Prey Abundance and Prey Selection by Snow Leopard (*uncia uncia*) in the Sagarmatha (Mt. Everest) National Park, Nepal

Report

for

International Snow Leopard Trust

Snow Leopard Conservancy

Snow Leopard Network

By

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EXECUTIVE SUMMARY

Predators have significant ecological impacts on the region's prey-predator dynamic and community structure through their numbers and prey selection. During April-December 2007, I conducted a research in Sagarmatha (Mt. Everest) National Park (SNP) to: i) explore population status and density of wild prey species; Himalayan tahr, musk deer and game birds, ii) investigate diet of the snow leopard and to estimate prey selection by snow leopard, iii) identify the pattern of livestock depredation by snow leopard, its mitigation, and raise awareness through outreach program, and identify the challenge and opportunities on conservation snow leopard and its co-existence with wild ungulates and the human using the areas of the SNP. Methodology of my research included vantage points and regular monitoring from trails for Himalayan tahr, fixed line transect with belt drive method for musk deer and game birds, and microscopic hair identification in snow leopard's scat to investigate diet of snow leopard and to estimate prey selection. Based on available evidence and witness accounts of snow leopard attack on livestock, the patterns of livestock depredation were assessed.

I obtained 201 sighting of Himalayan tahr (1760 individuals) and estimated 293 populations in post-parturient period (April-June), 394 in birth period (July –October) and 195 November-December) in rutting period. In average, ratio of male to females was ranged from 0.34 to 0.79 and ratio of kid to female was 0.21-0.35, and yearling to kid was 0.21- 0.47. The encounter rate for musk deer was 1.06 and density was 17.28/km^2. For Himalayan monal, the encounter rate was 2.14 and density was 35.66/km^2. I obtained 12 sighting of snow cock comprising 69 individual in Gokyo. The ratio of male to female was 1.18 and young to female was 2.18.

Twelve species (8 species of wild and 4 species of domestic livestock) were identified in the 120 snow leopard scats examined. In average, snow leopard predated most frequently on Himalayan tahr and it was detected in 26.5% relative frequency of occurrence while occurred in 36.66% of all scats, then it was followed by musk deer (19.87%), yak (12.65%), cow (12.04%), dog (10.24%), unidentified mammal (3.61%), woolly hare (3.01%), rat sp. (2.4%), unidentified bird sp. (1.8%), pika (1.2%), and shrew (0.6%) (Table 5.8). Wild species were present in 58.99% of scats whereas domestic livestock with dog were present in 40.95% of scats. Snow leopard predated most frequently on wildlife species in three seasons; spring (61.62%), autumn (61.11%) and winter (65.51%), and most frequently on domestic species including dog in summer season (54.54%).

In term of relative biomass consumed, in average, Himalayan tahr was the most important prey species contributed 26.27% of the biomass consumed. This was followed by yak (22.13%), cow (21.06%), musk deer (11.32%), horse (10.53%), wooly hare (1.09%), rat (0.29%), pika (0.14%) and shrew (0.07%). In average, domestic livestock including dog were contributed more biomass in the diet of snow leopard comprising 60.8% of the biomass consumed whilst the wild life species comprising 39.19%. The annual prey consumption by a snow leopard (based on 2 kg/day) was estimated to be three Himalayan tahr, seven musk deer, five wooly hare, four rat sp., two pika, one shrew and four livestock.

In the present study, the highest frequency of attack was found during April to June and lowest to July to November. The day of rainy and cloudy was the more vulnerable to livestock depredation. Snow leopard attacks occurred were the highest at near escape cover such as shrub land and cliff.

Both predation pressure on tahr and that on livestock suggest that the development of effective conservation strategies for two threatened species (predator and prey) depends on resolving conflicts between people and predators. Recently, direct control of free – ranging livestock, good husbandry and compensation to shepherds may reduce snow leopard - human conflict. In long term solution, the reintroduction of blue sheep at the higher altitudes could also "buffer" predation on livestock.

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1. INTRODUCTION

For the first time in more than 40 years, scientists have spotted the elegant and endangered snow leopard on the southern slopes of Mount Everest, after being locally extirpated by man in the ‘60s. Shrestha (2004) recorded scats and pugmarks of snow leopard at Phorche (4000m) and Ngozumba glaciers near Thagnak Goth respectively, and as observed in 2004 (Ale and Boesi 2005), which is one of the few really encouraging in regard to snow leopard conservation.

The return of a large carnivore to Sagarmatha would bring mixed reactions from the management perspective. It is likely lead to increase the conflict, not only those between people and the snow leopard, but about nature conservation in general. Carnivores often limit the number of their prey, thereby altering the structure and function of entire ecosystems (Schaller 1972, Terborgh et at 2002, Treve & Karanth 2003, Gilg et al 2003, and Sinclair et al 2003). Shrestha (2004 and 2006), and Ale and Boesi (2005) reported the kid to female ratio of Himalayan tahr is now alarming low, being 0.1 where as it was about 0.6-0.8 in 1991-1992 (Lovari et al in press) in Sagarmatha National Park (SNP). This might have been due to predation by snow leopard, but this speculation has not confirmed yet. Similarly, the abundance of musk deer is expected to decrease in this area might be due to the increase in snow leopards (field visit 2004 and 2006). An analogy can be drawn to the dramatic effect of wolves that returned to Yellowstone, the world’s oldest national park (Berger et al 2001 and Ripple & Beschta 2004). Whatever the reasons for a reduction in snow leopard prey, the effects may be indirect as well as direct, as a shortage of natural prey can lead to increased predation on domestic livestock, which in turn may provoke herders to kill snow leopards (McCarthy and Chapron 2003). For this reason, destruction of the habitat of snow leopard prey species may affect the predator more seriously than direct impacts on its own habitat.

Knowledge of a predator's diet is important not only for understanding its ecology, but also for predicting its influence in the dynamics of the prey populations, and for designing and implementing conservation programmes. Factor affecting prey choice in leopards differs across its distribution range, and need to be understood as it occupies diverse habitats. Such an understanding would reflect the ability of leopard to adapt to landscapes modified by humans, and prove important for effecting conservation planning. Thus, studying the food habitats of leopards in relation to their prey base is essential for better management of their habitats, especially for the returned and recovered snow leopard as an important top predator to this world heritage site. The feeding habit of snow leopards can estimate availability of food for them and can estimate the relative volumetric contribution of the food (prey species) in the diet. How many Himalayan tahr or other alternative prey species do snow leopard require on the top of the world? These some of ecological questions to be answered and further research data is necessary to answer these questions. Knowledge of food ecology of snow leopard, focusing on ecology (density, population characteristics and habitat use pattern) of prey species is one of the major prerequisites to address the issue of conservation of snow leopard as well as to assess the possibility of multiple-use range resource management in SNP.

Driven by concern for snow leopards future in SNP because their future are still seriously at risk, this research is focus on feeding ecology of snow leopard, abundance of prey species and identifying conservation action and addressing issues related to the depredation of livestock to gain keystone species conservation and nature conservation in SNP.

2. OBJECTIVES

The overall aim of the study was to explore diet of snow leopard, abundance of prey species, and identifying conservation action and addressing issues related to the depredation of livestock to gain keystone species conservation in SNP.

The specific objectives of the project are to:

i) investigate the density, population characteristics and habitat use pattern of the wild prey species; Himalayan tahr, musk deer, pika and pheasants,

ii) investigate diet of the snow leopard and to estimate prey selection by snow leopard,

iii) identify the pattern of livestock depredation by snow leopard, its mitigation, and raise awareness through outreach program, and

iv) identify the challenge and opportunities on conservation snow leopard and its co-existence with wild ungulates and the human using the areas of the SNP.

3. STUDY AREA

The study was carried out between April and December 2007 (9th April – 9th June, 9th July – 19th August, 4th September – 14th October and 16th November – 16th December, 2007) in Sagarmatha National Park. (27º45' and 28º07' North and 86º28' and 87º07' East) lies in the Solukhumbu district (Figure 1) of the northeastern region of Nepal. It was gazetted in July 1976 and inscribed on World Heritage List in 1979 and has area of 1,148 sq. km. The park encompasses the upper catchments of the Dudh Kosi River system, which is fan-shaped and forms a distinct geographical unit enclosed on all sides by high mountain ranges. The northern boundary is defined by the main divide of the Great Himalayan Range, which follows the international border with the Tibetan Autonomous Region of China. In the south, the boundary extends almost as far as Monjo on the Dudh Koshi.

The study area reveals two distinct vegetation habitats: scrubland and forest. Forest (open forest) the altitude of 3,000 – 4,000m a.s.l. is dominated by *Pinus wallichiana, Abies spp*. and *Betula utilis*. These patches of open forest grade higher up into the alpine and sub alpine grassland/scrubland zones (4,000 – 5,000 m a.s.l.) with the mats of *Juniperus spp*. and *Rhododendron spp* (see Buffa et al 1998, for vegetation detail). In additional to snow leopards, Himalayan tahr and musk deer, wildlife in the park include game bird species such as Himalayan monal *Lophophorus imejanus*, Tibetan snow cock *Tetraogallus tibetanus*, and blood pheasant *Ithaginus cruentus*, as well as several mammals species such as the pika Ochotona himalayana, the Himalayan weasel *Mustela sibiricia,* the hill fox *Vulpes vulpes,* and the golden jackal *Canis aureus* (Lovari et al in press). Stone marten *Martes foina* and Yellow-throated Himalayan Marten *Martes flavigula flavigula* were also recorded in 2007.

The weather is pleasant during the autumn, months of October and November. But in the winter season the weather is cold and Snowfall is very common. Daytime temperatures do not exceed 50 Celsius. During spring season, the days are warmer. Sherpas are of great cultural interest, having originated from Salmo Gang in the eastern Tibetan province of Kham, some 2,000km from their present homeland. There were an estimated 3,500 Sherpas residing in the park in 1997, mainly in the south and distributed among 63 settlements.

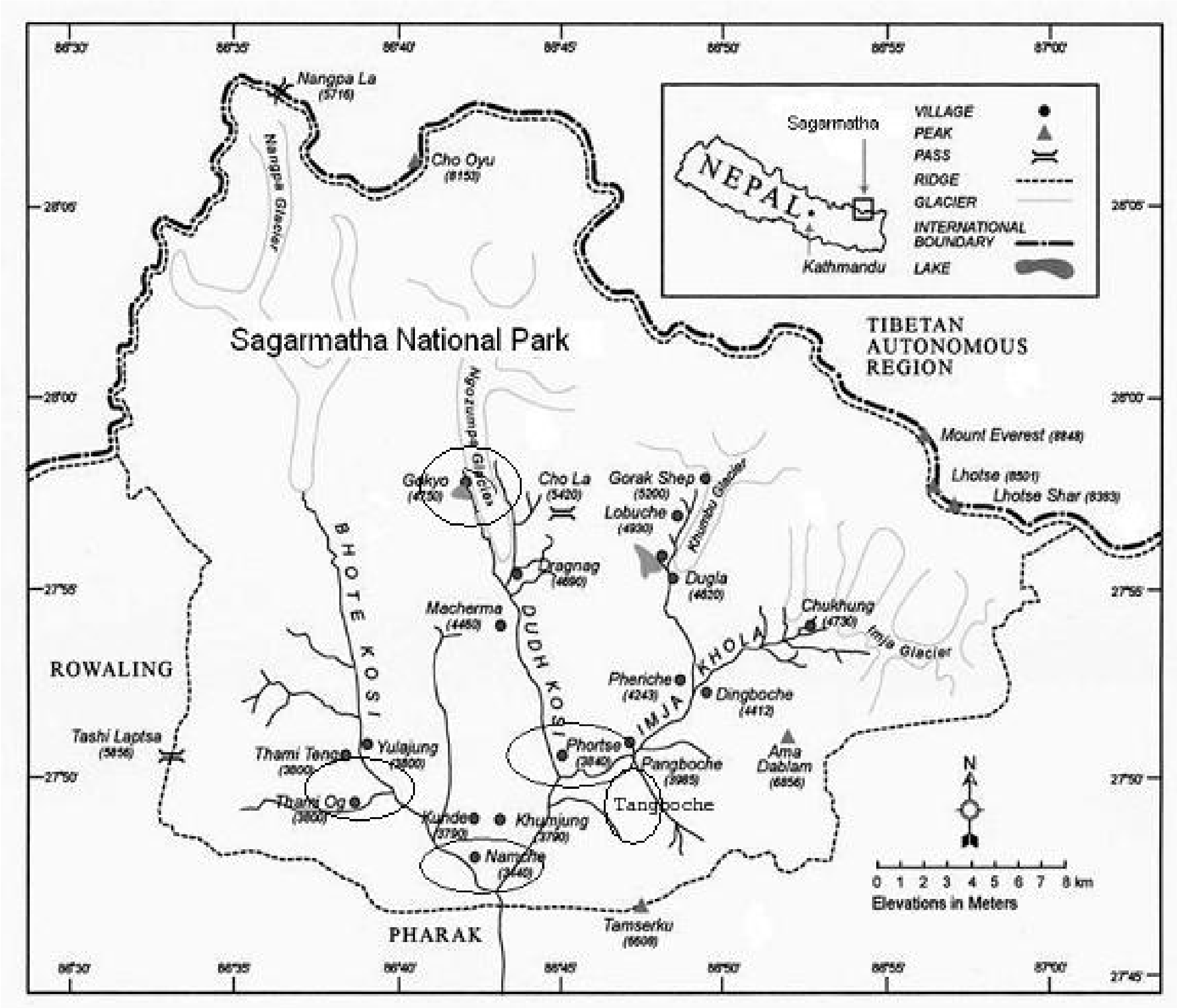


Figure 1. Map showing study area, Sagarmatha National Park, Nepal.

4. MATERIALS AND METHODS

I adopted the following methodologies to meet the above aims:

4.1 POPULATION STATUS AND ABUNDANCE OF WILD PREY SPECIES

4.1. 1 Himalayan tahr

Vantage points and regular monitoring from trails (Jackson and Hunter 1996) was decided as the main sampling method for observations on the tahr. Once animals were sighted, the place was observed using 7 X 35x spotting scope for further classification. I classified them into 1) young (<1 year old), 2) yearling (1-<2 years), 3) adult female (≥2 years) and 4) adult males. The adult males were further classified into five class on the basis of their pelage color and mane size: Class I (1-2 years old), a short mane on their withers, slightly more furry and stockier than females, and dark brown in color, Class II (3-5 years old), a much longer mane down to their hocks down to their hocks, much larger and hairier than females, dark brown in color; class III (>5 years old, blond), a large , dark brown shoulder mane, with lateral brown hair fringe around the backbone and up to twice the size of a female; Class IV (> 5 years old, pale brown), a large, light brown mane with a lateral brown to blondish hair fringe around the dark brown backbone (body size as class III males); and Class V (5 years old , dark brown), a large, blondish mane with a lateral blondish hair fringe around the dark brown backbone (body size as class III males) (S. Lovari pers. com).

Each observation was treated as one group or sighting, irrespective of number of individuals seen. For each observation, the herd size, sex and age composition, and the following habitat attributes: habitat type, landform type, altitude, slope, and aspect were noted. Four survey blocks were surveyed consists of 15-33 km^2 in size, a total of c. 86 km^2, the survey blocks, which represent the four main valleys of Sagarmatha: Namche (15km^2), Phortse (18.3km^2), Gokyo(33 km^2), and Thame (20km^2).

4.1.2. Musk deer

Fixed line transect method was used to estimate the density of musk deer in five blocks (Namche, Phortse, Thame and Tangboche). We surveyed altogether 29 transects with 21 km in length. We surveyed in Gokyo valley but we did not sighted musk deer. We searched each area on each side of transect up to a distance of approximately 30 meter to estimate the density. Encounter rate (number/km/each search effort) and density (number/km^2) were estimated.

4.1.3. Himalayan Monal and Blood pheasant

Himalayan Monal and Blood pheasant abundance was carried out by a belt drive method following Nawaz 2000, Bibby et al 1992, Sutherland 1996, and Gaston 1980. We surveyed altogether 32 transects with 23.5 km in length. We searched each area on each side of transect up to a distance of approximately 30 meter. Encounter rate (number/km/ each search effort) and density (number/km^2) were estimated. The density was calculated as follows:

Density (number/km2) = Total Search area/ total population
Where, Search area (A) = length of transects x width
Total search area = A x frequency of survey

4.1.4. Snow cock

Vantage points and regular monitoring from trails was adopted to count the snow cock in different blocks. Whenever sighted, we recorded group numbers, male, female and young.

4.2 DIET OF THE SNOW LEOPARD AND PREY SELECTION

Diet of snow leopard was determined through microscopic hair identification method. The hairs remains of prey species in scats were used for species identification. The basic principle of this method lies in the microscopic hair examination. This method required of scat samples, reference hair sample, preparation of identification key, and identification of unknown hairs in scat sample.

4.2.1. Scat sample and reference hair sample

Snow leopard scats were collected within the study area between March and December 2007. The scats were identified on the basis of size and associate signs such as scrapes and pugmarks. Scats of red fox were distinguished with relatively small size and canidae's pugmark is quit different from felidae species. Some area (Namche) was also presented inside the forest and forest leopard might also visit forest and edge of forest. Therefore scats from forest leopard in the suspected area were distinguished following criteria defined by Shrestha and Basnet (2005) and Jackson and Hunter (1996). The collected scats samples were sun-dried, labelled and stored in polythene bags. Later on, the samples were transported to National Forensic Science Laboratory, Government of Nepal for further analysis.

Reference hair samples were collected from mammals, both domestic and wild, know to occur in the study area. Hairs were collected in complete tufts from different body part which included a representative sample of all hair types.

4.2.2.. Preparation of identification key

A complete tuft of hair was cleaned thoroughly in liquid soap and water, and was dried between blotting paper. The hairs were then studied color and texture, medulla pattern, cross section pattern, and scale pattern as described by Brunner and Coman (1974).

Each reference sample was examined macroscopically for their color by using a suitable background and texture. The sample was then subjected to treatment with 30% hydrogen peroxide overnight for microscopic examination. The samples were dipped in xylene for 3-4 hours, so that the xylene enters the medulla and removes the gases and pigments. The sample was further subjected to wet mount preparation with D.P.X. and observed under bright field microscopic (400x). The detail characteristic of cortex and medulla were observed. The numerical measurement in micrometer of both cortex and medulla were taken using calibrated ocular micrometer measurement at ten intervals along the shaft. These measurements were then converted to micrometer and their mean value was calculated. Similarly, average diameter of medulla and their types were determined. Also, medullar index were taken and their average was ascertained. The above calculations were made only from medullated hair. Medullary Index (MI) was calculated using the formula as follows:

$$\text{Medullary Index (MI)} = \frac{\text{Width of medulla}}{\text{Width of cortex}}$$

A tuft of hair was inserted into a straw pipe and molten wax was sucked into it. Once the wax was solidified the straw was cut open to get the stub and the cross sections were obtained with the help of a blade. These sections were treated with xylene to remove wax and viewed under microscope for cross section detail.

The characteristics of cuticular scale along the hair shaft from the root to tip were noted. Thin layer of nitrocellulose lacquer (white nail polish) was applied on the surface of micro slide and the hair samples were placed horizontally on them. As the lacquer dried the impression hair surface was formed on it and the hair samples were peeled off and the impression or cast was viewed under microscope.

4.2.3.. Identification of unknown hair in scat and estimation of prey consumed

Each scat was soaked overnight in liquid dettol soup with water and it was washed carefully over a sieve with a mesh width of 1mm. Remains such as bones, teeth, hooves, hair and feathers were removed, air dried and stored. The 20 hair at random from each scat (Mukherje et al 1994) were examined to circumvent the possible biases (Karanth & Sunquist 1995) and then compared with a reference key and microphotography, using microscopic hair slide preparations which were exactly same as done in key preparation.

Microphotography of the representative cross sections, medulla and scale patters along the length of the hairs of each species were taken at a standard magnification. Compared to the direct comparison and descriptive dichotomous key, photographic reference has been found more convenient and easy to use in the routine identification of unknown hairs. Therefore, a photographic reference key and microscopic examination of cuticular scale and medullary types, thickness of cortex and medulla, medullary index etc which are considered as diagnostic tool in identification of species were undertaken in this study. I compared our criteria with those develop by Oli (1993) for identifying mammalian hair found in snow leopard scats colleted in Annapurna region of Nepal.

Statistical analysis

The scat contents are presented as 'frequency of occurrence' (number of scats in which a food type was present) and percentage frequency of occurrence (% of scats in which a prey item was detected). Although frequency of occurrence of mammalian prey species in carnivore scats is a commonly used parameter in predation studies, if prey sizes are highly variable the importance of smaller prey species can be considerably overestimated using this approach. Therefore a method developed for mountain lions puma concolor, by Ackerman et al (1984), was used to calculate the total biomass consumed for each prey species, assuming that the digestive system and feeding habitats of snow leopard mountain lions are comparable. Ackerman et al (1984) conducted feeding trails and found a linear relationship between ingested biomass per deposited scat (Y), and the live weight of the prey species (X). The resulting linear relationship, Y=1.98+0.035X, can then be applied in the form of correction factor, to convert frequency of occurrence to relative biomass consumed. The average weight of females as 60.5 kg (S. Lovari pers. Comm.) is considered the live weight of Himalayan tahr. Snow leopard usually kills livestock aged below 2 years old. Therefore, weight of young livestock (According local people: 150 kg) is taken for live weight of livestock. Other live weight of wild prey species is taken from Prater (1998).

$$\text{Relative biomass consumed} = \frac{\text{(relative frequency occurrence X correction factor)}}{\sum\text{(relative frequency occurrence x correction factor).}}$$

$$\text{Relative number of individuals consumed (\%)} = \frac{\text{(Relative biomass consumed X body weight)}}{\sum\text{ (Relative biomass consumed X body weight)}}$$

4.3 PATTERN OF LIVESTOCK DEPREDATION

Based on available evidence and witness accounts, I recorded the time of day of each attack, the number and species of all the livestock killed or injured in the attack, the predator species involved, the ecological condition, and the nature of interaction, if any, between villagers and the predator. The spatial locations of attack sites were recorded by GPS and the distance from each attack site and to the nearest forest, shrub land, and cliff were noted.

5. RESULTS

5.1 POPULATION STATUS AND ABUNDANCE OF WILD PREY SPECIES

5.1.1 Himalayan tahr

1. Population status of Himalayan tahr before birth season (April to June 2007)

I obtained 69 sighting of Himalayan tahr (620 individuals) and estimated total 293 populations. In average, the ratio of male to female was 0.56, kid to female was 0.21, and yearling to kid ratio was 0.21. Mean group size was 8.12 (range: 1-30, standard deviation=7.3) (Table 5.1).

The male to female ratio was highest in Namche (0.69) and it was followed by Phortse (0.52), Gokyo (0.44) and Thame (0.44) (Figure 5.1.A). The kid to female ratio was highest in Gokyo (0.33) and then it was followed by Phortse (0.21), Thame (0.2), and Namche (0.16) (Figure 5.1.B). The yearling to kid ration was highest in Gokyo and Thame (0.33) and it was followed by Namche (0.27), and Phortse (0.11) (Figure 5.1.C).

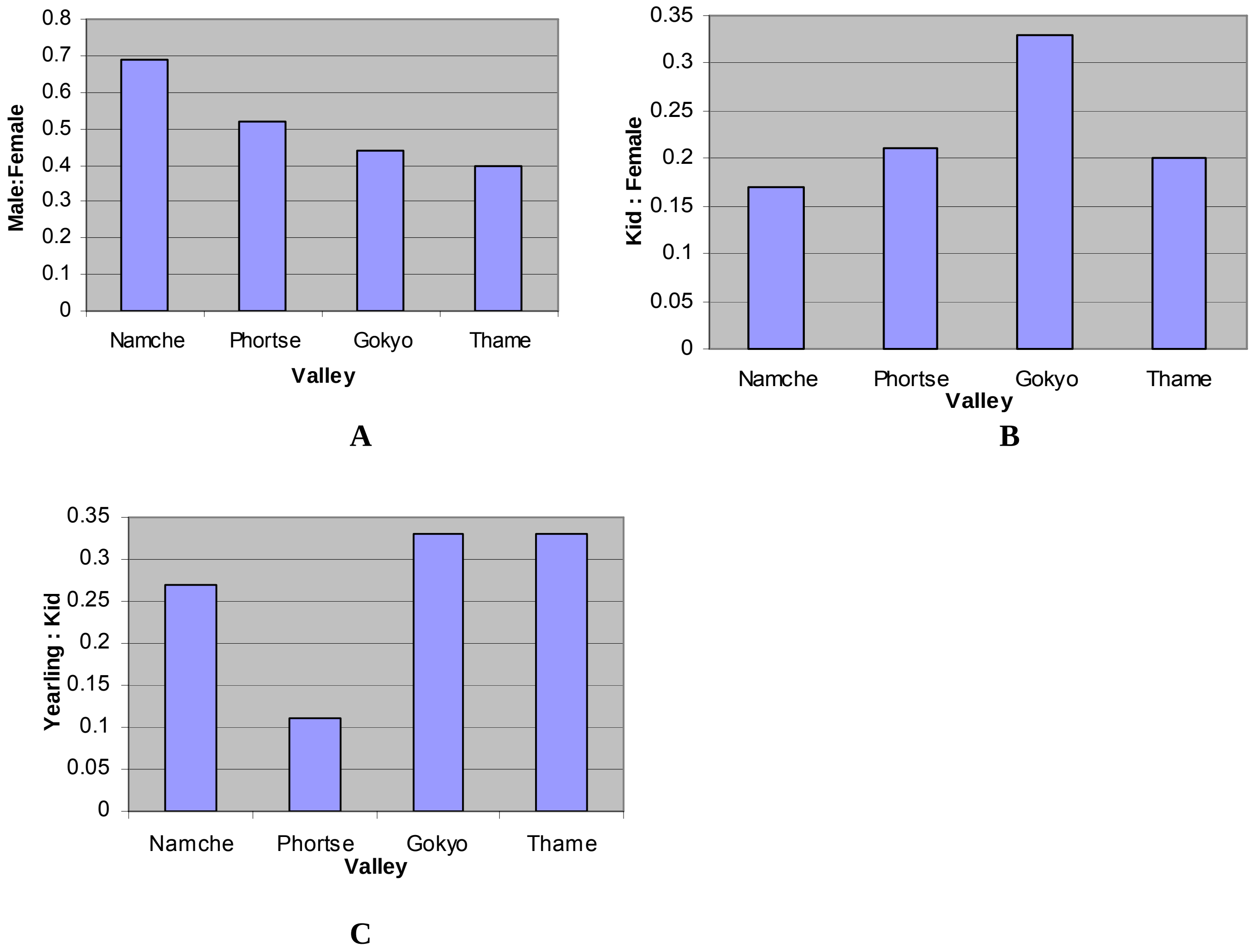


Figure 5.1. A. ratio of male to female, B. ratio of kid to female and C. ratio of yearling to kid

Table 5.1 Tahr population structure based on known numbers of different tahr repeated total counts and classification) and all animals tallied four valley April to June 2007 (n=69)

Himalayan tahr	Namche				Phortse				Gokyo				Thame			
	Known number (n=14)		All animal tallied (n= 21)		Known number (n= 14)		All animal tallied (n= 38)		Known number (n= 4)		All animal tallied (n=5)		Known number (n=4)		All animal tallied (n=5)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Female	44	53.01	66	51.96	82	55.78	238	57.07	20	51.28	27	52.94	14	58.33	15	60
Yearling	2	2.40	3	2.36	3	2.04	6	1.43	3	7.69	3	5.88	1	4.166	1	4
Kid	8	9.63	11	8.66	23	15.64	52	12.47	5	12.82	9	17.64	3	12.5	3	12
Total yearlings and kids	10	12.04	14	11.02	26	17.68	58	13.90	8	20.51	12	23.52	4	16.66	4	16
Male Class I	2	2.40	2	1.57	3	2.04	22	5.27	2	5.12	3	5.88	2	8.33	2	8
Male Class II	2	2.40	4	3.14	6	4.08	21	5.03	4	10.25	4	7.84	0	0	0	0
Dark Brown (Class III)	9	10.84	21	16.53	9	6.12	13	3.11	0	0	0	0	2	8.33	2	8
Pale Brown (Class IV)	10	12.04	12	9.44	6	4.08	31	7.43	5	12.82	5	9.80	1	4.16	1	4
Blond (Class V)	5	6.02	7	5.51	15	10.20	37	8.87	0	0	0	0	1	4.16	1	4
Unidentified male	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total males	29	34.93	46	36.22	39	26.53	124	29.73	11	28.20	12	23.52	6	25	6	24
Unidentified (all)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**83**	100	127	100	**147**	100	417	100	**39**	100	51	100	**24**	100	25	100
Density (animal/km^2)	**5.53**				**8.0**				**1.17**				**1.2**			

2. Population status of Himalayan tahr during birth season, (July to Oct 2007)

I obtained 79 sighting of Himalayan tahr (908 individuals) and estimated total 394 populations. In average, the ratio of male to female was 0.34, kid to female was 0.35, and yearling to kid ratio was 0.47. Mean group size was 11.39 (range: 1-44, standard deviation=8.85 (Table 5.2).

The male to female ratio was highest in Gokyo (0.47) and it was followed by Thame (0.46), Phortse (0.4), and Namce (0.16) (Figure 5.2.A). The kid to female ratio was highest in Thame (0.42), then it was followed by Phortse (0.36), Namche (0.34), and Gokyo (0.26) (Figure 5.2.B). The yearling to kid ratio was highest in Gokyo (0.76) and it was followed by Phortse (0.46), and Namche (0.11), and Thame (0.36) (Figure 5.2.C).

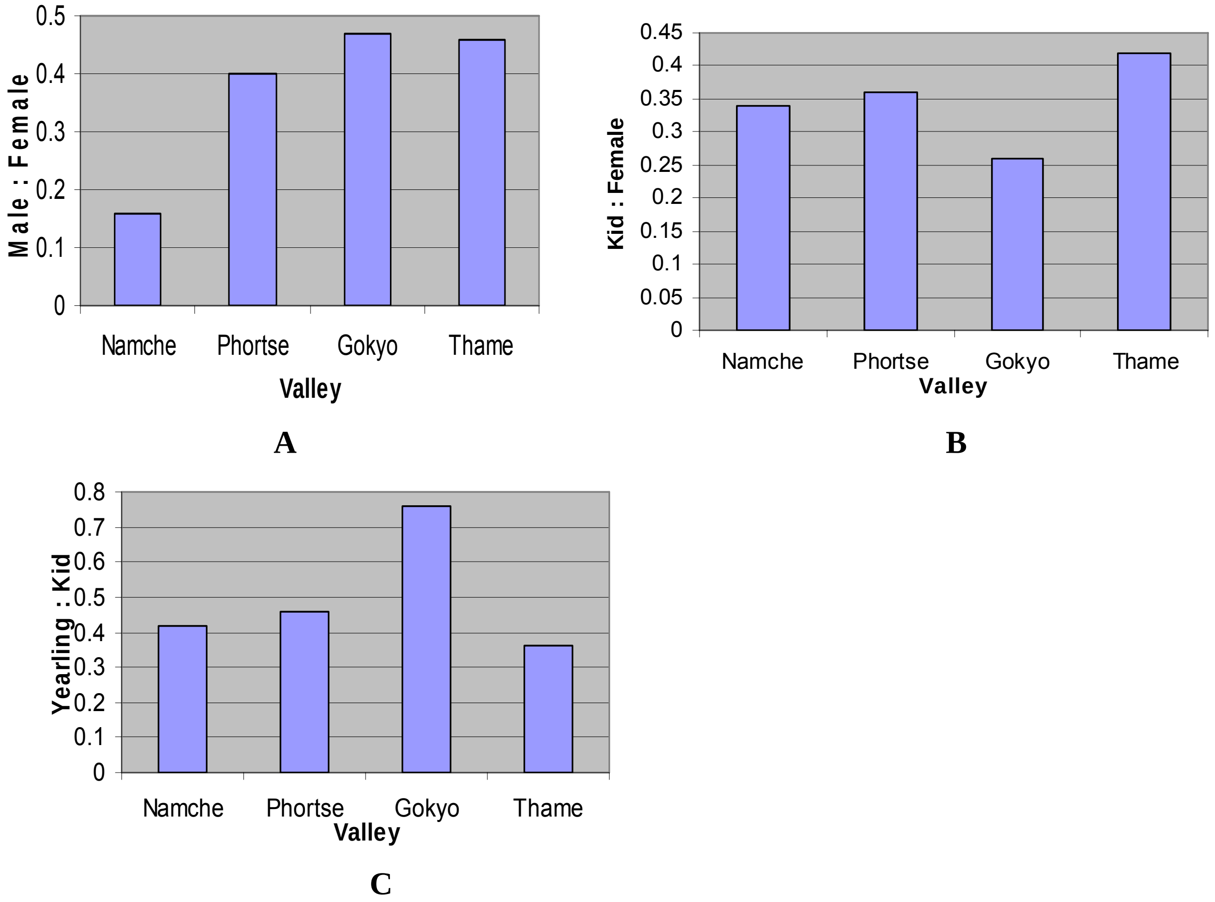


Figure 5.2. A. ratio of male to female, B. ratio of kid to female and C. ratio of yearling to kid

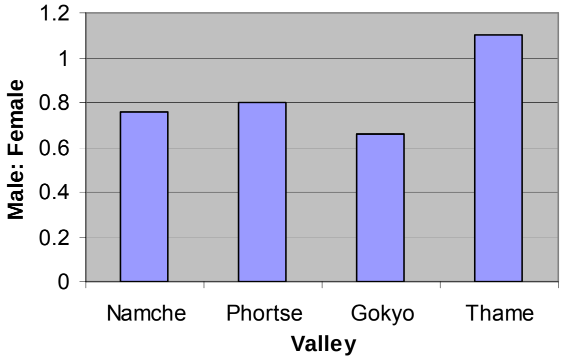
Table 5.2 Tahr population structure based on known numbers of different tahr repeated total counts and classification) and all animals tallied four valley July to Oct. 2007 (n=79)

Himalayan tahr	Namche				Phortse				Gokyo				Thame			
	Known number (n=10)		All animal tallied (n= 21)		Known number (n=12)		All animal tallied (n=37)		Known number (n=5)		All animal tallied (n=12)		Known number (n=4)		All animal tallied (n=9)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Female	70	60.34	151	60.4	87	46.03	244	50.62	31	50	63	51.21	10	37.03	26	49.1
Yearling	7	6.03	22	8.8	16	8.46	42	8.71	7	11.29	13	10.56	6	22.22	4	7.55
Kid	25	21.55	52	20.8	40	21.16	90	18.67	8	12.90	17	13.82	3	11.11	11	20.8
Total yearlings and kids	32	27.58	74	29.6	56	29.62	132	27.38	15	24.19	30	24.39	9	33.33	15	28.3
Male Class I	1	0.86	3	1.2	7	3.70	11	2.28	0	0	0	0	0	0	0	0
Male Class II	0	0	3	1.2	8	4.23	16	3.31	4	6.45	9	7.31	1	3.70	1	1.89
Dark Brown (Class III)	4	3.44	4	1.6	2	1.058	21	4.35	3	4.83	9	7.31	2	7.40	2	3.77
Pale Brown (Class IV)	5	4.31	11	4.4	11	5.82	26	5.39	5	8.06	8	6.50	8	29.62	8	15.1
Blond (Class V)	2	1.72	4	1.6	14	7.40	24	4.97	4	6.45	4	3.25	1	3.70	1	1.89
Unidentified male	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total males	13	11.20	25	10	42	22.22	98	20.33	16	25.8	30	24.39	12	44.44	12	22.6
Unidentified (all)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**116**	100	250	100	**189**	100	482	100	**62**	100	123	100	**27**	100	53	100
Density (animal/km^2)	**7.73**				**10.32**				**1.86**				**1.35**			

3. Population status of Himalayan tahr during rutting season, (Nov to Dec 2007)

I obtained 53 sighting of Himalayan tahr (232 individuals) and estimated total 195 populations. The ratio of male to female was 0.79 and kid to female was 0.25. Yearling to Kid ratio was 0.35. Mean group size was 4.37 (range: 1-24, standard deviation=6.52) (Table 5.3).

The male to female ratio was highest in Thame (1.1) and it was followed by Phortse (0.8), Namche (0.76), and Gokyo (0.66) (Figure 5.3.A). The kid to female ratio was highest in Thame (0.33), then it was followed by Phortse (0.27), Namche (0.25), and Gokyo (0.16) (Figure 5.3.B). The yearling to kid ration was highest in Gokyo (1) and it was followed by and Thame (0.5), Namche (0.45), and Phortse (0.15) (Figure 5.3.C).



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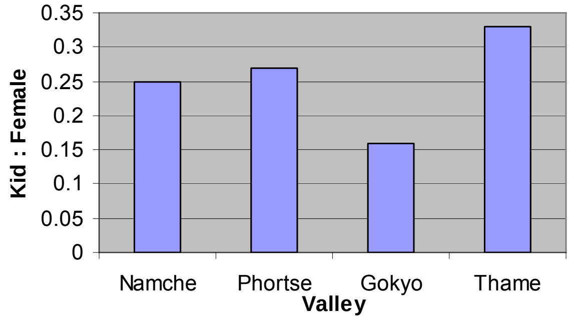

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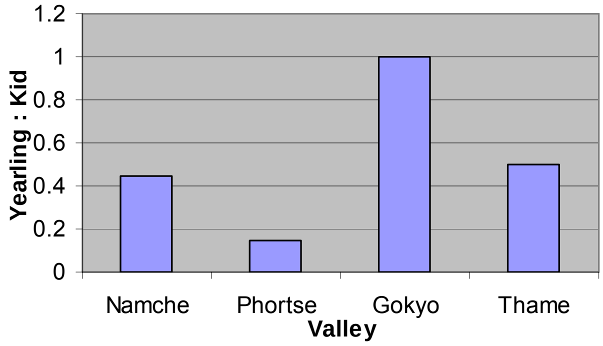

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Figure 5.3. A. ratio of male to female, B. ratio of kid to female and C. ratio of yearling to kid

Table 5.3 Tahr population structure based on known numbers of different tahr repeated total counts and classification) and all animals tallied four valley Nov_Dec 2007 (n=53)

Himalayan tahr	Namche				Phortse				Gokyo				Thame			
	Known number (n=31)		All animal tallied (n=35)		Known number (n=10)		All animal tallied (n=12)		Known number (n=1)		All animal tallied (n=1)		Known number (n=4)		All animal tallied (n=5)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Female	35	46.67	43	46.74	44	53.0	47	47	12	50.0	12	50.0	4	30.8	6	37.5
Yearling	3	4.00	5	5.43	2	2.4	2	2	2	8.3	2	8.3	1	7.7	1	6.3
Kid	8	10.67	11	11.96	9	10.8	13	13	2	8.3	2	8.3	2	15.4	2	12.5
Total yearlings and kids	11	14.67	16	17.39	11	13.3	15	15	4	16.7	4	16.7	3	23.1	3	18.8
Male Class I	4	5.33	4	4.35	0	0.0	0	0	1	4.2	1	4.2	0	0.0	0	0.0
Male Class II	2	2.67	1	1.09	6	7.2	8	8	1	4.2	1	4.2	1	7.7	1	6.3
Dark Brown (Class III)	2	2.67	5	5.43	8	9.6	8	8	3	12.5	3	12.5	0	0.0	0	0.0
Pale Brown (Class IV)	14	18.67	16	17.39	5	6.0	5	5	0	0.0	0	0.0	4	30.8	4	25.0
Blond (Class V)	7	9.33	7	7.61	15	18.1	17	17	3	12.5	3	12.5	2	15.4	2	12.5
Unidentified male	0	0.00	0	0.00	0	0.0	0	0	0	0.0	0	0.0	0	0.0	0	0.0
Total males	29	38.67	33	35.87	34	41.0	38	38	8	33.3	8	33.3	7	53.8	7	43.8
Unidentified (all)	0	0.00	0	0.00	0	0.0	0	0	0	0.0	0	0.0	0	0.0	0	0.0
Total	**75**	100.00	92	100.00	**83**	100.0	100	100	**24**	100.0	24	100.0	**13**	100.0	16	100.0
Density (animal/km^2)	**5**				**4.5**				**0.72**				**0.65**			

4. The change of kid to female ratios of tahr throughout the year

In average of all valleys, there was a decline in kid to female ratios from 0.35 in July to October (birth season) and 0.25 in Nov – Dec (rutting season). Similarly, there were the declines of kid to female ratios in valley wise from birth season to rutting season (Figure 5.4).

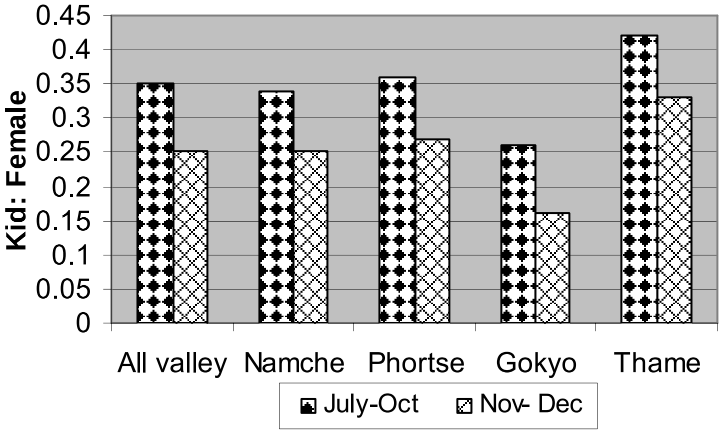


Figure 5.4 Change in kid to female ratios of tahr in SNP, 2007

5.1.2 Musk deer

I obtained 140 individual of musk deer comprising ratio of male to female was 0.67 and ratio of young to female was 0.08. In average, the encounter rate was 1.06 and density was 17.28/km^2. The encounter rate was the highest in Tangboche (2.2) and it was followed by Phortse (0.92), Namche (0.83), and Thame (0.17) (Table 5.4). In Gokyo valley, musk deer were not sighted.

Table 5.4 Population detail of musk deer in four valleys in SNP, 2007

Valley	Transect length (km)	Frequency of survey	Male	Female	Young	Total	Encounter rate	Individual/ km^2
Namche	5.162	9	14	25	0	39	0.83	13.99
Phortse	7.573	8	24	27	5	56	0.92	15.40
Thame	2.478	9	3	1	0	4	0.17	2.98
Tangboche	3.1	6	12	26	2	41	2.20	36.73
Total			53	79	7	140		
Average							1.06	17.28

5.1.3 Himalayan monal

I obtained 312 individual of monal comprising ratio of male to female was 1.38 and ratio of young to female was 0.23. In average, the encounter rate was 2.14 and 35.66number/km2. The encounter rate was the highest in Phortse (3.33) and it was followed by Namche (0.94). Similarly the density was also higher in Phortse (55.55 number/km2) than Namche (15 number/km2). In Gokyo valley, 11 monal comprising 3 males and 8 females were sighted in random sites, and similarly 3 monal comprising 1 males and 2 females were sighted in Thame.

Table 5.5 Population detail of Himalayan monal in four valleys in SNP, 2007

Valley	Transect length (km)	Frequency of survey	Male	Female	Young	Total	Encounter rate	Individual/ km^2
Namche	5.162	9	17	20	7	44	0.94	15.78
Phortse	10.058	8	148	99	21	268	3.33	55.55
Total			165	119	28	312		
Average							2.14	35.66

5.1.4 Blood pheasant

I obtained 63 individual of monal comprising ratio of male to female was 1.55 and ratio of young to female was 0.6. In average, the encounter rate was 0.61 and 10.39number/km2. The encounter rate was the highest in Tangboche (1.34) and it was followed by Phortse (0.39) and Namche (0.12). Similarly the density was also the highest in Tangboche (22.40number/km2) and it was followed by Phortse (6.63number/km2) and Namche (2.15number/km2). In Gokyo valley, 11 monal comprising 3 males and 8 females were sighted in random sites, and similarly 3 monal comprising 1 males and 2 females were sighted in Thame.

Table 5.6 Population detail of blood pheasant in four valleys in SNP, 2007

Valley	Transect length (km)	Frequency of survey	Male	Female	Young	Total	Encounter rate	Individual/ km^2
Namche	5.162	9	3	3	0	6	0.12	2.15
Phortse	10.058	8	14	6	12	32	0.39	6.63
Thame	2.478	9	0	0	0	0	0	0
Tangboche	3.1	6	14	11	0	25	1.34	22.40
Total			31	20	12	63		
Average							0.61	10.39

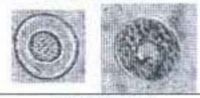
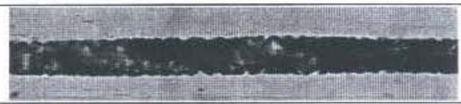
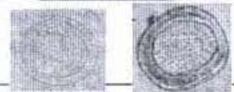
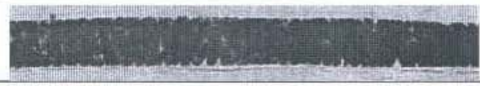
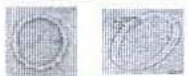
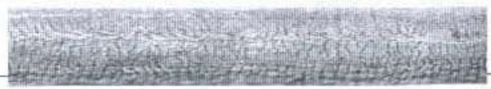
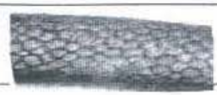
5.1.5 Snow cock

I obtained 12 sighting of snow cock comprising 69 individual in Gokyo. The ratio of male to female was 1.18 and young to female was 2.18. Mean group size was (range: 1-19 standard deviation=6.52)

5.2 THE HAIR IDENTIFICATION KEY

The key included a total 13 species (8 wild species and 5 domestic) know to occur in the study area. The photographic reference key developed in the study was used to analyze all scat samples. Cortex diameter and medulla index (ratio of medulla to cortex), distribution of pigments and pattern, arrangement of medulla, and cross sectional details were the most valuable aids in the identification of the unknown hair. Maximum and minimum cortex diameter, medulla index, photographic references of scale, medulla, cross section and diagnostics features of the 10 species included in the key are presented in the table 5.7.

Table 5.7. COMPARATIVE MAMMALIAN HAIR IDENTIFICATION KEYS (VALUE OF CORTEX DIAMETER AND MI MEASURED IN MICROMETER)

SPECIES	CORTEX DIAMETER	MI (I)	CUTICULAR SCALE	MEDULLA	TS MEDULLA	Pattern and Characteristics
YAK	70-110	0.119				**Scale**: crenate, irregular wave; **Medulla**: fragmented; **TS**: oval large
DOG	25-75	0319				**Scale**: crenate, irregular wave; **Medulla**: continuous and discontinuous; **TS**: circular large medulla
SNOW LEOPARD	40-70	0406				**Scale**: rippled, irregular wave; **Medulla**: continuous; **TS**: circular large medulla
COW	45-60	0.431				**Scale**: smooth, regular wave; **Medulla**: continuous; **TS**: circular medium medulla
HORSE	30-55	0.531				**Scale**: slightly crenate, irregular wave; **Medulla**: continuous; **TS**: somewhat oval medium medulla
HIMALAYAN TAHR	65-175	0.717				**Scale**: smooth, regular wave; **Medulla**: continuous **TS**: circular large medulla
GOAT	150-215	0.722				**Scale**: rippled, irregular wave; **Medulla**: continuous **TS**: circular and oval large medulla
HARE SP.	25-65	0.763				**Scale**: dentate, chevron; **Medulla**: continuous **TS**: oval partition medulla
RED FOX	60-85	0.788				**Scale**: dentate, chevron; **Medulla**: continuous **TS**: circular large medulla
SHREW SP	12.5-22.5	0.802				**Scale**: dentate, diamond, coronal; **Medulla**: continuous **TS**: oval dumb bell shaped
HOUSE RAT	40-110	0.871				**Scale**: dentate, chevron; **Medulla**: continuous **TS**: circular, concavo-convex divided medulla
PIKA	10-55	0.880				**Scale**: dentate, chevron; **Medulla**: continuous **TS**: circular large medulla
MUSK DEER	150-335	0.943				**Scale**: smooth, broad petal; **Medulla**: continuous; **TS**: circular, hollow medulla

5. 3 SPECIES COMPOSITION IN THE LEOPARD'S DIET

5.3.1 Overall diet

Twelve species were identified in the 120 scats examined. The prey consumed included 8 species of wild and 4 species of domestic livestock including dog. This yield an average of 1.38 prey items per scat. Most of the scat samples (67.5%) contained remains of only one prey species, whilst two and three species were present in 27.5% and 4.1% respectively, and four species were present in only 0.8% of the scats. Five scats comprised mainly plant materials. Similarly, six scats comprised mainly stone and soil.

Snow leopard predated most frequently on Himalayan tahr and it was detected in 26.5% relative frequency of occurrence while occurred in 36.66% of all scats, then it was followed by musk deer (19.87%), yak (12.65%), cow (12.04%), dog (10.24%), unidentified mammal (3.61%), woolly hare (3.01%), rat sp. (2.4%), unidentified bird sp. (1.8%), pika (1.2%), and shrew (0.6%) (Table 5.8). Wild species were present in 58.99% of scats whereas domestic livestock with dog were present in 40.95% of scats.

5.3.2 Seasonal trend in diet

Snow leopard predated most frequently on wildlife species in three seasons; spring (61.62%), autumn (61.11%) and winter (65.51%), and most frequently on domestic species including dog in summer season (54.54%).

Himalayan tahr was the most frequently occurring item in spring (33.72%), summer (24.24%) and autumn seasons (27.77%) whilst it was ranked in third occurring item (6.88%) in winter. Musk deer was the most frequently occurring item in winter (48.27%) whilst it ranked in second in spring (13.95%), and third ranked in summer (15.15%) and autumn (11.11%). Yak was occurred in snow leopard diet in second ranked during summer (18.18%), whilst it was occurred in third ranked during spring (12.79%), autumn (11.11%), and winter (6.88%). Cow was occurred in snow leopard diet in second ranked during summer (18.88%), autumn (22.22%), and winter (10.34%). Horse and dog were also the alternative opportunistic diet of snow leopard and they were present in 5 – 11% diet of snow leopard throughout the year. Small mammals and bird species were also supplementary diet in autumn and spring season.

5.8 Prey species composition in snow leopard scats (n= 120) in SNP, March to December 2007

	All season (n=120)			Spring (n=66)		Summer (n=21)		Autumn (n =10)		Winter (n=23)	
PREY	n	A	B	n	B	n	B	n	B	n	B
Wild species	**98**	**81.64**	**58.99**	**53**	**61.62**	**15**	**45.45**	**11**	**61.11**	**19**	**65.51**
Himalayan tahr	44	36.66	26.5	29	33.72	8	24.24	5	27.77	2	6.89
Musk deer	33	27.5	19.87	12	13.95	5	15.15	2	11.11	14	48.27
Woolly hare	5	4.16	3.01	3	3.48	0	0	1	5.55	1	3.44
Rat sp.	4	3.33	2.4	2	2.32	1	3.03	1	5.55	0	0
Pika	2	1.66	1.2	1	1.16	0	0	1	5.55	0	0
Shrew sp.	1	0.83	0.6	1	1.16	0	0	0	0	0	0
Unidentified mammal	6	5	3.61	3	3.48	1	3.03	0	0	2	6.89
Unidentified bird sp.	3	2.5	1.8	2	2.32	0	0	1	5.55	0	0
Domestic livestock	**68**	**56.65**	**40.95**	**33**	**38.37**	**18**	**54.54**	**7**	**38.88**	**10**	**34.48**
Yak/Napki	21	17.5	12.65	11	12.79	6	18.18	2	11.11	2	6.89
Cow/calf	20	16.66	12.04	7	8.13	6	18.18	4	22.22	3	10.34
Dog	17	14.16	10.24	10	11.62	4	12.12	1	5.55	2	6.89
Horse	10	8.33	6.02	5	5.81	2	6.06	0	0	3	10.34
Total	**166**	**138.33**	**100**	**86**	**100**	**33**	**100**	**18**	**100**	**29**	**100**

n= count of frequency
A= % Frequency of occurrence
B= % Relative Frequency of occurrence

5.3.3 Relative biomass and relative number of individual consumed

In term of relative biomass consumed, in average, Himalayan tahr was the most important prey species contributed 26.27% of the biomass consumed. This was followed by yak (22.13%), cow (21.06%), musk deer (11.32%), horse (10.53%), wooly hare (1.09%), rat (0.29%), pika (0.14%) and shrew (0.07%). In average, domestic livestock including dog were contributed more biomass in the diet of snow leopard comprising 60.8% of the biomass consumed whilst the wild life species comprising 39.19%.

In spring, Himalayan tahr was the most important prey species making up 34.10% of the biomass consumed and it was followed by yak (22.82%), cow (14.52%), horse (10.37%), dog (8.19%), musk deer (8.10%) and other small mammals. In summer, yak and cow were the most important prey species making up each 27.5% and it was followed by Himalayan tahr (20.78%), horse (9.16%), musk deer (7.46%), dog (7.24%) and rat sp. (0.31%). In autumn, cow was the most important prey species making up 39.11% of the biomass consumed and it was followed by the tahr (27.11%), yak (19.55%), musk deer (6.36%), dog (3.86%), woolly hare (2.02%), and rat sp./ Pika (0.67%). In winter, musk deer was the most important prey species making up 31.03% of biomass consumed and it was followed by cow and horse (each 20.42 %), yak (13.61%), tahr (7.71%), and horse (5.37%) (Table 5.10).

5.9 Live body weight of prey species and correction factor (biomass per deposited scat)

PREY	Body weight (Kg)	correction factor (kg/scat)
Wild species		
Himalayan tahr	60.5	4.0975
Musk deer	10.7	2.3545
Woolly hare	1.5	1.5
Rat sp.	0.5	0.5
Pika	0.5	0.5
Shrew sp.	0.5	0.5
Domestic livestock		
Yak/Napki	150	7.23
Cow/calf	150	7.23
Dog	25	2.855
Horse	150	7.23

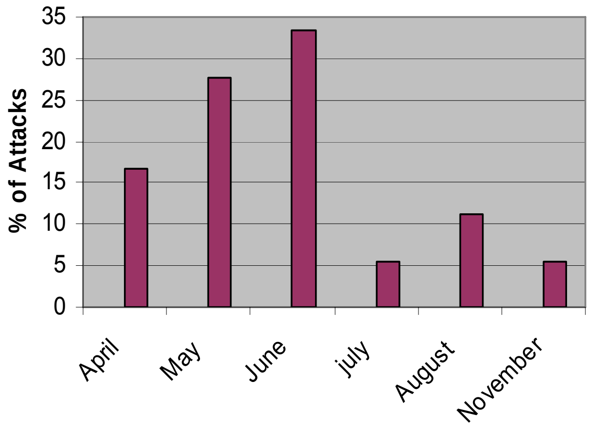
5.10 Calculation of relative biomass and relative number of individuals consumed by a snow leopard population, based on 120 scats collected in SNP, March- December 2007

PREY	All season		Spring		Summer		Autumn		Winter	
	A	B	A	B	A	B	A	B	A	B
Wild species	**39.19**	**83.64**	**44.07**	**83.89**	**28.57**	**70.10**	**37.46**	**90.46**	**40.16**	**87.43**
Himalayan tahr	26.27	11.22	34.10	14.19	20.78	14.37	27.71	8.10	7.71	2.80
Musk deer	11.32	27.33	8.10	19.08	7.46	29.19	6.36	10.53	31.03	63.89
Woolly hare	1.09	18.82	1.29	21.68	0	0	2.02	23.93	1.41	20.73
Rat sp.	0.29	15	0.28	14.45	0.31	26.53	0.67	23.93	0	0
Pika	0.14	7.5	0.14	7.22	0	0	0.67	23.93	0	0
Shrew sp.	0.07	3.75	0.14	7.22	0	0	0	0	0	0
Domestic livestock	**60.8**	**16.56**	**55.92**	**16.27**	**71.43**	**30.02**	**62.53**	**9.65**	**59.83**	**12.73**
Yak/Napki	22.13	3.81	22.82	3.83	27.50	7.67	19.55	2.30	13.61	1.99
Cow/calf	21.06	3.62	14.52	2.43	27.50	7.67	39.11	4.61	20.42	2.99
Dog	7.07	7.31	8.19	8.25	7.24	12.12	3.86	2.73	5.37	4.73
Horse	10.53	1.81	10.37	1.74	9.16	2.55	0	0	20.42	2.99
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

A=Relative biomass consumed (%)
B=Relative number of individuals consumed (%)

5.4 PATTERN OF LIVESTOCK DEPREDATION

A total of 18 depredation events (calf= 6, Napki=4, cow = 4, horse young=3 and sheep=1) were recorded from April to December 2007. Four incidents were attributed on the based of visual confirmation of the snow leopard, and the rest based on the tracks, claw marks, or the condition of the livestock carcass. Two (11.11%) of the 18 recorded events occurred inside the goth, 8 (44.44%) were in the pasture land, 4 (22.22%) were inside the forest and 4 (22.22%) were near the agriculture land. Fourteen livestock (77.77%) of the attacks occurred were at the age of below two years and 3 were between 2 to 5 years and 1 (5.55%) were more than 8 years old. The frequencies of depredation were highest from April to June and lowest to July to November (Figure 5.5.A). Eleven (61.11%) attacks occurred were in day (61.11%) and 3 (16.66%) were in nigh, 2 (11.11%) were in morning and 2 (11.11%) were in evening. Most of the attacks were at more than 500m far from the Goth (66.66%) and forest (55.55%). The highest attacks occurred were at less than 500m distance from village, shrub land and cliff. This data showed that snow leopards attack the livestock at near the escape cover (near shrub land and cliff) (Figure 5.5.B). Most of the attacks occurred were during cloudy (38.88%) and rainy day (38.88%) and few attacked were during sunny day (22.22%) (Figure %.5.5.C). The attack evidences suggested that snow leopard use to drag the livestock from 1 to 100 meter and attack at neck at first.



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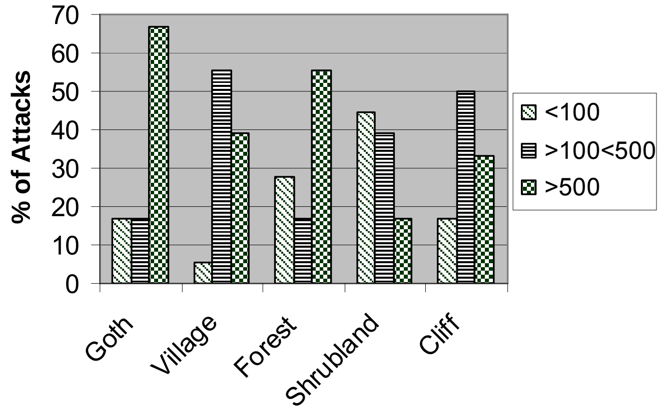

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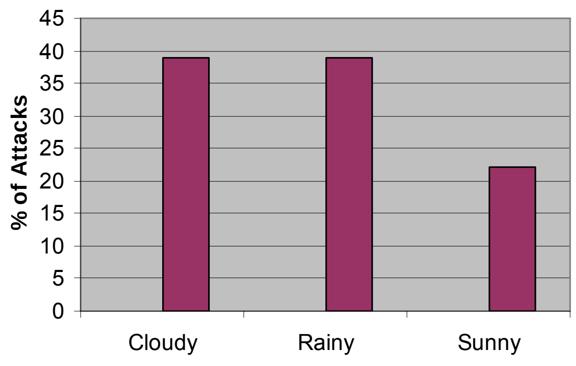

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Figure 5.5 A. % monthly attacks of livestock by snow leopard, B. % attacks of livestock by snow leopard at the different distance from Goth, village, forest, scrubland, and cliff, and C. % attacks of livestock by snow leopard with different weather condition

5.5 OUTREACH PROGRAM

In outreach program, I conducted the Awareness program in schools for grade seven and eight, Conservation art contest for grade six to nine, and story about snow leopard and color printing on snow leopard picture for grade one to five.

Overview:

1st Pre-outreach Snow Leopard Knowledge/Attitude Questionnaire

The prepared questionnaire sheets were distributed to the students and asked to give answer of 20 questions relating to snow leopards.

2nd Conservation Presentation (1 hour)

I took class for grade 7 and 8 on the title in title “Mountain ecosystem and snow leopard conservation” and talk about on the following topics:

1. Ecology and mountain ecosystem

2. Protected areas, conservation areas, buffer zone and hunting reserve of Nepal

3. Conservation laws

4. Biology and behavior of snow leopard

5. Snow leopard conservation issues

I told story “*Pasang and the Sheep Thief* “ to grade 1 to 5 related about snow leopard was written by Rabin Nepali and illustrated by Shanta Hitang. Each student received story book, copy and pencil. They were also asked participate to coloring on snow leopard sketches.

3rd Conservation Art Contest

Students (grade 5 – 9) are asked to participate in art contest with the theme “Mountain and Snow leopard” and we gave a talk about snow leopard and their place of mountain ecosystem. We provided drawing sheet, pencil and color print for each participate.

Students receive pencil/pen and small notebook.

They all receive a certificate of participation

The winners (first/second/third) receive small prize (note dairy, pencil, geometry box and color print according to wining grade).

4th Post-outreach repeat questionnaire (~1-2 months following outreach presentation)

Each student was asked the same questions from the original Knowledge/Attitude Questionnaire and Awareness Increase Indicator Questionnaire (10 questions) related with snow leopard and its prey species.

Six outreach activities conducted in 2007:
1) 7th May 2007 – Khumjung Secondary High School, Khumjung (grade 7 and 8). Pre-outreach Questionnaire, Conservation Presentation and Art Contest.

2) 15 June 2007 – Shree Phortse Primary School, Phortse (grade 1 to 5). Listening story, photo presentation of snow leopard and prey species, and coloring on snow leopard sketches.

3) 12 August 2007- Listening story, photo presentation of snow leopard and prey species, and coloring on snow leopard sketches.

4) 25 August 2007- Shree Thame Lower Secondary High School (grade 7). Pre-outreach Questionnaire and Conservation Presentation

5) 23 September – Khumjung Secondary High School (grade 7 and 8) Post-outreach Questionnaire and Awareness Increase Indicator Questionnaire

6) 15 October 2007- Shree Thame Lower Secondary High School (grade 7). Post-outreach Questionnaire and Awareness Increase Indicator Questionnaire

6. DISCUSSION

6.1 HIMALAYAN TAHR POPULATION

I estimated of tahr of 293 individuals during April to June (before birth season), 394 individuals during July to October (birth season) and 195 individuals during November to December (rutting season). In average, this data revealed the mean population of tahr was 294 (standard deviation = 99.5) in 2007. Lovari (1992) estimated 300 populations in 1989. Ale (2007) estimated 277 populations of tahr in 2005. This data of study revealed that population has not growing in sagarmatha recently what Lovari estimated over a decade ago. No comparative study is available from the Himalayas on population growth rates of tahr, but surveys in New Zealand indicates that they are prolific breeders in absence of predation and hunting. The continued monitoring of tahr in Carneys Creek provides an indication of long-term changes in the abundance of tahr in the eastern Southern Alps (Forsyth and Tustin 2001). Annual summer or autumn counts during 1984-96 have shown that the abundance of females did not increase following the government moratorium on helicopter-based hunting in the Two Thumb Range in 1983 (r-= 0.02 ± 0.02 SE; Forsyth 1999). However, in neighboring North Branch, which was leasehold land where recreational hunting had been prohibited, the female population increased rapidly (r = 0.28 ± 0.06; Forsyth 1999). Counts at 14 sites in Southern Alps, New Zealand, 1978-1979 and 1991-1996 revealed a six-fold increase in the mean abundance of tahr (Forsyth & Hickling 1998).

In the present study, tahr groups ranged in size from 1-30, with the average 8.12 during April-June (before birth), ranged 1-44, with the average 11.39 during July-October (birth season) and ranged 1-24, with the average 4.37 during November – December (rutting season). Lovari (1992), in the 1982 (September/October), documented considerably smaller group size in Sagarmatha (Pangboche-Phortse: median 5; range: 1-53; n=9; and Namche: median 4; range: 1-7; n=7). The average group size of tahr in Sagarmatha may have increased over the decade due to the reoccurrence of snow leopard (Ale and Boesi 2005) which may cause such adaptation in tahr behavior. Annapurna (13.8, range 1-57; n=134: Gurung1995) and Langang (15, largest group 77: Green 1979) exhibited much larger groups of tahr. Among others, this apparent difference in average group size in different localities may be attributed to the degree of habitat ruggedness that characterizes particular localities. This in turn influences distribution and abundance of food and predation pressure. Sagarmatha supports smaller group sizes of thar than that of Langtang and Annaupurna, perhaps because the former is more rugged than the later two areas. The overall tahr density was 3.4/km2 during April-June (before birth), 4.58/km2 during July-October (birth season), and 2.26/km2 during November – December (rutting season) in 2007. Gurung (1995) reported tahr at density of 7.7/km2 in the parts of Annpurna (57) with no hunting. In the absence of hunting or natural predation, food can be the principle factor limiting the size of the populations. In Langtang area of Lanagtang National Park, local density of tahr reached as high as 24/km2, where tahr were neither hunted nor was their habitat grazed by livestock. On the other hand, Yala, with ten times more domestic sheep and eight times more cattle than Langtang supported low tahr density (6/km2). In the absence of hunting in the parts of New Zealand, tahr attain densities of >30/km2 (Tustin and Challies 1978) but with regular hunting their population maintain a density of 5/km2. In the Sagarmatha, the park banned hunting of tahr and any other wildlife species in 1976, but allowed grazing by local livestock (yak and yak/cattle crossbreed). In the case of Sagarmatha no substantial increment in tahr population size has occurred since the 1009s suggests that one or more limiting factor may have been impacting tahr populations. In 2006, though the dietary overlap between Himalayan tahr and livestock was high (83%), high competition would not be expected since forage availability was not so scarce in rangelands (Biomass (wet weigh): 2276-2643 Kg/ha) (Shrestha 2007). In the absence of hunting, it is plausible that current low tahr density in Sagarmatha can be attributed to predation by recent colonizing snow leopards. Snow leopard predated most frequently on Himalayan tahr 36.66% of all scats (Table 5.8).

The reproductive rate (ratio of kid to female) was 0.21 in April-June (before birth), 0.35 in July-October (birth season) and 0.25 in November – December (rutting season) which showed the low reproductive success of tahr in 2007. Such alarming low reproductive success of tahr has been reported from the area since 2004 (Shrestha 2004 and 2006, and Ale 2005 and 2007). By contrast, Schaller (1973) reported a kids-to-females ratio of 0.56 in Kang Chu, east Nepal (tahr population hunted here) and 0.57 in Annapurna region of west Nepal (with no large predators in tahr habitat) (Gurung 1995). The kids to female ratios of thar in Pangboche/Phortse and Namche in 1991 and 1992 (Iovari 1992) were within normal range.

In 2007, the estimated kid 76 from birth season were decreased into 21 in rutting season showed 72.36% kid mortality rate from birth to rutting season. As no disease has been reported from the region, predation should be responsible for young mortality. The snow leopard preying on tahr kids could have increased by one, in turn increasing the predation pressure. Young mortality due to predation can be high in ungulates (64% in some species: Bergerud 1988), and predators may affect prey population sizes and structure through mortality (Terborgh et al 2002, Sinclair et al 2003). A sample of 20 adult males was darted, weighted, aged, and ear tagged as part of the EV-K2-CNR project in November 2004 (Ale 2005 and S. Lovari Pers. Comm.). The mortality per year of tagged tahr on November 2005 was 20% (Andrea et al 2006) while it was 18.75% in 2007 (Table 6.1).

Table 6.1 Survival of tagged male tahr during 2005-2007 in Namche

Year	2004Nov	2005Nov	2007Nov
No. of male tagged tahr	20	16	10
%mortality per year	0	20	18.75

6.2 MUSK DEER POPULATION

In average, the encounter rate of musk deer was 1.06 and the density was 17.28 km2 comprising ratio of male to female was 0.67 and ratio of young to female was 0.08 in 2007. During the silent drive count on 50 hectares of Phortse forest in 1987, Kattel (1992) recorded 23 musk deer(ratio of female to young was 4:1 and male to female was 1:3) and estimated density of 46/km2. In present study, I recorded density of musk deer 15.4 km2 in Phortse. This data revealed that the population of musk deer has decreased considerably in recent from a decade ago as reported by Kattel. In Phortse forest, there is strict protection of musk deer from park and local people. Most of the livestock were grazed in pasture land so there would not expected the competition between livestock and musk deer. One plausible factor that caused the decrease of musk deer population may be due to predation. Besides this, an inescapable factor is the sign of deforestation such as landslide and eroded forest are becoming increasingly visible in Phortse forest. In average, musk deer was the second major prey species (constituted 27 % of all scats) of snow leopard in 2007 while the most frequently occurring item in winter (48.27%) (Table 5.8).

6.3 DIET OF SNOW LEOPARD

With 120 scat analysis, 12 species (8 species of wild and 4 species of domestic livestock) were identified in snow leopard scat including bird and unidentified mammals. In average of the season, Himalayan tahr was the most dominated diet of snow leopard. Musk deer was the second most frequently consumed prey species. The livestock were also important diet for the snow leopard constituted fairly in the diet. All livestock (yak, cow, horse and dog) present in 40.95 % (relative frequency) of the scats. Small mammals and unidentified bird sp. were also constituted as a supplementary food in the diet of snow leopard. The unidentified birds might be game birds such as Himalayan monal, blood pheasant, and snow cock as they were abundance in SNP.

Over most of snow leopards range, they are primarily dependent upon blue sheep (Annapurna: Oli et al 1993 and Langu: Jackson 1996 of Nepal, and Chundawat and Rawat: 1994 in northwestern India) or Asiatic ibex (Tomur Feng: Schaller 1988a in China and Zailisky-Alatau: Zhirjakov 1990 in USSR), Sagarmatha is unusual in that it lacks both blue sheep and ibex, but supports Himalayan tahr. In Chitral of Pakistan (Schaller 1977), markhor was the most frequently eaten prey species and Marmots constituted a significant proportion of snow leopard's diet in Xinjiang, Qinghai and Gansu Province, China (Schaller et al 1987, 1988a, b), and in Annapurna, Nepal(Oli et al 1991). Marmot and markor are also absent in Sagarmatha.

In three season (spring, summer and autumn), the diet of snow leopards concentrates (range: 24% - 33%) on tahr while in winter the diet concentrates (48%) on musk deer. In average, snow ate most frequently on livestock in summer and it was constituted 54% of the scats Figure 6.1 and Table 5.8). However, livestock depredation largely depends on climate, escape cover and other factors (see also 6.4). Horse and dog were also the alternative opportunistic diet of snow leopard and they were present in 5 – 11% diet of snow leopard throughout the year. Small mammals and bird species were also supplementary diet in autumn and spring season.

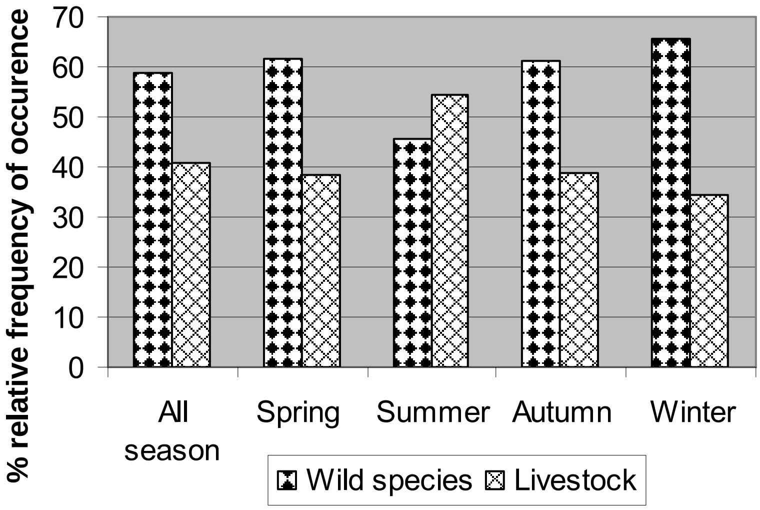

Figure 6.1 Diet compositions of wild mammals and domestic livestock in Snow leopard scats.

In all average of all season, Himalayan tahr was the most important prey species contributed 26.27% of the biomass consumed. In winter season, musk deer was the most important prey species contributed 31% of the biomass consumed. However, in average sample between wild and livestock, domestic livestock were contributed more biomass in the diet of snow leopard throughout the year.

It has been estimated that an adult snow leopard (45 kg) requires 1.5 to 2.5 kg meat per day (Wemmer and Sunquist 1988). Assuming an average diet of 2 kg per day for a snow leopard, the biomass consumed by snow leopard was calculated and the number of prey species required was determined. The annual prey consumption by a snow leopard (based on 2 kg/day) was estimated to be three Himalayan tahr, seven musk deer, five wooly hare, four rat sp., two pika, one shrew and four livestock (Table 6.2). Ale (2007) estimated six individual of snow leopard in the study area. The annual prey consumption by six snow leopard was estimated to be nineteen Himalayan tahr, 46 musk deer, thirty one woolly hare, twenty five rat sp., twelve pika, six shrew sp., and twenty eight livestock (Table). The increase of prey consumed by snow leopard was calculated when livestock is made unviable to snow leopard. The predation pressure on Himalayan tahr or wildlife species increase by 155%, if their access of livestock is restricted (Table 6.3).

Table 6.2 Estimation of Annual biomass consumption and prey species eaten by snow leopard in 2007

Prey	Relative biomass consumed (A)	Biomass consumed per year[a] (B)	Live weight of prey	Prey eaten per year by a snow leopard	Prey eaten per year by six snow leopard
Wild species	**39.19**	**286.087**		**23.49743**	**140.9846**
Himalayan tahr	26.27	191.771	60.5	3.169769	19.01861
Musk deer	11.32	82.636	10.7	7.722991	46.33794
Woolly hare	1.09	7.957	1.5	5.304667	31.828
Rat sp.	0.29	2.117	0.5	4.234	25.404
Pika	0.14	1.022	0.5	2.044	12.264
Shrew sp.	0.07	0.511	0.5	1.022	6.132
Domestic livestock	**60.8**	**443.84**		**4.678813**	**28.07288**
Yak/Napki	22.13	161.549	150	1.076993	6.46196
Cow/calf	21.06	153.738	150	1.02492	6.14952
Dog	7.07	51.611	25	2.06444	12.38664
Horse	10.53	76.869	150	0.51246	3.07476
Total	**100**	**730**		**32.85505**	**197.1303**

[a] Assuming an average diet of 2 kg per day (730 kg per year) for a snow leopard and B= (A X 730/100).

Table 6.3 Estimation of the increase of prey consumption by snow leopard when livestock is restricted to snow leopard.

Wild species	[1]Relative biomass consumed(A)	[2]Biomass consumed in terms of livestock biomass(B)	Biomass consumed per year(A+B)	Prey eaten per year by a snow leopard	Prey eaten per year by six snow leopard
Himalayan tahr	26.27	297.5501	489.3211	8.087953	48.52772
Musk deer	11.32	128.2173	210.8533	19.70591	118.2355
Woolly hare	1.09	12.34601	20.30301	13.53534	81.21204
Rat sp.	0.29	3.284718	5.401718	10.80344	64.82062
Pika	0.14	1.585726	2.607726	5.215452	31.29271
Shrew sp.	0.07	0.792863	1.303863	2.607726	15.64636
Total	**39.19**	**443.7767**	**730**	**59.95582**	**359.7349**

[1]Relative biomass consumed when livestock available
[2] Biomass consumed in term of livestock biomass of total 443.77 kg (see table 6.2).

A snow leopard would need 1.5 kg per day or 548 kg per year (Schaller 1977). Jackson and Ahlborn (1984) estimated the food requirements at 1.3-2.0 kg per day (at least 822 kg per year) and an adult snow leopard eats 20-30 blue sheep annually. He suggested that a blue sheep population of 150-200 animals would be required to support an adult cat. However, Wemmer and Sunquist's (1988) estimated 1.5-2.5 kg/day) and an adult snow leopard eats 26 blue sheep annually. They estimated a population of 260 blue sheep sized prey would be required to support an adult cat. Based on this data, In present study the mean population 294 of tahr (ranged: 195-394), along with the current abundance of other prey species (muck deer, game birds, small mammals, and livestock), would provide sufficient food for snow leopards to sustain themselves and build up their population in Sagarmatha at least for several years to come. On the contrary, the return of the snow leopard has brought about a sharp decrease of Himalayan tahr and musk deer. It is very alarming as to the tahr: the snow leopard is taking nearly all the kids of the tahr at each reproductive season. Loss of natural prey is a threat to the species throughout its range, sometimes caused by competition for grazing with domestic livestock. These pressures on wild prey can drive snow leopards to seek alternative prey among domestic stock, and so lead to resentment and killing of the cats by herders. Whatever the reasons for a reduction in snow leopard prey, the effects may be indirect as well as direct, as a shortage of natural prey can lead to increased predation on domestic livestock, which in turn may provoke herders to kill snow leopards (McCarthy and Chapron, 2003).

6.4 PATTERN OF LIVESTOCK DEPREDATION

Rates of livestock depredation by large carnivores can be influenced by local environment conditions such s abundance of natural prey (Meriggi and Lovari 1996 and Mizutani 1999) and rainfall (Woodroffe and Frank 2005, and Kolowski and Holekamp 2006), as well by socio-ecological factors including livestock husbandry practices (Ogada et al 2003 and Michalski et al 2006) and characteristics of attacked farms, village, and livestock enclosures (Mech et al 2000 and Ogada et al 2003). In the present study, the highest frequency of attack was found during April to June and lowest to July to November. The day of rainy and cloudy was the more vulnerable to livestock depredation. Snow leopard attacks occurred were the highest at near escape cover such as shrub land and cliff. Most of livestock were graze freely and unguarded in SNP which is one factor that facilitate snow leopard to attack the livestock. However, they kept their livestock near house during winter season and providing them stock dry grass.

Most of the carnivore species are in global decline. Conflicts with people, particularly over depredation on livestock, is one of the major causes of this decline. Snow leopards are reported to kill throughout their range and themselves often killed in revenge (Schaller 1977, Schaller et al 1987, 1988a, 1988b, Sherpa and Oli 1988, Annenkov 1990, Fox et al 1988, 1991, and Jackson et al 1994). Livestock predation by snow leopard has also been one of the major causes of conflict between snow leopard and humans in mountain protected areas of Nepal such as SheyPhoksumdo National Park, Kanchanjunga Conservation Area and Annapurna Conservational Area (Oli 1991, Jackson et al 1994, and Richard et al 1999). Snow leopard had killed few livestock and no more threat to local herder's live hood in 2004 (Ale 2005). However, the picture may not remain the same forever particular when cats will start supplement their diets with the livestock beyond the level tolerable to local herders. From my field experienced in 2004, 2006 (see Shrestha 2007) and 2007, I found that more local herder were aggressive and had negative attitude toward snow leopard because the depredation rate has increased per year.

6.5 CONSERVATION CHALLENGE AND OPPORTUNITIES

Both predation pressure on tahr and that on livestock suggest that there is challenge for conservationists and biologists to conserve this recovering snow leopard. Faced this issues, the development of effective conservation strategies for two threatened species (predator and prey), in an important and world-famous national park and recognized as an UNESCO World Heritage Site, depends on resolving conflicts between people and predators. Recently, direct control of free – ranging livestock and good husbandry may reduce the livestock depredation. Compensation to shepherds will also help. In long term solution, the reintroduction of blue sheep at the higher altitudes could also "buffer" predation on livestock. Prior this, the systematic study on about whether there is sufficient food for ungulates and livestock should be done, however, Shrestha (2007) suggested that forage availability was not so scarce in Monlga and Phortse rangeland in 2006 even if food overlap between livestock and Himalayan tahr was high (83%). Similar study or carrying capacity of high altitude rangeland in Gokyo valley and Pheriche valley should conducted prior to reintroduce the blue sheep on the areas.

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OUTREACH PROGRAM

Plate 1. Khumjung Secondary High School, Khumjung (grade 5 to 8) Everest Region: Student Art Contest with the theme “Mountain and Snow leopard”

Plate 2. Shree Phortse Primary School, Phortse, (grade 1 to 5) Everest region: coloring on snow leopard sketches

Plate 3. Shree Himalayan primary School, Namche (4 to 5 grade), Everest region (grade 1 to 5): coloring on snow leopard sketches

Plate 4. Conservation presentation student class for grade 7 and 8 on the title "Mountain ecosystem and snow leopard conservation"

Plate 5. Shree Phortse Primary School, Phortse (grade 1 to 5). Listening story "*Pasang and the Sheep Thief*"