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*Case Study*

# Human–carnivore conflicts in a recently established Pakistani national park

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***Abstract:*** Human–carnivore conflicts (HCCs) are increasing globally. These conflicts may encompass competition for food resources, crop and livestock depredations, and attacks on humans. Concerns over conflicts may result in retaliatory killings of carnivores and negative views of wildlife or landscape conservation. Yet, despite the economic and conservation implications of HCCs, data regarding the magnitude and severity of the conflicts may be lacking because many incidents are unreported. To better inform this issue, we compared HCC data for 2016 to 2018 obtained from official records of the Punjab Wildlife and Parks Department for a newly established national park in the Punjab Region of Pakistan to data we obtained regarding HCCs based on a survey of 200 households from 25 villages abutting the park. The households surveyed reported 250 incidents of livestock lost to leopards (*Panthera pardus*), jackals (*Canis aureus*), and red foxes (*Vulpes vulpes*) during the study period. Most of the losses (83%) were attributed to leopards. In contrast, official data reported 42 animals lost for the villages studied, with most losses attributed to leopards. Thus, official agency records underreported depredation losses by >80%. Because of HCC, 19% of households supported eliminating leopards from the park, and 25% of households supported fencing the park to prevent leopards from entering human settlements. However, 47% of the households also supported increasing programs focused on improving herding practices and enhanced livestock infrastructure that might prevent attacks. Our results suggested new opportunities for wildlife officials to help residents mitigate HCCs while enhancing local support of carnivore conservation.

***Key words:*** carnivores, conservation, depredation, human–wildlife conflicts, leopards, livestock, national parks, Pakistan, *Panthera pardus*, stakeholder perceptions, wildlife damage

**Human–wildlife conflicts** are increasing globally, with adverse consequences for both humans and wildlife (Messmer 2000, Woodroffe et al. 2005, Redpath et al. 2015, Anand and Radhakrishna 2017). In rural areas where agricultural lands and rangelands abut protected areas, mammalian carnivores are more likely to be involved in conflicts, as these species may compete with humans for food and represent a direct threat to humans and domestic animals (Mishra 1997, Conover 2002, Conforti and de Azevedo 2003, Miller et al. 2016, Morehouse and Boyce 2017). In these settings, human–carnivore conflicts (HCCs) may cause significant economic losses (Mishra 1997, Treves and Karanth 2003, Patterson et al. 2004, Graham et al. 2005).

The proximate causes of HCCs may include human behaviors that decrease the natural prey base for carnivores, combined with poor escape capabilities of domestic animals and poor livestock husbandry practices (Ogada et al. 2003). Large carnivore attacks on humans may increase negative public attitudes toward species (Riley and Decker 2000, Baldus 2004, Conover 2008). If large carnivore removal efforts increase after attacks on humans, these actions can have long-term demographic importance for carnivore populations (Mizutani 1999, Treves and Karanth 2003, Distefano 2005, Inskip and Zimmermann 2009, Ratnayeke et al. 2014, Broekhuis et al. 2017, Penteriani et al. 2017). Nonetheless, HCCs are now viewed as inevitable (Binot et al. 2006) and may create negative attitudes toward conserva-

tion and underpin retaliatory killing of carnivores (Conforti and de Azevedo 2003, Ogada et al. 2003, Kolowski and Holekamp 2006, Holmern et al. 2007).

Despite the potential species conservation impacts of HCCs, the extent to which the conflicts are officially reported to management agencies is unknown (Conover 2002). This HCC reporting discrepancy is particularly true in developing nations (Songhurst 2017). Disparities in the extent that local residents incur losses and the extent to which these losses are reported and documented in official records may occur for a variety of reasons, including perceptions regarding the importance of making reports, about the growth of predator populations, and about the likelihood and amount of compensation (Karanth et al. 2013, Loveridge et al. 2017). These disparities are important to recognize because such data are used by management agencies to set conservation policies and implement damage abatement programs. Both agency representatives and stakeholders may not accurately understand the extent of HCCs and the governmental services available to address conflicts, resulting in misconceptions about the appropriateness of services available from that government agencies to address wildlife conflicts (Conover et al. 2018).

In Pakistan, HCCs are a major issue in rural areas (Roberts 1997). This is particularly the case in northern Pakistan, where large carnivores such as common and snow leopards (*Panthera pardus* and *P. uncia*, respectively), Asiatic and brown bears (*Ursus thibetanus* and *U. arctos*, respectively), gray wolves (*Canis lupus*), and lynx (*Lynx lynx*) are commonly reported as the source of financial losses, human injuries, and fatalities (Dar et al. 2009, Din and Nawaz 2011, Bibi et al. 2013, Hameed et al. 2013, Perveen and Abid 2013, Kabir et al. 2014). Ahmad et al. (2016) reported that carnivores were responsible for 34% of livestock losses in their study area, which is equal to an annual economic loss of $189 USD per household. Dar et al. (2009) reported similar economic valuations for losses in the same region; predators were responsible for 24% of financial losses associated with livestock.

While Ahmad et al. (2016) focused on bears, in many parts of rural Pakistan, leopards may be a greater source of conflict (Dar et al. 2009, Kabir et al. 2014). Leopards kill large livestock such as adult bovids and equids in Pakistan (Roberts 1997), but goats (*Capra aegagrus hircus*) and sheep (*Ovis aries*) may be particularly susceptible to leopard predation because their smaller size (25–50 kg) facilitates being easily killed and then quickly dragged to a safer site for consumption. Dar et al. (2009) reported that leopards were responsible for >90% of predation-associated livestock losses in Machiara, Pakistan. Goats and sheep comprised 85% of these losses, a prominence also observed by Kabir et al. (2014). Such patterns of loss are typical of livestock–leopard conflict elsewhere in Asia and Africa (Sekhar 1998, Madhusudan 2003, Ogada et al. 2003).

The purpose of our study was to describe the extent of HCCs, public perceptions of these conflicts, and local suggestions on mechanisms for mitigating these conflicts in the newly established Murree Kahuta Kotli Sattian National Park, Punjab, Pakistan. Villages within and adjacent to this park often report the loss of livestock to carnivores as well as occasional direct attacks on humans. Because there are no compensation programs with which government agencies might respond directly to individual losses, we hypothesized that the extent of such HCCs is not fully recognized by the wildlife agencies charged with managing such conflicts. To test this hypothesis, we surveyed 200 households adjacent the park to determine villagers' perceptions of losses and compared these data to summary data of reported conflict incidents derived from the records maintained by the Punjab Wildlife and Parks Department for 2016 to 2018. We also collected data on how villagers perceive carnivores and how villagers suggest carnivores should be managed. Our research provides a baseline for local managers and stakeholders interested in identifying potential management approaches to mitigate HCCs.

## Study area

The study was conducted in 1,211-km$^2$ Murree Kahuta Kotli Sattian National Park located in the tehsils of Murree, Kotli Sattian, and Kahuta in the Rawalpindi District of Pakistan (Figure 1). This district is on the southern slopes of the northwestern Himalayas and is principally comprised of mountain tracts with rich valleys traversed by rivers. Murree Kahuta Kotli Sattian National Park is a newly estab-

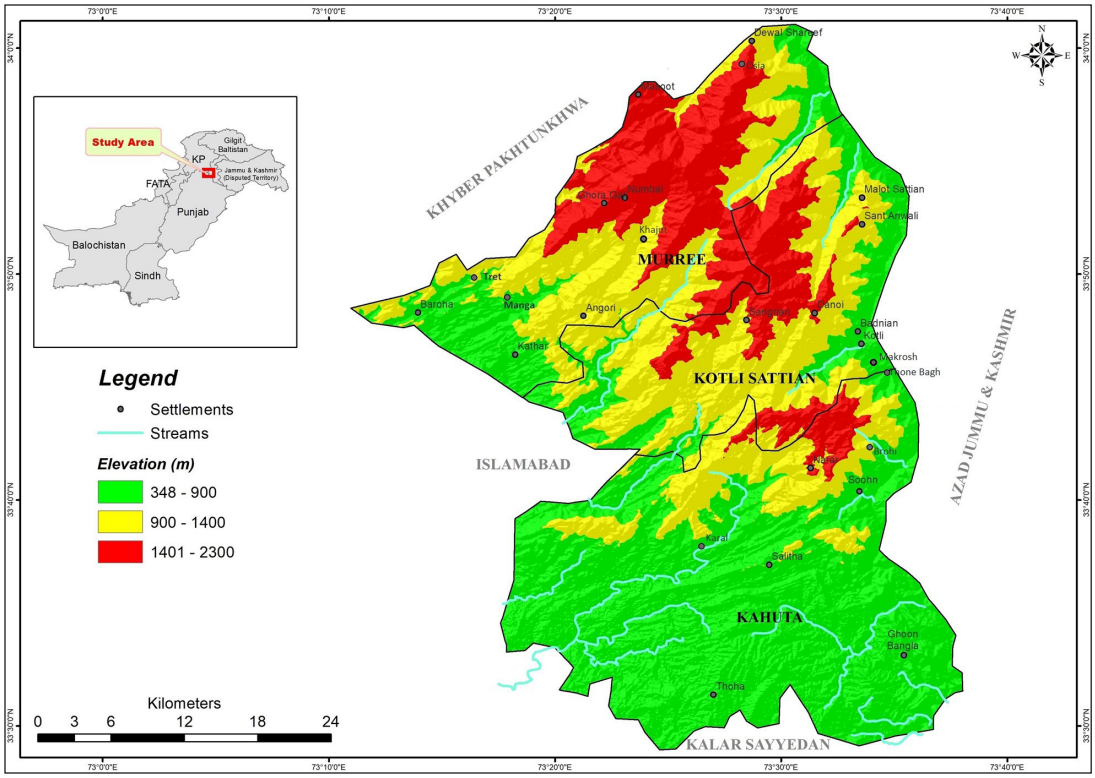


**Figure 1.** Map of Murree Kahuta Kotli Sattian National Park, Pakistan, indicating elevation gradient, riparian areas, and study villages.

lished park, declared in 2009 under the Punjab Wildlife Act (Protection, Preservation, Conservation and Management 2007). Elevation of the study area varies from approximately 300 m to >2,100 m (Khan 1994). The climate in Rawalpindi is warm and temperate with pronounced seasonality. The average annual rainfall is 1,249 mm, most of which falls during the monsoon season. The driest month is November, with an average of 16 mm of precipitation, while July precipitation peaks with an average of 237 mm. June is the warmest month of the year, averaging 32°C, while average January temperature is 10°C (Government of Pakistan 2006).

Most villages are surrounded by communal grazing lands that in turn abut the pine or broad-leaf forests that comprise much of the park's natural habitat (Khan 1994). Notable larger mammal species of Murree Kahuta Kotli Sattian National Park include leopards, barking deer (*Muntiacus muntjack*), wild boars (*Sus scrofa*), and rhesus macaques (*Macaca mulatta*). Other carnivore species in the park include red foxes (*Vulpes vulpes*), golden jackals (*Canis aureus*), leopard cats (*Prionailurus bengalensis*), jungle cats (*Felis chaus*), small Indian civets (*Vivirricula indica*), yellow-throated martens (*Martes flavigula*), Indian gray mongooses (*Herpestes edwardsii*), and small Asian mongooses (*H. javanicus*; Khatoon et al. 2019*a*, *b*). Wolves and bears are not reported to inhabit the park, though complete wildlife surveys of the park remain to be conducted.

## Methods

We completed surveys in 25 villages: Thone Bagh, Makrosh, Kotli, Manga, Karal, Osia, Narar, Masoot, Angori, Brohi, Baroha, Sant Anwali, Khajut, Ghoon Bangla, Dewal Shareef, Kathar, Salitha, Sangrian, Ghora Gali, Danoi, Tret, Thoha, Badnian, and Mallot Sattia (Figure 1). We selected the villages surveyed based on data from, and discussions with, park managers that confirmed HCCs. In this region, 2 populations are generally associated with villages: year-round residents and semi-nomadic herders who inhabit the villages during the winter months, after which they return to

northern regions of Pakistan. For this study, all data were derived from interviews with year-round residents.

To conduct our research, we surveyed 200 households (mean: 8 per village; range = 5–12) from November 2017 to April 2018 to assess livestock losses that occurred between September 2016 and April 2018 (Appendix 1). In each village, households (sampling unit) were randomly selected to represent approximately 5% of the total households within each village. Household selection was random with respect to respondent education or profession. Surveys were conducted in Urdu or where necessary in a local dialect (Pothwari or Hindko). Surveys were conducted by the senior author with the assistance of 2 wildlife watchers from the Punjab Wildlife and Parks Department.

For each household, we interviewed the male head of household. If he was absent, his elder son or the female head of household was interviewed. Other people present in a household usually helped in the recall of depredation cases. We collected information on household demographics, education, employment, livestock holdings, wildlife sightings, conflicts with and perceptions of large carnivores, and livestock losses from September 2016 to 2018. When discussing wildlife species, we asked respondents to describe the characteristics of the species to verify identification. We used color photographs of predator species during the interviews to ensure correct identification. We used a global positioning system unit (Garmin GPSMap® 64sc, New Taipei City, Taiwan) to record survey site information.

We administered the surveys using semi-structured questionnaires and qualitative data collection. The questions were both closed and open-ended with a primary goal of collecting data on carnivore occurrences, predation, and risk or damage to life and property. Closed-ended questions included those that were categorical in nature (e.g., yes or no questions) or quantitative (e.g., numbers of livestock owned). Respondents were asked questions about the circumstances surrounding carnivore attacks on livestock, the number and locations of livestock involved, and the carnivore species responsible. Respondents were also queried regarding the actions they take to minimize conflict with carnivores as well as their opinions on management actions that might help reduce future risks of conflict.

### Agency data

We obtained data on reported cases (January 2016 to April 2018) of livestock loss and carnivore attacks in the 25 villages surveyed from the Punjab Wildlife and Parks Department to further assess the spatial and temporal variability of officially reported losses. The agency compiled data based on reports made by villagers who are seeking compensation despite the fact that there is no official compensation scheme for losses due to conflicts in Punjab. Information in these reports is variable but typically includes the village, date, species, and numbers of livestock lost, and in some cases, the reported predator.

### Data analysis

The structured interviews collected from the 200 randomly selected households were the main data source. Data were pooled in SPSS (ver. 16.0; SPSS Inc., Chicago, Illinois, USA) and analyzed using 1-way ANOVAs to assess differences in loss rates of livestock species, differences in attributed predator species, and differences in the monthly losses. Chi-square tests were used to assess differences in nocturnal and diurnal depredation rates and seasonal (summer vs. winter) differences in livestock losses.

## Results

All 200 households maintained domestic animals; 89% reared goats, 83% kept cattle (*Bos taurus*), and 34% kept domestic water buffalo (*Bubalus bubalis*). In addition, 16.5% of households raised pigeons, and 82% kept poultry. A subset (36%) of these households reported that their primary economic activities were subsistence agriculture, including crop farming and livestock rearing. Other professions in the region included teachers (14%), retired government officers (6.5%), landowners (7.5%), government servants (12.5%), self-employed (9%), and unemployed (14.5%). Average, median, and range of annual income of surveyed households is Rs 121,808 PKR ($983 USD in August 2018), Rs 100,000 PKR, and Rs 0–600,000 PKR, respectively.

### Domestic animal losses

Forty-one percent of respondents reported livestock losses, with a total of 250 domestic an-

**Table 1.** Numbers and relative percentages of livestock and domestic birds reported as lost to predators between September 2016 and April 2018 from 25 villages in Murree Kahuta Kotli Sattian National Park, Pakistan.

| | Goats | Cows | Poultry | Buffalo | Pigeons | Total |
|---|---|---|---|---|---|---|
| Number killed | 150 | 53 | 43 | 4 | 0 | 250 |
| Percent | 60 | 21.2 | 17.2 | 1.6 | 0 | 100 |

imals reportedly killed by carnivores (Table 1). Goats comprised 60% of animals reported lost to predators, followed by cows (21%), poultry (17%), and buffalo (2%). All 25 villages reported losses of domestic animals, though there was spatial variance across villages in the extent of these losses and in the prey types (Figure 2). For instance, 150 goats were reported killed by predators during the surveyed time frame, which equates to 0.75 per household. However, goat losses varied from $n = 0$ in 2 villages, to $n =$ 12–15 in 6 villages during the study time frame. The locations of livestock losses were nearly evenly divided between occurring within the mud-based structures that serve to house livestock and occurring in areas away from the villages and adjacent to or within forests. Nearly half (49.5%) of households experienced more livestock losses in pens and buildings where livestock are kept when not grazing, while 50.5% of respondents reported more losses in areas around forests and away from villages. The reported figure of 150 goats constituted an economic loss of Rs 4,500,000 PKR or $32,142 USD (Rs 30,000 PKR or $214 USD per household), while 53 cows killed constituted and economic loss of Rs 3,710,000 PKR or $26,500 USD (Rs 50,000 PKR or $500 USD per household).

Survey respondents reported the problem animals as leopards, golden jackals, and red foxes. The percentage of attacks attributed to leopards was highest (83%), followed by foxes (12%), and jackals (5%; Figure 3). Leopards reportedly killed goats, cows, and buffalo, while respondents indicated that foxes and jackals attacked only poultry. Losses of pigeons were not reported. In addition to livestock and domestic animal losses, 26% of respondents reported that wild boars were responsible for damaging their crops.

Predators killed livestock throughout the year but showed strong daily and seasonal patterns. Among all depredations combined, 74.4% occurred at night ($\chi^2 = 47.896$, df = 1, $P$ <0.0001). For all domestic species combined, spring and summer months had significantly higher (95.2%) predation rates than cold weather months (4.8%; ANOVA across all months: $F = 2.1$; $P$ <0.05; Figure 4). Peak depredation months were May through July (collectively accounting for 65% of predation events). In contrast, the percentage of depredation events that occurred between November and February was <1%. Thus, human–carnivore conflicts in this region increase during the spring months, are most common in the summer, and taper off in the fall months. This pattern held for each domestic animal species, with all poultry events, and 56.8% and 20% of goat and cow losses, respectively, occurring during summer months.

## Strategies used to reduce losses

When households perceived that there was a risk of predation on domestic animals (for instance, due to sightings or due to agitated behavior of livestock), a variety of immediate and non-exclusive strategies were used with the goal of deterring attacks. Making noise was a common response to the perceived presence predators. Of the 200 households, 48% reported making noise by yelling, 24% reported using firecrackers, and 9% reported firing guns in the air to scare off predators. Fire (generally a large bonfire near where domestic animals are kept) was reported to be used by 22% of respondents. Other reported deterrence approaches included the releasing of dogs (*Canis familiaris*; 7%) and limiting roaming by livestock when perceived risk was high (12.5%). For those households that raised poultry ($n = 178$), 34% reported using cages or coops to protect against losses to wild carnivores.

Based on the open-ended responses, 30% of households report some type of retaliatory trapping or killing of predators following livestock losses. These efforts were solely oriented toward leopards. This value should be treated as inexact, as respondents may not feel comfortable sharing detailed information, or con-

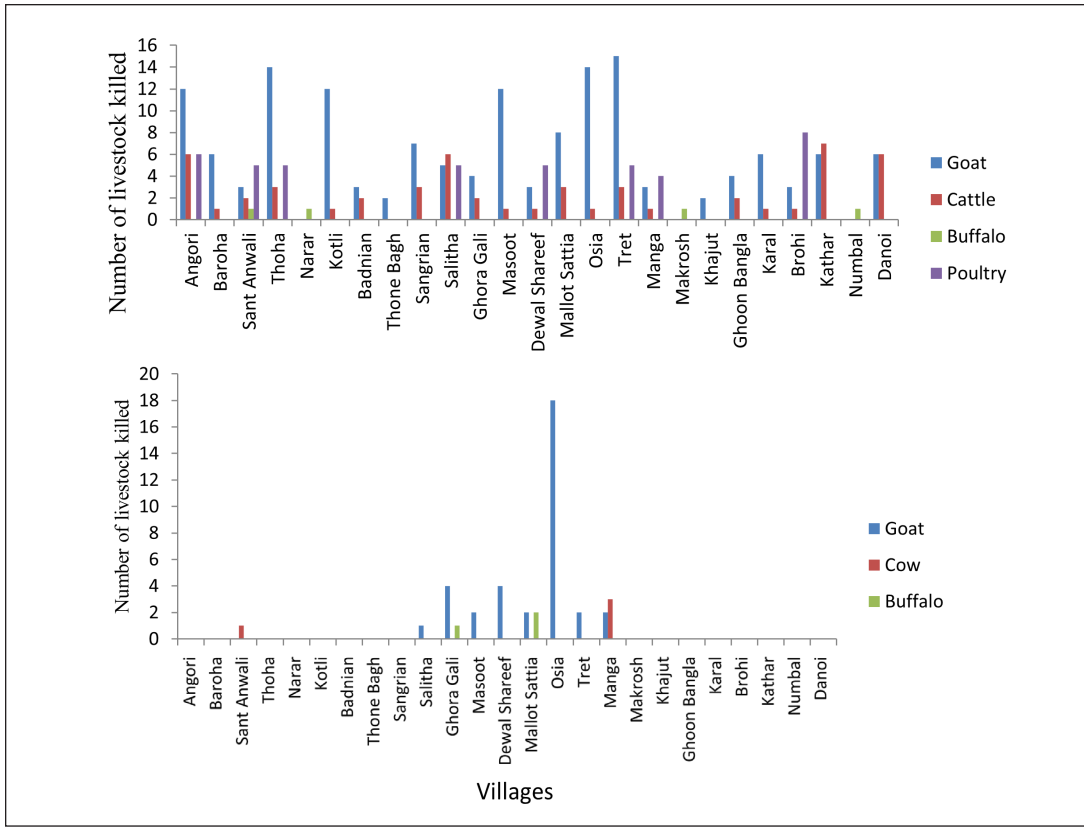


**Figure 2.** Livestock losses reported for each of the 25 studied villages in Murree Kahuta Kotli Sattian National Park, Pakistan, September 2016 to April 2018. Top: number of reported losses based on household survey responses. Bottom: number of losses based on reports made to the Punjab Wildlife and Parks Department.

versely, may exaggerate the extent to which they report retaliation against leopards.

## Livestock husbandry and depredation

Survey respondents used 1 of 3 herding approaches for protecting livestock: directly observing the livestock while they were free-roaming (35%), directly observing the livestock and keeping 1 or more guard dogs (37.5%), or not directly observing or guarding the livestock. The later approach was used by 27.5% of respondents and simply involved allowing livestock to roam and graze freely in open pasture. Although the locations of livestock depredations could not always be attributed to particular sites, the total number of depredations that occurred to survey respondents that practiced each type of herding approach could be calculated. Those who guarded their free-roaming livestock without or with dogs suffered 16% and 24% of all losses, respectively, while the 27.5% of the population who allowed livestock to roam without direct oversight suffered 60% of losses.

## Managing conflicts

Respondents perceived leopards as the major livestock predator and as a risk to human safety. The question "Have you ever been attacked by a leopard?" resulted in a positive answer 25.5% of the time, though this value may be inaccurate due some respondents answering based on a feeling of risk rather than having experienced a direct attack. However, 74.5% of respondents did allude to documented attacks in previous years, in other localities, or to a possible attack that occurred in Narar during this study.

In response to the open-ended questions of how to manage the risk represented by leopards, 43.5% expressed a need to directly manage the leopard population or the park to reduce conflict events. This included 19% who

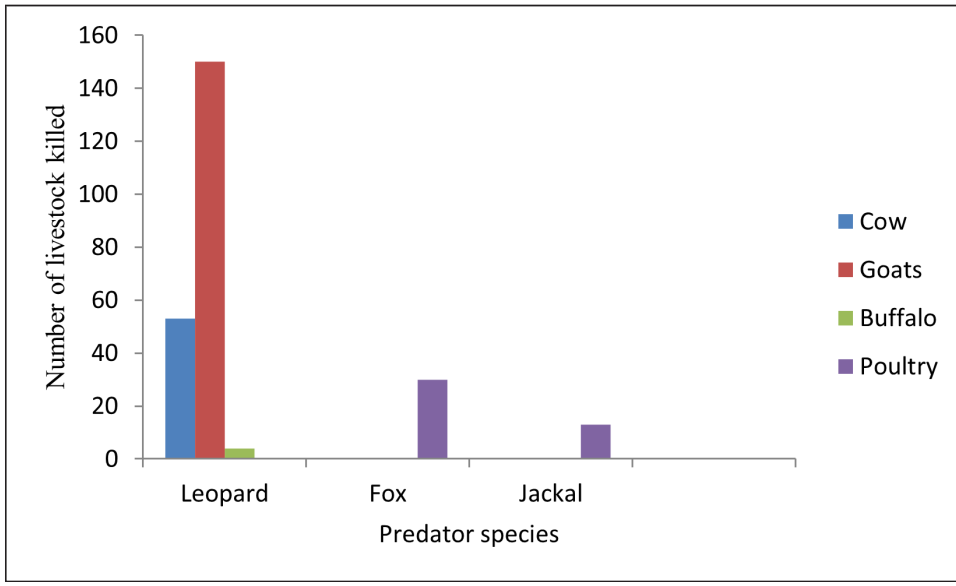


**Figure 3.** Number of domestic animal losses attributed to each species of carnivore in villages in Murree Kahuta Kotli Sattian National Park, Pakistan, September 2016 to April 2018.

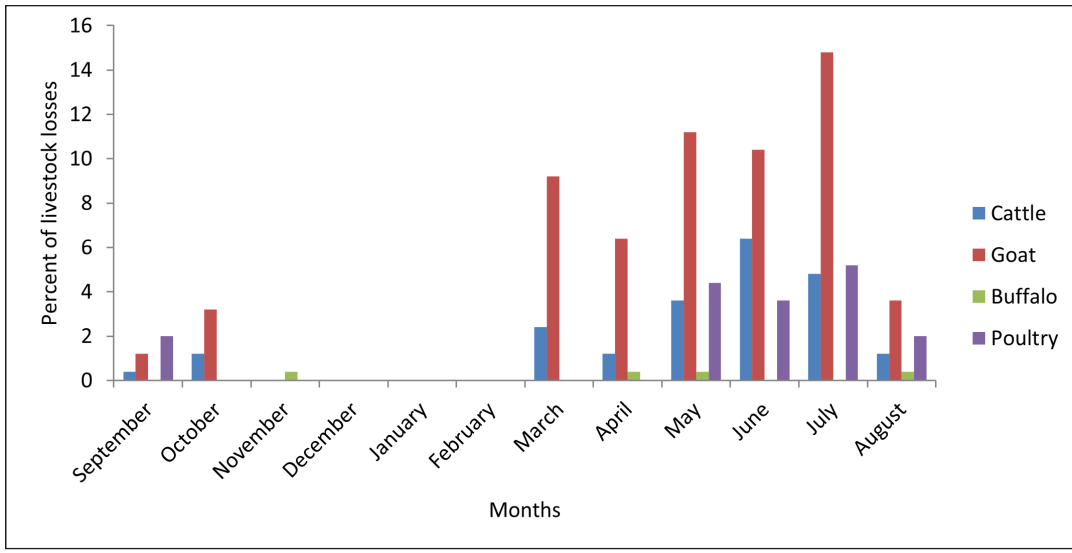


**Figure 4.** Livestock predation events reported per month in villages in Murree Kahuta Kotli Sattian National Park, Pakistan, September 2016 to April 2018.

desired to eliminate leopards from the forest and 24.5% who suggested fencing the park to prevent leopards from entering human settlements. In contrast, 46.5% indicated a desire to improve husbandry practices, including 35.5% who expressed a need for greater awareness of programs focusing on better herding practices and livestock protection from carnivores, and 11% who highlighted the need to build better livestock shelters to prevent leopard attacks. The remaining respondents (10%) did not express opinions about carnivores and the safety of their livestock.

## Agency data

Among the 25 surveyed villages, 42 animals were reported lost to the Punjab Wildlife and Parks Department during the 27 months of analyzed data (Figure 2). All losses were reported due to leopard predation. There was also 1 loss of human life that was possibly due to a leopard attack. This later case involved the death of

a 14-year-old girl in the village of Narar. The individual was killed while walking near sunset in a forested area adjacent to the village.

Further, only 9 of the 25 villages had official reports of livestock losses. Thus, there was a 36% underreporting of the village-level spatial extent of livestock losses to the agency. Among the reported livestock depredations, there was significant seasonal variation ($\chi^2 = 4.009$, df = 1, $P < 0.05$), with 66% of reports occurring during the summer months and 33% for winter months. Across the 9 villages, 60% of depredations were reported by the villagers to have occurred during night ($\chi^2 = 1.435$, df = 1, $P > 0.05$).

## Discussion

Our results suggested that HCCs may be more widespread than indicated by official reports because people often do not report incidents. Survey respondents reported 250 animals were lost, yet only 43 losses were reported to the Punjab Wildlife and Parks Department. Given that we only surveyed 5% of village households during the 20-month survey period, it was apparent that villagers were not reporting most losses of domestic animals to government agencies, and the actual unreported losses may have been higher. Conflicts with large carnivores also affected stakeholder desires for increased predator removal efforts as well as for more information on improved animal husbandry. These themes suggest opportunities both to learn more about the scale and scope of conflicts as well as opportunities to reduce the burden of conflicts.

Although no previous study has been conducted on HCCs in our study area, the levels of human–carnivore conflict found in Murree Kahuta Kotli Sattian National Park reflect general patterns reported from other locations in Pakistan (Bibi et al. 2013, Chattha et al. 2013, Kabir et al. 2014, Ahmad et al. 2016). Every village surveyed reported conflicts, despite the survey efforts focusing on just a small proportion of each village population. While the extent of the conflicts varied across villages, it is clear that leopard predation on goats was a primary concern. These types of conflicts and their associated spatial variance are similar to those reported elsewhere in Pakistan (Dar et al. 2009, Qamar et al. 2010, Bibi et al. 2013, Chattha et al. 2013) and elsewhere in Asia and Africa (Rahalkar 2008, Sangay and Vernes 2008, Koziarski et al. 2016) for mid-sized livestock. While other predators (e.g., foxes and jackals) may also play a conflict role in the region, from a numerical and human perception perspective, they do not appear to drive human–wildlife conflicts to a similar extent as leopards.

Differences between the official records of depredations and numbers derived from survey results suggest that summaries of conflict based solely on official records under-reported the extent of conflict. In this study, this generalization was supported both from a numerical framework (83% lower numbers of reported losses despite a period of data collection that was 4 months longer) and from a spatial framework (only 36% of villages had reported depredation to the agency that maintains this information). This was not because of poor record-keeping by the agency. Rather, it appears that those who suffer losses report them primarily in hopes of gaining compensation despite the lack of such a program. Thus, the poor official record is based on 2 factors. First, unlike in some regions (e.g., in neighboring Khyber Pakhtunkhwa province), the lack of a provincial aid program specifically for people who lose livestock due to leopard attacks potentially disincentivizes the reporting of conflicts. Second, there are no awareness programs designed to encourage villagers to report depredation events to the Punjab Wildlife and Parks Department.

The lack of mechanisms to ensure that official records of conflict reflect levels of perceived conflict is problematic. Biases in reporting conflict and a lack of a reliable mechanism for people to report conflict may result in difficulties when attempting to fully understand the scope and scale of conflict. Loveridge et al. (2017) noted a similar reporting bias in Zimbabwe; livestock losses were commonly underreported, and losses by some predator species were less likely to be reported (i.e., all losses reported to the Punjab Wildlife and Parks Department were caused by leopards). The underreporting of depredations by some species may be because of the decreased risk of some species such as jackals and foxes also attacking humans, as well as local ambivalence toward depredation by some species. Such underreporting of conflict events may ultimately result in biases in management policies.

The dynamics of this conflict are similar to

that found elsewhere (Sangay and Vernes 2008, Dar et al. 2009, Kabir et al. 2014, Ahmad et al. 2016). Although leopards are often more active during the day (Azlan and Sharma 2006, Ramesh et al. 2012, Lynam et al. 2013), leopard attacks were generally nocturnal with the highest rates of depredation recorded during summer months and a depredation peak from May to July. This pattern may be due in part to the lifestyle of local people and periods of vulnerability of livestock, in combination with inadequate livestock housing and insufficient corral construction. Summer brings higher elevation snowmelt, at which point people increase use of summer pastures that lack livestock shelters or pens, facilitating attacks. During the winter, people generally avoid using these pastures and also limit livestock roaming so predation decreases. Further, during winter months, natural leopard prey may also become more accessible because of altered habitat use, increased snow-depth limiting the escape strategies of wild prey species, an increased availability of natural prey mortality due to winter weather, and decreased disturbance by villagers and livestock.

From a human perspective, the results of living with carnivores are both high levels of perceived personal risk and high levels of reported retaliation. While this study was not designed with a primary purpose of assessing personal risk or retaliation, the reported numbers are high. Collectively, these results indicate that human–carnivore conflict in Murree Kahuta Kotli Sattian National Park is a significant concern for local inhabitants who respond to these risks in ways that may further endanger both people and wildlife. Thus, there is a need for an informed management plan that balances the need to secure the economic resources of local people while also protecting the local predator populations, thereby mitigating the conflict.

There is widespread recognition that the retribution against large carnivores may have only a weak association with actual or perceived livestock losses and may be more closely associated with a sense of personal fear and social motivations (Naughton-Treves et al. 2003, Marchini and Macdonald 2012, van Eeden et al. 2018). These high levels of conflict result in views of the park and of predators that are not ecologically tenable. For instance, a large proportion of respondents suggest fencing the park or controlling leopards as a management strategy to reduce conflict. While there are settings where fencing as a predator management approach is used, such an approach is generally controversial because of issues relating to costs, the necessary spatial scale, the ability of predators to navigate such fences, and the unintended ecological consequences of such approaches to non-target species (Hayward and Kerley 2009, Packer et al. 2013, Woodroffe et al. 2014).

Similarly, while lethal control of predators may reduce conflicts, the costs of such programs are potentially significantly higher than nonlethal approaches for mitigating conflict (McManus et al. 2015). Further, such approaches (i.e., especially the direct targeting of leopards to reduce population numbers) could result in a predator population that is ecologically insufficient to play the nuanced role of top predator. For instance, decreased leopard numbers might result in locally increased wild boar populations given that wild boars are an important prey species for leopards (Achyut and Kreigenhofer 2009, Taghdisi et al. 2013). In our study, a quarter of respondents indicated that wild boars caused crop damage; if leopards reduce boar numbers, leopard declines might exacerbate existing conflicts over crop losses. While there are no official efforts to take up fencing or culling management approaches in Murree Kahuta Kotli Sattian National Park, the widespread suggestion that such methods need to be undertaken suggests the need for better local education related to the ecology of large predators.

On the other hand, the extent of leopard–livestock–human conflict is so high that management actions may be necessary. Indeed, recognition of this necessity appears to exist at a local level, as 48.5% of surveyed individuals expressed the need for assistance with animal husbandry and predator-proof infrastructure. Even simple measures taken by management agencies may be helpful. For instance, encouraging reduced conflict through better corralling of livestock might greatly reduce depredation and associated retaliation. Further, advising people inhabiting the area to reduce the time spent by livestock grazing in the absence of a herder may be particularly helpful, as several studies have shown that unattended livestock are particularly susceptible to predation (Oli et al. 1994, Mishra 1997, Sillero-Zubiri and Lau-

renson 2001, Espuno et al. 2004, Ikeda 2004, Namgail et al. 2007).

In Murree Kahuta Kotli Sattian National Park, the small proportion of individuals that allowed livestock to roam without direct herder oversight suffered disproportionately high levels of loss. Thus, enhancing husbandry and infrastructure, combined with existing strategies such as the use of herders and guard dogs, may offer opportunities to support local livelihoods and protect local leopard populations against excessive retaliation (Robel et al. 1981, Oli et al. 1994, Cozza et al. 1996, Mishra 1997, Ogada et al. 2003, Patterson et al. 2004, Wang and Macdonald 2006, Van Bommel et al. 2007). Local people already commonly use dogs to guard livestock, but the success of this approach in the region is not well understood. Depending on the local types of dogs, the mere presence of dogs may not deter leopard attacks (Kolowski and Holekamp 2006). Indeed, in some regions, leopards may be attracted to villages to feed on dogs, which may increase the likelihood of leopard–livestock or leopard–human encounters (Butler et al. 2014, Athreya et al. 2016).

## Management implications

Given the risk that leopards represent to livestock and to people living in and around Murree Kahuta Kotli Sattian National Park, there is a clear need for the implementation of context-specific management approaches. The need for conflict resolution approaches to be locally tailored is increasingly recognized. Such approaches might include: (1) the design of robust monitoring strategies to track the extent and spatial locations of conflicts, (2) assistance to villages to reduce the likelihood of conflict or respond to conflict in a more pronounced manner, and (3) the design of approaches to enhance local awareness of predator ecology and husbandry mechanisms for reducing conflict. The absence of a clear mechanism for accurately monitoring the extent of human–carnivore conflicts in the region is particularly problematic. Given the near global recognition of the importance of human–carnivore conflicts, as well as the limited resources available to address these conflicts, there is general agreement that resources should be directed to locations where conflict risk is greatest. Predicting future depredation risk from past patterns of conflict can lead to intervention approaches for reducing carnivore–livestock conflicts. However, the application of such approaches requires detailed and unbiased baseline temporal and spatial information on conflict events.

## Supplemental material

Supplemental material can be viewed at https://digitalcommons.usu.edu/hwi/vol16/iss1/16.

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