Human–Wildlife Interactions 9(1):48–57, Spring 2015

Human–felid conflict in corridor habitats: implications for tiger and leopard conservation in Terai Arc Landscape, India

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Abstract: We use the Rajaji-Corbett corridor in the Terai Arc Landscape (TAL) in India to examine the pattern of human–felid conflict in wildlife corridors and its implications for the long-term persistence of tigers (*Panthera tigris*) and leopards (*Panthera pardus*) in the landscape. We administerd a questionnaire survey of people residing in and around the corridor and also examined forest department records. Results revealed that leopards caused more frequent losses, whereas tigers caused greater economic losses. Local communities perceived leopards as a bigger threat than tigers, due to the intrusive nature of leopards (i.e., entering villages and houses and carrying off livestock and, in some cases, children). Although people currently are tolerant of wild felids, they are likely to become hostile to them in the future; we discuss specific strategies to resolve the conflicts.

Key words: human–felid conflict, human–wildlife conflict, India, leopard, Rajaji-Corbett Corridor, Terai Arc Landscape, tiger

Wild animals that spill over or disperse from source patches often have a negligible chance of surviving in corridors that generally provide low-quality, exposed habitat (Lees and Peres 2008). Further, these animals become susceptible to being killed by humans (Morrison and Boyce 2009), especially where corridors are narrow and in populous landscapes. Persecution by humans is one of the biggest factors contributing to the decrease in large carnivore populations outside of protected areas (Woodroffe and Ginsberg 1998). For any conservation effort to succeed, it is important to have the support of local communities (Tilson and Nyhus 1998, Madden 2004). The Rajaji-Corbett corridor in the Terai Arc landscape (TAL), which is a globally important ecoregion (Olson and Dinerstein 2002) and has significant populations of tigers (*Panthera tigris*; Figure 1) and leopards (*Panthera pardus*; Figure 2; Johnsingh et al. 2004), provides an opportunity to understand the human–wildlife conflicts that may occur in such corridors.

The TAL has an average human density of approximately 550 individuals per km^2, which makes it one of the most populous regions in India (Johnsingh et al. 2004). It also has a large tiger population, with recent estimates of 353 $\pm$ 33 (95% confidence interval) tigers on the Indian side of TAL (Jhala et al. 2011). In the entire TAL, the Corbett Tiger Reserve (CTR) has the highest density (19.6/100 km^2) of tigers (Jhala et al. 2008, Jhala et al. 2011). Another important area for tigers in this landscape is Rajaji National Park. This is a proposed tiger reserve where the tiger population is rapidly recovering following relocation of the Gujjars (a forest-dwelling community) outside east Rajaji National Park in 2004 (Harihar et al. 2009, Harihar and Dutta 2011). These 2 protected areas together form the Rajaji-Corbett Tiger Conservation Unit, which has the potential to support 150 adult tigers (50% of the tiger population in TAL), if functional connectivity between these 2 source areas is established (Johnsingh 2006, Jhala et al. 2011). Therefore, the Rajaji-Corbett corridor, being the only functional corridor between these 2 important protected areas, provides critical connective habitat in the Rajaji-Corbett Tiger Conservation Unit (Johnsingh et al. 2010). In recent years, rapid growth of the tiger population in CTR (Jhala et al. 2011) has resulted in tigers dispersing and spilling out of the reserve and using the Rajaji-Corbett corridor more frequently to move to the Rajaji National Park (Johnsingh and Negi 2003, Johnsingh et al. 2004, Harihar and Dutta 2011, Harihar and Pandav 2012). This, together with the high density of humans, can potentially result in increased human–tiger conflicts in the corridor.

Figure 1. Tiger (*Panthera tigris*; *photo courtesy S. Sen*).

Figure 2. Leopard (*Panthera pardus*; *photo courtesy S. Sen*).

There are no population estimates of leopard density for the landscape. However, it is known that leopards occupy the entire TAL, with variation in the intensity of use across the landscape (Johnsingh et al. 2004, Jhala et al. 2011). In Terai habitats, tigers tend to displace leopards, while in Shivalik habitats, such as Rajaji-Corbett corridor where terrain complexity is greater, leopards coexist with tigers (Johnsingh et al. 2004). However, leopard density (2.07/100 km^2 to 9.76/100 km^2) was inversely related to tiger density in the Rajaji National Park, reflecting significant displacement interaction (Harihar et al. 2011). Moreover, because leopards were marginalized, there was a shift of leopard diet to include domestic livestock (Harihar et al. 2011). It is pertinent to the Rajaji-Corbett corridor because increase in tiger movement can lead to higher depredation of livestock by leopards.

Few studies have examined human–wildlife conflict in the Rajaji-Corbett corridor (Dhaundiyal 1997, Ogra and Badola 2008),focusing mostly on elephants (*Elephas maximus*; Dhaundiyal 1997). One study quantified cattle depredation by tigers and leopards in and around the CTR (Corbett Foundation, unpublished report), and the forest department has maintained records of felid attacks on people and livestock that were reported by people seeking compensation. It is, however, not possible to obtain a clear picture of the conflicts based on these records. In this study, we investigated the pattern of human–large felid conflict in the corridor and analyzed its economic impact and the perceptions of the community members living inside and along the corridor.

Study area

The Rajaji-Corbett corridor (29° 37′ 21″ to 29° 52′ 49″ N, 78°20′01″ to 78° 36′ 18″ E) is situated in the foothills of the Himalayas in the lower Siwaliks and extends from Rawsan River in the west to the North Kotri range in the east (Figure 3). It falls within the administration of Lansdowne forest division, which comprises 4 forest ranges (administrative sub-units). Of these, Laldhang and Kotdwar ranges represent 80% of the corridor area. The corridor is approximately 10 km long and 4 to 5 km wide (Singh et al. 2005). The altitude varies from 150 m near the southern boundary to 1,150 m above sea level along the northern boundary (Johnsingh et al. 2004). In the northern part of the corridor, there are a number of villages on hills, but it is the southern portion of the corridor that includes large settlements and is densely populated (Dhaundiyal 1997).

Methods

We administered semi-structured questionnaire surveys and informal interviews in villages located in the northern and southern portions of the corridor (n = 29) and in Gujjar settlements (n = 6) within the forest. Villages within a 2-km buffer of the forest corridor were selected for sampling. Selection of villages for sampling was based on systematic design allowing for representation of villages in the entire corridor that largely falls within Laldhang and Kodwar ranges. Of the 29 villages sampled for this study, fifteen were in Kotdwar range (twelve in the southern area and three in the northern area), and fourteen were in Laldhang range (eleven in the southern area and three in northern area).

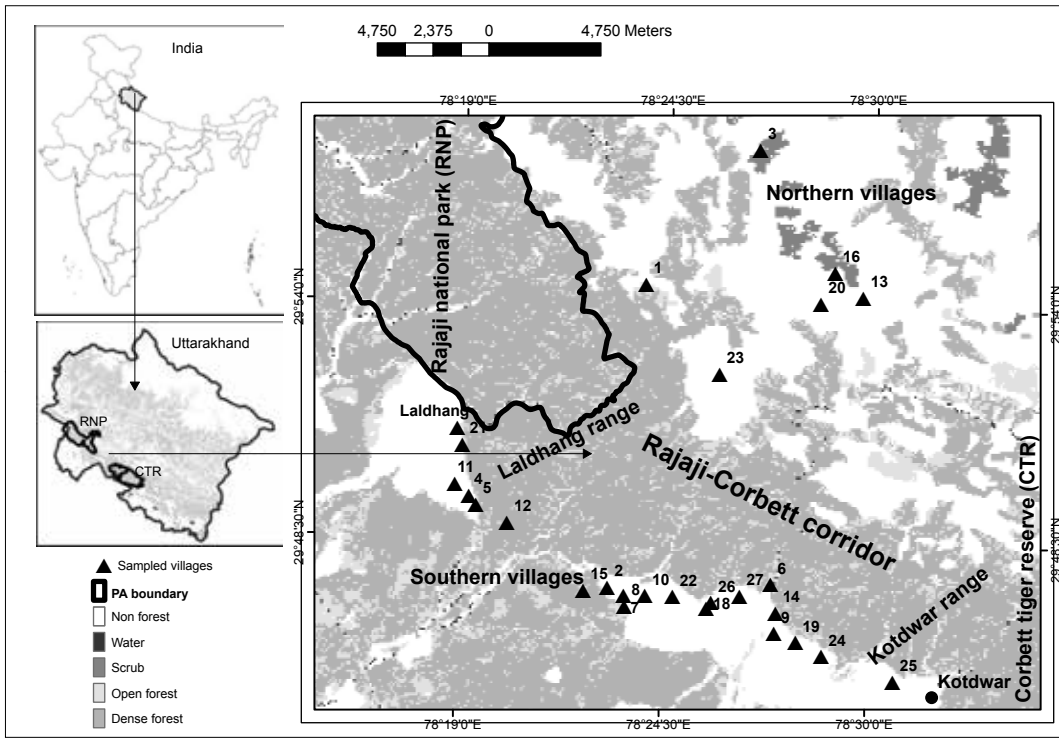

Figure 3. Map showing of Rajaji-Corbett corridor and sampled villages.

Households comprised the primary sampling units. We randomly sampled an average of 18% (range = 5 to 33%) households in each village. Because some Gujjars already had migrated to the upper Himalayas at the time of the survey, all the remaining Gujjar deras (i.e., settlements comprising of 1 or more households) present in the area were surveyed. The sampled population (n = 353) contained 3 communities, including 314 Pahari households, 13 Boksa households, and 26 Gujjar deras. The head of the family usually was questioned; otherwise, the next lead person was interviewed. The questionnaire was conducted in Hindi, which is spoken and understood by most people in the region; however, we also used local assistants when necessary to communicate with those who spoke only Garhwali (the local dialect of the region). The interviewees were initially asked if they were facing felid-related conflicts. The questions were designed to obtain detailed information on conflicts with tigers and leopards in the previous 2 years (April 2008 to April 2010) to avoid memory-related variations in the answers. For each reported conflict, we asked the interviewee to categorize the location (within a house, within a village, between village and corridor forest, periphery of corridor forest, or inside forest), season (winter [November to February], summer [March to June] or monsoon [July to October]), and time of the day (morning [0400 hours to 1200 hours], mid-day[1200 hours to 1600 hours], evening [1600 hours to 2000 hours] or night [2000 hours to 0400 hours]). The survey also included questions about demography, socioeconomic status of the household, livestock herding practices, and total economic value of cattle lost. To determine perceptions toward large carnivores and their conservation, we asked a range of questions, including:

1. Do you think having tigers and leopards in the jungle are beneficial for you?
2. Do you feel that tigers and leopards are a threat to you psychologically or economically?
3. Do you have any awareness of tigers and their conservation programs?
4. Have you heard of any tiger or

leopard being poisoned by other villagers in retaliation to cattle predation?
5. Do you want the tigers to be eliminated by, for example, the forest department?
6. Interviewees (villagers) also were asked for their opinion on conflict-management approaches.

We used previous studies and information provided by trusted locals and Gujjars who have knowledge of the real market values of livestock, to quantify the monetary loss due to tiger and leopard attacks borne by each household. Information on conflict management undertaken by the forest department was collected both by interviewing forest department officials and examining forest department management plans.

Data were analyzed to understand the conflict status and socioeconomics of households facing conflict. We investigated if there was any emerging spatiotemporal pattern to these conflicts. We also calculated the total number of livestock lost and total economic losses faced by different communities, villages, and ranges. We calculated frequencies and percentages for different responses; advance analyses were conducted in SPSS (Statistical Package for the Social Sciences, version 16; 2006, Chicago, Ill.). The analyses included initial testing for normality using Kolmogorov Smirnov and Shapiro-Wilk tests. Pearson's chi square, Kruskal-Wallis, and Mann Whitney U tests were subsequently performed to compare conflicts between various target categories.

Results

Socioeconomic status of people facing conflict

Of the 29 villages surveyed, 24 villages reported conflicts with tigers or leopards. In addition, all 6 Gujjar settlements reported conflict. Of 353 households surveyed, six reported some conflict with tigers, 82 households with leopards and 10 households with both, in the past 2 years. Conflicts varied among communities ($\chi^2 = 7.06$, $P \leq 0.029$), with conflicts reported by 50% of the Gujjar deras, 31% of Boksa, and 26% of the Pahari households. There was a significant difference ($\chi^2 = 17.07$, $P \leq 0.00$) between the frequencies of conflict in Laldhang (38%) and Kotdwar (18%).

Most households (55%) that reported conflict had small (<0.8 ha) agricultural landholdings, and 25% did not have any landholding. Only 7% of households had large (≥1.6 ha) landholdings, and 5% had medium-sized (0.8 to 1.6 ha) landholdings. The remainder (9%) did not provide details on their landholdings. The least common economic class or livelihood activity of those reporting conflict was the business (4%) group, followed by the service income group (7%), laborer (12%), livestock husbandry (13%), and agricultural (16%). The most common economic class or livelihood activity of those reporting conflict was the multisource income group (44%). Some households (3%) declined to reveal their source of income. The average livestock holding was 8.8 head/household. Gujjar community had 21.6 head/household, which is higher than both Boksa (4.5 head/household) and Pahari (6.7 head/household). Most (93%) households reporting conflict stated that they depended upon the forest for resources, such as fodder, fuel wood, or other nontimber forest products.

Livestock herding practices

Of the 88 households (66 southern and 22 northern households) that owned livestock and provided information on their livestock grazing and herding practices, 69% grazed their livestock in and around the corridor forest, while 28% households stall-fed their livestock, and 2% households stall-fed, as well as grazed, their livestock in the corridor. Of the 61 households that grazed their cattle in the forest, 65% accompanied their livestock during grazing. Because Gujjars are a forest-dwelling community, they have typical herding practices that vary from 1 dera to the other (Figure 4).

Livestock loss to tigers and leopards

In total, 23 cattle (2 bullocks, 21 buffaloes) from 16 households (0.7 head/household/year) were lost to tiger in 2 years. Across the range, the Laldhang range at 69.6% (16 of 23) faced higher losses, as compared to the Kotdwar range at 30.4% (7 of 23; U = 3.500; $P \leq 0.005$).

Leopards caused a loss of 241 head of livestock from 92 households in 2 years (1.3 head/household/year). Calves of domestic cows

(*Bos primigenius indicus*) were most frequently lost (32%, 77 of 241). The loss was more severe in the Laldhang range at 59.8% (144 of 241) than the Kotdwar range at 40.2% (97 of 241; U = 799.00; $P \leq 0.019$; Figure 5).

Economic loss

The total monetary loss due to tigers (for 16 households) accounted for U.S. $8,533 in 2 years (2008 to 2010). In the case of leopards (for the 92 households), the monetary loss amounted to $7,039 in 2 years (2008 to 2010). Thus, mean loss incurred per household per year was $267 (ranging from $3 to $1,819 per household) due to tigers and $38 (ranging from $2 to $579) due to leopards.

Households reporting conflict due to tigers in the Laldhang range (n = 9) suffered an average annual loss of $343 per household (ranging from $3 to $1,819). In the Kotdwar range (n = 7) households lost $169 per household annually (ranging from $7 to $496). In the case of leopards, in the Laldhang range (n = 40), households faced an average annual loss of $52 per household (ranging from $2 to $579). In Kotdwar range ($n$ = 52) households suffered a loss of $27 per household per year (ranging from $3 to $289).

Gujjars (n = 13) were the most affected, suffering a mean loss of $392/household/year (ranging from $3 to $1,819) due to tiger attacks and around $62 (ranging from $8 to $455)/household/year due to leopards. The forest village of Kumbhikhal (n = 5) suffered a mean loss of $100/household/year (ranging from $7 to $413) due to tigers and comparatively lower $16/household/year (ranging from $8 to $99) due to leopards.

The economic loss to households (n = 3) located in villages outside the corridor due to tiger was about $221/household/year (ranging from $99 to $413). In comparison, loss suffered by these households (n = 74) were much lower in the case of leopards, i.e., an average loss of $52 annually per household (ranging from $2 to $578).

Loss to human life

Two villages, located in northern border of the corridor, reported 10 leopard attacks on humans that occurred between 1989 and 2005, of which, nine were fatal (Uttarakhand Forest Department. unpublished data). There have been no such reports in the subsequent years, except 1 case in 2009. Of the 11 cases, five occurred within the village (with four of these occurring inside house premises); two occurred in the forest, one on the forest periphery; details for the remaining three were not available. Ten of the victims were children aged three to ten; one was a teenager, and one was an adult. Five were female, and seven were male. Seven of the 11 cases happened during monsoon season, two in summer, and two in winter. Most (64%) attacks occurred at dusk. Only 1 attack each was reported during morning, mid-day, and night; while the specific time could not be ascertained for 1 incident.

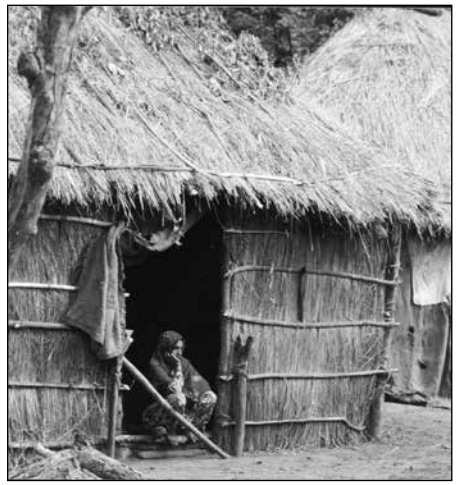

Figure 4. Typical home of a Gujjar settlement.

Spatial and temporal patterns of livestock–felid conflict

Survey results revealed that 87.5% (14 of 16) tiger attacks on livestock took place inside the corridor. Only 1 attack occurred inside a village, i.e., Kumbhikhal, which itself is situated inside the corridor forest; 1 respondent was not sure of the place. The frequency of attacks varied across season ($\chi^2 = 4$, $P \leq 0.046$) with most (75%) occurring during winter, followed by monsoon (25%); none occurred during summer. Tiger attacks most frequently occurred at night ($\chi^2 = 18.38$, $P \leq 0.001$) with 63% attacks, compared to 12% occurring at midday, 1 attack in the morning, and one in the evening. Two respondents could not recall the time of incident.

The frequency of leopard attacks on livestock varied across location ($\chi^2 = 39.48$, $P \leq 0.001$); thirty-five of ninety-two were within forest boundaries; 21 attacks were inside the house, thirteen inside the village, eight at the periphery of the corridor forest, and 6 attacks were between the village and forest. Nine households could not recall the exact location of attack. Of 21 incidents that occurred inside the house premises, details on livestock housing was provided for 15 incidents. Although more attacks were recorded in temporary kuccha sheds (9) than permanent pucca sheds (6), the difference was not significant ($\chi^2 = 0.60$, $P \leq 0.607$).

The frequency of leopard attacks also varied among seasons ($\chi^2 = 16.96$, $P \leq 0.001$) and time of day ($\chi^2 = 21.59$, $P \leq 0.000$). Most (40%) leopard attacks occurred during winter, with 28% in summer and 21% in the monsoon season. Some (11%) households could not recall the season of the incident. Attacks were most common during mid-day (28%) or at night (25%), while 17% occurred during the evening, and only 2% attacks occurred in morning. Many (28%) interviewees could not remember the exact time of the attack.

Perception of conflict

Of the 353 households surveyed, 44 households did not answer the question of threat perception. The remaining 309 households had varying opinions ($\chi^2 = 238.74$, $P \leq 0.00$); 178 households viewed leopards as a threat to their livelihood and security; one saw tigers, not leopards, as a threat; 32 households felt threatened by both the species, and ninety-eight did not see either of them as a serious threat. About 25% of households facing conflict expressed willingness for elimination of leopards, but only 4% were willing for tigers to be eliminated. All households ($n = 98$) denied any cases of poisoning of large carnivores.

Conflict prevention strategies

Of 87 households that answered the question about their conflict prevention strategies, 65 households reported that they implemented various methods to protect their cattle against predation. Most (51%) households commonly used auditory deterrents, such as shouting, drumming canisters, and detonating fire crackers when a tiger or leopard was seen or heard near the village. Other precautions and deterrents included keeping livestock inside an enclosure (26%), proactively guarding the livestock while grazing (11%), using flashlights (6%), and lighting a bonfire (3%).

Most (90) households answered the question of conflict management. Of these, 65 households offered a variety of ideas on how conflicts could be managed. A common suggestion (46%; 30 of 65) was that the forest department should repair and maintain the solar powered electric fencing. Some (13) households welcomed the idea of a participatory approach and suggested

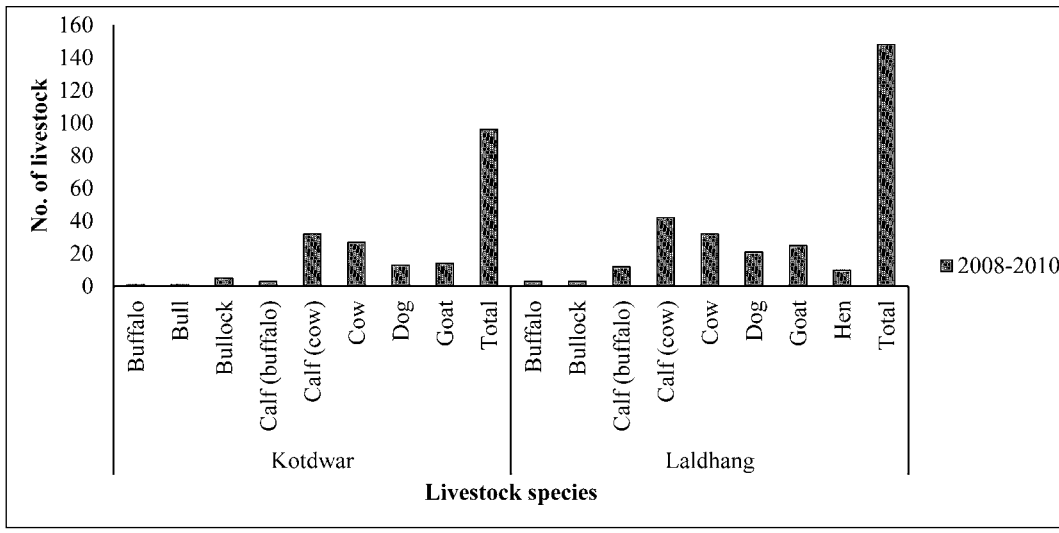

Figure 5. Livestock loss due to leopards during 2008 to 2010 across forest ranges in and around Rajaji-Corbett corridor.

that they should be given some rights over forest resources, including forest grazing rights and rights to collect nontimber forest products, such as grass, in return for assisting with conflict mitigation and conservation programs. A majority (62%) of Gujjars suggested that they should be relocated outside the forest to minimize conflict. Another notable response from 14% of households suggested that large carnivores should be culled when they pose conflicts.

Discussion

Large-bodied felids, such as tigers and leopards, are prone to conflicts with humans (Inskip and Zimmerman 2009), especially when they use wildlife corridors in human-dominated landscapes. Human–felid conflict was substantial in and around the crucial Rajaji-Corbett corridor, with conflicts reported by many households and villages and all the Gujjar settlements. The most important reason for such a high rate of conflict was the high dependency of people on the corridor for fodder and fuelwood and increased movement of tigers dispersing out of CTR.

Across forest ranges, Laldhang was facing more conflicts from both tigers and leopards, as compared to Kotdwar. This was partly due to Gujjar settlements that experienced higher conflicts than other communities. Gujjars are pastoral communities that depend on livestock for their livelihood; therefore, they have more livestock than other communities. This fact, along with their residing within the corridor, makes their livestock more vulnerable to depredation by felids. We found that economic loss due to both tigers and leopards was substantial, amounting annually to $267 and $38 per household, respectively. The loss due to tiger was much higher than leopards, because of frequent attacks by tigers on buffaloes, whose market price was 10 to 20 times more than that of domestic cow calves, which frequently were depredated by leopards. Despite this, leopards rather than tigers, were perceived as a threat by most households. This may be because leopard attacks were more frequent. Moreover, there have been some instances of leopards attacking and killing human beings. In comparison, attacks on humans by tigers were less frequent, and most losses were borne by the Gujjars. Even so, no tiger or leopard poisoning incidents have been reported in the area, and many people did not perceive either of the species as a threat, suggesting tolerance toward these felids. However, given the readiness of some to cull the problem animals and the high costs associated with conflicts, it is unlikely that people will remain tolerant for long, because there is a potential for conflict to increase in response to increasing felid population sizes in nearby source populations.

Most attacks by both tigers and leopards occurred within the forest. Leopards, however, are a resilient species known to live in forest fringes and capable of surviving at very high densities in human-dominated landscapes (Athreya et al. 2013). This is probably why attacks inside villages were by leopards rather than tigers. It can also be because the density of tigers is very low compared to that of leopards in the corridor forest (Johnsingh & Negi 2003), suggesting that while tigers are using the corridor for dispersion, many leopards are residents.

Management implications

There are many conflict resolution strategies that can be applied in the study area. Because tigers are chiefly affecting the livelihood of Gujjars, the resettlement of Gujjars outside the area may resolve the conflict, but it is a contentious issue, because not everyone is willing to move (Pallavi 2008, Joshi 2012, Agrawal 2014). However, during our survey, half of the sampled Gujjar households expressed their interest in being relocated out of the forest. Gujjars residing within Laldhang and Kotdwar ranges can be resettled in the southern periphery of the Chiriyapur range of Haridwar forest department through adequate relocation packages (Johnsingh et al. 2010).

In terms of managing human–leopard conflicts, fencing around villages would be a preventive measure, as 37% of leopard incidents occurred inside the village boundaries. Another preventive measure is manipulation of habitat to discourage leopards from entering human settlements. This would involve weed management, as weeds, such as lantana (*Lantana camara*) provide cover to leopards. Again it is suggested that the local people help with the cleaning up of the landscape and planting useful

plants in their fallow lands, so as to avoid the profusion of weeds. It is pertinent to integrate people's participation because people are ready to help in mitigating conflict in this study area if they are recognized as stakeholders of forest resources on which almost all of them depend.

Poor livestock husbandry and grazing in carnivore habitats make livestock more vulnerable to depredation by felids (Inskip and Zimmermann 2009). When cattle are left unattended, they are more vulnerable than when they are grazed near the villages (Treves et al. 2009). We found that 35% of households did not accompany their livestock, and 25% were not taking any precautions to protect their livestock from predation. Simple herd management strategies, such as more humans per livestock herd when in a carnivore habitate, will likely reduce rates of predation by carnivores (Wang and Madconald 2006). We found that the weaker sections of human society (i.e., forest-dwelling communities and farmers with only a small amount of land) were most severely affected by human–felid conflict. Hence, both people and wildlife should be given equal consideration while formulating management strategies to achieve lasting conservation goals.

Buffer forests and corridors are important for conservation of large carnivores, such as tigers and leopards, that are landscape-dependent species. Although effective conservation is usually measured by the stability or increasing trend of population size of the species of interest, resulting conflicts are rarely recognized. In our study, use of the corridors by tigers and leopards between RNP and CTR has resulted in conflicts with humans. In the wake of increasing tiger population in these PAs that this corridor connects, conflicts are likely to increase and may evoke negative responses from the people toward both tigers and leopards. Therefore, conservation measures are required to be conceived in a landscape perspective because source-sink dynamics and movement of tigers are linked to human–carnivore interactions and conflicts. It may be important to estimate optimal population sizes in the source areas, rather than aiming to increase or double the population size of these carnivores, as advocated by certain conservation agencies and local management.

Efforts should be directed to minimise present and future conflicts in order to prevent this corridor from becoming functionally redundant due to retaliatory measures by the people. The results of this study provide a basis for conflict resolution mechanisms based on spatio-temporal patterns of these conflicts, species-specific losses, their cost, and communities involved. We suggest that solutions should involve engaging communities to maintain fences and weed management, guided herding practices, better compensation for the losses and where absolutely necessary and attainable, relocation of human settlements. It is critical that human-felid conflicts in the Rajaji-Corbett corridor are minimised to maintain functionality of the corridor towards strengthening the long-term viability of tiger and leopard populations together with protecting the livelihood of local communities. Current policy direction demands landscape level conservation plan which includes strategies for management in core, buffer and corridor habitats. Therefore, it is important to consider deeper understanding of the conflict potentials in corridor habitats to enable long-term viability of carnivore populations in local and landscape scales.

It is critical that human–felid conflicts in the Rajaji-Corbett corridor are minimized to maintain functionality of the corridor toward strengthening the long-term viability of tiger and leopard populations while protecting the livelihood of local communities.

Acknowledgments

We gratefully acknowledge World Wide Fund for Nature for funding this study. We thank the Uttarakhand Forest Department, the Director and Dean of the Wildlife Institute of India and the Vice Chancellor and the Dean of the Forest Research Institute University for providing permissions and for making the project possible. We thank A. Harihar for his initial support and suggestions. We are thankful to the 2 reviewers and the editor for providing valuable input on the earlier versions of the manuscript.

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