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Livestock depredations by leopards in Pir Lasura National Park, Pakistan: characteristics, control and costs

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Conservation of large carnivores in protected areas with high human use or habitation is challenging due to ecological, political and socioeconomic factors. Understanding underlying patterns of human–carnivore interactions is vital for their conservation. We investigated patterns and costs of livestock depredations by common leopards *Panthera pardus* in and near Pir Lasura National Park, Pakistan, using standardized questionnaires to collect data from 133 respondents during 2014–2015. Respondents lost 209 animals to leopard attacks, primarily goats (78.5%), followed by dogs (11%). Most leopard depredations of livestock occurred during the day, with almost 60% occurring during 9:00–11:00 h and 14:00–16:00 h. Greatest numbers of livestock killed was during May–July (60.9%) followed by December (9%). Most attacks occurred when livestock were not guarded (48.9%) and fewest when guarded by humans and dogs (2.3%). Most livestock depredations occurred in larger herds of ≥ 20 animals (58%). Respondent's perceptions of leopards were negative, with most (79.7%) stating their unwillingness to conserve leopards. Eight leopards were reportedly killed in retaliation to livestock. Livestock depredations by leopards represented almost 9% of the annual income of respondents. Our study provides several insights to mitigate human leopard conflict including use of humans and dogs to guard livestock during times of peak vulnerability (e.g. late morning and during summer, May–July). Further, improved corrals could reduce access to livestock by leopards and local communities should be aware of more effective corral designs. Reducing livestock depredations and corresponding economic losses could improve perceptions of local communities and promote tolerance towards leopards, reducing retaliatory killing and facilitating coexistence.

Keywords: common leopard, conflict mitigation, costs, human–carnivore conflict, Pir Lasura National Park

Conservation of wildlife has become increasingly challenging due to factors including increasing human populations, habitat loss and degradation, and unsustainable use of natural resources (Khorozyan et al. 2015, Shehzad et al. 2015, Stein et al. 2020). These factors have resulted in an increase in human–wildlife interactions, which has greatest adverse effects on large-bodied species, including carnivores (Hill et al. 2020). Consequently, conflicts with humans is a primary driver of declines in carnivore populations globally (Ripple et al. 2014). These conflicts increasingly occur as an outcome of greater human activities near protected areas that harbor larger carnivore populations than adjacent areas (Consolee et al. 2020, Lubis et al. 2020). Communities living in or near protected areas depend on livestock for their subsistence which has resulted in an upsurge in the number of livestock, often at densities many times greater than wild prey species (Khorozyan et al. 2015). Such abundances of domestic prey can result in attacks on livestock by carnivores resulting in negative attitudes of local communities towards carnivores (Kabir et al. 2014, Hussain et al. 2019, Khan et al. 2020, Kumbhojkar et al. 2020).

Human–carnivore conflicts are evident in many forms including crop raiding (Hoare 2012), killing pets and livestock (Miller et al. 2015, Hussain et al. 2019, Gray et al. 2020, Khan et al. 2020), loss of property (Treves 2009) and injuring or killing humans (Naughton-Treves 1998, Ratnayeke et al. 2014). Human–carnivore conflicts have become an important conservation issue as well as a rural livelihood issue since many carnivores have been persecuted by local communities in retribution to livestock depredation (Chetri et al. 2020, Morehouse et al. 2020, Russell 2020). Consequently, historic distribution ranges of many carnivores species including common leopards *Panthera pardus* have contracted (Jacobson et al. 2016). Livestock depredation by carnivores impacts rural communities as they depend on livestock for their subsistence and usually belong to the lowest income categories. Therefore, loss of livestock to carnivores can place extreme economic burdens on these people. Nevertheless, human–carnivore conflicts can be mitigated by outreach and education programs, capacity building, improving livestock pens, compensation schemes to improve the livelihood of local communities, conserving wild prey populations (Allen et al. 2017, Balfour et al. 2019, Lubis et al. 2020) and habitat restoration (Mahmood et al. 2019, Mariela et al. 2020).

The leopard was once widely distributed across northeastern Pakistan but its distribution here and across the country has decreased because of persecution over livestock depredation (Roberts 1997, Sheikh and Molur 2004). Our objectives were to characterize the timing and frequency of leopard depredations of livestock as well as to evaluate the efficacy of existing livestock husbandry practices to mitigate depredation risk and estimate economic losses sustained by livestock owners due to leopard depredations. Overall, we predicted that leopards would kill livestock more frequently at night, to reduce potential encounters with humans. We further predicted that leopards would kill livestock more frequently during summer, when forage more distant from villages and vulnerable livestock neonates are available. Finally, we predicted that an increased number of conflict mitigation techniques used would reduce the frequency of livestock depredations by leopards.

Material and methods

Study area

We conducted the study in and near Pir Lasura National Park (PLNP; 33°25′92″–33°29′31″N, 74°05′64″–74°03′02″E), District Kotli, Pakistan (Fig. 1). The overall study area comprised 17 183 ha and included PLNP, which encompasses 1580 ha area with elevations ranging from 1000 to 2000 m a.s.l. The area is predominantly subtropical pine vegetation, with higher elevations containing sub-tropical dry evergreen forests. Average annual rainfall in the study area is 1500 mm. There are four distinct seasons: summer (May–July), autumn (August–October), winter (November–January) and spring (February–April). Prominent wildlife species include the common leopard *Panthera pardus*, rhesus monkey *Macaca mulatta*, Asiatic jackal *Canis aureus*, barking deer *Muntiacus muntjak*, wild boar *Sus scrofa*, desert hare *Lepus nigricollis dayanus*, Indian pangolin *Manis crassicaudata*, Kaleej pheasant *Lophura leucomelanos* and common peafowl *Pavo cristatus* (Roberts 1997, Grimmett et al. 2009, Akrim et al. 2018). Estimated density of wild prey species of leopard in the study area was 57 individuals km^{-2} and estimated density of domestic livestock was 260 individuals km^{-2} (Akrim et al. 2018).

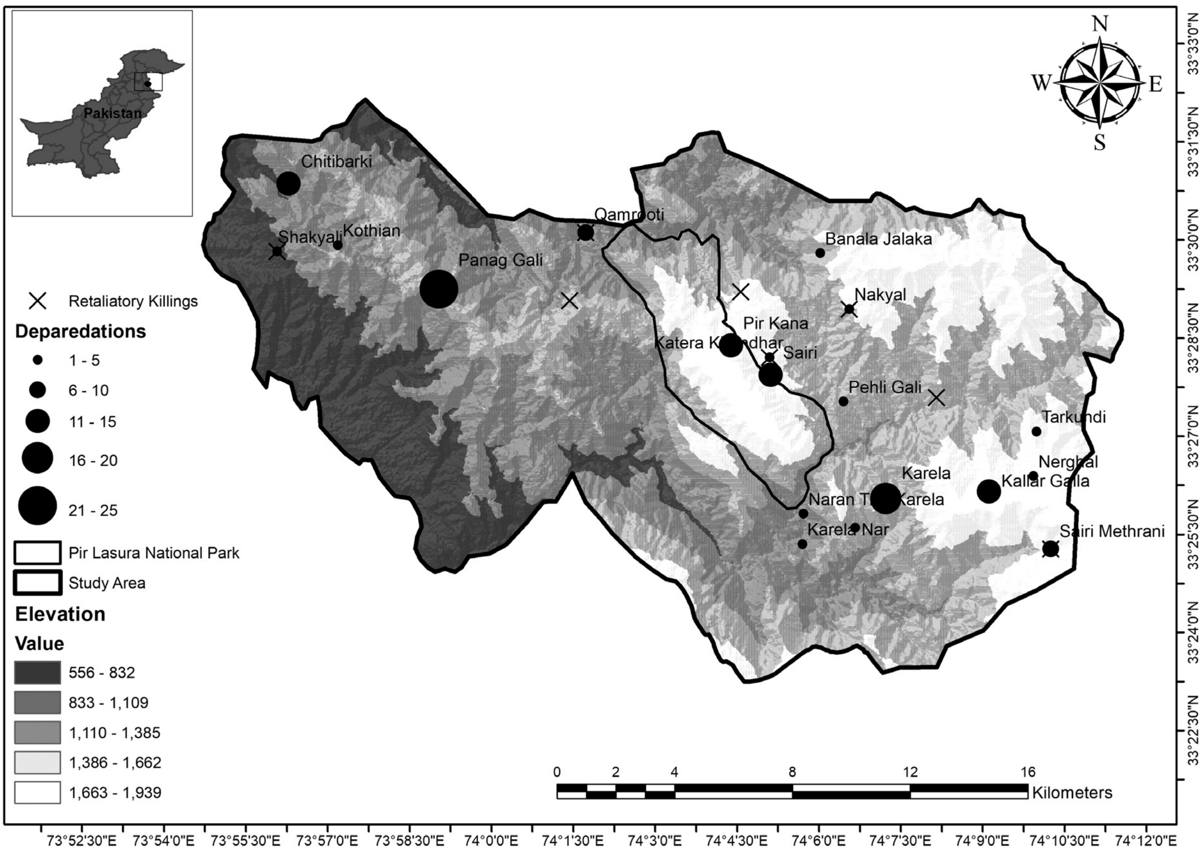

Figure 1. Locations of livestock depredation and retaliatory killing of common leopard *Panthera pardus* in and around Pir Lasura National Park, Pakistan, 2014–2015.

Domestic animals kept by local people include cattle *Bos taurus*, buffalos *Bubalus bubalis*, goats *Capra aegagrus hircus*, dogs *Canis lupus familiaris*, horses *Equus* spp. and rabbits *Oryctolagus* spp. Most people living in the study area maintain livestock for milk and meat production and depend on livestock for subsistence (Akrim et al. 2018).

Methods

We obtained written permission to conduct this survey from the Department of Wildlife Management (PMAS-AAUR/2646), as approved by the Ethical Committee (dated 30 April 2012). Permission included guidelines to ensure we conducted this research while respecting local beliefs and economic and cultural interests. Before administering the questionnaire (Supplementary material Appendix 1), we met with Department of Forest, Wildlife and Fisheries staff to identify villages that had experienced losses of livestock to leopards. We held unstructured meetings and group discussions at these villages, then selected participants from these meetings using the consecutive sampling method (Setia 2016).

We requested information on livestock depredations by leopards from January 2014 to December 2015. To reduce bias, we assured respondents that information provided would be kept confidential. We assessed whether respondents could identify leopards by requesting they select the image of a leopard from images of carnivores native to the area. We asked each respondent to provide the number and types of livestock killed by leopards, and the approximate time of day, month and year depredations occurred. We considered livestock depredated by leopards when respondents reported direct observation of the attack or damage to the throat or neck of the killed animal. We requested the locations of leopard attacks, whether the attack occurred within their respective village, and visited each when possible, recording locations with a handheld GPS unit.

We asked each respondent whether they penned livestock in their village at night. Further, we requested whether humans and/or dogs were present to guard grazing livestock when leopard depredations occurred and herd size (< 10, 11–19 or ≥ 20 animals) at the time of attack. We asked respondents whether they have killed leopards in response to livestock depredations. We also asked each individual whether they were willing to conserve leopards, if they were aware of the conservation status of leopards, and if they knew of the government agency in Pakistan responsible for leopard management and the potential legal consequences of killing leopards. Finally, we asked each respondent to report their average monthly household income.

We used χ^2 analyses to analyze temporal patterns in livestock depredations and frequencies of depredations in relation to conflict mitigation. We used local livestock market prices (in Pakistani Rupee converted to USD) to estimate their economic value and losses incurred by respondents as follows: average price of goat = $200 (Rs. 21 000/-); cow, buffalo and ox = $2402.80 each (Rs. 252 000/-); horse = $2884.50 (Rs. 300000/-); dog = $96.12 (Rs. 10000/-); and rabbit = $4.72 (Rs. 500/-).

We used binary logistic regression to determine respondent's willingness to conserve common leopard (coded as 1) or do not want to conserve (coded as 0) leopards in and near PLNPark, Pakistan. Respondent willingness to conserve was classified as dependent variable while, income, level of education, financial loss due to predator, livestock holding and number of livestock lost to predator were classified as covariates.

Results

We interviewed 133 respondents from 19 villages who lost at least one livestock or dog to leopard depredation during 2014–2015 in and around PLNP. Individual interviews on average required 25 min to complete. Majority of respondents were included in least educated category having 0–5 years of formal education (70.7%) and most respondents were farmers (47%, Table 1). The mean number of livestock and dogs owned per respondent was 12.5 animals; overall composition of these animals were goats (79%), cattle (8%), dogs (5%), sheep (4%), buffalo (2%), with oxen, horses, mules and rabbits each representing (< 1%).

Overall, respondents reportedly lost 209 animals (1.57 livestock/respondent) from leopard attacks. Domestic animals killed were primarily goats (78.5%), followed by dogs (11%), rabbits (5.3%), cattle (1.4%), buffalo (1.4%), ox (1.4%) and horse (1%) ($\chi^2 = 452.02$, df = 6, p-value < 0.001). Most attacks (67%) occurred at six villages including Panag gali (15.8%), Karaila (15.0%), Pir kana (9.8%), Sairi (9.8%), Kallar galla (8.3%) and Chitibakri (8.3%) (Fig. 1). We found weak positive correlation between number of livestock holding and number of livestock lost to leopard by respondents (r = 0.113).

Most leopard depredations of livestock occurred during the day, with almost 60% occurring during 9:00–11:00 h (n = 53, 40%) and 14:00–16:00 h (n = 23, 17.3%). A secondary peak occurred during 21:00–22:00 h (n = 25, 18.8%). Livestock depredations by leopards occurred throughout the year with the greatest number of livestock killed during July (n = 30, 22.6%) followed by June (n = 27, 20.3%), May (n = 24, 18%) and December (n = 12, 9%) ($\chi^2 = 48.29$, df = 11, p-value < 0.001) (Fig. 2). More depredations occurred during 2015 (n = 86, 65%) than in 2014 (n = 47, 35%) ($\chi^2 = 11.43$, df = 1, p-value = 0.001).

Most (n = 129, 97%) respondents penned livestock in villages at night, while few (n = 4, 3%) did not ($\chi^2 = 117.48$, df = 1, p-value < 0.001). A similar number of livestock depredations occurred within villages (n = 66, 49.6%) as occurred when livestock were grazing outside of villages (n = 67, 50.4%) ($\chi^2 = 0.008$, df = 1, p-value = 0.93). Leopard depredations of livestock decreased with increasing intensity of guarding ($\chi^2 = 59.69$, df = 3, p-value < 0.001). Most attacks occurred when livestock were not guarded (n = 65, 48.9%), followed by livestock guarded only by humans (n = 38, 28.6%), guarded only by dogs (n = 27, 20.3%) and guarded by humans and dogs (n = 3, 2.3%). Most livestock depredations occurred in larger herds of > 20 animals (58%), followed by herds of 10–19 animals (25%) and herds < 10 animals (17%) ($\chi^2 = 37.23$, df = 2, p-value < 0.001).

Respondent's perceptions of leopards were negative, with most (n = 106, 79.7%) stating their unwillingness to conserve leopards. The binary logistic regression model showed

Table 1. Characteristics of respondents in and near Pir Lasura National Park, Pakistan.

Characteristics of respondents	Sub-category	Number	Percentage
Number of questionnaires		133	
Number of villages surveyed		19	
Respondent education (years)	0–5 years	94	70.7
	6–10 years	20	15
	11–12 years	4	3
	13 years – and above	15	11.28
Occupation of respondents	Labor	17	13
	Farmer	62	47
	Govt Job	17	13
	Student	12	9
	Private job	3	2
	Shopkeeper	14	11
	Herder	6	5
	Driver	2	2
Gender	Male	119	89.47
	Females	14	10.53
Knowledge about conservation status of leopard	Yes	8	6.02
	No	125	93.98
Knowledge about authority responsible for conserving leopard	Yes	117	87.97
	No	16	12.03
Willingness to conserve leopard	Yes	27	20.30
	No	106	79.70

that 60.4% of variability in respondent's willingness to conserve leopard were based on predictor variables (−2 log likelihood = 69.826, Cox and Snell $R^2 = 0.384$, Nagelkerke $R^2 = 0.604$). Among five covariates fitted in the binary logistic regression model only one covariate 'level of education' was found to be significantly different ($p = 0.000$), while four variables including; income ($p = 0.969$), financial loss during the study period ($p = 0.396$), livestock holding ($p = 0.132$), and number of livestock lost to predator ($p = 0.205$) were not statistically different (Table 2).

Eight leopards were reportedly killed in retaliation to livestock depredations, three in 2014 and 5 in 2015 (Fig. 1). Most respondents (n = 125, 94%) were unaware that leopards were considered globally vulnerable to extinction by the International Union for Conservation for Nature (Stein et al. 2020). However, most (n = 117, 88%) were knowledgeable of the local authority responsible (Forestry, Wildlife and Fisheries Department) for wildlife conservation and that fines or imprisonment could be imposed for killing leopards.

Livestock depredations by leopards resulted in an overall estimated loss of 62 457 USD during 2014–2015 (235 USD per respondent per year), with mean annual losses to each respondent ranging from 26 to 1442 USD. Reported average (± SD) monthly household income was 227 ± 87 USD and ranged from 80 to 500 USD.

Discussion

Leopard depredation of livestock was common in and around PLNP, with losses representing a substantial pro-

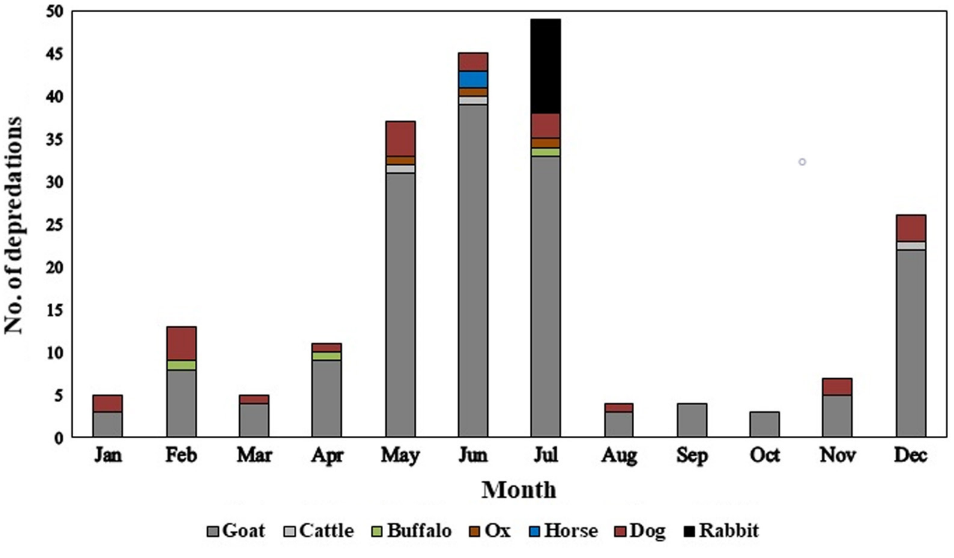

Figure 2. Monthly frequency of common leopard *Panthera pardus* depredations on livestock in and near Pir Lasura National Park, Pakistan, 2014–2015.

Table 2. Binary logistic regression of covariates affecting respondent's willingness to conserve leopard in and near Pir Lasura National Park, Pakistan.

Covariates	B	SE	Wald	df	Sig.	Exp(B)
Income	0.000	0.000	0.002	1	0.969	1.000
Financial loss	0.000	0.001	0.721	1	0.396	1.000
No. livestock holding	−0.148	0.098	2.264	1	0.132	0.863
Level of education	0.479	0.095	25.572	1	0.000	1.614
No. livestock to predator	−0.623	0.492	1.605	1	0.205	0.536

portion of the annual income of affected livestock owners. Timing of leopard attacks was variable with peak occurrence during late morning, likely a consequence of grazing livestock more distant from villages unattended. Livestock depredation by leopards during daytime also was reported by Kabir et al. (2014). Woodroffe et al. (2007) found the risk of leopard attack was higher during the daytime for larger herds in Africa. We also recorded secondary peaks during late afternoon and evening, similar to leopard depredations of livestock at Machiara National Park, Pakistan (Dar et al. 2009) where livestock depredation by leopards were greatest during 16:00–17:00 h and 21:00–01:00 h. In contrast, Ahmed et al. (2012) reported more leopard attacks at night in central India. Variability in timing of leopard depredations is likely related to multiple factors including animal husbandry practices and alternate prey availability.

Leopard depredations of livestock occurred year-round but predominantly during summer (May–July). During summer, people generally leave their livestock unattended to graze in open fields away from villages which undoubtedly increased their vulnerability to leopard attack. Summer is also when livestock are born, which are more vulnerable to predation than adults. During summer, locals also grow corn and livestock are herded to wooded areas to protect their crops which can also increase their vulnerability to leopard attack. Livestock near Hwange National Park, Zimbabwe were more prone to depredation by carnivores when herded to wooded areas to protect crops (Kuiper et al. 2015). A secondary peak of leopard attacks occurred during December. That fewer depredations by leopards occurred during winter was likely a consequence of communities keeping livestock in corrals, providing them forage from grass collected during spring through fall (F. Akrim unpubl.).

Since livestock have reduced anti-predatory skills, they are more vulnerable to predation by wild carnivores (Nowell et al. 1996). Prey species weighing 25–50 kg are most vulnerable to depredation by leopards as they can be killed and dragged to secure locations (Dar et al. 2009, Bibi et al. 2013). The most commonly depredated animal in this study were goats (82%) which are in the optimal prey size range (< 45% body weight) for leopards (Carbone et al. 1999, Hayward et al. 2006). Leopards were considered a major predator of livestock, including goat and sheep, in other areas of Pakistan (Dar et al. 2009, Bibi et al. 2013, Kabir et al. 2014, Qamar et al. 2016) and in the Sariska Tiger Reserve, India (Sekhar 1998). We found that domestic dogs were the most frequently depredated after goats. In our study area, domestic dogs are often used for guarding livestock but are not penned with livestock or otherwise restrained; therefore, these dogs are also more prone to leopard attacks. Our findings are supported by previous work that documented leopard depredations of dogs (Dar et al. 2009, Kabir et al. 2014). Finally, abundance of wild prey can influence frequency of leopard attacks on livestock; Khorozyan et al. (2015) reported that large cats kill more livestock when wild prey declines to a minimum threshold. The diet of common leopard at PLNP comprised 35% wild prey and 59% domestic prey species (Akrim et al. 2018). That estimated abundance of livestock (260 heads km^{-2}) was about 5 times greater than wild prey species of leopard (57 individuals km^{-2}; Akrim et al. 2018) in our study area further explains the frequency of attacks and importance of livestock to leopard's diet.

The presence of humans and dogs were most effective in reducing leopard attacks on livestock, both inside and outside villages. Dogs or humans alone were substantially less effective in reducing leopard depredation on livestock and highest frequency of attacks occurred when livestock was left unattended. Local people engage in multiple activities while tending livestock such as collecting fodder and fuel wood, reducing their vigilance toward livestock. We suggest that reduced attacks in the presence of humans and dogs occur because dogs can alert herders when predators such as leopards are present. The effectiveness of dogs protecting livestock from carnivores is well known (Rigg 2001, Gehring et al. 2010, Smith et al. 2010), and improved herding practices can reduce predator attacks on livestock (Ogada 2003). However, previous studies had shown that dogs alone were ineffective in reducing livestock depredations by leopards in Kenya (Kolowski and Holekamp 2006) and Machiara National Park, Pakistan (Dar et al. 2009, Kabir et al. 2014).

Our results showed that penning practices of livestock at night were ineffective in reducing leopard attacks, we suggest a consequence of poor pen construction facilitating leopard attacks (F. Akrim unpubl.). Poor corral structure has previously contributed to livestock losses to leopards inside villages (Dar et al. 2009, Kabir et al. 2014). In our study area corrals lacked adequate doors, windows, walls and often roofs. Woven plastic bags stitched together were frequently used as door and window coverings of corrals, facilitating entry by leopards. Improving conditions of corrals by constructing more durable walls and proper doors, windows and roofs can reduce livestock losses from leopard attacks (Samelius et al. 2020).

We demonstrated high total financial losses due to livestock depredation by leopards during this study. Though highly variable, economic losses due to livestock depredation by leopards represented on average almost 9% of the annual household income of respondents. High frequency of livestock losses to leopards and substantial economic losses undoubtedly contributed to the high proportion of respondents with negative attitudes toward leopards. People keeping livestock for subsistence frequently have negative perceptions toward carnivores due to economic losses inflicted (Dar et al. 2009, Parker et al. 2014, 2018, Page-Nicholson et al. 2017).

Reported livestock losses from leopard depredations were considerable; our study provides several insights that if implemented could reduce this risk. We recommend that humans and dogs guard livestock whenever possible, particularly during mornings and summer (i.e. May–July) and December when leopard attacks on livestock are greatest. Reducing the number of livestock guarded should also alleviate the number of depredations by allowing greater ability to monitor individuals in the herd. Current corral structures appear ineffective to prevent leopard attacks; local communities need to become aware of modifications or alternative corral designs to reduce livestock depredations by leopards. Also, it may be possible to keep dogs with livestock at night to further mitigate risk to livestock. Minimizing livestock depredations and corresponding economic losses while maximizing public outreach and education can shift human attitudes and promote tolerance toward leopards, reduce retaliatory killing and facilitate human–leopard coexistence.

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Supplementary material (available online as Appendix wlb-00782 at <www.wildlifebiology.org/appendix/wlb-00782>). Appendix 1.