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Pastoralist experience and tolerance of snow leopard, wolf and lynx predation in Karakoram Pamir Mountains

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Abstract

Human-carnivore conflict is a common conservation and livelihood issue in mountain communities. This study was conducted to understand nature and extent of socio-ecological interaction between pastoralism and wildlife conservation in cold deserts of Karakoram Pamir Mountains (KPM) between China and Pakistan. Study revealed that livestock depredation is a burning issue in KPM with varying intensity from place to place, depending upon wild prey abundance, herd size, herding practices, predator type and age. Snow leopard, wolf and lynx were the major predators, while Brown bear despite its presence was reported being less fatal to livestock. Snow leopard killed highest number of animals (88.7% n=1440) mostly sheep and goats whereas, wolf killed more juvenile yaks. Lynx was found occasionally predating on young domestic crop. Highest number of kills was recorded from pastures during summer months (July-Aug) when animals were free grazing or were kept inside pens at night. Wild prey base being abysmally low, livestock seemed offering a considerable portion of diet to carnivores. Despite considerable losses from carnivores, more respondents in KNP (Pakistan) buffer zone had sympathies for predators compared to those in TNR (China) who were annoyed of the carnivores. Although people attributed escalating human-carnivore conflict to a higher level of protection to wild animals in Protected Areas (PA) but efforts are still needed to judiciously integrate conservation with local livelihood and development needs, otherwise herders may continue losing their livestock to predators and retaliatory killing of endangered carnivore species i.e., Snow leopard and Wolf may continue unabated and would further destabilize the fragile mountain ecosystem.

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Introduction

With the apparent increase in population of domestic animals, livestock predation by large carnivores has increased and resultantly retaliatory killing of predators by pastoralists has now become a major conservation concern worldwide (Jackson *et al*., 1996; Jackson & Wangchuk, 2001; Mishra, 1997; Oli *et al*., 1994) and conservationists are raising alarms over human-wildlife conflict (Mech 1995; Western 1997; Breitenmoser 1998; Karanth and Madhusudan 2002). The conflict is emerging primarily because of poor understanding of the social, economic and ecological interaction between wildlife and herding communities where pastoralism is the major land use (Bagchi & Mishra, 2006). Approximately 25% of the world's land surface supports about 20 million pastoral households (around 200 million people) who keep livestock under extreme conditions on marginal rangelands which cannot be utilized otherwise for agricultural productivity (Degen, 2006).

The mountains of Asia harboring snow leopards and other large predators have long supported a wide array of large mammals and livestock coexisting since ancient times (Brower 1991; Fox *et al*., 1994, Schaller, 1998) where excessive grazing and constant trampling by ever increasing numbers of domestic herbivores have led to a widespread degradation of fragile alpine meadows and shrub land ecosystems, influencing the survival of wildlife (Fox *et al*., 1994, Jackson *et al*., 1996). Just other mountainous areas, livestock predation by snow leopard and other carnivores has been an important cause of trepidation amongst pastoralists in the Karakoram Pamir mountains, where snow leopard (*Uncia uncia),* Tibetan gray wolf (*Canis lupus chanco)* and Eurasian lynx *(Felis lynxisabellina)* are thought to be the major carnivores just like in trans-Himalayas (Fox, *et al.* 1991; Schaller& Kang, 2008).

The predators attack on livestock grazing inside or close to protected areas and often venture into cattle-sheds to take stock, and pose risk to human and damage local livelihoods, which provoke farmers to retribution (Conforti & de Azevedo, 2003). The clash particularly becomes serious; when endangered species are involved and rural livelihoods are threatened (Mishra, 2001; Saberwal *et al*., 1994).

Apart from socio-economic factors and bio-physical environment of individual pastures, predation also differs by location, prey type, season and herding systems, which are mostly site specific (Gurung&Thapa, 2004). It is also affected by increase in local abundance of carnivores, increase in livestock populations or decline in wild prey populations, increasing human populations, loss of natural habitat, and, in some regions, growing wildlife populations resulting from effective conservation initiatives (Saberwal *et al*., 1994). However, Treves & Karanth (2003) confirmed large carnivores specialize for predation on ungulates as carnivores readily take to killing livestock when opportunities arise in the area with higher livestock and lower wild ungulate abundance compared to relatively lower livestock and higher wild ungulate abundance areas but there could be other proximate causes responsible for the escalating levels of carnivore predation on livestock, and thus effect the distribution, density and dynamics of mammals in the region (Messier 1994; Oksanen, 2001; Festa-Bianchet *et al.* 2006; Crete 1999).

Normally an adult snow leopard is estimated to be 45 kg, requiring 1.5 to 2.5 kg meat per day (Wemmer and Sunquist, 1988). Decline in the number of hoofed prey may put Snow leopard into problems of survival and a shortage of normal prey may push the predator to switchover on marmots for up to 25% of its summer diet in alpine habitats (Bloom, 1995). Schaller (1977) reported wolf diet in Chitral and in Kunjerab comprised of domestic stock (38%), Himalayan ibex *Capra ibex* (37%), marmots *Marmota caudate aurea*(17%), Ladakhurial (*Ovisvegnei*), Marco Polo sheep *Ovisammonpolii* (2%), cape hare (2%) and grass (2%) whereas, Lnyx preyed on small and meso-prey

i.e., cape hare, wolves and occasionally marmots or, in Shimshall valley, the young of Bharal (Nawaz, 2009).

The Karakoram Pamir mountains harboring significant populations of endangered mammals, notably Marco Polo sheep and Snow leopard, constitute one of the most important wildlife areas in the mountains of Asia (Schaller *et al.*, 1987; Khan, 1996; Schaller & Kang, 2008) is subject to extensive pastoral use. Traditionally, ibex, blue sheep and Marco Polo sheep had been hunted excessively for food by local inhabitants and Chinese labor during the construction of the Karakoram Highway (KKH) in early seventies (Schaller, 1987). Overgrazing by livestock and removal of sparse natural vegetation for fire wood by locals has turned the rangelands into desert (Schaller *et al.*, 1987; Khan, 1996; Schaller & Kang, 2008). Excessive use of grazing lands together with illicit hunting deplete the density and diversity of wild herbivores (Mishra and Madhusudn, 2007)and intensify livestock depredation, which often annoy pastoralists to snow leopard and other carnivores disturb ecological functioning of PAs(Mishra *et al.*, 2003; Jackson *et al.*, 1996; Mishra 1997; Hussain 2003; Bagchi*et al.,* 2004). Engaging local residents in planning and management of PA scan thus be a central strategy to strengthen local support for PAs as community perceptions and attitudes effect the social and ecological interactions and thereby conservation effectiveness (Ferreira and Freire, 2009). Although communities, whose livelihoods directly depend on exploitation of local natural resources usually come into conflict with PAs (Anthony, 2007) but PAs also benefit rural inhabitants by providing access to road networks, employment, foreign aid, increasingly scarce ecosystem services and areas of safety during strife (Scherl *et al.*, 2004; Oli *et al.*, 1994).

This study was specifically designed to understand the nature, cause and extend of the pastoralism – wildlife conservation conflict in Karakoram Pamir Mountains that coexist since ancient times but not explored yet. This study aimed at investigating various aspects of the social, economic and ecological interactions among pastoralists, carnivores and herbivores; cognizant of prevailing animal competition, coexistence and people's perception of wildlife conservation to suggest effective remedies benefiting both pastoralists and wildlife species of the Karakoram Pamir mountain region.

Materials & methods

Study Area

The study area comprised of some 20,000 km² area in the Karakoram Pamir trans-border area (KP TBA) between China and Pakistan that is known to have significant populations of ungulates and carnivores i.e., Marco Polo sheep, snow leopard and blue sheep (Schaller& Kang, 2008).Eight major buffer zone valleys from both KNP and TNR were accessed for data collection on different social, economic and ecological parameters (Fig. 1).

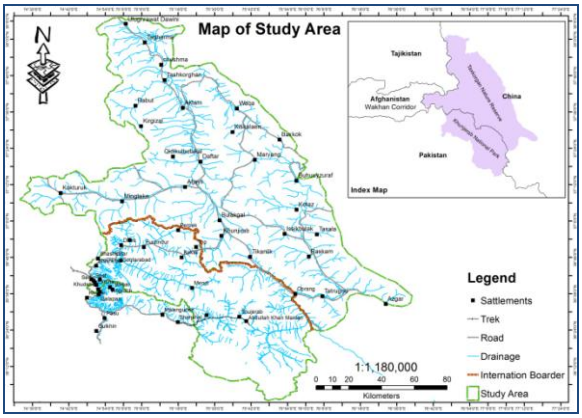

Fig. 1. Map of Karakoram Pamir Trans-border Area and study sites.

The Khunerab National Park (4455.06 km²: 74° 52' 33.21" E, 36° 56' 11.63"N to 76° 02' 26.96" E, 36° 13' 24.04" N) and the ecologically contiguous Taxkorgan Nature Reserve(15863 km²: 35°40'N-37°25'N, 74°30'E-76°50'E) were established to protect Marco polo sheep, snow leopard and other rare and unique wildlife species in their natural habitats, in 1974 and 1984, respectively(Schaller, 1987; Khan, 1996; Khan *et al.*, 2011). Both the mountain Reserves lie in the alpine zone with harsh winters, mild autumn and pleasant summers. Much of the terrain is too high

and arid to support dense vegetation. Below 3200m ASL, there are usually cliffs, screes, sand and silt, a desert that is so dry that few plants survive except along streams. Native trees like willow, tamarix, popular, juniper and birch are found in low-lying valleys, a few being as tall as 10m, greatly modified by human and livestock use (Schaller, 1987, 1988).

The PAs are known to have good populations of snow leopard, Brown bear, Marco polo sheep, blue sheep, Himalayan ibex, Golden marmot and Tibetan ass (Schaller, 1987; Wegge, 1988; Rasool, 1990, Khan, 1996; Ablimit *et al.*, 2011).Like the rest of trans-Himalayas, high mountain pastoralism is a prominent way of life and a major source of living (Fox *et al.*, 1994; Mishra, 2001). Some 12,750 Kirgiz, Tajik and Brusho people live in and around the protected areas and graze their livestock (77,000; 80% sheep & goats) on pastures and collect firewood from scattered forests and rangelands inside the Reserves (Beg, 2010; Zou *et al.*, 2010).

Survey

A total of 621 herder families, almost 25% of the total households (2506) were selected from four major buffer zone areas of the PAs, using simple random sampling method(Wang, 2009; Wegge, 2012)for semi-structured interviews held during May – September 2011. Respondents, mostly head of the family, either male or female having at least 5years'experience of pastoral life and herding on pastures, were contacted in person and interviewed. Various open and closed ended questions from the questionnaire were first read and explained and then appropriate responses were recorded instantly. Additional information acquired during the interview was also recorded in the note book. Questions were asked to get information about the household demography, education, livelihoods, reason for herding, number of livestock owned; herding practices; number of livestock lost to predators(during the last five years; 2007-2011); perceived problem carnivores; resource use and conservation issues. Livestock owners' perception of the conflict, losses inflicted by predators and their attitude towards carnivores was inquired during the interview. For every animal lost, species, sex, age, year, season, place, situation, herding style, and predator species were recorded. Herders were also questioned about extent of predation, possible mitigation measures, their opinion about conservation of predators and the legal status of their lands (tenure) surrounding the park during the interview.

The prevailing market value for each type of livestock was determined by interviewing herders, traders, and butchers at the nearest towns of Sost and Taxkorgan and their mean value for each type was used to estimate financial losses inflicted by different predators during the study period. Information about livestock holdings, predation losses and grazing lands was also acquired from the archival records maintained by the relevant departments and cross checked. Utmost care was taken to avoid assigning depredation cases mistakenly to either Snow leopard or Wolf and Lynx (Bagchi& Mishra, 2006; Namgail *et al.*, 2007). However, to minimize the likelihood of receiving inaccurate information, relevant PA staffs, agriculture and livestock department officials were also inquired about the key statistics.

Analysis

Field data for all variables were analyzed inSPSS version 13 software package (SPSS Inc., Chicago, Ill). Anderson-Darling test was used to test field data for normality. Analysis of variance (ANOVA) was applied to test variation in predation losses across four study zones. Pearson correlation(r) was used to test relation between livestock and total household income; predation and places (study zones); and the predators species and prey (livestock) killed. Chi square (χ^2) association test was used to assess statistical association between respondent's level of education and their attitude towards predators and the association between predators and livestock herding patterns. Strengths of statistical associations were further tested through percentage, mean and mode comparisons. Fatal predations by different carnivores i.e., snow leopard, wolf and lynx were compared using

Man-Whitney U test. We used Two Sample T-test to ascertain reliability of greater kills by snow leopard compared to animals killed by wolf and lynx. Predator 'hotspots' were characterized following Spearing (2002) 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 each Protected Area, and 'herd' is the total number of livestock owned by an individual farmer).

Results

Livelihood strategies

Financial valuation for both capital and annual incomes from domestic stock was estimated using prevailing average prices of the goods and products in the local markets. Goats seems to have maximum contribution in both capital (53.4%) as well as annual income categories (64.9%), followed by Yak-Sheep (32.9%), sheep (10.4%) as shown in Table4. Cattle reflected minimum share (< 3.5 %) in either categories of income from livestock. Pearson correlation showed strong positive correlations both for livestock selling and capital income ($r = 1.0$, $p < 0.05$) as well as for livestock owned and annual income ($r = 1.0$, $p < 0.05$). Poultry was kept to meet domestic food requirements only. Cultivable landholding was comparatively small (seldom exceeding 1 ha HH^{-1}), often fragmented and less productive. Cropping season was short (5-6 months) being in single and marginally double cropping zones. Mixed mountain agriculture was dominant particularly for subsistence in the single cropping zone at higher elevations where wheat, potato, barley and buck wheat were grown. Apart from income, livestock was also reared as a symbol of status, prestige and a movable asset for use on occasions of pleasure and sorrow in their routine rural life.

Pastoralism and herd dynamics

In 2009-2010, almost 95 percent of households (n=2506) reared a total of 160721 heads of livestock with an average herd size of 64 animals per household in the entire study area (Table 1). Average herd size per household was greatest in Taxkorgan (68 animal heads HH^{-1}) followed by Shimshal (22) and Ghulkin (11). Khunjerab area had the smallest herd with 8 animals per household on average. Only 5% of the households did not own any livestock. Herd composition also varied greatly with a greater proportion of goats (61.9%) than sheep (22.75%), cattle (8.82%) and yak (3.36%). Shimshal had highest proportion of goats (67.4%, n=10385) followed by Taxkorgan (64.2%, n=141065) whereas, Khunjerab (57.0%, n=5026) and Ghulkin (35.56%, n=1739) had more sheep than others. Majority of the households (71.43%), used to graze their livestock in pastures during summer months (May – Aug) while a few (28.57%) grazed their animals on fallow lands near villages even during summer. Livestock predation was significantly and positively correlated with the herds that were grazed on high land pastures (Pearson correlation $r=0.957$; $p < 0.05$) but not with the herds grazed near the village. In summer, majority of the livestock on pastures was grazed attended during the day time and kept in corals at night whereas, down in villages' animals were either tethered or grazed on nearby fallow lands and kept in sheds often next to their houses at night. Most of the fatal kills by predators (92.8%, n=806) had happened in summer pastures while attended grazing (50.5%, n=748) compared to unattended grazing (17.6%, n=748) and a lesser number was attacked down in villages (7.2%, n=806) during both attended as well as unattended grazing. A considerably higher number of livestock (31.8%, n=748) on pastures was attacked in pens at night (Fig 2). Predation seems to have a strong association with herding styles used by herders to graze and keep their stock on pastures ($\chi^2 = 81.044$, DF = 2, P= 0.000). Although majority (> 60%) of the stock had been penned up at night but higher incidence of fatal kill inside pens particularly at night is a question about predator proof designing of the corals, and greater number of attended animals compared to unattended non-lactating animals.

Table 1. House hold and zone wise size and composition of livestock herds in the study area (KP TBA).

Villages	HH	Goat	Sheep	Cattle	Yak	*Others	Total
Khunjerab	306	1536	2870	410	180	30	5026
House hold (average)		5.0	1.9	0.1	0.4	0.2	6.7
Percent of herd		30.56	57.10	8.16	3.58	0.60	
Ghulkin	140	324	620	537	38	220	1739
House hold (average)		2.3	1.9	0.9	0.1	5.8	11.0
Percent of herd		18.63	35.65	30.88	2.19	12.65	
Shimshal	360	7000	1500	670	1200	15	10385
House hold (average)		19.44	0.21	0.45	1.79	0.01	21.91
Percent of herd		67.40	14.44	6.45	11.56	0.14	
Taxkorgan	1700	90694	31579	899	12756	5137	141065
House hold (average)		53.35	0.35	0.03	14.19	0.40	68.32
Percent of herd		64.29	22.39	0.64	9.04	3.64	
Total	2506	99554	36569	2516	14174	5402	160721
Cumulative percent		61.94	22.75	1.57	8.82	3.36	

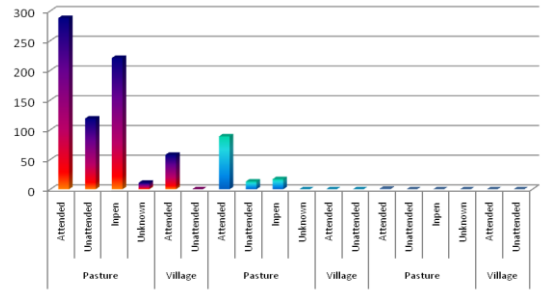

Fig. 2. Graph showing relation between kills and herding patterns in pastures and villages.

Predation losses and patterns

Totally, about 1440 domestic animals were preyed upon by predators during the study period. Predation varied greatly from place to place. Most were predated in Khunjerab (579) followed by Taxkorgan (577), Shimshal (212) and Ghulkin (72). Amongst prey victims, goats suffered a lot from predators (52%, n=1440) compared to sheep (36%), yak (8%) and cattle (3%) probably because of higher goat population. Goat kills were highest in Taxkorgan (333, n=758) followed by Khunjerab (295, n= 758). Sheep were killed more in Khunjerab (241, n=520) and more yaks were killed in Shimshal (60, n= 117) and Khunjerab (26, n=117) areas. On average, every household lost 152 goats, 104 sheep, 23 yaks and 9 cattle during the study period. Cattle in Taxkorgan escaped of predators in 2010 (Table 2).

Table 2. Livestock heads killed by predators during last five years (2007-2011) in KP TBA.

	Year	Goat	Sheep	Cattle	Yak	Total
Khunjerab	Total (5 years)	295	241	17	26	579
	Average (5 years)	59	48	3	5	116
	Percent HH loss per annum (5 years)	19	16	1	2	37.84
Ghulkin	Total (5 years)	61	11	0	0	72
	Average (5 years)	12	2	0	0	14
	Percent HH loss per annum (5 years)	9	2	0	0	51.43
Shimshal	Total (5 years)	69	55	28	60	212
	Average (5 years)	14	11	6	12	42
	Percent HH loss per annum (5 years)	4	3	2	3	58.89
Taxkorgan	Total (5 years)	333	213	0	31	577
	Average (5 years)	67	43	0	6	115
	Percent HH loss per annum (5 years)	3.92	2.51	0.00	0.36	33.94
Total	Total in all study zones	758	520	45	117	1440
	Average (5 years)	152	104	9	23	57.6
	Percent HH loss per annum (5 years)	6.05	4.15	0.36	0.93	2.30

Respondents attributed all types of livestock predation to three major carnivores including snow leopard, gray wolf and Himalayan lynx. Brown bear (*Ursusarctos*) despite its presence was not blamed for any kills. Unlike predation in the neighboring range countries, snow leopard was held responsible for highest predation on domestic stock accounting for 88.7% of the total losses (n=1440)followed by Wolf

(11.1%) and lynx (0.07%). There was an extremely high correlation in predation patterns of snow leopard and wolf (r = -0.999 P < 0.030) but snow leopard appeared to have killed highest number of livestock compared to wolf and lynx (W = 9752.5, P < 0.001 at 5% CI). Majority of snow leopard kills were goats (55.6%, n=1278) followed by sheep (36.8%) and yak (5.5%) whereas, wolf killed more sheep (31.06%, n=161) than yaks (29.19%), goats (28.75%) and cattle (11.18%). Lynx killed young of the sheep only.

Moreover, livestock predation also appeared to be a seasonal phenomenon highly associated with the herding patterns adopted by herders in the study area (χ^2 = 81.044, P < 0.001).Highest number of animals was killed in pastures during summer (May till August) compared to spring, autumn and winter seasons (Fig 3).

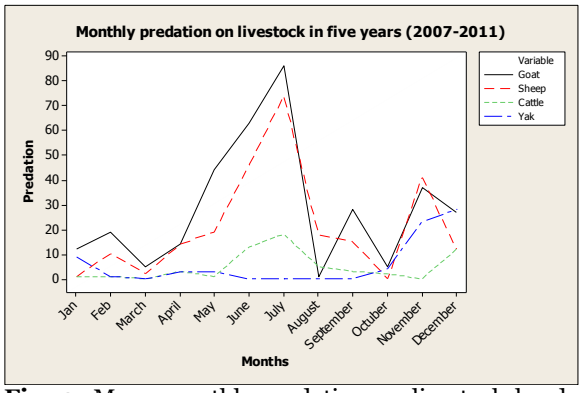

Fig. 3. Mean monthly predation on livestock heads (self-reported).

When compared the livestock kills across different study zones, maximum animals were found to be persecuted by large carnivores in Khunjerab (40.35%, n=1440) followed by Taxkorgan (40.07%, n=1440), Shimshal (14.97%, n=1440) and Ghulkin (4.79%, n=1440) as obvious from Fig 4.However, intensity of predation in terms of total stock and area was considerably high in Khunjerab than Taxkorgan and Shimshal areas. Average annual livestock loss in the study area during the past five years was about 58 animal heads per year, accounting for an average loss of 2-3 animals per household per year.

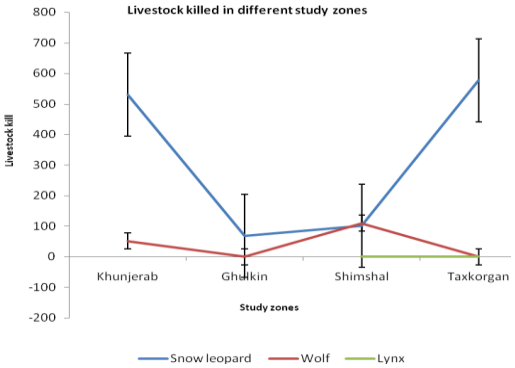

Fig. 4. Livestock predation in different study zones (2007-11).

Economic valuation of livestock losses

A total financial loss arising from livestock slay by carnivores during the study period was estimated at US $ 284480.87 for the entire study area during 2007-2011. The majority (81.3%) of these financial losses were attributed to Snow leopard kills followed by wolf (18.5%) and lynx (0.03%) categorically (Table 3). Maximum loss of US $ 125805.57 was incurred by Snow leopard killing goats, than yak (US $ 50555.40) and sheep (US $ 41778.30). Wolf inflicted heavy economic losses by killing yaks (US $ 33944.34), goats (US $ 7666.82) and cattle (US $ 7000.02) incurring some US $ 21.17 loss per household per year. Lynx had killed only sheep inflicting a total loss of US $ 88.89 in the entire study area during five years. Both snow leopard and wolf seem to have fulfilled their biomass need by killing easily available domestic stock (11.12 animals km^{-2}) than scarcely available wild prey (1.98 animals km^{-2}) arguably in accordance with their body size, weight and biomass requirements.

Financial losses incurred by large carnivores *viz.,* snow leopard, wolf and lynx were statistically compared using Two-sample T-test which proved that the kills by snow leopard had greater financial implications than that of wolf (T = 1.71, DF = 3.0, P = 0.093) though both the livestock kills and their economic losses from predation did not differ significantly among different study zones during the five study years (F = 0.73 (cal.) and F = 5.86 at 5% level, P = 0.586).However, the lack of difference

between the sample means may be due to differences between the population means or due to the variation within populations as experienced by Weiss (2005).

Table 3. Economic valuation of livestock losses from predation during 2007-2011 (US $).

Livestock	Unit value	Snow leopard	Wolf	Lynx	Overall
Goat	166.67	771.00	46.00	0.00	817.00
Loss (total)		128502.57***	7666.82**	0.00	136169.39
Loss (HH)/year		51.28	3.06	0.00	54.34
Percent of capital income		0.77	0.05	0.00	0.82
Sheep	88.89	470.00	50.00	1.00	521.00
Loss (total)		41778.30*	4444.50	88.89	46311.69
Loss (HH)/year		16.67	1.77	0.04	18.48
Percent of capital income		1.29	0.14	0.00	1.42
Cattle	388.89	27.00	18.00	0.00	45.00
Loss (total)		10500.03	7000.02*	0.00	17500.05
Loss (HH)/year		4.19	2.79	0.00	6.98
Percent of capital income		1.07	0.72	0.00	1.79
Yak	722.22	70.00	47.00	0.00	117.00
Loss (total)		50555.40**	33944.34***	0.00	84499.74
Loss (HH)/year		20.17	13.55	0.00	33.72
Percent of capital income		0.49	0.33	0.00	0.83
Total losses					
Loss (total) in five years		231336.30	53055.68	88.89	284480.87
Percent of total losses in five years		(81.31)	(18.64)	(003)	(100)
Loss (HH) per year during five years		92.31	21.17	0.03	113.51
Percent of capital income		0.744	0.170	0.0002	0.910

Local perception, attitude tolerance towards predators

Of respondents, 53% (n=621) perceived wolf being highly dangerous, 35 % said dangerous and rest of 12% considered it being either little or not dangerous to livestock whereas, 47% respondents considered snow leopard highly dangerous and 53% deemed dangerous compared to wolf (35%), lynx (4%) and brown bear (5%). Around 48% and 33% of the respondents considered lynx and brown bear as little or not dangerous at all (Fig 5). Majority of the respondents argued that predation by snow leopard and wolf had increased during the last one decade possibly due to their enhanced protection since notification of the national parks (51%) or wild prey base decline (49%) due to habitat degradation and excessive hunting for meat and trophies in the peripheries of protected areas. There was no consensus on better ways to mitigate predation threat to their livestock but a noticeable number of respondents (39%) asserted to improve wild prey base through effective protection and habitat restoration measures involving local communities and compensating them for their livestock losses.

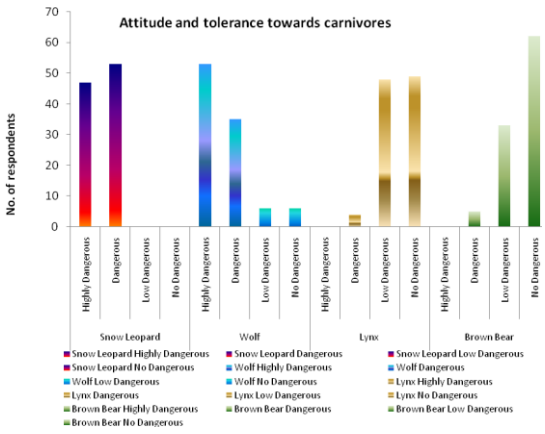

Fig. 5. Local perception, attitude and tolerance towards carnivores in study area.

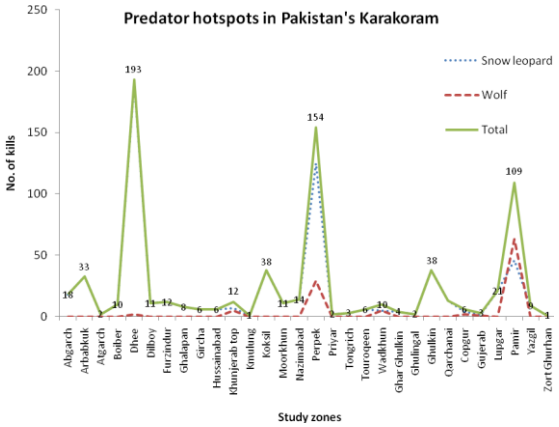

Fig. 6. predator hotspots in Pakistan's Karakoram (case of KNP).

There was a strong association between respondent's education and their attitudes or tolerance towards carnivores in the study (χ^2 = 10.772, DF = 4, P value = 0.029). Thirty-eight percent of the educated (> primary level education) and uneducated (< primary level) respondents suggested maintaining current population of carnivores in the study area. A larger group of 36.6% (educated) and 29.1% (uneducated) respondents proposed to increase whereas, 13.3% (educated) and 25.4% (uneducated) suggested decreasing their population in the study areas. Only a small fraction of educated respondents (5.5%) and of uneducated (2.7%) suggested complete elimination of the predators from the study area (Table 4). Positive attitude and tolerance of the majority of respondents [33% (increase) and 38% (maintain)] towards carnivores reflected their appreciation and awareness of the prey-predator ecological relationship compared to a smaller group (< 5%) which showed resentment against predators.

Table 4. Education verses attitudes and tolerance towards carnivores.

Category	Increase	Maintain	Reduce	Eliminate	Don't Know
Educated	33 (36.67)	35 (38.89)	12 (13.33)	5 (5.56)	5 (5.56)
Uneducated	32 (29.09)	42 (38.18)	28 (25.45)	5 (4.54)	3 (2.72)
Total	65 (32.50)	77 (38.50)	40 (20.00)	10 (5.00)	8 (4.00)

Identifying predation hotspots

The predator hotspots were identified for Pakistan's Karakoram following the Spearing criteria (Wang, 2008) and ranked for two top predators viz., Snow leopard and Wolf as kills by lynx were negligible (Fig. 2). Dhee having the highest score for all the three criteria was the top hotspot for snow leopard followed by Perpek and Pamir where Snow leopard was found to kill about 29%, 19% and 7% of the total livestock, respectively. Wolf kills scored highest in Pamir and Perpek with a percent kill of around 63% and 29%, respectively. For both predators, predation hotspots were Dhee, Perpek and Pamir with a percent total kill score of 29%, 23% and 15% respectively. Predation by carnivores varied spatially with snow leopards predating comparatively at lower altitudes and wolf predominating higher elevations on far off pastures. Yaks were more killed by wolf than snow leopard in Pamir area of Shimshal valley. Having no sufficient point data about predation of livestock in Taxkorgan, it is difficult to identify predation hotspots for TNR.

Discussion

High mountain pastoralism is a prominent way of life and a major source of livelihood in the mountain communities of Karakoram-Pamir border region. As evident from the study, people prefer goats, sheep and yak compared to other types of domestic stock, probably due to higher milk productivity, longer lactation periods, higher fat contents (in sheep milk) for high energy needs, and particularly for their ability to milk during dry season and droughts. Milk provides valuable products for pastoralists *i.e.,* butter, yoghurt, ghee and curds that are used by herders. Moreover, sheep and goat's contribution to soil fertility and moderating nutrient flows, through

manuring (droppings), particularly on very small fragmented and intensively cultivated land holdings might be another reason for preferring small ruminants in the study area. In summer, herds are maintained in pastures for grazing, first on sub-alpine pastures and then on alpine pastures as pastoralism is the predominant land use mainly due to fragmented landholding inadequate to grow enough fodder for livestock. Only in winter, animals are kept at lower altitudes, where they are supplemented with maize stover, wheat straw and hay. The study findings about livelihood options and summer pasturing are mostly in line with those of Schaller 1977, 1988; Schaller *et al.*, 1987; Zhou *et al.*2010; Beg,2010; Degen, 2006; Bagchi and Mishra, 2006; Fox *et al.*, 1994 and Mishra, 2001 from the neighboring countries of India, Nepal, China and Pakistan.

Livestock predation by snow leopard and other carnivores is an important cause of anxiety for herders in the Karakoram Pamir border area, who may resort to retribution in extreme cases. In our study, predation varied greatly from place to place, depending upon herd size and composition, and herding practices such as the presence or absence of a herder with livestock and structure of night pens. Largest numbers of animals were killed in Khunjerab, Taxkorgan and Shimshal where herd size was large, composition was diverse and stock was abundant. Previous research has reported similar findings from Annapurna area in Nepal and Tibet (Oli *et al.*, 1994; Jackson, 1999). Mann-Whitney tests proved higher number of kills by Snow leopard than wolf and lynx. Goats and sheep were more vulnerable to snow leopards than wolf which killed more yaks. Lynx appeared to attack lambs only.

Animals of comparatively smaller size and weight were attacked by snow leopards compared to wolf, which killed yaks tactfully, sometimes tending them on to ice in the inner shady darker valleys in Shimshal area. Wolf was reported to have killed <3 years old yaks apart from goats and sheep, whereas lynx was reported to had killed small and meso prey types *i.e.,* lambs and kids only. Our results endorse the findings of Gurung and Thapa, 2004; Mishra, 2001; Conforti and de Azevedo, 2003; Saberwal *et al.*, 1994; Fox *et al.*, 1991; Schaller *et al.*, 1988; Schaller& Kang, 2008; Mishra, 1997; Treves & Karanth, 2003; Mishra and Madhusudn, 2007; Mishra *et al.*, 2003; Bagchi*et al.,* 2004; Wegge, 1988; Nawaz, 2009; Namgail *et al.*, 2007; Oli, 1994; Sherpa and Oli 1988; Sangay and Vernes, 2008. However, contrary to the findings of Dar *et al.*, 2009 and Namgail *et al.*, 2007; wolf killed lesser number of livestock than snow leopard, which might be due to leopard's higher encounter rate with livestock reflecting its healthy population apart from livestock abundance in the study area.

Interestingly, all the three carnivores appeared to predate antagonistically, showing a clear partitioning of their niches in the study area. Results revealed a strong negative result for carnivore selection of prey species (livestock type). Despite the presence, brown bear was not blamed for killing of any livestock types in any part of the study area. Compared to villages, more animals were killed in high land pastures confirming that pastoralism is still a prominent land use in the area and possibly when animals were mostly free ranging in high land pastures mostly far off villages without appropriate guarding and when penned up in roofless corals at night. Contrary to similar studies from India (Bagchi, Mishra & Bhatnagar, 2004), Nepal (Oli*et al.*, 1994), Bhutan (Wang, 2006, 2009) and China (Schaller, 1987) numbers of attended kills on pastures while grazing and attacks in pens at night were higher than both unattended free grazing in pastures as well as in villages. Such anomalies might be due to acute shortage of wild prey or eco-behavioral changes among carnivores that co-exist with pastoralists since decades (Brower 1991; Fox *et al.*, 1994, Schaller, 1998; Jafri, 1995) though such a co-existence on shared habitats sometimes had been causative of transmitting fatal diseases from livestock to wildlife i.e., *Sarcoptesscabiei* infection caught by Blue sheep in Shimshal valley (Dagleish *et al.*, 2007).

Our study also supported the general perception that predation depends to a greater extend on availability of food; abundance of wild prey or livestock and age of the predator in our case (Noss, 1994; Dar *et al*., 2009). Higher predation was recorded from the places where natural prey was short and alternate prey (livestock) was more numerous. However, the seasonal pattern of predation was more like a function of herbivore population dynamics in the study area, greatly influenced by external factors and snow cover change. Notwithstanding the earlier observations (Lovari *et al*., 2009) that most of the predation occurs in winter during which carnivores descend down after wild as well as domestic herbivores, in our study summers got highest values for overall livestock predation, irrespective of the predator species, which might has happened because of the livestock taken to higher altitudes in peak summer (June-August) for grazing on new growth (most palatable grasses) appearing with gradual upward shifting of the snow line. An intrusion into the felid's habitat will ultimately increase the probability of encounter/interaction with snow leopards and chances of their retribution by herders will increase, which will ultimately affect the entire ecosystem (Pearson 2006; Scheffer& Carpenter, 2003).

Another significant aspect of our study is about wild and domestic herbivore coexistence and competition on shared habitats. The classical theory of 'niche' partitioning emphasizing inter-specific competitions and resource limitations in herbivore co-existence seemed not qualifying as such for Marco polo sheep in the Qarchanai valley of KNP. The study showed that population of Marco polo sheep had decreased considerably in Qarchanai (the only lambing habitat of Marco polo sheep in KNP) with a gradual decrease in the number of domestic herbivores grazed in the area, probably due to low annual recruitment to the population caused by high intake of lambs by the predators in the absence of livestock i.e., sheep and goat. Results are in agreement with Chundawat (1988) who studied that if the ratio goes below forty five blue sheep to one snow leopard, the blue sheep population will face a decline and smaller animals, as alternate prey in the diet of snow leopard, become critical when its major prey is not readily available. Although such density dependent interactions between domestic and wild herbivores have also been debated in many other regions by Stover, 1985; Prins, 1992; Fleischner, 1994; Noss, 1994;Voeten&Prins, 1999; Mishra, 2001).

Pastoral societies raise livestock often under extreme conditions on marginal rangelands that cannot be cultivated or used for other agricultural purposes to acquire milk, meat, wool/hair, leather and dung in addition to cash and transportation. Most of the livestock (99% sheep, 97% goats and 95% cattle) are managed by poor under vertical transhumance pastoral systems*(Transhumance is the seasonal movement of people with their livestock between higher pastures in summer and lower valleys in winter)*where animals serve as backbone of the household economy and even smaller predation may inflict larger financial implications to pastoralists. Each year Snow leopard, Wolf and other carnivores kill a number of these livestock resulting in significant economic losses for the poor people living in such remote areas and are in turn killed in retaliation. Majority of the kills have occurred in Dhee, Perpek and Pamir which could be the predation hotspots in Pakistan's Karakoram where herders can be educated in carnivore behavior and safety measures and trained in making predator proof corals, helping them not graze their animals in such places or at least graze the animals attended during the day time and pen up them properly in predator proof corals at night, so losses to carnivores could somehow be controlled (Gurung and Thapa, 2004; Schaller *et al*., 1987 in China; Schaller *et al*., 1994 in Mangolia; Jackson, 1999; Jackson & Wang, 2004).

Pastoralists often have strong negative attitudes towards snow leopard, wolf and other carnivores as the escalating conflict threatens their survival (Mishra

et al., 2003). In our study area, heavy losses were incurred by predators accounting for US $ 285580 in five years, estimating US $ 21.17 per capita loss per annum, inflicting a loss of about 12% and 25% of the annual per capita income of herders in rural areas of Gilgit-Baltistan and Taxkorgan. Despite heavy capital and financial losses from Snow leopard, majority of the respondents perceived wolf more dangerous than snow leopard, brown bear and lynx. Higher predation by snow leopard was however argued to be an outcome of the enhanced protection of predators after establishment of Protected Areas, wild prey decline due to their excessive hunting for meat and trophies outside Protected Areas and habitat degradation.

Most of respondents (38.4%) from Pakistan side of Karakoram suggested maintaining or increasing current population of carnivores in the study area, despite the fatal killing of their livestock. No incidents of killing snow leopards in retaliation were reported rather two snow leopards captured from inside the cattle sheds amidst predation were released back into wild safe by locals. Such an attitude and tolerance might be due to higher literacy and better understanding of ecosystem functions and the benefits associated with wildlife, particularly in the form of trophy hunting programme in the buffer zone areas of Khunjerab National Park (Khan, 2012; Ablimit *et al.*, 2011; Mishra *et al.*, 2007).Like Oli and others (1994), only a small fraction of the respondents (<5%), perhaps who suffered most, suggested eliminating carnivores from the study area. Contrary of KNP, majority of people, particularly herders, living in the peripheries of TNR were strongly against carnivores (Schaller, 1977, 1987; Schaller & Kang, 2008), probably because of their livestock losses to predators, lack of compensation, lack of awareness, stewardship, involvement and benefit sharing out of the conservation and management of wildlife in the area.

Conclusion

Human-wildlife conflict is a burning conservation and livelihood issue in the Karakoram Pamir mountain region leading towards retaliatory killing of endangered snow leopards and other carnivores. A part from prey and predator population, predation is also influenced by changes in climatic conditions particularly changes in snow cover, which control vegetation, distribution of herbivore and thus presence of their predators in the ecosystem. Excessive grazing by livestock causes serious food competition with wild herbivores on shared habitats but simultaneously offer a major portion of biomass to carnivores in natural prey deficit situations. People's perception and attitude towards PAs and tolerance for carnivores depend on their understanding of ecosystem functions, prey-predator relationship and most importantly the economic benefits they enjoy through trophy hunting, ecotourism and other non-consumptive resource use practices. Devising a comprehensive integrated conservation and development strategy, accommodating both the needs of wildlife as well as pastoralists is required to restore natural prey base, compensation for framers against predation, training in early warning and predator proof coral designing, zonation, education and awareness raising can make PAs beneficial both to wildlife and human communities.

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