Is their any correlation between abundance of blue sheep population and livestock depredation by snow leopards in the Phu Valley, Manang District, Annapurna Conservation Area?

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By

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Abstract

This study was undertaken in the Phu valley of Manang district in the Annapurna Conservation Area, Nepal, Spring, 2004 and 2005.

I used the Snow Leopard Management Information System ("second order" survey technique), to determine the relative abundance of snow leopards in delineated areas in Phu valley. Transects routes were plotted by randomly selected feasible landforms such as along ridgelines, cliff bases and river bluffs where snow leopards sign is likely to be found. Altogether, 16 transects (total length of 7.912 km) were laid down (mean transect length=0.495 km). They revealed, 54 sign sites (both relic and non-relic) and altogether 88 signs (72 scrapes, 11 feces, 3 scent mark, 2 pugmarks and 1 hair) were recorded (6.8 site/km and 11.1 signs/km). There were 61.1% non-relic and 38.9% relic sites. The density of snow leopards in Phu Valley may be 4-5 snow leopards/100 km^2.It was found that the Ghyo block had the highest sign density (13.6 mean sign item/km) and Phu block (9.8 mean sign item/km) and the lowest in Ngoru block (3.9 mean sign item/km.).

For blue sheep, direct count method was applied from different appropriate vantage points (fixed-point count). I counted total individuals in each herd and classified all individuals whenever possible, using 8 X24 binocular and 15-60x spotting scope. A total 37 blue sheep herds and 1209 individuals were observed in 192.25 km^2 of the study area (blue sheep density, 6.3 km^2). Average herd size was 32.68. Herd size varied from 1 to 103 animals (the largest so far recorded). The average sex ratio male to female for the entire survey area was 0.67. Recruitment rate was 47.13. The ratio of yearlings to adult female was 0.45. In Ghyo block had total 168 blue sheep (area, 44.08 km^2 or 3.8/ km^2 i.e. 137.2 kg/ km^2). Blue sheep density in Ngoru block showed 4.7/km^2 (area, 65.47 km^2). Highest density of blue sheep among three blocks was recorded in Phu block, 8.9/km^2 (or 320 kg/km^2) in its 82.70 km^2 area.

A standard questionnaire was designed, and interviews conducted for relevant information was collected on livestock depredation patterns (total household survey). Out of 33 households surveyed, 30 reported that they had livestock depredation by the snow leopard in 2004. Altogether 58 animals were reportedly lost to snow leopards (3.1% of the total mortality). Out of the estimated standing available biomass (1, 83,483kg) in the Phu valley at least 2220 kg or 1.3% of the total livestock biomass was consumed by snow leopards in the year of our study (2004). It was estimated that in the Phu valley annually 1.8 animals were lost per household to snow leopards. This means approx. Rs.413560 (US$ 5,908) is lost annually in the valley (US$ 179/household/annum). Ghyo block, had the highest animals loss (53.4%), followed by Phu block (36.2%) and Ngoru block (10.3%) to snow leopards.

There is positive correlation among the densities of blue sheep, relative abundance of the snow leopard and livestock depredation. Blue sheep is the main prey species of the snow leopard in Phu valley and its conservation therefore matters to reduce livestock depredation. A general patterns appears here that shows that blue sheep (prey) abundance determine snow leopard (predator) abundance and that livestock depredation by snow leopards may be minimal where there is good population of blue sheep, and vice versa.

Introduction and Objectives

In the high Himalayas, wild ungulates and their domesticated relatives and mammalian predators coexist (Fox et al. 1994, Miller and Jackson 1994, Schaller 1998).The endangered snow leopard *Uncia uncia* (estimated global population, 4,500 – 7,500) is spread over approx 1.6 million km^2 (McCarthy 2000). At least eight protected areas harbor snow leopards in Nepal (projected population 300 to 500); however, this figure needs field verification (Bajimaya 2001). Computer-based modeling suggests that Shey-Phoksundo National Park (SPNP) and Annapurna Conservation Area (ACA) are the only ones in Nepal that can support minimally viable population of 100 or more (Jackson and Ahlborn 1988). Sustainable predator-prey ratios and the retention of age-old pastorals civilizations in northern parts of ACA indicate a relatively sustainable ecosystem (Miller and Jackson 1994, Fox et al. 1994) where snow leopards may continue to thrive.

The remote Phu valley (84° 5' to 84° 13' E and 28° 40' to 28° 50' N) in the ACA in Nepal provides a quality habitat for the snow leopard, but the region continues to witness problem of illegal hunting, people-wildlife conflicts, and degradation of habitat. Due to abundant pastures in the valley, people here in the valley maintain traditional herds of yaks, horses, goats, cattle and sheep making the livestock herding a key economic activity. Unfortunately livestock depredation by the snow leopard has become a major problem in the valley. Theoretically snow leopards attack or kill the local livestock only when prey is either depleted or hard to find locally. In spite of abundant populations of blue sheep *Pseudois nayur*, the main prey of snow leopards in the region, what could be main cause of the snow leopard killing livestock instead of abundant blue sheep? Is local livestock herding responsible? How then can such practices be improved that minimize livestock depredation?

Recently, the importance of harmonious coexistence between the snow leopard and subsistence herders in the western Himalaya and central Asia has become one of the top conservation concerns of conservation agencies and donors (Gurung and Thapa 2004). Unless the interfaces of the existence are understood properly and appropriate strategies are applied, the coexistence may not be possible. With 16 years of conservation initiations, Annapurna Conservation Area Project (ACAP) of the King Mahendra Trust for Nature Conservation (KMTNC) has contributed in snow leopard conservation. Examples include ban on hunting, and full protection of prey species. However the people-snow leopard conflict has been tough to resolve. Although ACAP has so far implemented to compensate the loss indirectly by implementing conservation and development activities including income generating scheme, these have not been very effective.

The main objective of this study was to find out the primary factor of snow leopards-livestock conflicts among the compounded factors. "Is their any correlation between abundance of blue sheep population and livestock depredation by snow leopards?" Answering these questions is highlighted in this study. There are considerable amount deals of data exist on the proposed question but all previous studies have documented separately in pieces, and hence I will make a synthesis to better answer the question, pooling together all extant data, focusing on Phu valley in the ACA.

Study Area

The remote Phu valley is categorized as biotic, wilderness zone and the major hotspot of the wildlife in the sense of multiple lands use system categorized by KMTNC-ACAP. It is located at 4,052 m above sea level and is recently opened to the foreigners. The village is remotely located at three days walking distance from the nearest seasonal airstrip (Humde) or a week long walking distance from the nearest road head (Besisahar). The population of the Phu Village Development Committee (VDC) is 162 with 33 households. Phu valley is one of the least populated areas in Nepal. The community is traditional as the external influence has not either influenced or it has been absorbed in the local way of life. Livestock herding is the key economic activity. Agriculture is the subsistence (one crop per annum because of the harsh climate). In addition to these, trading plays important roles in the subsistence of the community. Local people believe in Budhism and thus killing of any live is sinful act.

Table 1: Potential snow leopard and blue sheep habitat, Phu VDC

Block	Cutting/cliff	Agriculture	Grassland	Shrubland	Sand/Gravel	Barren land	Lake	Total km^2
Ngoru	0	0.11	3.42	0.00	1.32	60.61	0.01	65.47
Phoo	0.00	0.57	11.76	0.55	0.93	68.88	0.01	82.70
Ghyo	0.08	0.28	8.42	1.44	0.39	33.55	0.00	44.08
Total	0.08	0.96	23.60	1.99	2.64	163.04	0.02	192.25

(Data source: FINNMAP 1:50,000 Topographic Map)

For the study purpose, Phu valley was divided into three different blocks based on permanent drainages (fig. 1).Inaccessible areas (permanent snow cover and glacier and above the 5500 meter) were excluded.

Phu Block (82.7 km^2): It lies north of the Chubuche ya ridge. The areas is extends all the way up to Phu village. Ubi Gomera, Kuniro Khola (river), locally known as Kunirojung, flows South thus dividing the study area into major East, North-East and South-west facing slopes.

Ngoru block (65.47 km^2): It lies north of Phu village. Starting from the upper catchments of the Phu river, this block includes Pangre and other adjacent areas. Phu Khola, (locally Palde Changma) flows south dividing the whole area into East and west facing major slopes.

Gyo block (44.1 km^2): This block is the major west-facing slope, east of the Phu Khola. It consisting of 5 major Kharkas (pastures), i.e. Kyang, Seibi, Kyo Lhe, Kunar, Gongle and Namjunge, Pangre Glacier limits its Northern extent and otherwise it extends up to the major range of Namjunge Kharka and the other peaks to the East. Phu Khola to the west and to the ridge above Kyang to the South. This area does not have any prominent drainage system. Small streams flow down to join the Phu River.

With a mixture of several grassy slopes interspersed with and very steep and broken terrain, Phu valley offers a suitable habitat for blue sheep and snow leopards.

Project designed and Methodology

Snow leopard: I used the Snow Leopard Information Management System (SLIMS) techniques (Jackson and Hunter 1996) focusing on the "second order", abundance surveys designed to collect quantitative data on snow leopards numbers and habitat use characteristics in area where snow leopards have been determined to exist.

The 1: 50,000 topo-maps were utilized to layout the transects within three blocks. A relatively large area was used to allow for the likelihood that some of the area was inaccessible which did not cross the 5500 m counter permanent snow, ice or dangerously steep ground. Transects were drawn considering with mapping feasible transects and choosing randomly from among many of the feasible ones. Many short transects up to 750m were conducted, rather than a few long transects that are 2 or more kilometers. Each transect was walked and was searched for sign within a 5 m wide strip on either side.

Indirect method was carried out to determine the relative abundance of snow leopards in delineated area because snow leopards are extremely difficult to observe directly, and therefore most data are expected to consist of indirect signs of presence. Transects routes were plotted by randomly selected feasible landforms where snow leopards sign is likely to be found, such as along ridgelines, cliff bases, river bluffs (Bajimaya 2001, McCarthy 2000, Jackson and Hunter 1996). As each transect was walked and I recorded the type of signs (scrapes, feces, pugmarks, spray/urine, or claw marks), the sign measurement, the estimate age of sign and whether sign was relic or non-relic. Within 20 m radius of the marked site, I recorded slope, elevation, habitat type, rangeland use, landform ruggedness, dominant topographic feature and substrate as mentioned in the SLIMS Manual.

Blue sheep: Direct count method was applied from different appropriate vantage points (fixed-point count). Total herds were counted, along with classification it was recorded their habitat feature and classify it's into sex composition and age classes. Observation was made in the morning (06.00-10) and evening (02.00-05.30) during active period by using 8 X24 binocular and 15-60x spotting scope.

Livestock depredation: A standard questionnaire was designed and collected relevant information through total house hold survey regarding livestock depredation especially by snow leopards. It was also interviewed with key informants, members of Conservation Area Management Committee ([1]CAMC), Snow leopard Conservation Committee ([2]SLCC) and Lama from monastery.

[1] CAMC is the main responsible and authorized Village Development Committee (VDC) level body of the ACA for their overall conservation of the natural resources within their VDC boundary (Conservation Regulation 2053)

[2] SLCC is the particularly responsible for the conservation of snow leopards and its prey species under CAMC.

Findings

Livestock management and practices

Ever since civilization was established in the region, livestock enterprises of Phu based on free range grazing system have been the backbone of their existence which has shaped their livelihood and traditional cultures. Livestock enterprise species in the region include native yak, cow, sheep, goat, horse. For the communities living in high altitude with extreme harsh conditions which are unfavorable for agriculture due to low and erratic rainfall, cold temperatures, rough topography and poor soil structure, livestock enterprise has provided them with a coping strategy for sustenance. Due to the significant uses of livestock critical for human sustenance, rearing livestock is a necessity as much as a tradition. Livestock population demonstrates a sheer show of wealth and status in the community just like in other communities of the world living in harsh conditions.

Total households number, residing the livestock in Phu village is 33 (1843 livestock heads) with yak (both male and female) comprising 32.01%, 7.7 % young yak, sheep 18.29%, goats 31.52%, cow 6.30% and horses 4.17% (Annex I). The average size of stock holding in Phu was 55.8 per household. Compared to that reported by Sherpa and Oli (1988) (2140 total heads), livestock then has decreased in numbers which shows livestock number has declined. My present counts show that an average 9.6 animal/km^2 and 612.03 kg/km^2 standing biomass was (estimated within 192.25 km^2 area: minimum assumed weight of different type of livestock by local knowledge).

Adult Yak and adult horses are largely free-roaming, but cattle are driven out each morning to forage nearby, to return of their own accord in late afternoon to spend the night in stables below the living quarters. During winter, sheep and goats often graze unattended, and also guarding lax. During daytime hours, all lambs, kids and young calves are kept within sight of the corral, being corralled with their mothers at night. Milking female yak, young yak and young horses are mostly herded out of the summer settlement or temporary corral located in their distinct pastures. A detailed livestock herding system of the Phu valley including the rotation grazing pastures in a year has been described by Gurung and Mc Veigh (2000).

Following are the seasonal use of different grazing grounds (Kharkas) but it mainly applies to the yak herds, because sheep, goats and cows are generally stocked around the village due to the fear of the snow leopard depredation.

Table no. 2: Seasonal use of grazing pastures by Phu Villagers

Month	Pastures
November-February	Ghyo block (Kyang, Gongule,Ghyo, Namjunge)
March-May	Kunar, Ramle, Kyo Lhe
June-July	Ngoru (block Pangre, Ngoru)
August-September	Phu block (Longu ,Noppu, Ramle)

Livestock depredation

Out of 33 households surveyed, 30 reported that they had lost livestock to snow leopard in 2004 (only 3 households no loss to snow leopards). On average 1.8 per household were lost to snow leopard and depredation rate was 3.1% (n=58: 28 goats, 16 sheep, one colt and 13 sub adult yaks (table 3). Within estimated standing available biomass (1,17,510 Kg) in the Phu valley at least (1,850 Kg) 1.3% biomass was consumed by snow leopards in a year are estimated in this study. Most animals were killed in December and no loss in October. Animals were vulnerable mostly in winter because of very poor guarding of livestock. The evening and morning attacks are near by corrals or on their way to and from the grazing lands. Total 35 in pastures, three in corral and 20 in near corral, animals were loss. In Ghyo block (Kyang, Jhong, Ghalekung, Kurung, Namjunge, Ghyo, Salde, Gongale,) highest number i.e. 31 animals (53.4%), Phu block (Ubi, Panji, Rama, Guiso, Longu, Ramle) 21 animals (36.2%) and in Ngoru block (Pangre, Ngoru) 6 animals (10.3%) were lost. Ghyo block is found vulnerable to livestock (especially Kyang site) this might be, because Kyang is the winter pasture and livestock rearing here is up to five months long period. Total 25 animals were lost in very broken terrain with rocky cliffs and followed by shrub land dominant with rolling terrain. It was found that highest number of 39 animals and 19 animals were lost during unattended herd and attended herd respectively. In my study the animal tending system in the valley was found to be very poor. During day time the animals were mostly unattended. The herders left the animals almost free in the pasture through out the day. It was found that adult yak, adult cattle and adult horses were not reportedly loss by the snow leopard during this period. Thapa (2000) reported (with their photo evidence) that 40 goats and sheep were killed by the snow leopard in a single night at corral in the same valley however during this study period mass killing of animals is not noted. However the corrals were found observed poor. In most of the summer pastures the corrals are almost non-existent. This makes the animals dispersed early in the morning or even they are collected in the evening. Very interestingly in the Phu valley, in my study period there was only one dog during five years period because of all the dogs were died by unknown disease before 10 years. The people of valley didn't wish to recapitulate dogs.

It is estimated that in the Phu valley annually 1.8 animals were lost per household due to snow leopards. In this study total US $ 5,908 (RS. 413560) lost per year in the valley which is US $ 179 (Rs.12560) per household per year (see in table no. 4). Young yak and young horses were financially valuable.

Table No. 3: Type and No. of livestock lost in Phu VDC (2004)

	Depredated livestock type							**% of livestock loss(n=58)**	
Block	Goat	Sheep	Adult yak	young yak	young horse	Total animals	Biomass (kg)	Goat	48.3
Ghyo	17	9	1	4		31	1080	Sheep	27.6
Ngoru	2		1	2	1	6	510	Adult yak	3.4
Phu	11	7		3		21	630	Young yak	19
Total	28	16	2	11	1	58	2220	Young horse	1.72

Note: Goat and Sheep=20kg, Adult yak=200kg, Young horse and yak=90kg in minimum weight

Table no. 4: Economic Impact

S.No.	Livestock Type	Loss Number	Estimated price US $	Total Loss US $
1	Goat	28	60	1680
2	Sheep	16	58	928
3	Young yak	11	200	2200
4	Young horse	1	300	300
5	Adult yak	2	400	800
	Total	58		5908

Blue sheep Population

Blue sheep were directly counted and were classified into sex and age classes in all three blocks. Altogether a total of 37 blue sheep herds and 1209 individual (biomass 43524 kg) were observed in the survey area of 192.25 km^2 with mean population density of (226.4 kg/km^2) 6.3/km^2 (table 5). As can be seen in the table, population density of blue sheep is remarkably low in the disturbed area (Ghyo block) in comparison to the relatively undisturbed block (Ngoru). Low blue sheep population in Ghyo block is obviously due to on going grazing activities. Average herd size is 32.68 animals and herd size varied from solitary animal (one adult ewe) to mixed herd of 103 animals, the largest so far recorded. Group size (mean 32.68, range: 1 to 103, n: 37) is comparable with the earlier study (Sherpa and Oli 1988).

In Ghyo block total 168 blue sheep were found within 44.08 km^2 i.e. 3.8/ km^2 (137.2 kg/km^2) blue sheep density is recorded. In Ngoru block blue sheep were recorded 4.7/km^2 within 65.47 km^2. Highest density of blue sheep that is 8.9/km^2 (320 kg/km^2) was recorded within 82.70 km^2 in the Phu block. The mean density is lower than that was found in the earlier study in the same area (3.7 to 12.1/km^2 Sherpa and Oli 1988) that was crude density. This figure still considerably higher than that was reported for other parts of Nepal, i.e. Dhorpatan (0.7 to 0.8 /km^2 Wilson 1981).

The sex ratio varied considerably one block to another block. Recruitment rate (lamb to female) was found to be on average 47:100 i.e. 4.7. Standard reproductive rates in stable populations of ungulates oscillate around 0.5-0.6 and reproductive rates in growing populations may exceed 0.7, in average (for citation, see Ale and Thapa 2004). The recruitment rate (47: 100, lamb-female) is found relatively low in the study area. The corresponding figures for several populations in Tibetan plateau range from 0.26 to 0.4 (Schaller 1998). At Dhorpatan about 50% of the blue sheep died between birth and 2 years of age, most during winter (Wegge 1979). The decline between young and the yearling class in Manang was 44.3 % (Ale and Thapa 2000). The ratio of yearling (both male and female) to adult female was found to be 0.45. The average sex ratio (female to male) for the entire survey area was 0.67. Some of the blue sheep populations in Tibetan plateau had extremely low male- to – female ratio (25:100, Schaller 1998), the reason being sexual segregation in these population. However, Wegge (1979) and Wilson (1981) in Dhorpatan in west Nepal found no evidence of sexual segregation on the fine alpine meadows.

Table No. 5: Herd classification of blue sheep

Block	AE	Lamb	Yearling	YR	MR	BR	Unidentified	Total	Area/ km^2	Density/ km^2
Ghyo	53	28	27	24	13	13	10	168	44.08	3.8
Ngoru	118	50	48	26	24	19	20	305	65.47	4.7
Phoo	264	127	124	76	59	38	48	736	82.70	8.9
Total	435	205	199	126	96	70	78	1209	192.25	6.3

(Note: YR=young ram, MR=middle ram, BR=big ram)

Most of the blue sheep herds were observed between the altitudinal range of 4300 to 4600 m and this trend was fairly consistent in all blocks. Blue sheep herds were found on average 26° slope and 212° aspect (n=37). On average 56.76% blue sheep herds were observed in grassland, 27.03% were shrub land, 5.4% were scree, 8.1% boulder and similarly 2.7% blue sheep were found in agriculture land (n=37). On average, 43.2% of the total numbers of herds were observed on rolling terrain, 32.4% were on broken terrain, 18.9% were on very broken terrain and 5.4% blue sheep were found on flat land. Of the total herds, 67.6% blue sheep were found in feeding activity, 18.9% were in moving activity and 13.5% blue sheep were observed in resting activity. Out of the total numbers of herds in the valley, 45.95% blue sheep were observed in middle part, 37.84% blue sheep were found in lower part and 16.22% blue sheep were found in upper part of the study area. Out of 37 herds, blue sheep were found 29.7% on hill slope and followed by 21.6% cliff, 10.8 valley floor, 8.1% boulder, 5.4% (ridge, stream, talus and not available) and 2.7 bowl (see annex II). It was estimated that the blue sheep herds were found on distance to cliff is 385 meter (n=37).

Abundances of snow leopards

With modifications to meet particular field conditions and data needs, the SLIMS was employed as detailed in early draft versions of the SLIMS Handbook. SLIMS provides a standardized approach for assessing the occurrence, distribution and relative abundance of snow leopards and their major prey (McCarthy 2000). Second order, a abundance surveys, are more rigorous and designed to collect quantitative data on snow leopard numbers and habitat use characteristics in area where snow leopards have been determined to exist.

After selecting general survey areas 1:50,000 topo-maps were utilized to layout transect routes. Transects were placed along landforms where cats are most likely to deposit signs i.e. ridgelines, cliff-bases, or V-shaped valley bottoms and streambed. Each transect was walked and searched for sign. At each detected snow leopard sign site, it was recorded the type of sign (scrape, feces, spray/urine, paw print, or claw rake), the sign measurement, the estimated age of sign, the distance to nearest cliff, and whether the site was relic or non relic. For each site it was recorded habitat features based upon the dominant conditions within 20 m radius of the marked site. These included slope, aspect, elevation, habitat type, rangeland use, landform ruggedness, dominant topographic feature, and substrate.

16 transects were laid down with a total length of 7.912 km (mean transect length=0.495 km). It was identified 54 sign sites (both relic and non-relic) and 88 pieces of sign. Individuals sign included 72 scrapes, 11 feces, three scent mark, two pugmarks and one hair were recorded within the total transect. Mean of sign sites were 6.8/km and 11.1 sign item/km. Out of 54 signs sites 61.1% non-relic and 38.9% relic sign types were found (see in table 6). Of this signs were determined by different landform ruggedness i.e. broken 35.2%, cliff 13%, rolling 31.5% and very broken terrain 20.4%. Ages of signs were found 53.4% old and 46.6% fresh. The survey area, which was conducted, is under seasonal grazing rangeland. Sign sites about 42.04% was dominated grass land, 42.04% barren land and 10.2% was scrub, 4.5% shrub land and 1.1 was rock with respect to habitat type of the survey area. The topographic feature most frequently associated with sign site was ridgeline was 68.5%, and followed by cliff 14.8%, hill 9.3%, 3.7% boulder and stream bed was 3.7%. Scrapes (n=72) were pre-dominantly found in ridgeline (69.4%), while feces were usually noted along the undisturbed trail.

It was found that the Ghyo block had the highest sign density of snow leopard i.e. 13.6 mean sign item/km. and similarly in Phu block 9.8 mean sign item/km and it followed the lowest sign density of snow leopard in Ngoru block i.e. 3.9 mean sign item/km. Snow leopards sign density /km of transect was not equal across three blocks. Ghyo block had a higher mean density of snow leopards sign/km of transect when compared to Phu and Ngoru blocks but no statistics were used for this report. This analysis should await for further study when more data will pour in. Variation in mean sign density among four seasonal may also be anticipated especially in winter and summer season because this data is the only spring season. The high pressure of snow leopard sign in the area is depending on their habitat suitability and availability of easy prey is recorded on this study.

Table no. 6: Sign site and sign density of snow leopards

Block	Transect(km)	Sign sites	Mean site/km	Sign (all)	Mean sign/km	Scrapes	Mean scrapes/km
Ghyo	1.3	13	10	24	13.6	18	13.8
Ngoru	1.8	8	4.4	9	3.9	7	3.9
Phu	4.8	33	6.9	55	9.8	47	9.8
Total	7.9	54	6.8	88	11.1	72	9.11

Table no. 7: All sign of snow leopards

						Site type		Sign Age	
Block	**Scrape**	**Feces**	**Hair**	**Scent**	**Pugmark**	**Relic**	**Non-relic**	**Old**	**Fresh**
Ghyo	18	3		2	1				
Ngoru	7	1	1						
Phu	47	7		1	1				
Total	72	11	1	3	2	21	33	47	41

Table no. 8: Habitat Characteristics of the snow leopard sign sites

% sign sites (n=54)

Landform Ruggedness		Dominant topographic feature		% of vegetation cover		Aspect		Slope (Degree)	
Broken	35.2	**Boulder**	3.7	**1 to 25**	46.3	**E**	31.5	< **15**	1.9
Cliff	13	**CLIFF**	14.8	**26 to 50**	24.1	**NE**	13	<**20**	5.6
Rolling	31.5	**Hill**	9.3	**50 to 75**	25.9	**SE**	16.7	< **25**	20.4
Very Broken	20.4	**Ridge**	68.5	**76 to 100**	3.7	**SW**	24.1	< **30**	29.6
		Stream	3.7			**W**	14.8	< **35**	18.5
								< **40**	18.5
								< **45**	5.6

Discussion

In the Phu valley the snow leopard is the main large predator. I encounter no sign of the presence of grey wolf *Canis lupus* throughout the survey area, but there was evidence of medium predators such as golden jackal *Canis aureus*, Red fox *Vulpes vulpes*, and small predators (e.g. martens, weasels and vultures). The sign density was more or less comparable with that reported from the Everest, Nepal (4.2 sign item/Km, with one-three cat/100 Km²: Ale and Thapa 2004; 2.1 scrapes/Km, with one cat/100 Km² in Central Ladak: Fox et al. 1991; 2.5 scrapes/Km, with approx. 3 cats/100 Km² in Upper Indus Valley: Fox and Chundawat 1997) and trans-Himalayan part of Nepal (2.8 all sign/Km: Fox and Jackson 2002). I speculate that density of snow leopards in Phu valley may be 4-5 snow leopard/100 Km² (with 11.1 all sign/Km). Oli et al. (1993) estimated 5-7 snow leopards/100 Km² in adjacent Manang Valley. The Langu Valley of West Nepal with snow leopards density of 8-10 cats/100 Km² one of the densest population, had 11 site/Km, 36 combined sign/Km with 11 scrapes/Km, where scrapes predicted 87% of snow leopards use an area (Ahlborn and Jackson 1988). Perhaps five to seven adult snow leopards used my study area. The abundance of scrapes, as well as tracks and droppings, may provide a rough index of relative numbers, but counts of scrapes as a measure of abundance must take into account differences in use of terrain by snow leopards from area to area (Schaller 1998), differential sign longevity and how it is influenced by seasonal changes in livestock disturbance, weather, flooding, animal behavior and different topography (Fox and Chundawat 1997, McCarthy 2000).

It is presumed that livestock depredation may be minimal if the sufficient natural prey is available to local predators. In Ghyo block (with snow leopard sign density 13.6/Km, and lowest blue sheep density of 3.8/Km² showed highest livestock loss i.e. 53.4% (n=58), whereas Ngoru showed lowest sign density with the lowest livestock depredation, but blue sheep density was medium among the three block. Although there seems to be pattern, more the snow leopards more the depredation problem when I try to fit blue sheep density in this pattern, the pattern seems no very clear cut. Obviously, there are other governing factors such as season, habitat quality and livestock guarding pattern as to why snow leopards kill livestock. For instance, Ghyo is basically scrublands that consist of broken terrain with cliffs, rocky outcrops, and a good habitat of the snow leopard. But this is also the winter pasture when animals are poorly guarded (in winter all able persons go for trading leaving behind elderly and young for guarding livestock and their other belongings).

In Ngoru, 10.3% livestock were reported to have been lost by snow leopards. This means the lowest numbers of livestock among the surveyed valleys. Here the blue sheep density is intermediate (4.7/Km²) among three block (but not the different from Ghyo though), and lowest snow leopards (3.9 sign/Km²). This is the pasture for adult yaks and horses (summer pasture). The low successful attacks to livestock could have been because of number of factors including low attack incidences (low snow leopards) and livestock types that graze there. It is predicted that the snow leopard occasionally kill adult yaks and horses.

Livestock depredation in Phu block is 36.2% (n=58). With the intermediate snow leopards sign density (9.8/Km). This block offers snow leopards both good habitat (broken terrain interspersed with cliffs) and abundant food, blue sheep (highest density 8.96/Km²). In the mean time, it also provides easy domestic prey (sheep and goats) particularly when they are not accompanied by herders. Sheep and goats are grazed on adjacent pastures around the village (Phu village).

Overall, there seems to exist positive correlation among three factor; blue sheep abundances, snow leopards abundances and livestock depredation incidences. But clear pattern is not obvious because many social and ecological confounding factors. No doubt blue sheep is the main prey species of the snow leopard, therefore the blue sheep population in the snow leopard habitat will have significant impact on reducing snow leopards depredation on livestock, but snow leopards may be opportunistic predator and take any prey including livestock (Schaller 1998). Provided that livestock guarded efficiently, snow leopards would have no option but rely on their natural prey (blue sheep) and other alternative food sources for subsistence. The distribution and abundance of predators are governed by the abundant and distribution of resources (prey) and vice versa, however variation enters from both ecological and social milieu.

To date, the changes in the herding patterns have considered being the main determinant of livestock depredation rate by predators. Sherpa (1998) urged that if herders carefully mind his herds, the chance of wildlife depredation can be drastically minimized as supported by this study. Jackson et al. (1996) found that combination of lax guarding practices; favorable habitat conditions, and high snow leopards density were particularly responsible for high depredation rate in the Khangsar village, in Nepal. However, snow leopards in Manang Valley took livestock despite the availability of blue sheep in relatively high numbers (Oli et al. 1993). This study suggested that snow leopards are more likely to encounter domestic stock, while taking advantages of the excellent cover available to them in the form of vegetation, steep slopes, rocky areas and broken terrain. The depredation of livestock intensity is however differs from pasture to pasture, from season to season, livestock species to species and numbers of natural prey presence (Gurung and Thapa 2004).

In Ghyo with lower density of blue sheep revealed higher snow leopards sign density than Phu and vice versa. Such observation is surprising, however this could be presence of high volume of livestock (>1 third biomass than blue sheep) in the study area, but it is too early to make a conclusion. Fox and Jackson (2002) also reported a similar questionable inverse relationship between snow leopards density and blue sheep in trans-Himalayan Nepal where blue sheep 2-4/Km² and 2.8 snow leopards sign item/100m and in Bhutan (blue sheep 4-6/Km² and 1.2 snow leopards sign item/100m). McCarthy (2000) reported similar negative relationship where Ibex *Capra ibex* density does not appear to be a particularly good predictor of snow leopards sign density in Mongolia. It has been shown that density of prey alone can not predict predator abundance. Biomass of all available prey, including livestock and small mammals, may prove a better predictor, but such a value is not easily obtained. Alternative prey species for snow leopards in Phu Valley may include Pika and Pheasants that occur in the area but no effort were made to record their abundance. However in the Phu valley there was no any evidence of marmot *Marmot bobac* and its signs.

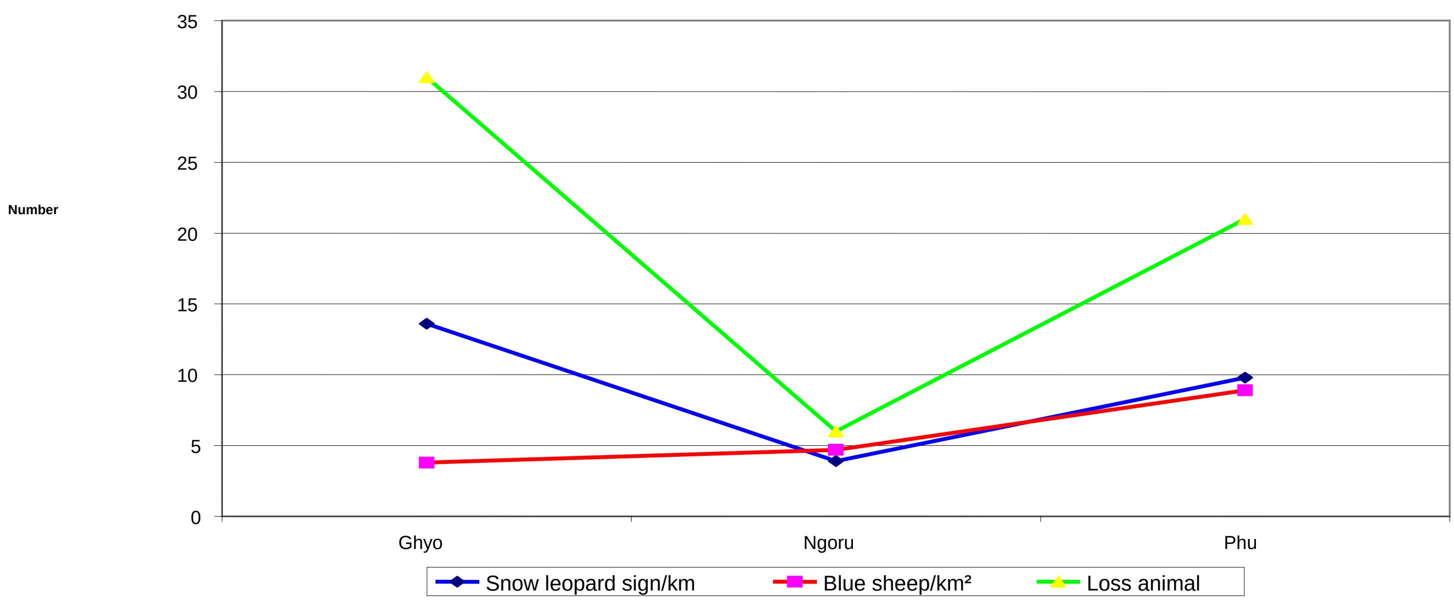
A knowledge of prey density and predator-prey ratios would help set limits for validating snow leopards numbers in a particular area. Clearly, there must be sufficient prey to support snow leopard numbers in a particular area. A snow leopard population is dependent on the number of prey animals present in the same general area. The snow leopard is an opportunistic predator capable of killing prey up to three times its own body weight. A snow leopard requires approximately 1.5 to 2.5 Kg of meat per day (Fox 1989) where Jackson and Ahlborn (1989) assumed that an adult snow leopard may require 20-30 blue sheep annually, i.e. 150-230 blue sheep are needed to support a single adult snow leopard (harvesting rate 13%). Schaller (1998) suggested a similar figure, i.e. a blue sheep population with 150-200 animals and an annual increment of 15% could support one wolf or one snow leopard if the population lacked other mortality causes such as poaching.

Dietary studies seem to suggest that livestock and/or marmots are important in sustaining a high density of snow leopard even when good numbers of blue sheep are present (Chundawat and Rawat 1994, Oli et al. 1993). Gurung (2002) found in Khangsar study area, where snow leopards were active (4.9 sign item/Km) and 7.3 blue sheep/Km² were found, however depredation rate is more or less similar to Jackson et al. (1996) and Oli et al. (1994). Based on Oli et al.(1994) scats samples, the diet content of the snow leopard show blue sheep (51.6%), marmots (20.6%) and livestock (17.8%) indicating significant proportion of livestock in its diet. The high rates of livestock depredation by snow leopards seem inconsistent with the high abundance and availability of blue sheep (304 Kg/Km²) and a sustainable predator-prey ratio of 1:114-1:159 (Oli et al. 1994). In Phu Valley estimated total blue sheep standing biomass is 43,524 Kg (where 226.4 Kg/Km²) where standing biomass of the livestock is triple (1,17,510 Kg). Analysis of predator-prey relationship indicated in the Phu Valley, predator/prey ratio of 1:113-1:181 on a weight basis. Natural prey the blue sheep in the Phu Valley adequately (1:147 animals; 1:4851 Kg) to support the estimated 5-7 snow leopards and possibly a few more. This study clearly has shown positive correlation among the densities of blue sheep, relative abundance of snow leopards and livestock depredation. Blue sheep is the main prey species of the snow leopard in Phu Valley and its conservation therefore matters to reduce livestock depredation. A general patterns appears here that shows the blue sheep (prey) abundance determine snow leopard (predator) abundance and that livestock depredation by snow leopards may be minimal where there is good population of blue sheep, and vice versa. However other confounding factors govern the livestock depredation which can not be neglected such as; 1) When both natural and domestic prey are present, livestock are more vulnerable (with no human presence) as they have lost anti-predator behavior, and that chances of predators killing domestic stocks are more because they are easy prey; 2) Livestock depredation rate depends on livestock type raised (e.g. sheep and goats are more vulnerable) and pattern of guarding; and 3) There exist what can be called livestock depredation hotspot, areas with broken terrains interspersed with cliffs, rock outcrops and patches of shrubs favored by snow leopards, in contrast to for example open place.

Table No. 11: Correlation between blue sheep population and livestock depredation by snow leopard

Block	Snow leopard sign/km	Blue sheep density/km²	Number of livestock killed
Ghyo	13.6	3.8	31
Phu	9.8	8.9	21
Ngoru	3.9	4.7	6

Figure 1: Correlation with blue sheep population and livestock depredation by snow leopards



Recommendations

- The study sites were all very close to one another, to properly answer the question would require sites that will provide the comparison e.g. different protected areas, high density vs low density livestock, etc. Thus to compare with this result there is highly essential to carry out another research in coming year (such as Manaslu Conservation Area).
- Moreover, in place like Phu, strong religious sentiments are against such mass killing and one such Lama is Karma Sonam Rimpoche, who took great conservation initiative 40 years ago. So,

ACAP honored this Lama with an award on the auspicious occasion of the 1995 environment day celebration. Recently, World Wide fund for Nature Conservation (WWF), Nepal honored this Lama with prestigious **"Abraham Conservation"** award on the auspicious of the 2003 world environment day. So, to encourage religion and balance ecosystem prey-predator should be fully protected.

- In fact snow leopards may find/guarded domestic stock much easier to hunt and kill than wary blue sheep because livestock are often poorly guarded. However if herders carefully mined his herd, the chances of livestock depredation can be drastically minimized so it will be productive to hire extra person to look after the animals especially in winter season.
- Promoting the use of improved breeds of guard dog and livestock showing a greater inclination for warding off or avoiding predators.
- Strengthening the existing a village-based snow leopard conservation sub-committee under the supervision of ACAP (such as awareness, training, financial support).
- At present situation local people are unable to understand the importance of the snow leopard conservation in terms of ecosystem balance because of being illiterate but if we aware them towards snow leopard as a monetary approach (i.e. eco-tourism program) there is no doubt that local people will love elusive cat.
- Compensation for livestock losses does not represent a sustainable strategy for several important reasons. For instance it requires a continual influx funding; it will not reduce livestock depredation losses in the future.
- Improved guarding of livestock, especially during winter, lambing or calving seasons, and when livestock is being grazed in pasture with broken, cover-rich terrain and at elevations in excess of 4000m.
- Detail Management plan should be prepared for the specific Snow leopard conservation.

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Annex I: Livestock record of Phu valley

SN	HHID	Yak	Chauri	Young Yak	Sheep	Goat	Cow	Horse
1	1	6	0	0	12	15	5	1
2	2	4	15	6	11	20	6	1
3	3	1	0	0	15	20	4	1
4	4	3	15	5	0	0	4	1
5	5	6	25	6	11	20	4	4
6	6	4	25	8	5	6	3	2
7	7	6	20	6	5	15	4	2
8	8	6	20	6	11	15	3	5
9	9	2	15	5	0	0	0	1
10	10	7	20	8	20	30	4	3
11	11	4	20	8	15	30	3	2
12	12	2	10	3	8	15	2	1
13	13	6	20	7	15	20	4	2
14	14	1	0	0	0	0	4	0
15	15	6	20	6	9	20	6	4
16	16	2	0	0	15	30	6	1
17	17	8	40	10	0	0	3	3
18	18	2	0	0	15	25	6	3
19	19	8	30	11	12	25	3	2
20	20	4	0	0	12	25	6	3
21	21	3	20	6	8	15	3	2
22	22	2	0	0	20	30	4	3
23	23	6	30	8	20	25	3	6
24	24	8	40	12	20	30	3	4
25	25	3	20	6	5	20	4	3
26	26	0	0	0	4	20	5	0
27	27	2	0	0	8	20	1	2
28	28	6	20	8	20	30	0	8
29	29	1	0	0	6	10	2	1
30	30	1	0	0	5	10	3	1
31	31	4	15	3	15	20	3	2
32	32	0	0	0	0	0	1	0
33	33	6	20	4	15	20	4	3
	Total	130	460	142	337	581	116	77

Annex II: Blue sheep herds description

Block	Herd sige	Distance to cliff	Elevation	Aspect	Slope	Habitat type	Ruggedness	Activity	Domotopo
Ghyo	12	300	4600	230	15	Grassland	Rolling	Resting	HIL
Ghyo	49	700	4627	230	30	Shrubland	Broken	feeding	HIL
Ghyo	1	600	4600	320	35	Grassland	Broken	feeding	RID
Ghyo	11	50	4627	200	25	Grassland	Rolling	feeding	CLF
Ghyo	22	100	4300	320	30	Grassland	Rolling	feeding	BOW
Ghyo	19	400	4250	320	20	Grassland	Rolling	feeding	VAL
Ghyo	13	500	4369	330	15	Boulder	Rolling	Moving	BOU
Ghyo	16	300	4800	340	25	Grassland	Broken	feeding	NA
Ghyo	15	900	4550	330	30	Shrubland	Broken	Resting	STR
Ghyo	10	700	4600	190	30	Grassland	Broken	Moving	STR
Phu	19	150	4300	190	15	Agriland	Rolling	feeding	HIL
Phu	16	200	4400	40	25	Grassland	Rolling	feeding	HIL
Phu	38	400	4450	40	35	Grassland	Broken	feeding	TER
Phu	19	900	4500	40	40	Grassland	VBR	feeding	TER
Phu	22	200	4550	190	5	Grassland	Flat	feeding	VAL
Phu	90	250	4650	170	15	Grassland	Rolling	feeding	VAL
Phu	32	500	4700	100	40	Shrubland	VBR	feeding	RID
Phu	5	400	4550	110	40	Grassland	VBR	feeding	HIL
Phu	52	25	4700	110	30	Shrubland	Broken	feeding	CLF
Phu	12	500	5035	180	25	Grassland	Broken	Moving	HIL
Phu	16	100	4600	230	30	Shrubland	Broken	feeding	CLF
Phu	47	200	4650	240	10	Shrubland	Rolling	feeding	HIL
Phu	57	50	4600	230	35	Grassland	VBR	Moving	CLF
Phu	25	50	4550	230	45	Boulder	VBR	Resting	BOU
Phu	20	200	4550	210	40	Scree	VBR	Resting	TAL
Phu	9	500	4600	160	40	Scree	VBR	Moving	TAl
Phu	64	500	4300	80	25	Grassland	Broken	Resting	HIL
Phu	71	50	4515	340	10	Boulder	Rolling	Moving	BOU
Phu	19	30	4600	150	15	Shrubland	Rolling	feeding	CLF
Phu	65	50	4670	160	5	Grassland	Flat	feeding	VAL
Phu	38	500	4700	340	25	Grassland	Broken	feeding	CLF
Ngoru	8	30	4500	340	30	Shrubland	Broken	feeding	CLF
Ngoru	85	100	4591	320	20	Grassland	Rolling	feeding	HIL
Ngoru	45	400	4900	320	25	Grassland	Rolling	feeding	NA
Ngoru	40	900	4800	120	25	Shrubland	Rolling	feeding	CLF
Ngoru	103	1000	5000	100	25	Shrubland	Rolling	feeding	HIL
Ngoru	24	1500	5000	320	15	Grassland	Rolling	Moving	HIL

Figure 1: Location map of the study area in the Phu Valley, Manang District