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BIOLOGICAL CONSERVATION

Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan

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ABSTRACT

Villages in Jigme Singye Wangchuck National Park, central Bhutan, report livestock depredation by wild carnivores including leopard (*Panthera pardus*), tiger (*Panthera tigris*), Himalayan black bear (*Ursus thibettanus*), and dhole (*Cuon alpinus*). In a survey of 274 households in six different geogs (sub-districts) within the park, 21.2% of households surveyed reported losses of a total of 2.3% of their domestic animals to wild predators over 12 months. This loss equated to an average annual financial loss equal to 17% (US$ 44.72) of their total per-capita cash income. Total reported losses during 2000 amounted to US$ 12,252, of which leopard and tiger kills accounted for 82% (US$ 10,047). Annual mean livestock loss per household (of those that reported loss) was 1.29 head of stock, equating to more than two-thirds of their annual cash income of $250. Lax herding, inadequate guarding practices, and overgrazing may have contributed to livestock losses. Approximately 60% of the households lacked proper stables for corralling their livestock at night and there was a significant correlation between the number of livestock lost and the distance between the household and the grazing pasture. Overall, reported predation rates have increased since the inception of the park in 1993 and since implementation of the Forest and Nature Conservation Act in 1995, which prioritises some of Bhutan's key livestock predators for conservation. We propose livestock intensification programmes, including pasture improvement, and financial compensation as short-term measures to reduce conflict between people and predators. In the long-term, we recommend that the feasibility of an insurance scheme should be tested, the possibility of relaxing the resource use restrictions in the Forest and Nature Conservation Act of 1995 be explored, and that farmers should be involved in managing human–wildlife conflicts – particularly through improving their own herding and guarding practices, and building proper corralling facilities and adopting reliable corralling procedures.

1. Introduction

Conflict between wildlife and humans is a significant problem in many parts of the world. Influential factors include increasing human populations, loss of natural habitat, and, in some regions, growing wildlife populations resulting from successful conservation programmes (Saberwal et al., 1994). Conflict can be particularly serious, where rural people live

in close association with protected areas (Mishra, 2001; Conforti and de Azevedo, 2003). Most protected areas in Bhutan support some form of land use, such as agriculture, livestock grazing and/or the harvesting of timber and non-timber forest products (Wang, 2004). Livestock holdings form an integral part of the local pastoral and agricultural economy, and grazing of substantial herds is widespread in, or adjacent to, protected areas. Predators attack livestock that are grazed in, or close to, forest areas, and venture into farms to take livestock, as well as posing risks to humans. Such damage to local livelihoods angers farmers who may resort to retribution (Conforti and de Azevedo, 2003), thereby breeding a conflict of interest between local communities and wildlife managers.

Human–wildlife conflict attracts greatest attention when the wildlife species involved is endangered or where the conflict poses a serious threat to human welfare (Saberwal et al., 1994). Both conditions apply to the situation in Jigme Singye Wangchuck National Park. The park harbours 17 of those mammals listed in Schedule I of Bhutan's Forest and Nature Conservation Act of 1995, of which tiger (*Panthera tigris*), leopard (*Panthera pardus*), Himalayan black bear (*Ursus thibetanus*), and dhole (*Cuon alpinus*) are among the highest priorities for conservation. In Bhutan, their survival is threatened by deteriorating habitat (due to overuse of the forest for grazing and collection of forest produce), declining numbers of wild prey and poaching. Dhole were previously widespread in Bhutan, but were perceived as pests of livestock, and poisoning by farmers exterminated the population. Seemingly as a result the wild pig (*Sus scrofa*) population increased, this resulting in serious crop damage (Choden and Namgay, 1996; Wang, 2004). In an attempt to rectify the pig-damage problem dhole were reintroduced into Bhutan in the early nineties and the species is now becoming reestablished. A parallel exists in the eradication of African wild dog (*Lycaon pictus*) partly due to conflict with cattle ranchers (Rasmussen, 1999).

For the first time in Bhutan, we examine the extent and magnitude of conflict between carnivores and agropastoralists in Jigme Singye Wangchuck National Park, and we propose measures that may reduce this conflict. We also describe traditional livestock-herding practices used in the park, quantify the perceived economic losses to local communities, and document their retaliatory actions. This paper also evaluates the impact of the Forest and Nature Conservation Act of 1995, by comparing reported predation patterns before and after implementation of the Act.

1.1. *Study area*

Jigme Singye Wangchuck National Park was selected as an appropriate study area (Fig. 1). The great altitudinal range within the park (150–5,000 m asl) accommodates extremely diverse habitats, from subtropical rainforests to alpine meadows and snow-capped peaks. The park contains more than 5,000 species of vascular plants, as well as 40 species of mammals (of which tigers and red panda (*Alurus fulgens*) are endangered and 15 other species are either vulnerable or threatened) and 391 species of birds (of which the white-bellied heron (*Ardea insignis*) is endangered and another 16 species are either vulnerable or threatened). The park supports 10–15% of Bhutan's tiger population in its cool and warm broadleaved forests. Important populations of red panda and musk deer (*Moschus chrysogaster*) live in the sub-alpine forests, and during the winter, black-necked cranes (*Grus nigricollis*) frequent the northern part of the glacier valley (3500 m asl). The park acts as a corridor between national parks (the Royal Manas National Park, in the south, and Jigme Dorji National Park and Trumshingla National Park, in the north), and has a reputation for conflict between its wildlife and its 5,000–6,000 human inhabitants.

2. Methods

We conducted a questionnaire survey in 2000. Our survey canvassed 274 randomly selected households from within six geogs (sub-districts) of the park (Fig. 1): Athang (56 households), Trong (44), Korphu (32), Phobji (21), Langthel (59), and Tansgibji (62). These households represented about 50% of the total households within the park. The geogs of Phobji, Langthel and Tangsibji were defined as the 'buffer zone' because they lie along the boundary of the park and have greater access to roads and other sources of livelihood. Athang, Trong, and Korphu, which lie further away from the park boundary, were defined as the 'inner zone'. Respondents (the head of the household or their spouse) were asked questions relating to household demographics, education and employment, number of livestock owned, livestock management, number of livestock lost to predation, perceived problem carnivores, resource extraction (including collection of non-timber forest products), and livelihood issues including financial self-sufficiency.

Interviews were conducted by members of park staff who have worked with these communities for several years, in order to minimise the likelihood of receiving inaccurate responses. Livestock kills were verified by a team comprising a local park official, a livestock extension agent (an official posted to a village to regulate livestock related issues, who is required to authenticate livestock kills by wildlife), and the head of the particular community. We trained park officials to identify the predator responsible for livestock kills using a combination of signs (such as pug marks, scrapes, scats, and attack marks, etc.). Demographic and livelihood data were cross-validated with records held by local government administrators. Information on livestock holdings, the number reported lost to predation, and details regarding grazing areas, were cross-checked with records maintained at the park head office. Secondary data on livestock numbers and numbers lost to predation for the years 1993 (prior to establishment of the park), 1995 (before enforcement of the act), and 2001 (after both the park and the act came into being) were collected from archival records kept at the park office. These data were used to evaluate questionnaire responses on changes in human and livestock demographics and to compare conflict trends before and after the establishment of the park in 1993, and enforcement of the Forest and Nature Conservation Act of 1995.

Data were analysed using Minitab version 13 (Hampton, 1994). Data were tested for normality using the Anderson–Darling test and the Levene's statistic was used to test for homogeneity of variance. Data were transformed by their natural logarithm when testing correlation between loss and
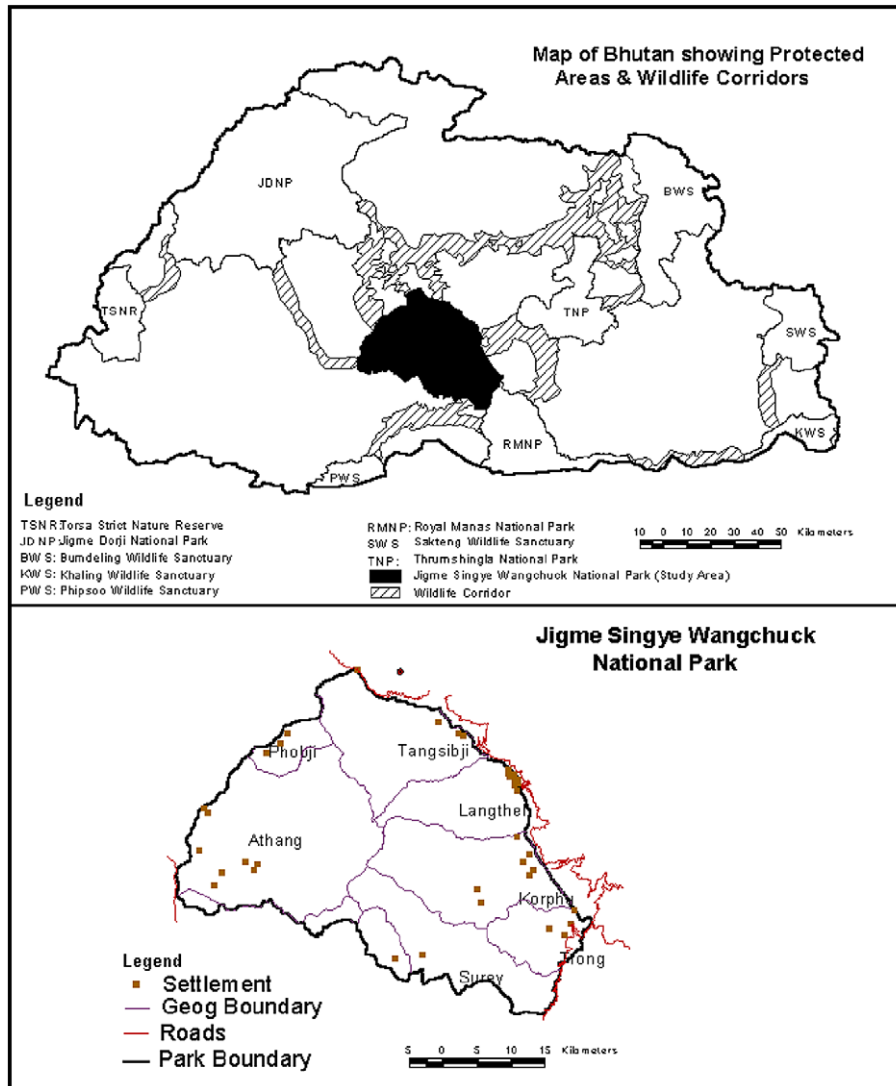
Fig. 1 – Location of Jigme Singye Wangchuck National Park (JSWNP) and study sites in Bhutan.

grazing in the far pastures and statistical tests used included simple *t*-tests, analysis of variance (ANOVA), Chi square test, and Tukey's test.

Predator 'hotspots' were characterised following Spearing (in Litt.) and were ranked according to each of the following three criteria: number of livestock killed; percentage of herd killed; and percentage of stockholdings killed. ('Stockholding' is the total population of livestock in the park, and 'herd' is the number of livestock owned by an individual farmer).

3. Results

3.1. Livelihood strategies

Park residents are primarily subsistence farmers within the local market economy. Livestock (20%) and cultivation (42%) formed the main sources of rural livelihoods, supplemented by non-farm activities (26%), such as business, government service or casual labour (*n* = 274). Twelve percent (12%) of farmers (*n* = 274) supplemented their livelihood by collecting forest products. Non-farm activities were more common

(59%) in the buffer zone (*n* = 142), than in the inner zone (41%) (*n* = 132).

Main sources of cash income among park residents were the sale of livestock (32%) and agricultural products (38%), non-farm products (16%), and forest products (14%) (*n* = 274). Most households in the higher altitude geogs of Phobji and Tangsibji obtained cash income from selling potatoes, yak meat, and yak products. People at lower elevations, in Langthel and Trong, depended on livestock and crops, such as mustard, oranges, cardamom or guava. Annual cash income per household was about 11,000 Bhutanese Ngultrums (about US$ 250 (range: 5US$–2500US$). Few individuals reaped substantial benefits from salaried or casual employment, but several families (14%) received remittances from family members working in office jobs in cities. Most households (95%) incurred cash expenditures for basic goods, such as salt, kerosene or schooling, while the others (5%) bartered.

Most of the vegetables and fruits sold came from kitchen gardens, while potatoes in the buffer zone were grown in the dry lands, especially in Phobji geog. Many households in both zones sold animal meat or products (Table 1).

Table 1 – Comparison of sources of cash incomes from livestock in inner and buffer zones of Jigme Singye Wangchuck National Park (2000)		
Livestock	Inner zone (%)	Buffer zone (%)
Milk/butter	32	53
Pig/pork	17	11
Poultry/poultry meat	16	1
Eggs	30	18
(*n* for inner zone = 132; *n* for buffer zone = 142).		

3.2. Herd dynamics or livestock holdings

In 2000, 85% of households (*n* = 274) reared a total of 3,275 head of livestock, with an average herd size of 12 head (SD = ±11.5) of stock per household (Table 2). Ownership of livestock by households was highly skewed (range: 0–105 stock per household). Most households (80%) owned 20 or less animals; 16% of households owned 21 or more animals; 4% did not own any animals.

Cattle generally made up 75% of the herd, the remainder comprising sheep, pigs, horses and yak (Table 2). The largest herd size of 105 was owned by one household in Phobji geog and consisted of 65 yaks, 36 sheep, 3 pigs, and a cow. The smallest herd consisted of one goat owned by a family in Athang geog. There was no significant difference between the mean livestock holding per household in 1995 (*n* = 477, mean 12.6, SE±0.6) and 2000 (*n* = 274, mean 12.0, SE±0.8).

Herding patterns in Jigme Singye Wangchuck National Park varied according to season, type of livestock, and agricultural practices, but followed long established traditional patterns that demand a high degree of cooperation among community members. Overall, significantly more households were resident (81%) than migrated (19%) (T = 19, *p* < 0.001, *n* = 274). All households in Korphu, Tangsibji and Langthel were resident, while in Trong 93% were resident and the remainder migratory. There was no significant difference in either Athang or Phobji, making the people of these geogs the most migratory.

Table 2 – Average composition of livestock herds per household in the study geogs of Jigme Singye Wangchuck National Park (2000)							
Geog	N	Cattle	Yak	Horse	Sheep	Pig	Average[a]
Athang	56	9.6	0.3	0.9	0.7	0.2	11.7
Trong	44	8.0	0.0	0.5	0.0	0.5	9.0
Korphu	32	7.3	0.0	0.6	0.0	0.1	8.0
Phobji	21	7.7	4.4	1.2	8.1	1.7	23.2
Langthel	59	7.5	0.0	0.2	0.1	0.4	8.1
Tangsibji	62	11.8	0.0	0.4	1.9	2.2	16.2
Livestock/ household		9.0	0.4	0.5	1.2	0.8	12
% of the total herd		75.0	3.3	4.6	10.1	7.0	100

N, number of households in the study *geogs*.
Eighty-five percent of households kept livestock; averages calculated from all households, including those that kept none.
a Average number of livestock held by a household.

Significantly more households grazed their cattle in fallow fields in forest near their villages (55%), than in distant pastures (more than one day's walk from human settlement) (21%) or in a combination of these two areas (24%) (T = −9.28, *p* < 0.001). Loss of livestock was significantly positively correlated with the percentage of the herd that was grazed in distant pastures (coefficient of correlation, r = 0.7, *p* < 0.001), but not with the percentage grazed near to the village.

Farmers either penned their livestock below their living quarters (when they had small herds), kept them in purpose built stables, left them unattended at night in the pasture or forest (particularly when livestock were in distant pastures) or tethered them in fields (Fig. 2). Approximately 60% of the households in the study geogs lacked proper stables for corralling their livestock, and consequently left them unprotected at night.

3.3. Livestock losses

Respondents reported a total of 76 (2.3%) domestic animals killed by predators in a period of one year. Farmers attributed 40 kills (53%) to leopards, 20 (26%) to tigers, 10 (13%) to dhole, and 6 (8%) to bears (Table 3). The majority of tiger kills were cows (95%), mostly occurring in Trong (42%) and Langthel (37%). The greatest proportion of leopard kills (35%) was reported in Athang, where there were no reports of tiger predation, and the fewest were in Tangsibji and Phobji (5%). Losses attributed to bears were most frequent in Athang (50%), while reported losses to dhole were most frequent in Phobji (40%).

Frequency of reported livestock losses was significantly greater in the inner zone (*n* = 41) than in the buffer (*n* = 35) zone (F = 7.23, *p* < 0.01). The greatest proportion of reported livestock loss occurred in Langthel (4.2%) and Trong (4%). Mean loss per household (that lost livestock) was 1.29 head of livestock per annum (Table 3), which would cost 84% of their annual cash income to replace these animals. This mean loss was considerably higher for households in Trong (3.2 per household) than in other geogs.

3.4. Economic valuation of losses

Economic loss to predators per household was estimated using average local prices in 2002 (Table 3). The total loss of
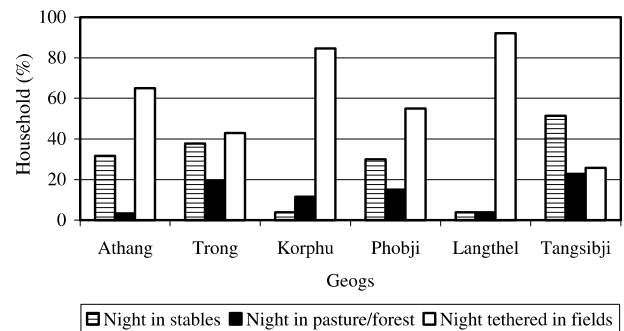

Fig. 2 – Methods of night-time livestock management practised by the farmers in Jigme Singye Wangchuck National Park (2000) (livestock penned below living quarters were included with those housed in separate stables).

Table 3 – Economic valuation of reported livestock kills (*n*) by wild predators in the study geogs in 2000

	Unit value (US $)	Tiger (US $)	Leopard (US $)	Bear (US $)	Dhole (US $)	Overall (US $)
Cattle	173.40	3295 (19)	5549 (32)	1040 (6)	1040 (6)	10924 (63)
Yak	319.10	0	319 (1)	0	0	319 (1)
Horse	187.70	0	536 (3)	0	0	536 (3)
Sheep	19.10	0	38 (2)	0	77 (4)	115 (6)
Pig	119.10	119 (1)	238 (2)	0	0	357 (3)
Total loss		3414 (20)	6681 (40)	1040 (6)	1117 (10)	12252 (76)
Mean loss						
-per hh[a]		12.46 (0.07)	24.38 (0.15)	3.80 (0.02)	4.08 (0.04)	44.72 (0.27)
-per hh[b]		58.86 (0.33)	115.19 (0.69)	17.94 (0.10)	19.26 (0.17)	211.24 (1.29)
Loss as a % of						
-total herd		26	53	8	13	100
-per capita income[a]		4.98	9.75	1.52	1.63	17.88
-per capita income[b]		23.53	46.06	7.17	7.70	84.46
-Urban cash income		10.94	21.41	3.33	3.58	9.81

Numbers in parenthesis represent numbers of individual killed.

hh, Household.

The conversion rate from Bhutanese Ngultrum was 1 US$ = 47 Ngultrums.

a Considering all the respondents (*n* = 274).

b Considering only the affected respondents (*n* = 58).

76 head of livestock was valued at US$ 12,252, of which the majority (89%, US$ 10,924) were cattle losses (*n* = 63) (Table 3). Leopards and tigers were held responsible for the majority of predation, being blamed for 53% and 26% of the total livestock loss, respectively, and US$ 10,095 of the total monetary loss. Bears and dhole together (8% and 13%, respectively) were responsible for the remaining 21% of livestock loss (US$ 2,157 of the total monetary loss).

Average annual household cash income was US$ 250 (*n* = 274). Overall, each household (including those that did not report losses) lost an estimated US$ 44.72 (Table 3) (approximately 17% of the annual household cash income. Mean losses only for households that reported livestock loss (*n* = 58) was US$ 211 (Table 3) (approximately 84% of the annual household cash income).

3.5. Predation trends before and after 1995

Overall predation increased significantly between 1993 and 2001 (*F* = 3.09, *p* < 0.01: Table 4). This comprised a significant increase in recorded predation between 1993 (mean = 0.16, SE = ±0.05,) and 1995 (mean = 0.29, SE = ±0.03) (*F* = 3.9, *p* < 0.01), no significant change between 1995 and 2000 (mean = 0.27, SE = ±0.04), and a non-significant increase between 2000 and 2001 (mean = 0.42, SE = ±0.08) (Table 4). There was a significant interaction between predator and year (*F* = 3.2, *p* < 0.001). According to our survey responses, leopards were responsible for most of the predation loss (*n* = 40), followed by tiger (*n* = 20), dhole (*n* = 10), and bear (*n* = 6) (see Table 3). There was a significant difference (*p* < 0.001) in reported predation loss between each pair of predators, tiger and leopard (+0.0105:+0.1428), leopard and bear (−0.1902:−0.0579), leopard and dhole (−0.1756:−0.0433), except bear and dhole (−0.0807:+0.0515): tiger-dhole (−0.0990:+0.0333), tiger-bear (−0.1136:+0.0187). Reported predation by each of leopard and dhole was significantly higher

Table 4 – Showing differences in mean predation in time from establishment of Jigme Singye Wangchuck National Park

Year	1993	1995	2000	2001	1993
Mean	0.16	0.29	0.27	0.42	0.16
Standard error (±)	0.05	0.03	0.04	0.08	0.05
p value		**	NS	NS	***

*, significant (*p* < 0.05).

**, very significant (*p* < 0.01).

***, highly significant (*p* < 0.001).

in 2001 (mean = 0.29, *F* = 3.9, *p* < 0.01 and mean = 0.07, *F* = 5.20, *p* < 0.01, respectively) than in all other years; there was no significant difference between the other years). Losses due to tiger and bear predation did not differ significantly between the four years (*F* = 1.86, *p* > 0.05 and *F* = 2.13, *p* > 0.05, respectively).

3.6. Identifying predator 'hotspots'

The top predation 'hotspots' in 2000 were ranked for each of the predators (Table 5). Trong was the top hotspot for tigers followed by Langthel and Tangsibji. Tigers were thought to be responsible for 42%, 37% and 16% of the total livestock kills in the three geogs, respectively. Athang, Langthel, and Korphu were leopard hotspots; losing 35%, 23% and 18% of the total livestock, respectively. Primary hotspots for predation by tigers and leopards were spatially distinct, with leopards predominating at higher altitudes than tigers, except in Langthel, where both felids seem to coexist. Bear damage appeared to be widespread although Athang suffered the greatest number of losses. Dhole populations appeared to be recovering in Phobji and Langthel, being considered responsible for 40% and 30% of the livestock taken in these areas.

Table 5 – Predation 'hotspots' in Jigme Singye Wangchuck National Park according to each of three criteria for each species of predator

Hotspot criteria	Tiger			Leopard			Bear			Dhole		
	n	%[a]	%[b]	n	%[a]	%[b]	n	%[a]	%[b]	n	%[a]	%[b]
Hotspot 1	Tr	Tr	Tr	A	K	A	A	A	A	P	P	P
Hotspot 2	L	L	L	L	A	L	TrPL	Tr	TrPL	L	L	L
Hotspot 3	T	K	T	K	L	K	KT	L	KT	T	Tr	T

n, number of livestock killed.

A, Athang; Tr, Trong; K, Korphu; P, Phobji; L, Langthel and T, Tangsibj.

a Percentage of the herd size.

b Percentage of the total livestock population of the park.

4. Discussion

Protected areas in Bhutan, instituted barely a decade ago, involve powerful conservation laws, strong ethics, and the Bhutan government prioritising conservation – this all within a cultural setting, where religious ethics are resonant with environmental protection. However, a disadvantage of strict conservation policies combined with a lax herding system within the park is the loss of livestock to wild carnivores. This sparks conflict between people and wildlife. Our survey of 274 households in 2000 in the Jigme Singye Wangchuck National Park revealed that 21.2% (58) of households believed they had lost livestock to wild predators during the previous year (averaging approximately 2.3% of their herd), and that perceived losses had increased significantly since 1993. Nonetheless, the percentage of households reporting lost livestock in our study was lower than figures reported elsewhere in the region (46% in Mongolia (Allen and McCarthy, in Litt.); 38% in Nepal (Oli et al., 1994); and 45% in Tsarap Valley of India (Spearing, in Litt.)). The financial loss represented by the livestock predation – about US$ 44.72 per household (over all households) – was also lower than losses reported from other countries in the region (these ranging from one quarter to almost half of the household cash incomes (Oli et al., 1994; Mishra, 1997; Jackson, 1999; Stahl et al., 2001; Spearing, in Litt.). Nevertheless, the farmers responding to our survey considered the losses they reported to be significant, and they were greater than losses reported elsewhere in India (Kibber wildlife sanctuary, 12% (Mishra, 1997); Hemis National Park, 2.3% in 1991 (Fox et al., 1991) and 12.4% in 2000 (Bhatnagaer et al., 2000); Tibet 9.5% (Jackson, 1999); and China, 7.6% (Schaller et al., 1987)).

When losses were calculated for only those households that reported loss the average was 1.29 head of livestock lost per annum (US$ 211) which may represent as much as 84.5% of their average annual cash income (US$250, Planning Commission, 2002). Similar levels of livestock loss were reported by Spearing (in Litt.) (2000) in the Tsarap Valley in North India, although there the financial value of US$ 203.9 represented about 54% of their annual cash income. Such losses, combined with restrictions on the use of natural resources, are likely to generate a hostile attitude towards conservation and may provoke retaliatory action by farmers (Schaller and Crawshaw, 1980; Rabinowitz, 1986; Conforti and de Azevedo, 2003). Farmers in our study expressed the opinion that it had become more difficult to rear livestock in the park. The

top five reasons they gave, in order of decreasing severity, were: (1) increased predation; (2) lack of fodder; (3) increased incidence of disease; (4) insufficient pasture; and (5) reduced milk quality. Fifty two per cent of the park residents blamed their present hardships on the park and the Forest and Nature Conservation Act of 1995, which had introduced a ban on the killing of wildlife together with restrictions on grazing and the collection of non-timber forest products (medicinal plants, aromatic plants, mushrooms, cane and bamboo etc.).

In agreement with the findings of Jackson (1999) and Jackson and Wangchuk (in Litt.), livestock kills in our study area varied by site, livestock type, and presence or absence of a herder (herders were generally absent when stock were grazed at remote pastures). Tigers and leopards attacked cattle, mostly in areas with less human activity. Dhole mostly killed sheep. Heavy predation on cattle by tigers and leopards is of serious concern because cattle are very valuable. Predation is known to be higher in heavily- or over-stocked areas (Oli et al., 1994; Jackson, 1999), and this sometimes leads to surplus killing (Stuart, 1988) as we too observed. In our study, this pressure was further compounded by transient grazers coming from outside the park.

Our analysis supported the general finding that where food – in this case domestic stock – is abundant, predation losses increase, leading to predation hotspots (Nass et al., 1984; Yom-Tov et al., 1995). In the French Jura, roe deer (*Capreolus capreolus*) abundance was greater in predator hotspots and areas rich in roe deer were more intensively used by lynx (*Felis lynx*), producing higher encounter rates between sheep and lynx (Stahl et al., 2001). Our study identified heightened predation levels, where livestock were heavily grazed in forest habitats used by predators. The hotspots for tigers and leopards did not overlap, except in Langthel, raising the possibility that leopards are excluded by tigers. It is important to educate farmers to avoid grazing their livestock in predator hotspots or, at least, to be especially vigilant there.

In other parts of the world, herd management has also been identified as a factor in predation rate (Robel et al., 1981; Oli et al., 1994; Mishra, 1997; Landa et al., 1999; Linnell et al., 1999; Bhatnagaer et al., 2000; Jackson and Wangchuk, in Litt.; Allen and McCarthy, in Litt.; Patterson et al., 2004) and it is obvious that more thoughtful and informed herd management has the potential to reduce losses (Rasmussen, 1999). Herds taken to graze different pastures were generally left unattended and were clearly associated with higher rates of reported predation, while the large numbers of households

that grazed their livestock in the forests near the village suffered fewer losses. Grazing in distant pastures has similarly been found to increase the vulnerability of livestock to predation elsewhere (Jackson, 1996; Mishra, 1997; McCarthy, 2000; Allen and McCarthy, in Litt.).

Nocturnal management of livestock in some villages was very poor. Approximately 60% of households did not pen their livestock, and when livestock were penned, the pens were poorly constructed and unlikely to be predator-proof.

Reported predation increased significantly between 1993 and 2001, with leopards being the main cause of livestock loss. Some respondents' claimed that increased predation was linked to the establishment of the park in 1993 and implementation of the Forest and Nature Conservation Act of 1995. Increases in depredation rates following establishment of protected areas and implementation of conservation rules have similarly been documented in India (Saberwal et al., 1994; Mishra, 1997; Jackson and Wangchuk, in Litt.; Maikhuri et al., 2001), Nepal (Oli et al., 1994; Studsrod and Wegge, 1995), and Tibet (Allen and McCarthy, in Litt.; McCarthy, 2000).

Our study suggests that a combination of lax herding, poor guarding practices, a lack of favourable cover, poor habitat condition and high predator densities combine to create conditions where depredation rates are high. Conservation success (apparently leading to a perceived increase in predator populations) and the imposition of strict restrictions on farmers' use of resources (by the Forest and Nature Conservation Act of 1995) may have exacerbated human–wildlife conflict in the park. With losses during 2000 almost equal to annual cash incomes for those households affected, there is an urgent need to address this problem. We suggest that government managers, researchers, and farmers work together to devise a conservation management strategy that accommodates the needs of both wildlife and farmers. Restoration of an adequate natural prey base together with a programme of compensation for livestock lost may minimise conflict by increasing farmers' tolerance of wildlife (Michelle and Smirnov, 1999). A suitable management strategy should be evidence-based, and should explore methods to improve livestock management, monitoring the abundance of prey species, assessing the ecological impacts of over-grazing, and the feasibility of a sustainable compensation scheme. In the short-term, a ban on transient grazers entering the park and on grazing in predator hotspots should reduce encounter rates between livestock and predators. Alternative benefits from community-based ecotourism, livestock intensification, and sustainable harvesting of non-timber forest products should be explored as such benefits could generate more favorable attitudes towards conservation (Conforti and de Azevedo, 2003). Emphasis should be on involving farmers in managing human–wildlife conflict and developing ways of enabling them to benefit from the existence of the park.

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