Livestock depredation by leopards, associated economic losses, and financial compensation to communities in Chhota Udepur district of central Gujarat, India

Shalu Mesaria, Wildlife Conservation Biology (WCB) Research Foundation, #9, Panchvati Society, Opp. Income Tax Office, Deesa Highway, Patan, Gujarat, India

Pratik Desai, Wildlife & Conservation Biology Research Lab, Department of Life Sciences, Hemchandracharya North Gujarat University, Patan, Gujarat, India; and Wildlife Conservation Biology (WCB) Research Foundation, #9, Panchvati Society, Opp. Income Tax Office, Deesa Highway, Patan, Gujarat, India *pratikdesai825@gmail.com*

Shruti Patel, Wildlife & Conservation Biology Research Lab, Department of Life Sciences, Hemchandracharya North Gujarat University, Patan, Gujarat, India

Dhaval Gadhavi, Deputy Conservator of Forests, Chhota Udepur Forest Division, Chhota Udepur, Gujarat, India

Anthony J. Giordano, Wildlife Conservation Biology (WCB) Research Foundation, #9, Panchvati Society, Opp. Income Tax Office, Deesa Highway, Patan, Gujarat, India; S.P.E.C.I.E.S. – The Society for the Preservation of Endangered Carnivores and their International Ecological Study, Ventura, CA 93006, USA; and Center for Human–Carnivore Coexistence, Colorado State University, Fort Collins, CO 80521, USA

Nishith Dharaiya, Wildlife & Conservation Biology Research Lab, Department of Life Sciences, Hemchandracharya North Gujarat University, Patan, Gujarat, India; Wildlife Conservation Biology (WCB) Research Foundation, #9, Panchvati Society, Opp. Income Tax Office, Deesa Highway, Patan, Gujarat, India; and WCB Research Foundation, #9, Panchvati Society, Opp. Income Tax Office, Deesa Highway, Patan, Gujarat, India; and S.P.E.C.I.E.S. – The Society for the Preservation of Endangered Carnivores and their International Ecological Study, Ventura, CA 93006, USA

Abstract: Livestock depredation by large carnivores has been documented across the entire Indian subcontinent. The failure of managers to mitigate livestock losses in landscapes dependent on subsistence agriculture poses a threat to the conservation of carnivores. For much of Gujarat, a western Indian state characterized by extensive semi-arid habitats, the Indian leopard (*Panthera pardus fusca*) is considered an apex predator. Increasing regional leopard populations in response to protection efforts has led to more attacks on humans, along with an increase in rates of livestock depredation. In many cases, the regional forest department financially compensates livestock owners for depredation caused by leopards. Herein, we report on data we collected on leopard-caused livestock depredations in the Chhota Udepur district of Gujarat for 2019–2020. Between November 2020 and March 2021, we recorded 104 distinct cases of leopard depredations that resulted in 134 livestock mortalities. Most attacks occurred in the middle of the night, with the greatest frequency occurring between 2100 and 0400 hours (n = 53). Interestingly, livestock depredations by leopards appeared to occur more in the monsoon season (66%) than during the drier seasons (Fisher's least significant difference [LSD], $P < 0.05$). We also found that not everyone enduring losses to leopards received full compensation for the value of their animals. Livestock kept in corrals at night were more vulnerable to leopard attack (R^2 = 38.6, $P = 0.01$) compared to free-ranging livestock foraging by day in farms and forests. We recommend that livestock compensation claims filed by communities be investigated and processed quickly and that compensation be based on fair value for domestic animals lost. To better understand the drivers of human–leopard conflict, we also encourage rigorous surveys of potential leopard prey species in forested areas adjacent to conflict hotspots as well as research to identify the most effective methods communities might use to safeguard their livestock.

Key words: community conservation, eco-sensitive zone, human–carnivore coexistence, human–wildlife conflict, Indian leopard, large carnivores, *Panthera pardus fusca*, predator–prey relationships, sustainable livelihoods, western India

Historically, humans have had a very complex relationship with carnivores, spanning from fascination to fear (Boomgaard 2001, Loveridge et al. 2010). Human–carnivore conflict (HCC) is

Figure 1. Indian leopard (*Panthera pardus fusca*) in Chhota Udepur district, Gujarat, India, 2019–2020 (*photo courtesy of WCB Research Foundation*).

globally widespread and can negatively impact the well-being of both wildlife populations and human livelihoods (Chattha et al. 2013, Awan et al. 2020). Although HCC includes the depredation of domestic animals such as livestock, it also includes direct attacks on humans as well as damage to urban or agricultural infrastructure and crops in both developing and developed countries (Messmer 2000, Qamar et al. 2010).

Depredation on livestock, and HCC with large and small carnivores, can often be greater in or around unprotected forests and/or at natural forest and habitat edges (Woodroffe and Ginsberg 1998, Qamar et al. 2010, Ramesh et al. 2020), or among and adjacent to other anthropogenic landscapes (Torres-Romero et al. 2020, Phosri et al. 2021, Torres-Romero and Giordano 2022). In India, HCC in recent years has increased due to the rise of anthropogenic activities around forested habitats (Chouksey et al. 2017, Ramesh et al. 2020).

Although the distribution of the leopard (*Panthera pardus*) is widespread across Africa and Asia, today it occupies only 67–75% of its historical range (Jacobson et al. 2016). Indian leopards (*P. p. fusca*; Figure 1) are particularly adaptable to human-dominated landscapes, and eventually this can lead to more human–leopard conflicts with human communities (Chellam 2010). Anand and Radhakrishna (2017) estimated that two-thirds of all extant Indian leopard populations are found in the states of Uttarakhand, Himachal Pradesh, Gujarat, Maharashtra, Madhya Pradesh, Karnataka, and Chhattisgarh. And yet, most cases of human–leopard conflicts have been reported from Uttarakhand, West Bengal, Himachal Pradesh, Gujarat, and Maharashtra (Athreya et al. 2007).

Despite that attacks on humans have increased even in relatively urban areas (Loveridge et al. 2010, Eklund et al. 2017), most cases of human–leopard conflicts involve livestock depredation in more rural areas. Abundant domestic animals may even help sustain leopard populations locally (Athreya and Belsare 2007), particularly where natural prey populations are relatively low. Access to domestic livestock can allow leopards and other predators to establish a foothold in anthropogenic landscapes (Daniel 2009) when otherwise not possible. Such conditions, which are still ongoing in many areas, often result in local communities enduring high economic losses, particularly given the importance of livestock to overall livelihood assets. The loss of cattle (*Bos taurus*), for example, among the most expensive of livestock, can lead to increased retaliatory killings of leopards and greater hostility of locals toward leopards, including individual leopards not engaged in conflict (Chouksey et al. 2017). Given these challenges, it is important for natural resource managers to better understand the patterns underlying local conflicts. More robust information regarding human–wildlife conflict patterns can lead to the development of more effective mitigation measures and ultimately help facilitate human–wildlife coexistence (Messmer 2000).

We conducted our study in the Chhota Udepur district of Gujarat, India. This district was declared an eco-sensitive zone in 2019 (Gujarat Forest Department 2016); the forested areas in this region are considered one of the most important ecological corridors for sloth bears (*Melursus ursinus*) and leopards in the state (Singh et al. 2018). The state forest department recorded 82 individual leopards in this district alone during a 2016 survey of regional wildlife populations (Gujarat Forest Department 2016). These forest patches are used by local communities to collect both timber and non-timber products and are grazed by livestock.

The main objectives of our study were to investigate livestock depredation patterns, assess information about economic losses incurred by communities, and evaluate financial compensation provided to communities by the local forest department. To achieve these objectives, we

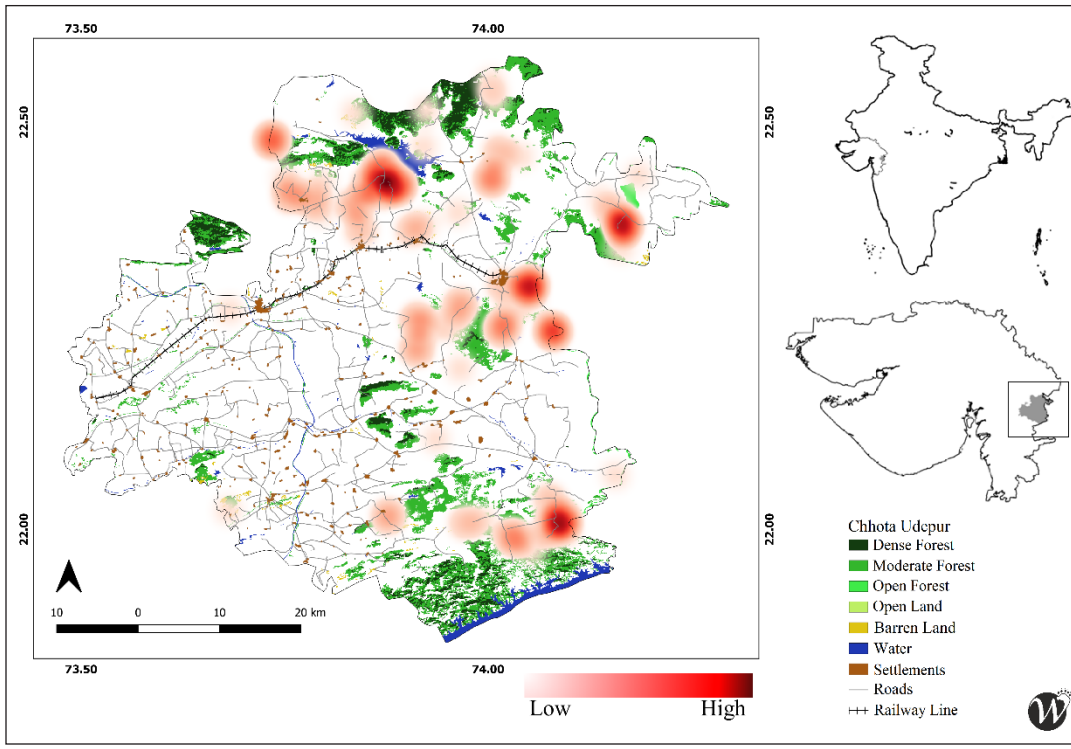

Figure 2. Livestock depredation by leopards (*Panthera pardus fusca*) across the Chhota Udepur district, Gujarat, India, 2019–2020.

collected information on livestock depredation occurrences caused by leopards as reported to the forest department of Chhota Udepur district between 2019 and 2020. We believe the analysis of these data can help establish baseline policies and practical guidance for the local forest department to address conflict issues, including the formulation of policies for efficient compensation.

Study area

The Chhota Udepur district is situated in the central part of Gujarat in western India (22.3085° N 74.0120° E; Figure 2). This region is known for its rich and diverse forest resources and falls within the state's sub-biotic zones 4B6 (Malwa Plateau) and 4B5 (Plains in Central Gujarat; Singh 2001). Major forest types include dry and semi-dry teak forests, small patches of semi-moist deciduous forests, dry mixed forests, bamboo breaks, and riverine forests; altogether, they comprise a total area of 757 km^2 (Singh 2001). Rocky outcrops and hills in these forested areas are often used by leopards for denning, foraging, resting, and as cover for hunting. Because many of these forests are significantly degraded due to unsustainable agricultural practices, mining, and expanding urban development, negative human–wildlife interactions increasingly plague nearby villages.

The climate of the study area is "tropical dry" with 3 distinct seasons: winter, summer, and monsoon. The temperature drops to 12°C in winter and rises to 45°C in summer. Rainy days are irregular, with most of the annual average rainfall of 450 mm occurring from July to September. Characteristic flora in the region includes teak (*Tectona grandis*), a dominant tree species, as well as Indian laurel (*Terminalia elliptica*), cutch tree (*Acacia catechu*), Coromandel ebony (*Diospyros melanoxylon*), axle-wood tree (*Anogeissus latifolia*), palas tree/khakharo (*Butea monosperma*), and small flowered crape myrtle (*Lagerstroemia parviflora*).

In addition to leopards and sloth bears, the striped hyena (*Hyaena hyaena*), Indian palm civet (*Paradoxurus hermaphroditus*), rusty-spotted cat (*Prionailurus rubiginosus*), Indian rock python (*Python molurus*), nilgai (*Boselaphus tragocamelus*), four-horned antelope (*Tetracerus quadricornis*),

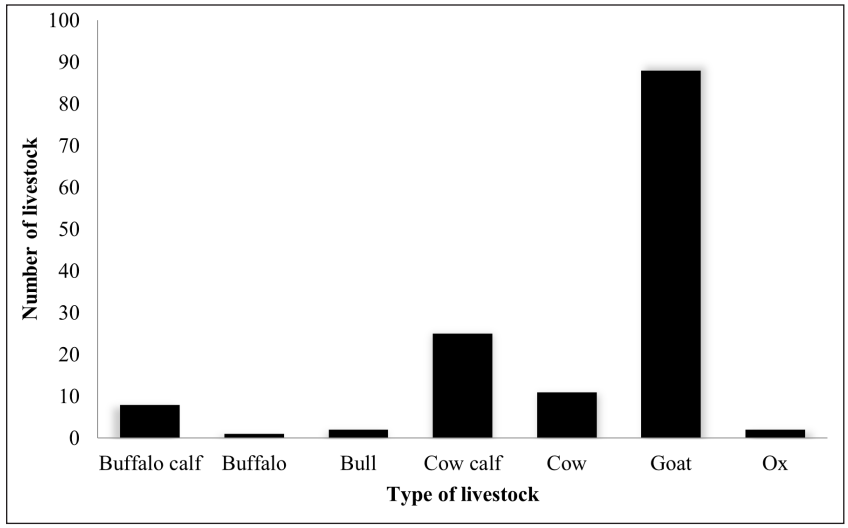

Figure 3. Type of livestock killed by leopards (*Panthera pardus fusca*) in Chhota Udepur district, Gujarat, India, 2019–2020, including: buffalo calves (*Bubalus bubalis*), buffalo, buffalo bulls (bull), calves of domestic cows (*Bos taurus indicus;* cow calf), domestic cows (cow), goats (*Capra hircus*), and domestic oxen (ox).

Indian wild boar (*Sus scrofa*), Indian muntjac (*Muntiacus muntjak*), Indian grey langur (*Semnopithecus entellus*), and Indian peafowl (*Pavo cristatus*) are among the diverse wildlife native to these landscapes.

Culturally, Chhota Udepur is considered a tribal district, with >80% of the human population dominated by the Rathva and Baria tribes. The livelihood of locals depends strongly on agricultural practices, including livestock rearing to supplement crop-based income. Goats (*Capra hircus*) and buffalo (*Bubalus bubalis*) are the most common livestock in the area, although some people also own domestic cows (*Bos taurus indicus*) and sheep (*Ovis aries*; Department of Agriculture and Farmers Welfare 2016). For the grazing and collection of forest products, villagers are also dependent on unprotected forested parts of the study area.

Methods

We collected information about livestock depredations caused by leopards from the office of the Deputy Conservator of Forest, Chhota Udepur Forest Division. We conducted surveys of local residents from November 2020 through March 2021. On the day of each depredation, local residents visited the nearby forest office to provide information on that incident; these records were compiled and stored by the forest department. The data recorded included information such as livestock type, number of livestock killed, name of the owner, location of the attack, time and date of the attack, and compensation both claimed and received by the owner. We extracted and processed this information for classification and further analysis, including plotting the coordinates of leopard conflict locations on a topographic map of Chhota Udepur district. We then used these data to generate a "hotspot" map using heatmap in Q-GIS®.

Finally, we calculated the average market price of different livestock from local markets at the time of loss and subsequently compared these averages with the value of compensation received by each owner. To determine if significant differences existed among locations, categories, and groups, with respect to the frequency of depredation occurrences, we calculated the Fisher's least significant difference (LSD; $\alpha = 0.05$) in SPSS® (SPSS Inc., Armonk, New York, USA).

Results

Between 2019 and 2020, we recorded 104 incidents of depredations caused by leopards involving 137 individual livestock. For at least 4 of these instances, we know that livestock were successfully rescued by their owners; in all other cases, livestock were killed. Goats (64.3%) were the most frequently depredated livestock in our

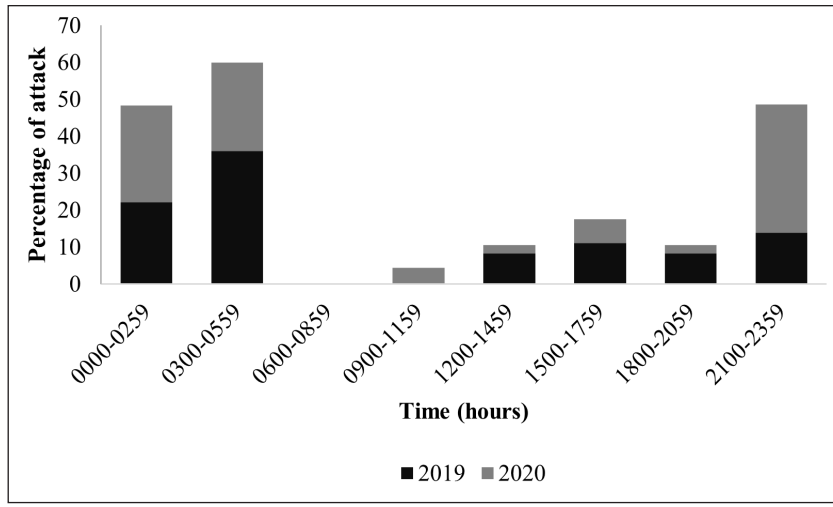

Figure 4. Circadian pattern of livestock depredation by leopards (*Panthera pardus fusca*) in Chhota Udepur district, Gujarat, India, 2019–2020.

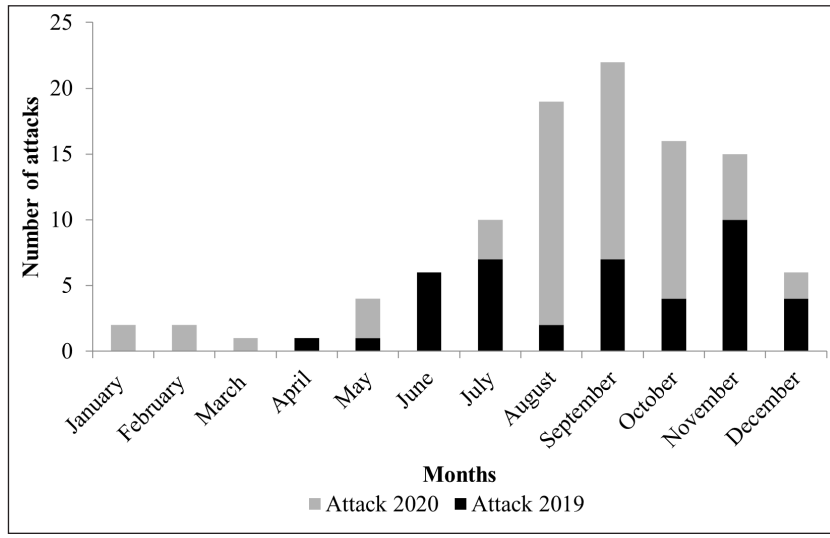

Figure 5. Cumulative livestock depredation by leopards (*Panthera pardus fusca*) for each month over 2 years in Chhota Udepur district, Gujarat, India, 2019–2020.

study area, followed by calves of domestic cows (18.2%), domestic cows (8.0%), buffalo calves (5.8%), buffalo bulls (1.5%), domestic oxen (*Bos taurus indicus*; 1.5%), and adult buffalo (0.72%; Figure 3). In 22.8% of instances, multiple goats were killed by leopards during a single predation event. Although livestock depredation varied across the district, livestock depredations occurred most often in villages, farms, and in proximity to substantial forest cover (Figure 3).

Most depredation incidents (82.7%) also occurred inside livestock corrals or "sheds." However, some livestock were also depredated inside forests (13.5%) and in the vicinity of farms (3.9%). The means from our Fisher's LSD ($R^2 = 38.6$, $P = 0.01$) analysis suggested that when livestock were kept in corrals, they were more vulnerable to leopard attacks relative to livestock grazing freely in farms and forests.

For 82 incidents (78.85%), the relative time of attack was mentioned in incident report secondary data. Approximately 66% of attacks occurred after sunset and before sunrise (1800–0559 hours). Attacks between late morning

Table 1. Average market price in U.S. dollars (USD [$]) of different livestock in the study area and compensation paid by the forest department upon depredation by leopards (*Panthera pardus fusca*) in Chhota Udepur district, Gujarat, India, 2019–2020. Types of livestock include: goats (*Capra hircus*), domestic cows (*Bos taurus indicus*; cow), calves of domestic cows (cow calf), buffalo (*Bubalus bubalis*), buffalo calves, domestic oxen (ox), and buffalo bulls (bull).

Cattle	Compensation per livestock	Average market value	Difference (%)
Goat	$36.10 USD	$59.92 USD	-23.82
Cow	$254.12 USD	$565.92 USD	-311.8
Cow calf	$153.85 USD	$86.55 USD	+67.3
Buffalo	$408.00 USD	$699.07 USD	-291.07
Buffalo calf	$137.53 USD	$119.83 USD	+17.7
Ox	$339.00 USD	$352.81 USD	-13.81
Bull	$217.50 USD	$66.57 USD	+150.93

(0900–1159 hours) and late afternoon (1500–1759 hours) were relatively infrequent (12.5%), and we recorded no attacks during 0600–0859 hours (Figure 4).

Although livestock depredation in our study area occurred throughout the year, we noted an increase in attacks during the months of June to November (monsoon and early winter); in fact, this period accounted for 78% of all attacks we recorded (Figure 5). We also found seasonal variation in livestock depredations (LSD, $P < 0.05$), with approximately two-thirds of cases occurring during the monsoon (66%), followed by summer (25%), and lastly, winter (9%).

Approximately $13,036 USD (based on $1 USD = ₹73.64 INR in 2020) in financial compensation was paid in total to livestock owners by the Gujarat Forest Department. These were considered "reparations" for livestock losses in the study area between 2019 and 2020. For some types of livestock classes, the average compensation value was less than the average market value (Table 1). Economic losses were higher when the community lost an adult domestic cow, buffalo, and goats. Interestingly, we found that the owners of both adult domestic cows and buffalo calves consistently received compensation above the average market value.

Discussion

We found evidence that livestock, particularly penned goats, were most frequently the target of leopard attacks across our study area. Among all domestic livestock, goats fall within the ideal size range of prey frequently selected by leopards (10–40 kg; Karanth and Sunquist 1995, Hayward et al. 2006). In an urban landscape of western India, one study found that domestic dogs (*Canis familiaris*), cattle, and domestic goats contributed substantially to the diet of leopards (Athreya et al. 2016). Across south Asia, other research found that smaller and medium-sized livestock appeared more vulnerable to depredation by leopards (Tamang and Baral 2008, Ramesh et al. 2020, Lamichhane et al. 2023), and our findings are therefore consistent with these other studies. We found that although goats represented 64% of total livestock killed by leopards, they only comprised 27% of the total livestock owned by locals across the study area (Department of Agriculture and Farmers Welfare 2016); this suggests they are more "preferred" by, or vulnerable to, leopards relative to other livestock. Ramesh et al. (2012), however, confirmed that the leopard's diet in the Western Ghats of India consisted of at least 21 prey species. Among these, wild ungulates larger than goats were often preferred prey, particularly chital (*Axis axis*) and sambar (*Rusa unicolor*) deer (Johnsingh 1992, Karanth and Sunquist 1995, Andheria et al. 2007, Mondal et al. 2011, Ramesh et al. 2012).

We also found that most attacks on livestock occurred in corrals. In general, these corrals were often beside homes and weakly constructed, with short walls made up of wooden logs or thorns. Though these walls might be sufficient to discourage the escape of livestock and prevent them from straying, they were not designed to prevent the entry of a predator like a leopard. Not surprisingly, we found that leopards primarily fed on livestock in enclosures at night, which is consistent with their primarily

nocturnal behavior (Ahmed et al. 2012).

Goats are also largely confined to these corrals overnight, when human presence, management, or husbandry are minimal, thus making them more vulnerable. Lamichhane et al. (2023), in their study of livestock depredations in the mid-hills of Nepal, found that goats in their corrals were also the livestock most vulnerable to leopards; although, like in our study, this often occurred at night, it also occurred during the day when their owners were in the field. In contrast, farmers in our study often allowed goats to graze in the forest during the day, when although they are seemingly more vulnerable, they continued to move about as they grazed, and leopards are thought to be less active. Relatively unprotected or "accessible" livestock corrals also make goats and other livestock more vulnerable to "surplus killing," a process whereby a single leopard or other predator kills >1 individual, sometimes many livestock, during a single visit (Jackson et al. 2010, Koirala et al. 2012), often in the same corral (Fernando 2016). In addition to the relative vulnerability of livestock due to poor husbandry practices, low availability or abundance of wild prey in central Gujarat (Singh 2006, Alam and Kumar 2012) may also be influencing leopard depredation rates and patterns in our study area, although this needs to be investigated more thoroughly.

We also found that nearly two-thirds of all attacks occurred during the monsoon season (i.e., in September). In contrast to our findings, Lamichhane et al. (2023) reported more depredations in the winter and summer months relative to the monsoon season. Prior studies across south Asia concluded that leopard-related depredation activity varies considerably (Sangay and Vernes 2008, Qamar et al. 2010, Suthar et al. 2018) across the region.

In Gujarat, other studies have documented attacks by leopards in both winter (Suthar et al. 2018) and during the monsoon season (Singh 2006, Alam and Kumar 2012). It is possible that in Gujarat, the monsoon may permit leopards to range and depredate more widely due to an overgrowth of vegetation and thus greater availability of cover, as well as the ability to move away from more permanent water sources, which may be a constraint during the drier months (Tamang and Baral 2008, Babrgir et al. 2017, Khorozyan et al. 2018).

Compensation of financial losses associated with the loss of property, including livestock, can increase a community's tolerance of human–wildlife conflict (Ogra and Badola 2008). Fair market value, however, should always guide compensation programs managed by the forest department, as locals are often unaware of such compensation schemes. The undervaluing of community property, assets, or resources can undermine tolerance for leopards and even lead to retaliation on leopards by locals (Bulte and Rondeau 2005, Karanth et al. 2012).

Finally, to better contextualize the prevalence of human–leopard conflict in the region, we call for rigorous surveys of potential leopard prey species in those forested areas adjacent to conflict hotspots. We also believe an assessment of practices to determine the most cost-effective methods communities might use to safeguard their livestock is long overdue. We therefore urge the forest department to develop and adhere to a fair, standardized system for valuing livestock, one that is transparent to communities and can facilitate effective compensation of locals in the region.

Based on our experiences, we recommend the use of neck bells on livestock as well as the possible installation of flashing lights as deterrents. Both are affordable and readily available to locals; theoretically, they may serve to confuse leopards and/or simulate human presence by creating noise or visual effects they will be cautious of or avoid. Whatever the tools deployed, it is critical that their relative effectiveness be assessed, as evidence-based information of this sort is lacking in the literature.

Management implications

In India, habitat degradation and a decline in prey species is a major problem leading to increased depredations. We recommend that the forest department implement a compensation scheme to consistently pay the fair value of livestock as reparations for communities and to create and restore more natural habitat preferred by the leopard's native prey species. We also recommend that locals build stronger, more secure corrals with few entrance/exit points to better protect livestock from predators and, if possible, use predator deterrents and/or keep lights on outside the house and near corrals to keep predators from attacking livestock.

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Associate Editor: Stotra Chakrabarti

Shalu Mesaria is a senior project fellow affiliated at WCB Research Foundation, India. She has a longstanding interest in understanding the traditional culture that coexists with the environment, and her recent work is centered on the outreach, education, and ongoing conflict with sloth bears and other wildlife in Gujarat, India. For her community education and awareness work, she was awarded Environment Educator of the Year 2022 by WeNaturalist. At present, she is surveying wildlife corridors in Gujarat to understand the potent issue of rising conflict between locals and sloth bears. She aspires to be a conservationist, and her interests are in understanding interdisciplinary approaches in conservation challenges along with techniques to study wildlife, zoonoses, and vector-borne diseases.

Pratik Desai is Ph.D. scholar in the Department of Life Sciences at Hemchandracharya North Gujarat University, Patan, and is studying the sloth bear habitat in non-protected areas of Gujarat to address human–sloth bear conflicts. He did education and outreach about the sloth bear and leopard in central Gujarat along with habitat and occupancy surveys and interacted with local people to determine their perception toward wildlife. He is a co-founder and the director of operations of WCB Research Foundation. He is a member of the International Association for Bear Research and Management, USA, as well as the Association of Zoologists, India. He has received instrument grants from Ideawild® Foundation, USA, for his Ph.D. research.

Shruti Patel completed her master's degree in zoology in 2020 from Hemchandracharya North Gujarat (HNG) University. She has submitted her master's thesis on the breeding behavior and habitat preferences of the Indian rock python. She is working with WCB Research Lab, HNG University, as junior research fellow of the sloth bear corridor and outreach program in central Gujarat. She is passionate about herpetofauna, especially snakes. She always keeps her doors open to learn new things. She wants to extend her expertise in wildlife research and management through various tasks.

Dhaval Gadhvi currently holds the charge of deputy conservator of forest, Wild Ass Sanctuary, Gujarat Forest Department. He studied veterinary science and animal husbandry and joined the Gujarat Forest Force through Gujarat State Forest Services. He got his training in forestry from the Central Academy of State Forest Services, Coimbatore, Tamil Nadu. He has been involved in various capacities to build programs on wildlife monitoring, rescue, and forest habitat management for the front-line forest staff of his division.

Anthony J. Giordano is the executive director and chief conservation scientist of S.P.E.C.I.E.S. – The Society for the Preservation of Endangered Carnivores and their International Ecological Study. He holds a double B.Sc. degree in evolutionary biology and environmental science, an M.Sc. degree in conservation biology, and a Ph.D. degree in wildlife ecology and management. Over the past 30 years, he has studied the biology and behavior of >55 species of carnivores in 30 countries, publishing >150 peer-reviewed articles, book chapters, and other scientific publications. A former member of the Board of Governors for the Society for Conservation Biology, past president of the Wild Felid Research and Management Association, and member of several IUCN Specialist Groups, he works to develop innovative socioeconomic and technological solutions that mitigate threats to carnivores, their prey, and other wildlife, and that ultimately facilitate coexistence with rural communities, across the tropical and mountainous regions of the world.

Nishith Dharaiya is an associate professor and in charge of the Wildlife and Conservation Biology (WCB) Research Lab at the Department of Life Sciences, Hemchandracharya North Gujarat University, Patan, India. He works on large carnivore ecology and their interaction with human in India. He is a founder and honorary director of research at WCB Research Foundation. He is a co-chair of the IUCN Sloth Bear Expert Team and a member of the International Association for Bear Research and Management, USA. He is also a member of the IUCN Human–Bear Conflict Management Specialist Team. He has co-authored the guidelines for human–bear conflict mitigations in India published by Ministry of Environment, Forest and Climate Change, Government of India.