to people between 1990 and 2014 on the Valparai plateau, Anamalai hills, India

Livestock losses

Over a 16-year period (1999 – 2014), in the Valparai landscape, 58 incidents of livestock loss were attributed to leopards, with an average of 3.6 incidents (± 0.8 SE) and range of 0 – 11 incidents per year (Figure 3). These 58 incidents resulted in the death of 62 livestock (23 cows, 33 calves, and six goats, Table 1) and injuries to 3 livestock (Figure 3). The number of livestock depredation incidents (Pearson's $r = 0.22$, $df = 14$, $P = 0.44$) and livestock deaths ($r = 0.21$, $df = 14$, $P = 0.42$) did not show a statistically significant increase over the 16-year period. In addition, other large carnivores (tiger, dhole) were involved in an additional 10 incidents in which 16 livestock were killed and 5 injured (Table 1). The 68 incidents included 30 in Tamil Nadu Forest Department (TNFD) records plus an additional 38 incidents between 2000 – 2010 involving livestock (cow, buffalo, goat) reported by respondents during interview surveys in 29 estate colonies. Of these 38 incidents, time was known in 32 cases; while two took place in the morning, the rest occurred in the afternoon. The morning incidents occurred when the livestock were left unattended in grazing pastures. Of 30 incidents that occurred in the afternoon, in 26 cases the livestock were left unattended inside the colony (n = 1), tethered in open sheds (n = 8), or unguarded in the grazing pasture (n = 17). Of 56 respondents who kept livestock in estate colonies, although corrals/sheds were available in all cases, 43.6% (n = 24) had only open corrals, 48.2% (n = 27) had closed corrals (remainder, information unavailable). In these 56 cases, herders were employed for day guarding in 76.8% (n = 43) households, while the rest lacked herders.

Table 1: Large carnivores depredation incidents and number of livestock lost between 1999 and 2014 in estate colonies on the Valparai plateau

Carnivore	Incidents	Buffalo	Cow		Goat
		Adult	Adult	Calf	Adult
Dhole	6	-	3	2	-
Leopard	58	-	23	33	6
Tiger	4	1	2	1	-

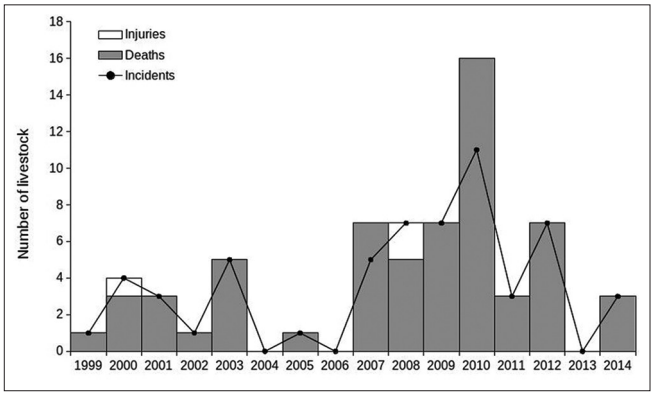

Figure 3
Conflict incidents related to livestock between 1999 and 2014 on the Valparai plateau, Anamalai hills, India

The department paid a total compensation of INR 58,500 (equivalent to USD 875.2 at 2017 exchange rates) for 22 livestock depredation incidents involving loss of 25 animals (cow and buffalo) amounting to an average compensation of INR 2,340 (± 197 SE) or USD 35 (± 3 SE) per animal. In an additional 8 cases, compensation was not paid as either the claims were not made, or the documents were incomplete or pending. Based on the reported economic value of livestock, the perceived loss due to depredation amounts to an average of INR 90,833 (± 6,233.9 SE) or USD 1358.9 (± 93.3 SE) per year with a mean loss of INR 8,425 (± 1,128 SE) or USD 126 (±16.9 SE) per animal. This indicates an average difference of INR 6,085 (USD 91) in the perceived loss and the compensation received per animal.

We used GLM analysis to explore significant correlates of livestock depredation in colonies on the Valparai plateau. The GLM analysis showed that the number of depredation incidents increased with increasing livestock numbers per colony (Table 2), while tending to decrease as distance from protected area and number of people in the colony increased (Figure 4). The significant and negative two-way interaction (L: P) coefficient suggests that besides the effect of livestock numbers, as number of people in a colony increased the incidence of depredation decreased (Table 2).

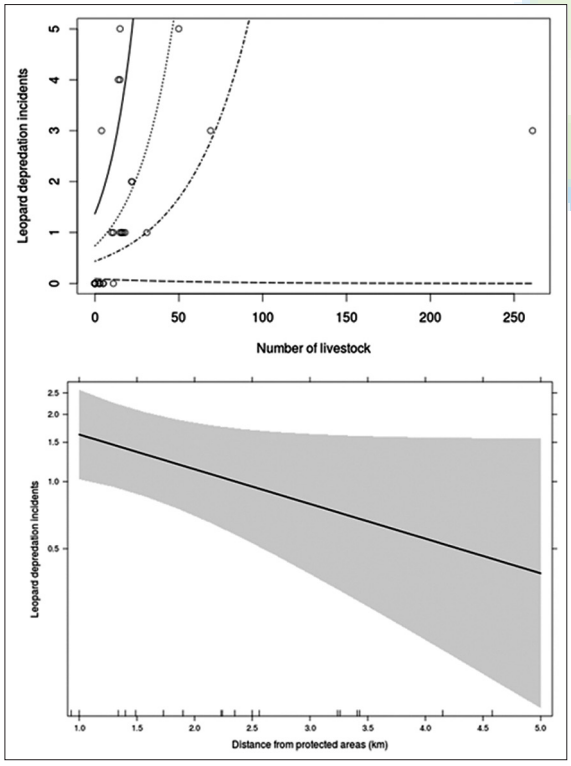

Figure 4

Leopard depredation incidents in relation to livestock population (upper panel). Holding other variables at median values, curves are GLM model fits for varying human numbers in colony: 66 people (minimum, full line), 300 (dotted), 500 (dotted and dashed), and 1100 (maximum, dashed). Effect of distance from protected area on depredation is shown as a line with 95% confidence interval bands (shaded) based on final GLM model (lower panel)

Household surveys

The average annual household income was INR 64,527 (± 2,802.2 SE) or USD 965.3 (±41.9 SE) in estate colonies of Valparai and INR 34,186 (± 5,778.5 SE) or USD 511.4 (± 86.5 SE) for adjoining tribal settlements in the year 2010. Labour work in the tea and coffee plantations was the major source of employment for people in the estate colonies, being the primary source of income for 117 (92.9%) out of 126 interviewed households. Dependence on estate work was significantly lower (14 of 36 households) for people in tribal settlements in comparison to estate colonies (χ^2 = 47.05, *df* = 1, *P* = 0.01). Livestock rearing was an important secondary source of livelihood for colonies on Valparai plateau, whereas, agriculture was important for tribal settlements. Out of the 3213 households in the 29 sampled colonies on Valparai plateau, 153 households (4.8%) kept livestock (cattle, buffaloes, goats). Of the livestock-keeping households in these colonies, we found livestock to be a source of income for people in 37 households that derived up to 30% of their income from livestock rearing (only three of the 162 respondents derived their entire income from livestock, Figure 5). This translated to an average of INR 1,887 (USD 28.2) of the average monthly total household income of INR 6,246 (USD 93.4) for the 37 livestock-dependent households in the year 2010. These 29 colonies had a total of 635 livestock (mean of 21.9 ± 9.0 SE; range 0 – 261). During the same time, overall holdings of different livestock species in Valparai region were as follows: 1,754 cattle, 77 buffaloes, 134 goat, 6,598 fowl, 11 ducks, 693 dogs, and 3 donkeys (18th Livestock Census conducted by the Government Veterinary Hospital of Valparai, 2010). The study area had a low intensity of annual livestock depredation events (see 'Livestock Losses'). A depredation event occurring in a household that derived income from livestock led to a loss averaging 8% of annual household income. Loss calculated across all livestock-keeping families, amounted to on average 2.4% of the annual household income.

Table 2: Results of the final generalised linear model (GLM) relating number of depredation incidents in a colony as the response variable with the following predictors: number of livestock (L) in the colony, number of people (P) in the colony, distance from the colony to protected area (PA) boundary in km, and distance to nearest forest fragment (FF) in km

	Estimate	Standard error	*t*	*P*
Intercept	0.9955	0.5717	1.741	0.0950
Number of livestock (L)	6.313e-02	1.647e-02	3.834	0.0008
Number of people (*P*)	-2.626e-03	1.445e-03	-1.818	0.0822
Distance to protected area (PA), km	-3.583e-01	1.795e-01	-1.996	0.0579
Distance to nearest forest fragment (FF), km	3.139e-02	4.658e-01	0.067	0.9469
L: P interaction	-7.255e-05	2.145e-05	-3.382	0.0026

Final model had a null deviance of 56.58 at 28 *df* and a residual deviance of 29.09 at 23 df

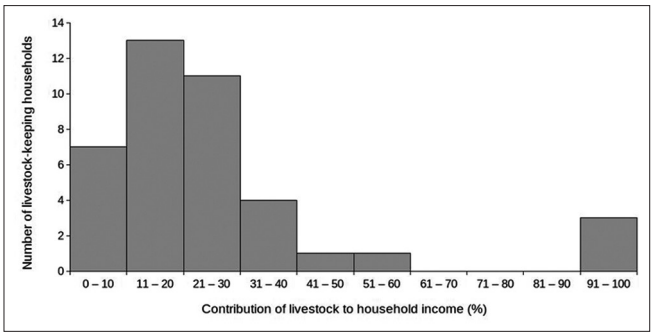

Figure 5
Dependency on livestock for income among 40 households that keep livestock in plantations of Valparai plateau.
Figure 2, 3, 4 and 5 – Source: Created by Authors

Leopard captures, injuries, and mortalities

The Forest Department captured and translocated 13 leopards between 2007 and 2015 (data from earlier are unavailable) in response to human-leopard encounters on the Valparai plateau. Of these, four were released far from the capture sites (100 km – 200 km), five were released within 50 km, three were taken into captivity, while the release site for one individual was not known. Our data on the condition of six of these individuals shows that all suffered injuries during the translocation process. In addition, during 2000 – 2015, 20 leopards died under non-natural circumstances, such as road accidents, snaring, and drowning in open water tanks in the estates (Tamil Nadu Forest Department records).

Perception towards leopards and management response options

We explored the number of direct encounters between people and leopards that did not lead to conflict and were therefore considered neutral. Half (50.3%) of the 161 respondents had seen a leopard sometime during their lifetime in the estates (average years of residence in Valparai was 34 years), while 60 people (37%) reported seeing one in the previous year (2010) alone. These encounters took place most often in or near colonies (24), with 19 in tea plantations, 4 inside forest, and 7 in a swamp, near stream or a forest-tea boundary.

We explored if personal encounters with leopards were related to the perception towards leopards. All respondents from tribal villages and 51.6% of those from estate colonies had neutral attitude towards leopards as they did not view the animal as a problem. The remaining respondents from estate colonies gave a ranking of 1 – 3 on the perception scale with none having an extremely negative (4 – 5) perception. Therefore, more people from the estate colonies viewed leopards to be a problem, although with low rankings on perception scale, when compared to people from tribal villages. When perceptions of people were analysed further, we found that respondents who had seen or encountered a leopard did not significantly differ in their perception from those who had not ($\chi^2 = 5.775$, df = 3, $p = 0.123$). Similarly, among those who kept livestock, perceptions appeared to be unrelated to whether or not any livestock depredation incident had occurred in their households ($\chi^2 = 4.479$, df = 3, $p = 0.214$). However, attacks on people in a colony did influence perception, with more negative perception ranks in colonies where previous attacks on people had occurred than in colonies with no attacks on people ($\chi^2 = 16.916$, df = 3, $p = 0.001$).

When asked about the measures to deal with human – leopard conflict, 79% of the estate respondents reported that changing their own behaviour (to reduce risk) was the best option; fewer respondents (2.5%) indicated preference for more interventionist methods of conflict management on the response scale such as monitoring leopard movement, chasing animal, translocation, or lethal control. Among tribal people, a higher percentage (91%) selected changing own behaviour and none chose translocation or lethal control as a management option. We analysed the attitudes on response index further for the people living in estate colonies, and found that people who had had personal encounters with leopards did not differ from those who had not in their choice of desired management option to deal with negative interactions with leopards ($\chi^2 = 10.343$, df = 5, $p = 0.06$). Preferred management response was also unrelated to livestock depredation at household level ($\chi^2 = 4.709$, df = 5, $p = 0.453$), but became more interventional when attacks on people had occurred in the colony ($\chi^2 = 12.421$, df = 5, $p = 0.029$). The perception and response ranks were not statistically significantly correlated among all respondents ($r = 0.10$, $df = 159$, $P = 0.20$) and among estate respondents ($r = 0.06$, $df = 124$, $P = 0.47$).

DISCUSSION

In a landscape of tea and coffee plantations and forest fragments on the Valparai plateau with a human population density of over 220/km² (in the estates), negative interactions with leopards comprised an average of less than 4 incidents/year involving livestock and about 1 incident/year involving humans. Further, there was no apparent increasing trend in conflict over the years of the study. Economic losses and individual experience of seeing leopards in the vicinity of their home or work places did not relate to negative perceptions or management interventions that people preferred. Attacks on people did influence perception and preferred interventions suggesting that human safety needs to be the major consideration in management of human – leopard interactions and conflicts.

Human-leopard conflict

Karanth and Madhusudan (2002) define human injury and death due to carnivores as the most severe form of human – carnivore conflict. Human – leopard conflict incidents involving attacks on people have been reported to lead to 29 deaths/year in Uttarakhand, 6 deaths/year in Gujarat, and 15 attacks/year in Northern West Bengal (Athreya et al. 2007; Marker and Sivamani 2009). Although conflict incidence in the study area is not high on a yearly basis, the attacks on people,

in particular, are a serious concern as they affect people's tolerance and attitudes towards leopards, and therefore need to be addressed (Madhusudan and Mishra 2003).

Our data shows that the attacks on people occurred mostly on young children who were unsupervised, and during late evenings. Guidelines for human-leopard conflict management by Ministry of Environment and Forests (2011) note that such situation-based attacks on people may result from accidental encounters that are avoidable by employing solutions that do not attract leopards in the vicinity of human-settlements, such as providing garbage disposal, sanitation, improving livestock corralling, as well as by advising people to accompany children and carry lights when going out in the evenings so that chance encounters can be avoided.

In addition to loss of human life, economic losses incurred by local communities due to loss of their livestock can contribute to a higher conflict perception, and therefore such losses should be quantified. In other landscapes, studies have reported that local communities lose up to 12% of their livestock and half their average per capita income annually to large carnivores (Mishra 1997; Madhusudan 2003). Wang and Macdonald (2006) studied depredation of livestock by large carnivores in Jigme Singye Wangchuk National Park in Bhutan and reported an annual economic loss to depredation equaling two-thirds of the annual income of households. In the Indian trans-Himalaya, economic loss to a household due to depredation by snow leopard and wolf amounts to 52% of the average annual per capita income (Mishra 1997). In Valparai, dependence on livestock as a source of livelihood is low as the people primarily derive their income from working in the plantation estates and livestock-keeping was a source of livelihood for less than 5% of people living in estate colonies, and therefore, the losses to depredation were concentrated among few households. In Valparai, livestock densities (cow, buffalo, and goat) were also low (<10 animals/km^2) when compared to other places in India where conflict is known to occur with large carnivores (Bagchi and Mishra 2006; Athreya et al. 2016). The availability of wild prey in the Valparai plateau (Sidhu et al. 2015) coupled with the low livestock density may account for the infrequent and relatively low incidence of conflict in the landscape. However, the analysis included a number of incidents reported by respondents but not documented in Forest Department records, indicating that owners do not always file for compensation and these cases generally go unreported. Also, some incidents involving loss of domestic chicken and domestic dog (pets) may go unreported, which may have led to a slight underestimate of conflict incidents and losses as assessed in this study.

Nearly 80% of the livestock depredation incidents occurred when an animal was unaccompanied by a herder and 71% occurred during late evenings or night. Thus, it was during late hours of the day when the livestock were more vulnerable to predators and attacks can be avoided by fixing existing corrals for livestock as almost half of the corrals used for livestock in Valparai were broken and unsafe against predators. Similar measures for livestock guarding are suggested in other areas where livestock are vulnerable to large predators (Mishra 1997; Wang and Macdonald 2006). Depending on their age, sex and use, livestock differed in their economic value to the owner, but such details were rarely considered under the compensation scheme. Further, the compensation paid by the Forest Department for livestock depredation appeared to be insufficient and only covered 28% of the reported cost of the animal.

Livestock depredation is known to be related to livestock densities and forest cover (Bagchi and Mishra 2006; Michalski et al. 2006). We found that colonies with high livestock numbers had a higher incidence of livestock depredation, but this was moderated by distance from protected area as well as human population in the colony. The number of people and livestock in a colony interactively influenced depredation, with lower incidence of conflict predicted in colonies with larger number of people. This may be because the tendency of leopards to avoid humans (Odden et al. 2014) is accentuated in larger colonies with more people, lights, and activities.

Perception and response

People's perception of leopards ranged from neutral to negative in this study. As our primary focus was on understanding and minimizing negative interactions, we did not specifically assess positive interactions (such as appreciation of leopards, desire to see wild leopards), although this may have existed among local people and others such as tourists in the landscape. As about 51,000 people live in the estates, the fact that 37% of respondents reported having seen a leopard in the previous year and more than half reported a neutral perception towards leopards is significant. This indicates a large, regular, and mostly neutral domain of interactions between humans and leopards, compared to which negative interactions were far fewer. Earlier studies that have focused on human – leopard conflict have seldom considered neutral interactions, which are important for understanding human tolerance and suitability of coexistence measures (Raman 2015).

All reported incidents of human injuries and loss of life attributed to leopards occurred in the tea and coffee plantation estate colonies on the Valparai plateau; no incidents were reported in surrounding tribal villages where a higher proportion of respondents reported neutral perceptions. This is similar to the results from an earlier study that found more positive attitudes among tribal than among non-tribal people towards wolves in Wisconsin (Shelley et al. 2011). Negative perceptions towards leopards in the present study were associated with threats to human life but not livelihoods. Other research has suggested that tolerance towards predators appears to not be associated with threats to livelihood as much as with a hunting culture (Treves et al. 2013) or social norms such as acceptance of retaliatory killings in a community and legalization by the concerned government (Treves and Bruskotter 2014). In the study region, as hunting is illegal, responses to attacks on people by the government agency (Forest Department) in the form of compensation payments or

leopard captures, along with associated media coverage (Bhatia et al. 2013) may create negative perceptions and expectations among residents for reactive interventions. Instead of actual loss, the likelihood of risk as a result of a person's occupation as well as early life experiences that make people relate to their surroundings are indicators of tolerance towards carnivores (see Naughton-Treves et al. 2003). Although estate people recognized leopard conflict as an issue and generally had more negative perception towards leopards, most still believed that changing their own behaviour was the best management tool to avoid negative interactions with leopards. This suggests a higher level of tolerance and that residents are likely to be receptive to pro-active management measures such as better livestock herding and adopting behavioural changes to avoid chance encounters with leopards.

To manage or mitigate human – leopard conflict effectively, it is also important to understand the effects of the adopted leopard management strategies. In our study area, at least 9 leopards were captured between 2007 and 2015 and released into new locations away from capture sites. Translocations may stress individual leopards involved (through physical and mental trauma to animal when captured and placed in unfamiliar conditions) and also affect the population by disrupting territorial behaviour of resident leopards (Athreya and Belsare 2007; Athreya et al. 2010). Leopard population interventions that impact behaviour of territorial individuals are likely to affect their interaction with people in the landscape. Odden et al. (2014) note that translocations "may either have only short-term local effects, may simply move the conflict to another area, or in the worst-case scenario, increase the level of conflict." Translocations represent a reactive system of conflict management which could thus be resource-demanding yet futile in addressing conflict resolution in the long term. Therefore, management strategies should consider the biology of the species and adopt more informed approaches suited to different kinds of situations as outlined elsewhere (MoEF 2011).

Implications for management

We found that the people living in the study area frequently sight leopards, predominantly have neutral perceptions of leopards, and are willing to change their own behaviour to minimize negative interactions with leopards. This provides a conducive space for using proactive conflict avoidance management options that include a combination of solutions particularly addressing human safety and locational and landscape level needs. For instance, most estate colonies have toilets that are away from the main housing facilities, open garbage dumps are a norm in the landscape, and a high proportion of livestock corrals are damaged and therefore vulnerable to carnivores. Supervising children in the evening hours, building toilets with lighting close to the houses, and moving the garbage dumps farther away while also keeping them covered (so that wild animals such as wild pigs or domestic animals like free-ranging domestic dogs are not attracted to the garbage, in turn attracting leopards) are measures that can further reduce conflict incidents between people and leopards in the landscape. To address financial losses borne by livestock-keeping households, a combination of conflict avoidance measures and enhanced compensation may be required to prevent or offset future losses. These include adopting improved herding practices involving attending to livestock during evening hours and improving the corrals, especially in colonies with high livestock densities Also, insurance schemes that take into account the market value of an animal may also be adopted. Management options such as translocation, also known to increase human-leopard conflict (Odden et al. 2014), must be avoided and carried out only when warranted in extreme circumstances following appropriate guidelines (MoEF 2011).

ACKNOWLEDGEMENTS

We are grateful to the Rufford Small Grants Foundation, UK, and Ecosystem Alliance, The Netherlands, for funding support and the Tamil Nadu Forest Department for research permits and several park managers, range officers, and forest staff for information and local support. We thank Sathish, Nisha Luiz, Shakthi Sridharan, and S. Harikrishnan for their help in carrying out interview surveys. We are grateful to Kavita Isvaran for discussions and help with analysis. We also thank Atul Joshi, M. Ananda Kumar, P. Jeganathan, and Kulbhushansingh Suryawanshi for useful discussions.

REFERENCES

Athreya, V. 2006. Is relocation a viable management option for unwanted animals? - The case of the leopard in India. *Conservation and Society* 4(3): 419–423.

Athreya, V.R. and A.V. Belsare. 2006. *'Carnivore conflict': support provided to leopards involved in conflict-related cases in Maharashtra*. New Delhi: Wildlife Trust of India.

Athreya, V.R. and A.V. Belsare. 2007. *Human-leopard conflict management guidelines*. Pune: Kaati Trust.

Athreya, V.R., S.S. Thakur, S. Chaudhuri, and A.V. Belsare 2007. Leopards in human-dominated areas: a spillover from sustained translocations into nearby forests? *Journal of the Bombay Natural History Society* 104(1): 13–18.

Athreya, V., M. Odden, J.D.C. Linnell, and K.U. Karanth. 2010. Translocation as a tool for mitigating conflict with leopards in human-dominated landscapes of India. *Conservation Biology* 25(1): 133–141.

Athreya, V., M. Odden, J.D.C. Linnell, J. Krishnaswamy, and K.U. Karanth. 2016. A cat among the dogs: leopard *Panthera pardus* diet in a human-dominated landscape in western Maharashtra, India. *Oryx* 50(1): 156–162.

Bagchi, S. and C. Mishra. 2006. Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). *Journal of Zoology* 268(3): 217–224.

Bauer, H. and H.H. de Iongh. 2005. Lion (*Panthera leo*) home ranges and livestock conflicts in Waza National Park, Cameroon. *African Journal of Ecology* 43(3): 208–214.

Bhatia, S., V. Athreya, R. Grenyer, and D.W. Macdonald. 2013. Understanding the role of representations of human–leopard conflict in Mumbai through media-content analysis. *Conservation Biology* 27(3): 588–594.

Bhattacharjee, A. and N. Parthasarathy. 2013. Coexisting with large carnivores: a case study from western Duars, India. *Human Dimensions of Wildlife* 18(1): 20–31.

Chandi, M. 2008. *Tribes of the Anamalais: livelihood and resource-use patterns of communities in the rainforests of the Indira Gandhi Wildlife Sanctuary and Valparai plateau. NCF Technical Report No. 16*. Mysore: Nature Conservation Foundation.

Conner, M.M., M.M. Jaeger, T.J. Weller, and D.R. McCullough. 1998. Effect of coyote removal on sheep depredation in northern California. *Journal of Wildlife Management* 62(2): 690–699.

Dickman, A.J. 2010. Complexities of conflict: the importance of considering social factors for effectively resolving human–wildlife conflict. *Animal Conservation* 13(5): 458–466.

Karanth, K.U. and M.D. Madhusudan. 2002. Mitigating human-wildlife conflicts in southern Asia. In: *Making parks work: strategies for preserving tropical nature* (eds. Terborgh, J., C. Van Schaik, L. Davenport, and M. Rao). Pp. 250–264. Covelo: Island Press.

Knowlton, F. F., E. M. Gese, and M. M. Jaeger. 1999. Coyote depredation control: an interface between biology and management. *Journal of Range Management* 52(5): 398–412.

Kumar, A., R. Pethiyagoda, and D. Mudappa. 2004. Western Ghats and Sri Lanka. In: *Hotspots revisited—Earth's biologically richest and most endangered ecoregions* (eds. Mittermeier, R.A, P.R. Gil, M. Hoffmann, J. Pilgrim, T. Brooks, C.G. Mittermeier, J. Lamoureux, and G.A.B. da Fonseca). Pp. 152–157. Mexico: CEMEX.

Landa, A., K. Gudvangen, J.E. Swenson, and E. Roskaft. 1999. Factors associated with wolverine *Gulo gulo* predation on domestic sheep. *Journal of Applied Ecology* 36(6): 963–973.

Linnell, J.D.C., J.E. Swenson, and R. Anderson. 2001. Predators and people: conservation of large carnivores is possible at high human densities if management policy is favourable. *Animal Conservation* 4(4): 345–349.

Madhusudan, M.D. 2003. Living amidst large wildlife: livestock and crop depredation by large mammals in the interior villages of Bhadra Tiger Reserve, south India. *Environmental Management* 31(4): 466–475.

Madhusudan, M.D. and C. Mishra. 2003. Why big, fierce animals are threatened: conserving large mammals in densely populated landscapes. In: *Battles over nature: science and the politics of conservation* (eds. Saberwal, V. and M. Rangarajan). Pp. 31–55. New Delhi: Permanent Black.

Manfredo, M.J. and A.A. Dayer. 2004. Concepts for exploring the social aspects of human–wildlife conflict in a global context. *Human Dimensions of Wildlife* 9(4): 317–328.

Marker, L. and S. Sivamani. 2009. Policy for human-leopard conflict management in India. *CAT News* 50(1): 23–26.

Mazzolli, M., M. E. Graipel, and N. Dunstone. 2002. Mountain lion depredation in southern Brazil. *Biological Conservation* 105(1): 43–51.

Michalski, F., R.L.P. Boulhosa, A. Faria, and C.A. Peres. 2006. Human–wildlife conflicts in a fragmented Amazonian forest landscape: determinants of large felid depredation on livestock. *Animal Conservation* 9(2): 179–188.

Mishra, C. 1997. Livestock depredation by large carnivores in Indian trans-Himalayas: conflict perceptions and conservation prospects. *Environmental Conservation* 24(4): 338–343.

MoEF. 2011. Guidelines for human – leopard conflict management. http://moef.nic.in/downloads/public-information/guidelines-human-leopard-conflict-management.pdf. Accessed on October 12, 2015.

Mudappa, D. and T.R.S. Raman. 2007. Rainforest restoration and wildlife conservation on private lands in the Western Ghats. In: *Making Conservation Work* (eds. Shahabuddin, G. and M. Rangarajan). Pp. 210–240, Ranikhet: Permanent Black.

Naughton-Treves, L., R. Grossberg, and A. Treves. 2003. Paying for tolerance: rural citizens' attitudes toward wolf depredation and compensation. *Conservation Biology* 17(6): 1500–1511.

Newmark, W.D., D.N. Manyanza, D.G.M. Gamassa, and H.I. Sariko. 1994. The conflict between wildlife and local people living adjacent to protected areas in Tanzania: human density as a predictor. *Conservation Biology* 8(1): 249–255.

Odden, M., V. Athreya, S. Rattan, and J.D.C. Linnell. 2014. Adaptable neighbours: movement patterns of GPS-collared leopards in human dominated landscapes in India. *PLoS ONE* 9(11): e112044.

R Core Team. 2015. R: a language and environment for statistical computing. http://www.R-project.org. Accessed on May 12, 2015.

Raman, T.R.S. 2015. Leopard landscapes: coexisting with carnivores in countryside and city. *Economic and Political Weekly*. http://www.epw.in/node/64799. Accessed on October 12, 2015.

Shelley, V., A. Treves, and L. Naughton. 2011. Attitudes to wolves and wolf policy among Ojibwe tribal members and non-tribal residents of Wisconsin's wolf range. *Human Dimensions of Wildlife* 16(6): 397–413.

Sidhu, S., T.R.S. Raman, and D. Mudappa. 2015. Prey abundance and leopard diet in plantation and rainforest landscape, Anamalai Hills, Western Ghats. *Current Science* 109(2): 323–330.

Simcharoen, S., A.C.D. Barlow, A. Simacharoen, and J.D. Smith. 2008. Home range size and day time habitat selection of leopards in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Biological Conservation* 141(9): 2242–2250.

Suryawanshi, K.R. 2013. *Human-carnivore conflicts: understanding predation ecology and livestock damages by snow leopards*. Ph.D. thesis. Manipal University, Manipal, India.

Treves, A. and J.T. Bruskotter. 2014. Tolerance for predatory wildlife. *Science* 344(6183): 476–477.

Treves, A., L. Naughton-Treves, V.S. Shelley. 2013. Longitudinal analysis of attitudes toward wolves. *Conservation Biology* 27(2): 315–323.

Treves, A., R.R. Jurewicz, L. Naughton-Treves, R.A. Rose, R.C. Willging, and A.P. Wydeven. 2002. Wolf depredation on domestic animals in Wisconsin, 1976–2000. *Wildlife Society Bulletin* 30(1): 231–241.

Wang, S.W. and D.W. Macdonald. 2006. Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. *Biological Conservation* 129(4): 558–565.

Windberg, L.A., F.F. Knowlton, S.M. Ebbert, and B.T. Kelly. 1997. Aspects of coyote predation on Angora goats. *Journal of Wildlife Management* 50(3): 226–230.

WLPA. 2003. *The Wildlife (Protection) Act, 1972 as amended upto 2003*. New Delhi and Dehra Dun: Wildlife Trust of India and Natraj Publishers.

Woodroffe, R. 2000. Predators and people: using human densities to interpret declines of large carnivores. *Animal Conservation* 3(2): 165–173.

Zimmermann, A., M.J. Walpole, and N. Leader-Williams. 2005. Cattle ranchers' attitudes to conflicts with jaguar *Panthera onca* in the Pantanal of Brazil. *Oryx* 39(4): 406–412.

Received: March 2016; **Accepted**: June 2017