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Carnivore-Caused Livestock Mortality in Trans-Himalaya

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Abstract The loss of livestock to wild predators is an important livelihood concern among Trans-Himalayan pastoralists. Because of the remoteness and inaccessibility of the region, few studies have been carried out to quantify livestock depredation by wild predators. In the present study, we assessed the intensity of livestock depredation by snow leopard *Uncia uncia*, Tibetan wolf *Canis lupus chanku*, and Eurasian lynx *Lynx l. isabellina* in three villages, namely Gya, Rumtse, and Sasoma, within the proposed Gya-Miru Wildlife Sanctuary in Ladakh, India. The three villages reported losses of 295 animals to these carnivores during a period of 2.5 years ending in early 2003, which represents an annual loss rate of 2.9% of their livestock holdings. The Tibetan wolf was the most important predator, accounting for 60% of the total livestock loss because of predation, followed by snow leopard (38%) and lynx (2%). Domestic goat was the major victim (32%), followed by sheep (30%), yak (15%), and horse (13%). Wolves killed horses significantly more and goats less than would be expected from their relative abundance. Snow leopards also killed horses significantly more than expected, whereas they killed other livestock types in proportion to their abundance. The three villages combined incurred an estimated annual monetary loss of approximately $USD 12,120 amounting to approximately $USD 190/household/y. This relatively high total annual loss occurred primarily because of depredation of the most valuable livestock types such as yak and horse. Conservation actions should initially attempt to target decrease of predation on these large and valuable livestock species.

Keywords Gya-Miru · Livestock depredation · Lynx · Snow leopard · Trans-Himalaya · Wolf

Livestock grazing is the primary land use on the dry-steppe rangelands of the Trans-Himalayan region (Fox and others 1994; Mishra 2001). However, increasing emphasis on livestock production in some areas, as is apparently occurring in the eastern Ladakh region of India's Trans-Himalayan region (Bhatnagar and Wangchuk 2001), can lead to conflict between pastoralists and large carnivores as reported elsewhere (Oli and others 1994; Polisar and others 2003). Evidence of increased livestock depredation by large carnivores in the Himalaya and Hindu-Kush mountains has been attributed to the increasing presence of livestock (Jackson and others 1996; Mishra 1997; Hussain 2003), and management of protected areas for biodiversity conservation must address such issues. However, they need also to recognize that increases in large carnivore populations as a result of the implementation of conservation laws may also lead to an increase in livestock depredation rate, especially in areas with decreased natural prey populations. Conservation of

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large predators and their primarily large ungulate prey in India's Trans-Himalayan region requires a better understanding of the human–carnivore conflict, including detailed monitoring of depredation rates.

Large carnivore populations are imperiled throughout the world, and their conservation is becoming a daunting challenge, especially in the wake of their conflict with human endeavours (Nowell and Jackson 1996; Treves and Karanth 2003). Snow leopard *Uncia uncia* and Tibetan wolf *Canis lupus chanku* are the major large predators on the Trans-Himalayan rangelands (Fox and others 1991; Mishra 1997). Both predators are declining globally, with the former assigned a status of highly ''endangered,'' whereas the latter is listed as a ''vulnerable'' species (International Union for Conservation of Nature and Natural Resources 1990). The Eurasian lynx *Lynx l. isabellina*, although primarily a hunter of small mammals such as hares *Lepus* spp. and marmots *Marmota* spp., is also known to attack domestic sheep and goats (Schaller 1998). These predators face three major threats: decreased prey populations, retaliatory persecution by pastoralists, and habitat fragmentation (Nowell and Jackson 1996; Schaller 1998). The establishment of a network of protected areas is underway in the Trans-Himalayan region of Ladakh (Chundawat and Qureshi 1999), with the conservation of large predator species and their prey a clear goal.

The present study evaluated the extent of livestock depredation by snow leopard, Tibetan wolf, and Eurasian lynx in three settlements within the proposed Gya-Miru Wildlife Sanctuary (GMWS) in Ladakh, India during a period of 2.5 years ending in early 2003. These data provide an overview of the depredation pattern and the importance of the resulting livestock losses to the economy of villages in the reserve. Effective management of large carnivores in the Indian Trans-Himalayan region depends on such information, and with several national and international organizations currently engaged in conserving large carnivores, such as snow leopard, its availability is critical to the targeting of conservation initiatives. Management issues are addressed and possible actions suggested to mitigate human–carnivore conflict and foster coexistence of large carnivores and pastoralists in the region.

Methods

Study Area

The proposed GMWS (33°N, 78°E) is located approximately 65 km southeast of Leh, the major city in Ladakh, India. It encompasses C. 340 km^2 at the western fringe of the Tibetan Plateau. The southern part of the sanctuary is relatively undulating, whereas the northern section is more rugged. Altitudes in the area ranges from 3800 to 5700 m. Located within the Trans-Himalayan mountains, the proposed reserve is in the rain-shadow of the Greater Himalaya, and the annual precipitation is probably approximately 100 to 300 mm within the study area. Climate is severe in winter, with the minimum temperature plunging to approximately –25°C. The region has a short growing season of approximately 3 months (June to August), and the primary productivity is low (Chundawat and Rawat 1994). Vegetation is characterised by dry alpine steppe, and dominant plant species include *Caragana* spp., *Artemisia* spp., *Eurotia* spp., and *Festuca* spp. A more detailed description of the area and vegetation can be found in Namgail and others (2004).

Mammalian herbivores in the area include the Tibetan argali *Ovis ammon hodgsoni*, blue sheep *Pseudois nayaur*, Ladakh urial *Ovis vignei vignei*, Himalayan marmot *Marmota himalayana*, Tibetan woolly hare *Lapus oiostolus*, and pika *Ochotona* spp. All of these wild herbivores share pastures with the livestock, which consist of yaks, horses, sheep, goats, and a limited number of donkeys, oxen, and cows. Of the domestic ungulates, the yaks and horses range freely, whereas sheep and goats (sometimes yaks also) are herded and penned in open corrals at night. A limited number of donkeys, cows, and oxen graze on pastures in the vicinity of the villages and are sometimes stall-fed.

Five villages are situated within the boundary of the prospective reserve, and the three highest villages—i.e., Gya, Rumtse, and Sasoma—were surveyed. The inhabitants are agropastoralists with major emphasis on livestock production. Other than grazing by livestock, the rangelands are exploited for fuel wood collection (e.g., woody species of *Artemisia* and *Caragana*).

Data Collection

Data were gathered by interviewing both villagers and herders during January through July 2003. All livestock reportedly killed during a period of 2.5 years (January 2001 through June 2003) were recorded. For every loss, species, sex, age, year, and predator type were recorded. Because of their low numbers, cows, oxen, and donkeys were combined into one livestock category: ''others.'' Data on the population size for each livestock type were gathered from the headman of Gya Village, who maintains a record of the annual

population size of various livestock types in the three villages. Population size was also checked against the records of the Sheep Husbandry Department in Leh and our own counting for a sample of households.

One adult person, preferably the head, from each family that possessed at least one type of livestock was interviewed. In most cases, we crosschecked the response of the family head by interviewing family members or hired persons that herded the livestock at the high pastures. This was done in light of some pastoralists' propensity to exaggerate the number of livestock loss to predators, perhaps in the hope of compensatory remittance from the government because such a scheme is in place in the region (Bhatnagar and others, 1999). The prevailing market value for each type of livestock was determined by interviewing herders, traders, and butchers in Leh.

Interviews were conducted after our presence in the area for 1 month, and after establishing a rapport with the villagers. Only those depredation cases were recorded that were clearly remembered and where the animal was either killed or injured to an extent that caused death. All reported cases with an ambiguous cause of mortality were not included. Care was also taken to avoid assigning depredation cases mistakenly to either snow leopard or wolf. Herders claimed that they could distinguish between a carcass killed by a wolf from that killed by a snow leopard based on evidence on the carcass of typical wolf attack on animal's hindquarters and snow leopard attack on the neck or throat as well as by the presence of predators' tracks on the kill site.

Although we provided overall information for the entire area, the depredation cases of Rumtse and Sasoma were merged and analysed separately from those of Gya Village. Rumtse and Sasoma are near each other and approximately 1 km up the Gya river valley from Gya Village. These upper areas have more undulating terrain in their surroundings, whereas Gya has more rugged terrain (preferred by snow leopard; Jackson and Hunter 1996). Data were analysed separately because (1) there is likely to be a difference in livestock vulnerability to different predators (e.g., livestock of Gya Village, including the few households at Lato, are perhaps more vulnerable to snow leopard), especially during the periods when the livestock are grazed on pastures close to villages and penned in open corrals at night and (2) in the case of difference in the extent of depredation among the villages, different remedial interventions could be appropriately targeted.

Selective killing of different livestock types was tested using modified chi-square test: log-likelihood chi-square test (χ_L^2; Manly and others 1993). In case of rejection of the null hypothesis (no selection), Bonferroni-adjusted 95% confidence intervals were constructed to determine which animals were killed selectively. A livestock type was killed more than expected based on its relative abundance if the lower confidence interval was greater than its population proportion, whereas it was killed less than expected when the upper confidence limit excluded its population proportion.

Results

In early 2003, the 63 households surveyed reported a total of 4132 head of livestock, giving an average of 66/household. These households had a human population of 252 or an average of 4 people/household. Goats (approximately 1910) comprised bulk of the livestock population (46%), followed by sheep (approximately 1456 or 35%), yak (approximately 544 or 13%), horse (approximately 129 or 4%), and ''other'' (approximately 93 or 2%). All of the households interviewed possessed sheep and goats, whereas fewer possessed yaks (56 households or 89%), horses (49 or 78%), and ''other'' (30 or 48%).

There were no significant differences in proportional losses of livestock types ($\chi^2 = 8.75$, $df = 4$, $P > 0.05$) or proportion losses attributed to predator type ($\chi^2 = 0.82$, $df = 2$, $P > 0.05$) between Gya village and the Rumtse and Sasoma villages. Data were therefore pooled, and results were based on the sum of the depredation cases in the three villages, although some distinctions were made, where required, for future comparison (Table 1).

The three villages reported a total of 295 animals lost to predation, an annual loss of 2.9% of the livestock holdings, or 1.9 livestock head/household/y. Overall, domestic goats were the major victim (32%; n = 295), followed by sheep, yaks, horses and, ''others'' (Table 1). Wolves killed horses and ''others'' significantly more than expected ($\chi_L^2 = 95.84$, $df = 4$, $P < 0.01$; Table 2) because the lower confidence limits for these livestock types were greater than their respective population proportions. Snow leopards also killed horses more than expected ($\chi_L^2 = 31.31$, $df = 4$, $P < 0.01$) because the lower confidence limit for this livestock type was greater than its population proportion, whereas they killed sheep, goats, yaks, and ''others'' in proportion to their relative abundance (Table 2).

The wolf was the most important predator, accounting for 60% (n = 295) of total livestock lost by all three villages during the 2.5-year period, followed by the

Table 1 Livestock losses to predators in three settlements of the Gya-Miru Wildlife Sanctuary, India

	Gya		Rumtse/Sasoma		Overall	
	Total killed*	Percent killed	Total killed*	Percent killed	Total killed*	Percent killed
Livestock						
Yak	23	13	22	19	45	15
Horse	17	9	20	18	37	13
Sheep	57	31	32	28	89	30
Goat	65	36	29	26	94	32
Others [a]	20	11	10	9	30	10
Total	182	100	113	100	295	100
Predator						
Tibetan wolf	108	59	70	62	178	60
Snow leopard	70	39	42	37	112	38
Eurasian lynx	4	2	1	1	5	2
Total	182	100	113	100	295	100

* Over a period of 2.5 years (Jan 2001–June 2003); [a]cows, oxen and donkeys

Table 2 Confidence intervals (95%) for population proportions of livestock killed by large carnivores

		Tibetan wolf				Snow leopard			
				Bonferroni confidence intervals				Bonferroni confidence intervals	
Livestock type	Population proportion *(n = 4132)*	Total killed*	Proportion killed	*Lower*	*Upper*	Total killed *	Proportion killed	*Lower*	*Upper*
Yak	0.132	26 (23)	0.146^{0}	0.085	0.207	19 (15)	0.170^{0}	0.087	0.252
Horse	0.031	21 (6)	0.118^{+}	0.062	0.174	16 (3)	0.143^{+}	0.066	0.220
Sheep	0.352	57 (63)	0.320^{0}	0.239	0.401	29 (39)	0.259^{0}	0.163	0.355
Goat	0.462	48 (82)	0.270^{-}	0.192	0.347	43 (52)	0.384^{0}	0.277	0.491
Others[a]	0.023	26 (4)	0.146^{+}	0.085	0.207	5 (3)	0.045^{0} [b]	0.000	0.090
Total	1.000	178	1.000			112	1.000		

$^{+}$ killed more than expected; $^{-}$killed less than expected; ^{0}killed in proportion to abundance; *Figures in parentheses indicate expected frequencies; [a]Cows, donkeys and oxen; [b]Inference unreliable due to few animals killed

Table 3 Annual monetary losses incurred by Gya and Rumtse/Sasoma villages due to livestock depredation

			Monetary Loss (US$*)			
Village	Yak	Horse	Sheep	Goat	Others	Total
Gya	2130.9	2048.0	882.0	986.3	521.9	6569.5
Rumtse/Sasoma	1785.2	2467.9	455.7	435.8	407.1	5551.7
Total[†]	3916.1 (69.8)	4516.0 (93.1)	1338.0 (21.2)	1822.1 (28.9)	929.0 (31.4)	12121.2 (192.4)

[†] Figures in parentheses indicate estimated annual monetary loss per household. *1 US$ $\approx$ 47.4 INR

snow leopard, which killed 38% of the total number lost. Snow leopards reportedly killed 47 animals during 4 incidents of multiple killings in corrals at night with a mean (± SD) of 11.7 (± 5.6) individuals/attack. Lynx depredation on livestock was quite low, with only 2% (n = 295) reported during the entire period (Table 1).

Estimated Monetary Loss

The approximate monetary value of different-aged livestock was as follows: (1) yak USD \$107.10 (for <1 year old) to \$338.30 (for >6 years old); (2) horse \$195.7 (for <1 year old) to \$389.20 (for >6 years old); (3) sheep \$10.30 (for <6 months old) to \$65.50 (for >4 years old); (4) goat \$ 11.50 (for <6 months old) to \$59.90 (for >4 years old); (5) ''others'' (cows, oxen, and donkeys) \$16.30 (for <1 year old) to \$83.80 (for >6 years old). Although the values were calculated according to the ages of the animals lost, only ranges are listed here. The values of livestock were converted to United States dollars at the exchange rate of USD 1:INR 47.4.

Based on these values, the three villages incurred an estimated annual monetary loss of approximately USD $12,120.00 or approximately $190.00/household/y (Table 3). The severity of the annual monetary loss was affected mainly by depredation of the most valuable species such as yaks and horses. The 63 families surveyed incurred an estimated annual monetary loss of approximately $3,900.00 for yak losses and $4,500.00 for horse losses, or $70.00/household for yaks and $93.00/household for horses calculated on the basis of the number of households that possessed these livestock types (Table 3).

Discussion

Livestock depredation by wild carnivores and the antagonism it generates, i.e., retaliatory killing of these carnivores by pastoralists, is becoming a serious conservation issue in the Indian Trans-Himalayan region (Bhatnagar and others 1999; Mishra and others 2003). The study area at the edge of the Tibetan Plateau, with wolf as the most important predator on livestock, suffers intense retaliatory persecution. Wolf pups, for example, are removed from dens and killed by people, who are then applauded and rewarded (Tashi Gyatso, personal communication 17, Jan 2003). We found three death-fall traps and one pit-trap in the study area, all targeted primarily at wolves, although villagers claimed that they were abandoned as a result of the implementation of conservation laws. We strove to minimise the extent of misleading claims, but we cannot rule out that pastoralists ascribed some fraction of livestock mortality to wolf and snow leopard that was actually caused by other factors such as poisonous plants, diseases etc., and later scavenged by predators, as has been reported in Nepal (Oli and others 1994).

Although not as important as the wolf in terms of overall depredation, the snow leopard is notorious for breaking into livestock pens and killing large numbers of sheep and goats at one time. If caught inside the pen, it is generally clubbed or stoned to death (Jackson and others 1996; Bhatnagar and others 1999). Although four such multiple killings occurred in the study area during the 2.5-year time span of information, no retaliatory killings were reported. Finally, lynx depredation may have been underestimated to some extent, for it attacks only sheep and goats, and pastoralists tend to forget such incidences more easily, perhaps because of their relatively low economic value. Others have also reported low livestock depredation (2% of total livestock loss) by lynx in Ladakh (Bhatnagar and others 1999). Rare incidents of retaliatory lynx killing by villagers reportedly occurred in the GMWS within the time frame of this study, although not in the villages surveyed here (Namgail 2004).

Sheep and goats were the major victims of predation, in part a consequence of their predominance in the multiple killings by snow leopard in corrals at night. Nevertheless, they were killed proportionally less than their relative abundance. The selective depredation of horses by both of the large predators may be related to vulnerability associated with their being untended on the rangelands, but the disproportionate killing of cows, oxen, and donkeys by wolves is more difficult to explain because ''others'' are generally kept close to the villages.

The average annual loss per household because of depredation of approximately USD $190, or a per capita loss of approximately USD $48, in the GMWS represents 18% of the average per capita annual income (USD $265 for 2000 through 2001) in the state of Jammu and Kashmir. Although the per capita income for the study area was not available and could be lower than that of the state, given the less commercial activities in the area (Namgail and others 2004), the USD $48 per capita is a substantial loss. In a similar study in Nepal, reported annual monetary losses were USD $47 to $49/household during 1988 to 1990, which amounted to a quarter of the average annual per capita income of Nepal (Oli and others 1994). Similarly, in the Kibber Wildlife Sanctuary in Himachal Pradesh, India, reported monetary depredation loss was approximately USD $128/household or a per capita loss of approximately USD $26, which represents 11% of the annual per capita income of the state (Mishra 1997). Thus the annual per capita loss in relation to the state's annual per capita income is relatively higher in the GMWS compared with Kibber, which could be attributed to the greater proportion of adult (>5 years old) yaks (65% of total yak loss) and horses (52% of total horse depredation) lost to predators in the GMWS.

Mitigating The Conflict

Although some degree of conflict between pastoralists and large carnivores seems inevitable in areas where livestock production is the mainstay of the economy, the level of conflict could be minimised by providing incentives to the communities, which currently do not benefit directly from carnivore conservation (Mishra and others 2003). Recently, the results of this study led the International Snow Leopard Trust to initiate a conservation-linked income generation program in the three villages aimed at enhancing the living conditions

of the local people and tied to agreements to refrain from persecuting large carnivores for their occasional depredation of livestock. Villagers are also being encouraged to initiate a self-governed livestock insurance program, similar to one that has proved to be effective in the Spiti region of India's Trans-Himalayan region (Mishra and others 2003).

The multiple killings by snow leopard in corrals at night can be minimised by improving existing corral structures, which are poorly built with low walls and no ceiling; they are designed only to keep the livestock in rather than predators out. This problem is widespread throughout most of snow leopard range, and several remedial measures have been tested, including building leopard-proof corrals (Jackson and others 1996). Several conservation organizations are successfully working toward this end in the region, and their introduction of culturally appropriate corral-improvement programs using local materials and expertise should also be initiated in the GMWS.

Hired herders commonly tend livestock in the GMWS, unlike in other agropastoral areas in the region where women and children commonly herd the livestock, with the latter often resulting in high levels of livestock depredation (Bhatnagar and others 1999). However, the number of herders (27 in the present study area) is perhaps inadequate for a livestock population of approximately 4132 (153 livestock/herder). With a growing population of livestock, the number of herders should also increase; however, because young people today are not willing to take up this lifestyle (Tashi, personal communication 17 Jan, 2003), the tending of livestock will become more problematic. In any case, less emphasis is placed on tending large livestock such as yaks and horses, which range free for most of the year. Because the depredation of these livestock types accounted for the bulk of the monetary losses in the area, people need to tend them more vigilantly and preferably herd the vulnerable individuals (female and young) back to the high-altitude camps during the night.

Although the GMWS supports several wild ungulate species that serve as a natural prey base for the predators, the density of these was low ($0.3/km^2$; Namgail, Mar. 2003). Furthermore, at least two wild ungulates—wild yak *Bos grunniens* and kiang or the Tibetan wild ass *Equus* kiang—have reportedly gone locally extinct in the last two centuries (Namgail and others 2004). Therefore, the relatively high livestock depredation in the GMWS could also be explained by a decreased natural prey population. In such a scenario, it would be desirable to see reserve management lead to an increase in the populations of natural prey. Still, the abundant domestic livestock, especially sheep and goats, which have decreased vigilance and escape abilities, may remain more profitable to snow leopard and wolf in terms of energy gain with regard to searching and handling time. Thus, both protective measures for livestock (e.g., predator-proof corrals) and improved herding techniques are necessary to resolve the conflict between pastoralists and wild carnivores.

One alternative livestock-protection option involves the use of shepherd dogs (Coppinger and Coppinger 1993). Herding dogs are currently used in the study area (Namgail and others 2004), but their effectiveness as livestock guardians is not known. Conversations with the herders revealed that they do not train these dogs, and many become feral, for unsatisfied herders often abandon them, and they in turn become a threat to the wild herbivores. One such dog killed a young Tibetan argali in the study area in 2002 (T. Morup, personal communication 25 Jan, 2003). Therefore, the dogs should be trained properly for effective livestock guarding, and the feral ones should be eliminated. Apart from this, poor veterinary care seems to be a factor that increases the livestock mortality because of large carnivores. For example, during the present investigation, we came across a pack of wolves attacking a subadult yak that was rescued by a villager but died from the injury within a couple of days because of lack of veterinary care. Villagers reported many such incidents, which could be minimised by providing proper treatment to predator-injured animals rescued by herders.

The provision of monetary compensation is a commonly applied solution that encourages pastoralists to tolerate wild carnivores in their vicinity (Nowell and Jackson 1996). Although a compensation scheme by the Jammu and Kashmir government has been in place in the GMWS since 1994, pastoralists are generally dissatisfied with it, largely because of low compensation rates and the time and cost involved in the process (U. Phuntsog, personal communication May 12, 2003). Moreover, the lack of staff in the Wildlife Department renders it unable to verify most of the depredation cases reported by the villagers, often resulting in some fraudulent herders being compensated. In any case, most of the budget of the Wildlife Department goes toward compensating livestock losses, which leaves little for other programs crucial for saving endangered predators such as the snow leopard and their prey species. An alternative to compensation could be to invest these monies in human resources and infrastructure development, such as training herders and improving corrals, which will distribute the benefit equitably.

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