Chapter 5
Interactions Between the Himalayan Tahr, Livestock and Snow Leopards in the Sagarmatha National Park

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Abstract Competition between wild ungulates and livestock for resources and interactions between these two and large predators are widely regarded as a major management issue in the Himalayas. Real data supporting these claims are scarce, but badly needed for developing good management strategies, which will effectively protect both wild ungulates and their predators in the Himalayas. Our study was done in August/September of 2006 in the Mongla and Phortse regions of the Sagarmatha National Park (SNP) with the aim of determining: (i) habitat overlap between tahr and domestic livestock, (ii) overlap in diets of tahr and domestic livestock, (iii) the effect of predators on tahr and (iv) explore the composition of vegetation in the region. Vantage points and regular monitoring from trails were used to observe the tahr and livestock. Direct observation and micro histological techniques were used to determine the overlap in diets of tahr and livestock. Diet of snow leopard was determined by scat analyses, which involved the microscopic identification of hair. There is overlap both in space and diet between tahr and livestock. Analysis of faecal samples revealed 24 species of plants in the faeces of tahr and 31 in those of livestock, of which 22 species were common to both. In total, 45 plant species were recorded at Mongla and 54 at Phortse. Two species of wild and four species of domestic mammals were identified in the scats of snow leopard, with that of Himalayan tahr being the most frequent. In terms of domestic animals, the hair of yak was most frequently

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found in the faeces of snow leopard. The results of a questionnaire revealed that the snow leopard is the main predator of domestic livestock. We conclude that there is currently no serious competition between livestock and tahr for food, the main threat now comes from the decline in plant productivity in the region due to overgrazing. This trend could seriously change the situation, as tahr and livestock would then compete for food. The most effective way of reversing this trend is to introduce measures that limit the amount of grass that is harvested for feeding livestock during winter, which is rapidly increasing.

Keywords Himalayan tahr • Snow leopard • Livestock • Prey-predator dynamics

5.1 Introduction

5.1.1 General Background

The Himalayan tahr *(Hemitragus jemlahicus*) belongs to the family Bovidae and is a migratory herbivore common at high altitudes. The Red Data Book of the Fauna of Nepal (BPP 1995) has categorized it as a species likely to become extinct, while IUCN has listed it in its category NT: near threatened. The Himalayan tahr, one of three species of tahr, is native to the Southern range of the Himalayan Mountains, including the Sagarmatha National Park (SNP) and is one of the most common species there. The other two species of tahr include the Nilgiri tahr *(Hemitragus hylocrius)* found in Southern India and Arabian tahr *(Hemitragus jayakari)* in Oman.

In our study area, the Khumbu region, which is a part of the Sagarmatha National Park (SNP), agro-pastoralism is the main occupation of the majority of people. Though tourism is emerging as an alternative source of income for people, those living in remote areas are still dependent upon traditional agriculture. Yak and its hybrids are the major livestock at high altitudes, while cows prevail at low altitudes. Domestic livestock in grazing the mountain pastures are thought to compete with wild herbivores by depleting resources and degrading the pastures (Schaller 1977; Shah 1998; Richari et al. 1992). The presence of livestock intensifies the competition between plant species and results either in the loss of species or in coexistence by partitioning of resources between species, spatially or temporally (Gause 1934; Begon et al. 1986). Buffa et al. (1998) and Shrestha (2006) note a spatial overlap in the occurrence of wildlife (tahr) and domestic animals, which is likely to lead to competition for food and habitat destruction due to overpopulation. Wildlife-livestock competition for resources is therefore widely regarded as a major management issue, particularly in the mountainous protected areas, such as the Shey Phoksundo National Park, Rara National Park, Khaptad National Park, Makalu Barun National Park, Dhorpatan Hunting Reserve, Kanchanjunga Conservation

Area and the Annapurna Conservation Area (Shrestha et al. 1990; KMTNC 1997; Richard et al. 1999; Basnet 2002).

The return of the snow leopard to the Mount Everest National Park (Ale and Boesi 2005) is likely to lead to conflicts between local people and snow leopard, if in the future this predator kills significant numbers of domestic animals. This predator may already have had a significant ecological effect on the prey-predator dynamics and community structure in the region. Shrestha (2004) and Ale and Boesi (2005) report that the kid to female ratio of the Himalayan tahr is now alarmingly low: 0.1, whereas it was about 0.6–0.8 in 1991–1992 (Lovari et al. 2006). This might be due to predation of juveniles by snow leopard, but this remains to be confirmed. As snow leopard and common leopard are potential predators of tahr, conservation of tahr results also in the conservation of pastures and large predators, which in turn play a critical role in maintaining the ecological integrity of the region. In order to preserve wildlife and improve the standard of living of local people, it is crucial that managers understand the interactions between humans and wildlife. Therefore, it is extremely important to develop a proper conservation strategy for the tahr in the SNP. However, neither this problem, nor the tahr-livestock prey-predator relationships in this area have been studied systematically and it is unknown, whether the grass cover in the area is sufficient to support both tahr and livestock.

5.1.2 Study Objectives

The overall aim of this study was to investigate: (1) interactions between Himalayan tahr and livestock, (2) effect of predators on both these ungulates and (3) the composition of the vegetation of alpine pastures in tahr habitats in the Sagarmatha National Park.

The specific objectives were to:

1. investigate the habitat overlap between tahr and livestock by comparing their use of this habitat in terms of altitude, aspect, slope, percentage vegetation and terrain type;
2. determine the differences in the diet of tahr and livestock and relative proportions of the different food plants in their diets;
3. determine the effect of predators on tahr and livestock – for this the percentage of scats containing hair of particular items of prey (Himalayan tahr and livestock) was determined and the loss of both tahr and livestock due to predators estimated;
4. explore diversity, productivity and vegetation cover of alpine pastures/meadows in tahr habitats;
5. determine conservation implications for tahr, pasturelands, main predators of tahr and the associated high-altitude ecosystems.

5.2 Study Area

Sagarmatha National Park (SNP, 27°45′-28°07′ N, 86°28′-87°07′ E) is in the Solo Khumbu district (Fig. 5.1) in the north-eastern region of Nepal. This National Park was founded in July 1976 and included on the World Heritage List in 1979. It has an area of 1,148 km^2. The park encompasses the upper catchments of the Dudh Kosi river system, which is fan-shaped and forms a distinct geographical unit surrounded 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 natural environment of the SNP is strictly protected. It hosts 28 species of mammals, 199 species of birds, 6 species of amphibians and 7 species of reptiles. The weather is usually sunny in autumn, October and November, but in winter the weather is cold with frequent falls of snow. The local people, the Sherpas, having originated from Salmo Gang in the eastern Tibetan province of Kham, some 2,000 km apart from their present homeland, are of great cultural interest. There were approximately 3,500 Sherpas in 63 settlements, mainly located in

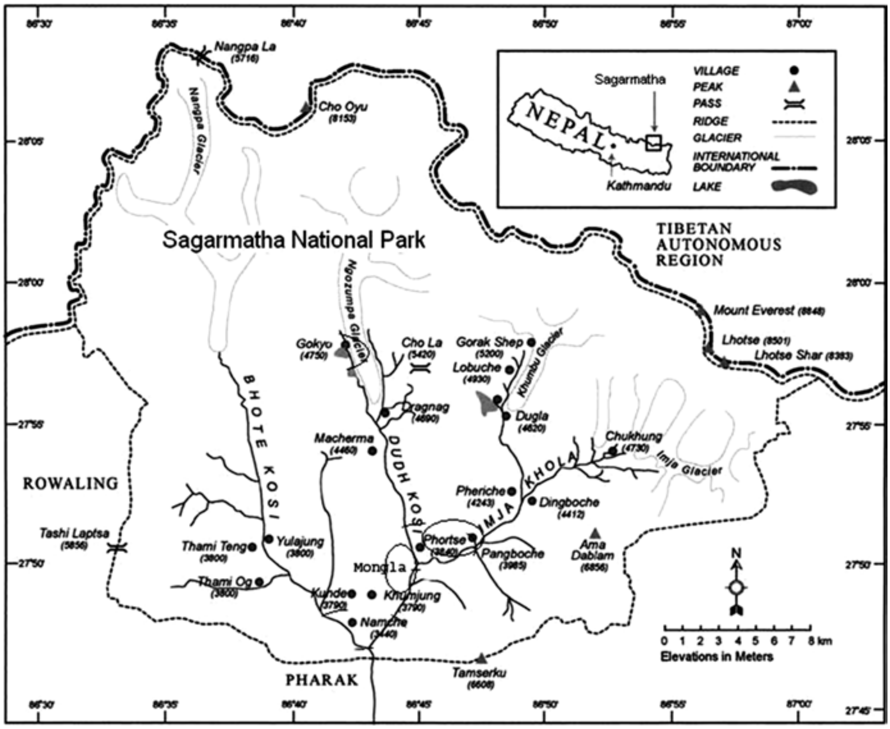

Fig. 5.1 The Sagarmatha National Park

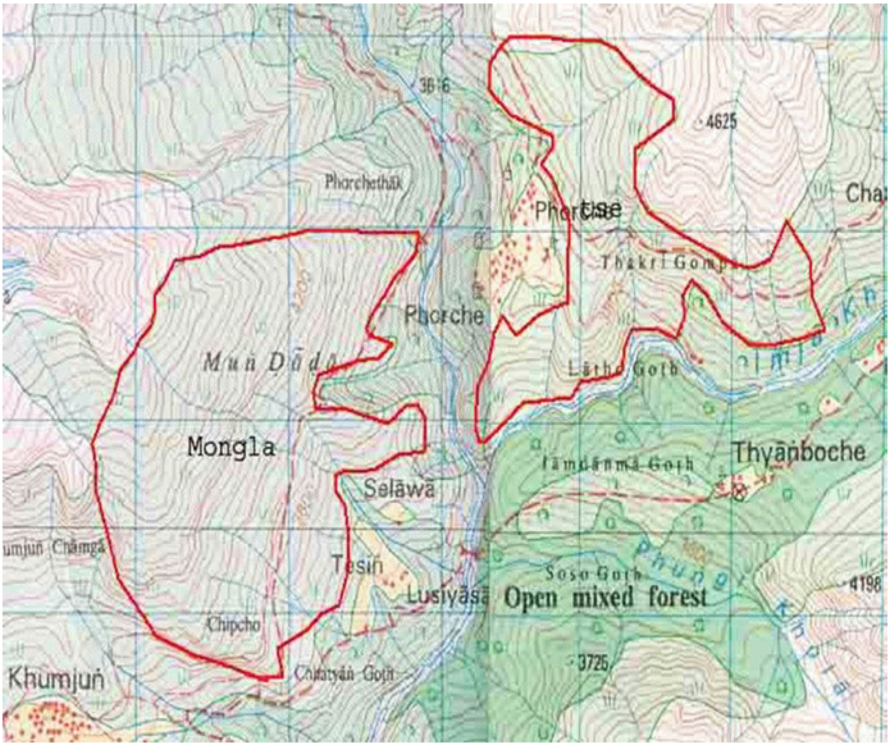

Fig. 5.2 The location of the two study areas at Mongla and Phortse

southern part of the park, in 1997. The study area is located in the Mongla and Phortse rangelands in the Sagarmatha National Park (Fig. 5.2).

5.3 Materials and Methods

5.3.1 General Field Methods

This study was done in August-September 2006. The areas selected were based on the distribution of tahr, which was identified in a previous study carried out in 2004 (Shrestha 2006).

Vantage points and regular monitoring from trails (Jackson and Hunter 1996) were the main methods used to record the numbers of tahr and livestock. Opportunistic observations of tahr and livestock made during the vegetation survey provided additional data to those recorded in the fixed-point counts.

Once animals (tahr or livestock) were located, the area was searched and animals identified using a 7×35 telescope. Each observation was treated as one group or sighting, irrespective of the number of individuals seen. For each sighting, the following information was noted for an area with a radius of approximately 30 m centered on the point of the highest aggregation of animals:

1. date and time of observation;
2. species of animal: tahr, yak hybrid (yak, nak, cow, dzom, zopkyo or ox);
3. group size and type (group types identified were: all males, females with young or mixed groups);
4. sex and classification of tahr: female (adult female and yearling), male (class I, class II and class III) and kid, following Schaller (1977);
5. slope;
6. aspect;
7. terrain type;
8. vegetation type;
9. distance to ridgeline;
10. distance to cliff;
11. GPS location of the point on the trail from where animals were sighted (wherever possible) and any other remarks.

5.3.2 Habitat Overlap Between Tahr and Livestock

Habitat overlap between tahr and livestock was investigated by comparing the habitats, in which these animals were observed, in terms of altitude, aspect, slope, percentage vegetation cover and terrain. The altitude, aspect and slope were measured using GPS and a Brunton Compass meter. The vegetation categories were grassland, rocks covered by vegetation and scrub. Similarly, the terrain was categorized on the basis of ground surface morphology as smooth, rugged or very rugged. A flat terrain with isolated undulating or small rocks was classified as smooth. Distinctly undulating or rugged surface, including ravines and gullies with some large rocks was classified as rugged. The presence of droppings was used to estimate the degree of spatial overlap.

5.3.3 Dietary Overlap of Tahr and Livestock

5.3.3.1 Direct Observation

This was done in tahr areas using binoculars during the active feeding periods between 7–12 a.m. and 3–5 p.m. Signs of plants having been recently eaten, such as exudation of sap, crushed tissue, fresh clippings etc. were recorded. A herbarium sheet for each plant species was prepared and taken to the Central Department of

Environmental Science, Tribhuvan University, Kathmandu and The National Herbarium, Godabari Centre, Kathmandu, for determination.

5.3.3.2 Micro Histological Analyses

A microscopic analysis of the indigestible plant fragments in dung, mainly epidermal parts, which are characteristic of different plant groups (Metcalfe 1960), was used to identify the plants eaten by the ungulates. This method is commonly used for studying diets of ungulates, as it is simple, effective and accurate (Baumgartner and Martin 1939; Anthony and Smith 1974; Dearden et al. 1975; Holechek et al. 1982). It has one limitation: the amount forage consumed cannot be quantified.

5.3.3.3 Faecal Analysis

Samples of faeces of tahr were collected from feeding sites in different habitats. They were kept in paper bags and each day's collection was labeled and air-dried separately for a minimum of 72 h. After drying, individual faecal samples collected on the same day were mixed thoroughly and packed in airtight polythene bags. Later on, the samples were transported to the laboratory of the Department of Environmental Sciences, Tribhuvan University, for further analyses.

Simultaneously, different plant species were collected and used to prepare reference slides for different tahr habitats. Slides were prepared following the method used by Vavra and Holechek (1980) and Jnawali (1995), and used by Fjellstad and Steinheim (1996) and Chetri (1999). The dried plant samples were separately ground to a small size in an electric blender. The resultant powder was sieved through two sieves (1 and 0.3 mm mesh size) placed one above the other. The material that did not pass through the 0.3 mm sieve was used to prepare slides. A teaspoonful of each of the final samples was treated with warm 10% NaOH solution in a test-tube and heated in a boiling water-bath for 4–6 min. The particles were allowed to settle in a cold water-bath before the supernatant dark fluid was removed. This procedure was repeated until a relatively clear supernatant solution was obtained. Then, the material was washed 3–5 times with warm distilled water and dehydrated using 25%, 50%, 75%, 90% and then 100% alcohol. The alcohol-treated samples were finally treated using a series of solutions of xylene and alcohol in which xylene gradually replaced the alcohol. A small amount of material was dried between tissue paper and mounted in DPX under a 24 × 50 mm cover slip. The slide was air dried for 5–6 days.

The slides of faecal samples were prepared in the same way as the reference slides, except that 10% NaOH solution was replaced by a 5% NaOH solution, before which the faecal samples were lightly washed with warm distilled water to remove soil. A total of five slides were made of each composite faecal sample, and labeled.

The reference slides were studied as recommended by Holechek and Gross (1982). A diagnostic key for each plant species was prepared using free hand sketches and any distinct character of the plant fragments in the faeces was noted and photographed and compared with the histological features of the plant material on the reference slides. The features include cell wall structure, shape and size of cells, hairs and trichomes, shape and size of stomata and inner-stomatal cells, fiber structure and arrangements of veins.

A compound microscope with 100× magnification lens and an ocular measuring scale was used to observe and measure the plant fragments on the slides of faecal material. On each slide, ten fragments were identified in at least one transect of the slide using the identification key and photographs of the epidermis of the reference material. Only fragments recognized as epidermal tissue and consisting of at least four plant cells or with visible stomata were recorded. In total, 200 fragments from faecal samples of both livestock and tahr were identified.

5.3.3.4 Statistical Analysis

To evaluate the niche breadth of plant species in the diet of each species, Levin's measure of niche breadth (B) was calculated using the following formula cited in Krebs (1999):

$$B = \frac{1}{\sum_{i=1}^{n} P_i^2},$$

in which P_i is the percentage of total samples belonging to species i ($i = 1, 2, \ldots, n$) and n is the total number of species in all samples. The value of B increases with increasing number of species in the diet. A low value indicates that a species is selective and eats only a few plant species.

In order to estimate dietary overlap between two species, the Simplified Morisita's index (C_H) was calculated using:

$$C_H = \frac{2\sum_{i=1}^{n} P_{ij} P_{ik}}{\sum_{i=1}^{n} P_{ij}^{2} + \sum_{i=1}^{n} P_{ik}^{2}},$$

where P_{ij} and P_{ik} are the proportions of the resource used by the two species, j and k. The degree of overlap varies from zero to one; zero indicates no overlap and one complete overlap.

The Relative Importance Value (RIV) for each plant species in a faecal sample was calculated using the method described by Jnawali (1995):

$$RIV_i = D_i \sqrt{f_i},$$

where RIV_i is the relative importance value for species *i*, D_i is the mean percentage of species *i* in the sample an f_i is the frequency of species in the sample.

5.3.4 *Floristic Composition*

5.3.4.1 Sampling

A detailed vegetation analysis of the floristic composition of the study area was done based on a set of "modules", which are cross sections across the valley, centered on the valley floor and including the entire altitudinal range on either side. There were three "modules" for each rangeland (Mongla and Phortse), evenly spaced at intervals of 3 km throughout the expected range of the tahr in this region. At each of these "modules", six transects were established following the altitudinal contour, each of which was 100 m long. These transects were located at a range of altitudes, with 100–150 m separating them. Sites in the valley, which were covered by bushes and shrubs, were excluded, since tahr spend most of the time feeding in open areas (Schaler 1973). Along these transects, 1 × 1 m quadrats were placed 20 m apart. The plant cover in each quadrat and the use by livestock of the area in the vicinity of each quadrat were determined. The percentage cover of individual plant species, percentage of bare soil and rock in each quadrat were estimated visually following Smart et al. (1976). A sub-plot of 25 × 25 cm was randomly selected in each quadrat and all the vegetation in this sub-plot was removed and weighed. The fresh weight of the grass was then used to estimate wet biomass per unit area of pasture. Species area curves were plotted to calculate the minimum number of squares required for determining the floristic composition of the study area (Jnawali 1995), which was found to be 18.

5.3.4.2 Statistical Analysis

Simpson's Index of Diversity (Krebs 1994) was used to measure floral diversity:

$$D = 1 - \sum_{i=1}^{S} P_i^2$$

where *D* is Simpson's index of diversity, P_i the proportion of individuals of species *i* in the community and *S* the number of species in the community. Simpson's diversity index ranges from 0 (low diversity) to a maximum of (1 – 1/*S*).

Sørenson's index of similarity (ISs, Krebs 1994) was used to compare similarity of plant species in two habitats, A and B:

$$ISs = \frac{2C}{A+B} \times 100,$$

where C is the number of species common to both habitats, A the total number of species in habitat A and B the total number in habitat B.

Vegetation analysis – the following values were calculated:

Frequency of species A: $$f_A = \frac{\text{Number of quadrats in which species A occurred}}{\text{Total number of quadrats}} \times 100$$

Relative frequency of species A: $$RF_A = \frac{f_A}{\sum_{i=1}^{S} f_i} \times 100$$

Density of species A: $$D_A = \frac{\text{Number of individuals of species A in all quadrats}}{\text{Total number of quadrats} \times \text{Size of quadrat}}$$

Relative density of species A: $$RD_A = \frac{\text{Number of individuals of species A}}{\text{Total number of individuals of all species}}$$

Abundance of species A: $$A_A = \frac{\text{Total number of individuals of species A}}{\text{Number of quadrats, where species A occurred}}$$

Relative abundance of species A: $$RA_A = A_A \times 100$$

Importance Value Index: $$IVI_A = RF_A + RD_A + RA_A$$

Frequency classes: based on the prominence value, PV, species were assigned to one of five frequency classes (Sharma 2002) as follows:

PV	Frequency class
<1	very rare
1–5	rare
5–25	common
25–75	abundant
> 75	very abundant

5.3.5 Productivity and Forage Availability

The percentage cover of individual species in each quadrat was estimated visually following Smart et al. (1976). Prominence values, PV, were calculated and used to quantify the abundance of species at both of the rangelands following the method of Dinerstein (1979):

$$PV_A = M_A \sqrt{f_A},$$

where PV_A is the prominence value for species A, M_A is the mean percentage cover of species A and f_A is described above. Then the abundance of each species was categorized as very rare ($PV_A \leq 1$), rare ($1 < PV_A \leq 5$), common ($5 < PV_A \leq 40$) or abundant ($PV_A > 40$).

5.3.6 Effect of Predators on Himalayan Tahr and Livestock

In order to estimate the effect of predators on Himalayan tahr and livestock, the presence and identification of tahr or livestock hair in predator scat was determined by examining the scat under a microscope. Economic loss of livestock to predators was also estimated.

5.3.6.1 Microscopical Identification of Hair

The hairs in predator scats were used to determine the diet of the predators. The analysis of scat samples required a reference collection of hair samples, an identification key and slides of hair from scat.

Twenty scats of snow leopard were collected from the study area. The scats were identified on the basis of their size and associated signs, such as scrapes and pugmarks. The samples of scat were sun-dried, labelled and stored in polythene bags for laboratory analysis.

Each sample was first examined macroscopically and the colour and texture recorded. The sample was then put into 30% hydrogen peroxide overnight prior to microscopic examination. Each bleached sample was observed under a microscope at 400× magnification. The sample was then wet mounted in D.P.X. and the cortex and medulla of the hairs and the details recorded. The micrometer measurement of both the cortex and medulla were recorded at ten intervals along the shaft of each hair. These measurements were then converted to millimetres and the mean calculated. Similarly, the average diameter of the medulla was determined. In addition, medullar indices and their averages were calculated. The above calculations were made only for medullated hair. The medullary Index (MI) was calculated using the formula

$$MI = \frac{\text{Width of medulla}}{\text{Width of cortex}}.$$

A tuft of hairs was inserted into a straw and then molten wax was sucked into the straw. Once the wax solidified, the straw was cut open, the wax core and embedded hair removed and cross sections obtained by transversally cutting it with a razor blade. The sections were treated with xylene to remove the wax and viewed under a microscope.

The characteristics of the cuticular scales along the shaft of each hair from the root to the tip were noted. A thin layer of nitrocellulose lacquer (white nail polish) was applied to the surface of microscope slides and the hair samples placed horizontally on them. As the lacquer dried an impression of the surface of each hair formed, then the hair was peeled off and the impression viewed under a microscope.

Microphotographs of representative cross sections, medulla and scale patterns along the length of the hairs of each species were taken at a standard magnification. Compared to direct comparison and using the dichotomous key, reference to photographs proved more convenient and easier for the routine identification of hair. Therefore, a photographic reference key and microscopic examination of cuticular scales and the medullary type, thickness of cortex and medulla, medullary index etc., which are diagnostic tools for identifying species, were used in this study. Descriptions of the hair in the key includes only the maximum diameter of the primary guard hair and the most diagnostic features of the hair of each species. The key includes the eight wild and five domestic mammals found in the study area (not presented here).

Each scat was soaked overnight in liquid dettol mixed with water and then washed carefully over a sieve with a mesh width of 1 mm. Remains, like bones, teeth, hooves, hair and feathers were removed, air dried and stored. Microscope slide preparations of the hair in every scat were used to identify the species of prey by using the key and the microphotographs of the hair of potential prey as was done in preparing the key.

5.3.6.2 Statistical Analysis

The scat contents are presented here as “frequency of occurrence” (number of scats containing the hair of a particular species of prey) and “percentage frequency of occurrence” (% of scats containing the hair of a particular species of prey).

5.3.7 Depredation of Livestock

The questionnaires completed by the local herders at Phortse and the results of the group discussions gave an indication of the economic loss due to the depredation of livestock by snow and common leopards.

5.4 Results

5.4.1 Abundance of Himalayan Tahr

During the observations at the Mongla and Phortse pasturelands there were a total of 25 sightings of Himalayan tahr, which in total was 319 animals with an estimated total population of about 125, whereas there were a total of 113 individuals in the 15 sightings of livestock (Tables 5.1 and 5.2). The male to female ratio was 0.72, kid to female ratio 0.46 and yearling to kid ratio 0.65. Mean group size was 12.76 (range 1–38, standard deviation 10.65).

5.4.2 Composition and Numbers of Livestock

The 113 individuals of livestock included yak, jopkyo, cow, ox and calf. Yak made up 56% of the livestock in the study area, followed by jopkyo, cow, ox and calf (Table 5.2).

Table 5.1 Structure of the tahr population based on absolute numbers and all the animals seen at Mongla and Phortse in the summer of 2006 (n = 25)

	Mongla				Phortse			
	Known number		All animals tallied		Known number		All animals tallied	
Himalayan tahr	No.	%	No.	%	No.	%	No.	%
Female	14	42	70	45	36	39	73	44
Yearling	5	18	32	21	10	11	21	13
Kid	5	15	22	14	18	19	32	19
Total yearlings and kids	***11***	***33***	***55***	***35***	***29***	***30***	***53***	***32***
Male I	2	6	6	4	10	11	13	8
Male II	3	9	19	12	5	5	7	4
Male III	3	9	6	4	13	15	18	11
Total males	***8***	***24***	***31***	***20***	***28***	***30***	***38***	***23***
Total	**33**	**100**	**155**	**100**	**92**	**100**	**164**	**100**

Table 5.2 Numbers of the different kinds and percentage composition of the livestock observed at Mongla and Phortse in the summer of 2006

Livestock	No.	%
Yak	63	56
Jopkyo	33	30
Cow	8	7
Ox	5	4
Calf	4	3
Total	113	100

Table 5.3 Habitat preferences (frequency) of Himalayan tahr and livestock at Mongla and Phortse, in summer 2006

Habitat variable and category	Himalayan tahr, % (n = 25)	Livestock, % (n = 15)	Habitat variable and category	Himalayan tahr, % (n = 25)	Livestock % (n = 15)
Habitat type			Slope		
Barren	0	0	0°–30°	8	**33**
Grassland	**96**	**100**	31°–60°	**76**	**67**
Shrubland	4	0	61°–90°	**16**	0
Forest	0	0			
Terrain type			Aspect		
Cliff	0	0	East (69°–113°)	0	0
Very rugged	**36**	0	Southeast (204°–248°)	28	20
Rugged	**36**	**47**	South (159°–203°)	**52**	**73**
Rolling	28	**53**	Southwest (114°–158°)	20	7
Flat	0	0	West (249°–293°)	0	0
Altitude (m)			Distance to escape terrain (m)		
3,601–3,800	**24**	0	0	8	0
3,801–4,000	**44**	27	1–50	**32**	0
4,001–4,200	20	**66**	51–100	**48**	13
4,201–4,400	8	7	101–150	0	7
4,401–4,600	4	0	> 150	12	**80**
Position on slope			Nearest water source (m)		
Low	**40**	0	<200	**68**	7
Middle	**40**	**87**	201–400	4	0
Upper	20	13	> 400	28	**93**

Preferred habitats are in bold

5.4.3 *Preferred Habitat of Himalayan Tahr and Livestock*

Grassland was the preferred habitat of both tahr (96% of cases) and livestock (100% of cases). Tahr preferred very rugged (36%) and rugged (36%) slopes, whereas livestock preferred rolling (53%) and rugged slopes (47%). Tahr equally preferred the lower and middle slopes (40%), while livestock preferred the middle slopes (87%). Tahr preferred to graze at altitudes between 3,600 and 4,200 m and livestock between 4,000 and 4,200 m. Tahr preferred mostly southern aspects (52%) as did the livestock (73%). Both tahr and livestock preferred 31–60° slopes (76% and 67% respectively). Tahr was also found on slopes greater than 61°, which were avoided by livestock. Livestock was found on gentle slopes (0–30°) more frequently than tahr. Livestock was found in areas more than 150 m from escape terrain, whereas tahr occurred in areas less than 100 m from escape terrain (Table 5.3).

Droppings of both these ungulates were found in 45% of the squares at Phortse and 33% of those at Mongla, and there were no droppings of either ungulate in 5% of the squares in Phortse and 17% at Mongla. There were droppings in the remaining 50% (in both regions) of either tahr or livestock, but not of both.

5.4.4 Diet Composition

5.4.4.1 Diet of Himalayan Tahr

Of the 24 species of plant in the droppings of tahr, 53% were grasses and sedges belonging to 6 taxa: *Carex anomoea*, *Avena* sp., *Poa* sp., *Trisetum spicatum*, Cyperaceae sp. and *Imperata* sp. They were followed by *Gueldenstaedtia himalaica* and *Potentilla* sp., whereas *Pedicularis siphonantha*, *Persicaria capitata*, *Androsace sarmentosa*, *Trachyspermum ammi*, *Habenaria aitchisonii* and *Ephedra gerardiana* made up only a small fraction of the diet (Table 5.4). Niche breadth of tahr was $B = 0.0137$.

In the diet of tahr, the highest RIV was for *Avena* sp. followed by *Carex anomoea*, *Poa* sp., *Gueldenstaedtia himalaica*, *Trisetum spicatum*, Cyperaceae sp. and *Potentilla* sp. Remaining species had very low RIVs (Table 5.4).

5.4.4.2 Diet of Livestock

Of the 31 plant species found in the droppings of livestock, 38.5% were grasses and sedges belonging to 6 taxa: *Avena* sp., *Carex anomoea*, *Trisetum spicatum*, Cyperaceae sp., *Poa* sp., and *Imperata* sp. They were followed by *Cotoneaster microphyllus*, *Potentilla* sp., *Bistorta affinis*, *Gueldenstaedtia himalaica*, *Polygonatum hookeri*, *Saxifraga brachypoda*, *Anaphalis contorta*, *Rhododendron lepidotum*, whereas *Anaphalis triplinervis*, *Fragaria daltoniana* and *Gentiana* sp. made up only a small fraction of the diet (Table 5.5). Niche breadth of livestock was $B = 0.0175$.

In the diet of livestock, the highest RIV was for *Avena* sp. followed by *Carex anomoea* and *Cotoneaster microphyllus*. Among the species with low RIVs were *Gentiana sp.*, *Habenaria aitchisonii* and *Androsace sarmentosa* (Table 5.5).

5.4.5 Dietary Overlap Between Tahr and Livestock

Remnants of 22 species of common plants were found in tahr and livestock droppings (Tables 5.4 and 5.5). *Morina nepalensis* and *Ephedra gerardiana* were found only in tahr droppings, while *Gentiana* sp., *Gerbera gossypina, Notholirion macrophyllum, Parnassia nubicola, Polygonatum hookeri, Polygonum* sp., *Saxifraga parnassifolia,*

Table 5.4 Species of plants found in the droppings of tahr, their relative percentage and relative importance value (RIV)

Species name	%	RIV
Graminoids	**28.0**	**146.1**
Avena sp.	19.0	117.1
Imperata sp	2.5	5.6
Poa sp.	6.5	23.4
Sedges	**25.0**	**109.2**
Carex anomoea	13.5	70.1
Cyperaceae *sp.*	5.5	18.2
Trisetum spicatum	6.0	20.8
Herbaceous plants and shrubs	**47.0**	**120.6**
Anaphalis contorta	2.5	5.6
Anaphalis triplinervis	1.5	2.6
Androsace sarmentosa	1.5	2.7
Bistorta affinis	3.5	9.3
Cotoneaster microphyllus	4.5	13.5
Cyananthus hookeri	2.5	5.6
Cypripedium himalaicum	1.0	2.6
Ephedra gerardiana	1.0	1.4
Fragaria daltoniana	2.5	5.6
Gueldenstaedtia himalaica	6.0	20.8
Habenaria aitchisonii	1.0	1.4
Morina nepalensis	3.0	7.3
Pedicularis siphonantha	1.5	2.6
Persicaria capitata	1.5	2.6
Potentilla sp.	5.5	18.2
Rhododendron lepidotum	3.5	9.3
Satyrium nepalense	2.0	4.0
Saxifraga brachypoda	2.5	5.6

Salvia hians and *Sedum* sp. were found only the droppings of livestock. The Morisita index of niche overlap between livestock and tahr was high: $C_H = 0.83$.

5.4.6 Floristic Composition and Vegetation Analysis

5.4.6.1 Rangeland at Mongla

At Mongla, 71.48% of the ground is covered by vegetation, the remaining 18.29% by bare soil and rock (10.23%). Vegetation consists of 45 species. The strongly dominant taxon (taxon with the largest *f*-value) at Mongla was the sedge (grass) *Avena* sp., followed by *Cotoneaster microphyllus*, *Rhododendron lepidotum* and *Carex anomoea* – Annex 5.1. The Simpson's diversity index for Mongla is $D = 0.941$.

Table 5.5 Species of plants found in the droppings of livestock, their relative percentage and relative importance value (RIV)

Species name	%	RIV
Graminoids	**18.5**	**84.7**
Avena sp.	14.0	74.1
Imperata sp.	1.0	1.4
Poa sp.	3.5	9.3
Sedges	**20.0**	**74.3**
Carex anomoea	8.5	35.0
Cyperaceae sp.	5.0	15.8
Trisetum spicatum	6.5	23.4
Herbs and shrubs	**61.5**	**161.3**
Anaphalis contorta	3.0	7.3
Anaphalis triplinervis	2.5	5.6
Androsace sarmentosa	0.5	0.5
Bistorta affinis	4.0	11.3
Cotoneaster microphyllus	8.0	32.0
Cyananthus hookeri	1.5	2.6
Cypripedium himalaicum	2.0	4.0
Fragaria daltoniana	1.0	1.4
Gentiana sp.	0.5	0.5
Gerbera gossypina	1.0	1.4
Gueldenstaedtia himalaica	3.5	9.3
Habenaria aitchisonii	0.5	0.5
Notholirion macrophyllum	1.5	2.6
Parnassia nubicola	3.0	7.3
Pedicularis siphonantha	1.5	2.6
Persicaria capitata	1.0	1.4
Polygonatum hookeri	3.5	9.3
Polygonum sp.	2.5	5.6
Potentilla sp.	6.5	23.4
Rhododendron lepidotum	3.0	7.3
Salvia hians	1.0	1.4
Satyrium nepalense	2.0	4.0
Saxifraga brachypoda	3.5	9.3
Saxifraga parnassifolia	3.4	9.3
Sedum sp.	1.0	1.4

5.4.6.2 Rangeland at Phortse

At Phortse, 81.64% of the ground is covered by vegetation, 14.56% by bare soil and 3.8% by rock. Vegetation consists of 54 species. The dominant species (taxon with the largest *f*-value) at Phortse is *Carex anomoea*, followed by *Avena* sp., *Gerbera gossypina* and *Pedicularis siphonantha* – Annex 5.2. The Simpson's diversity index for Phortse is $D=0.937$.

5.4.6.3 Sørenson's Index of Similarity (ISs)

The Sørenson's index of similarity (ISs) for Mongla and Phorte is *ISs* = 0.83 (83%), which indicates that the species at these two study sites are similar.

5.4.7 Productivity and Availability of Forage

The productivity of both rangelands was very similar: 2,643 kg/ha (wet weight) and 2,276 kg/ha (wet weight) at Mongla and Phortse, respectively.

Based on the prominence value, at Monga, 4 species were found in the droppings of tahr and livestock that are very abundant or abundant (*Avena* sp., *Carex anomoea*, *Cotoneaster microphyllus* and *Rhododendron lepidotum*), 12 species that are common (*Anaphalis contorta*, *Androsace sarmentosa*, *Cyananthus hookeri*, *Fragaria daltoniana*, *Gerbera gossypina*, *Habenaria aitchisonii*, *Notholirion macrophyllum*, *Persicaria capitata*, *Potentilla* sp., *Satyrium nepalense*, *Saxifraga brachypoda* and *Saxifraga parnassifolia*), 9 that are rare (*Bistorta affinis*, *Gueldenstaedtia himalaica*, *Imperata* sp., *Cyperaceae* sp., *Poa* sp., *Polygonatum hookeri*, *Salvia hians*, *Sedum* sp. and *Trachyspermum ammi*) and 6 that are very rare (*Anaphalis triplinervis*, *Parnassia nubicola, Pedicularis siphonantha* and *Trisetum spicatum*) – Table 5.6.

At Phortse, 4 species found in droppings of tahr and livestock are abundant (*Avena sp. Carex anomoea*, *Polygonatum hookeri* and *Rhododendron lepidotum*), 15 are common (*Bistorta affinis*, *Cotoneaster microphyllus*, *Cyananthus hookeri*, *Fragaria daltoniana*, *Gentiana* sp., *Gerbera gossypina*, *Gueldenstaedtia himalaica*, *Imperata* sp., *Notholirion macrophyllum*, *Parnassia nubicola*, *Pedicularis siphonantha*, *Persicaria capitata*, *Polygonum* sp. and *Potentilla* sp.), 7 are rare (*Anaphalis contorta*, *Habenaria aitchisonii*, Cyperaceae sp., *Poa* sp., *Saxifraga brachypoda*, *Saxifraga parnassifolia* and *Trachyspermum ammi*), and 3 are very rare (*Salvia hians*, *Satyrium nepalense* and *Sedum* sp.) – Table 5.6.

5.4.8 Effect of Predators on Tahr and Livestock

In total, 20 scats were analyzed. The prey consumed included two species of wild and four species of domestic mammals. The most frequent prey of snow leopard is Himalayan tahr, which was detected in 55% of the scats, followed by yak (25%), cow (20%), musk deer (20%), dog (10%) and horse (10%) (Table 5.7). Wild species were present in 75% and domestic species in 65% of scats.

The results of the questionnaire indicate that snow leopard is the main predator of domestic livestock. Between January 2005 and September 2006, snow leopard killed 16 animals belonging to 8 farming families (Table 5.8).

Table 5.6 Prominence Value (PV) of the species most frequently eaten by tahr and livestock at Mongla and Phortse

		Species prominence Value (PV)	
Sp. No.	Species name	Mongla	Phortse
1.	*Anaphalis contorta*	6.9	1.3
2.	*Anaphalis triplinervis*	0.7	–
3.	*Androsace sarmentosa*	5.8	–
4.	*Avena* sp.	84.9	58.2
5.	*Bistorta affinis*	3.2	7.1
6.	*Carex anomoea*	44.1	67.7
7.	*Cotoneaster microphyllus*	102.6	21.9
8.	*Cyananthus hookeri*	11.1	17.1
9.	*Fragaria daltoniana*	7.8	8.2
10.	*Gentiana* sp.	–	10.3
11.	*Gerbera gossypina*	10.1	11.9
12.	*Gueldenstaedtia himalaica*	4.3	6.3
13.	*Habenaria aitchisonii*	5.7	1.2
14.	*Imperata* sp.	1.9	6.0
15.	Cyperaceae sp.	1.2	5.0
16.	*Notholirion macrophyllum*	9.3	10.3
17.	*Parnassia nubicola*	0.8	18.7
18.	*Pedicularis siphonantha*	0.7	8.2
19.	*Persicaria capitata*	17.1	16.4
20.	*Poa* sp.	1.3	0.8
21.	*Polygonatum hookeri*	4.3	40.6
22.	*Polygonum* sp.	–	8.6
23.	*Potentilla* sp.	10.8	11.6
24.	*Rhododendron lepidotum*	55.7	63.6
25.	*Salvia hians*	2.1	0.3
26.	*Satyrium nepalense*	8.8	0.1
27.	*Saxifraga brachypoda*	9.7	2.0
28.	*Saxifraga parnassifolia*	5.6	2.5
29.	*Sedum* sp.	2.1	0.4
30.	*Trachyspermum ammi*	1.6	1.5
31.	*Trisetum spicatum*	0.2	–

Table 5.7 Absolute and relative frequencies of occurrence of prey items in the diet of snow leopard (n=20)

Prey species	Frequency of occurrence	% Frequency of occurrence
Himalayan tahr	11	55
Yak	5	25
Musk deer	4	20
Cow	4	20
Dog	2	10
Horse	2	10

Table 5.8 Percentage composition of the six types of livestock killed by snow leopard at Phortse during 2005–2006

Livestock type	% killed by snow leopard (N = 16)
Yak	43.7
Nak	12.5
Jom	0.0
Jopkyo	0.0
Cow	31.2
Ox	12.5

5.5 Discussion

5.5.1 Status and Population of Himalayan Tahr and Livestock

Based on these results it is estimated that 125 tahr inhabit the rangelands at Mongla and Phortse. Lovari (1992) estimated that there were 300 tahr in 1989 present in the SNP at Namche, which includes the Mongla and Phortse valleys. He also estimated there were 27 individuals/km^2 in the area between Phortse and Pangboche. Shrestha (2006) surveyed tahr in 2004 and records 205 Himalayan tahr in the Namche (including Mongla), Phorche and Thame valleys of the SNP. In October-November 2004 there were 104 tahr in Gokyo, Phortse and Namche (including Mongla), and 3.2 and 5.1 individuals/km^2 in Phortse and Namche valleys, respectively, and in August-November 2005, 277 tahr in Gokyo, Phortse, Namche and Thame valleys and the number of individuals/km^2 of tahr ranged from cca. one in the Gokyo to as many as seven in the Namche valley (Ale 2006). Based on these data, it is likely that the population of tahr is smaller than was recorded in 1989 by Lovari (1992). The ratio of kid to female recorded in this study was 0.46, which is similar to that recorded by Ale (2006). For both pasturelands, the low kid-to-female ratio is consistent with what has been regularly reported for the area since 1992 (Lovari 1992, Sandro Lovari, personal communication). In contrast, Schaler (1973) reports a kid-to-female ratio of 0.56 in Kang Chu, eastern Nepal, where tahr is hunted, and 0.57 in the Annapurna region of western Nepal, an area where there are no large predators of tahr (Gurung 1995). The low kid-to-female ratio in Sagarmatha may be due to predation or disease. Snow leopard has recently re-colonized the Everest region. In order to determine, whether predation by snow leopards is responsible for the low kid to female ratio of Himalayan tahr in Sagarmatha, the diet of snow leopards there is currently being studied.

During this study only a small number of livestock (113 individuals) grazed the pastures at Mongla and Phortse, compared to the 3169 at Namche and Khumjung VDC (VDC is an administrative region in Nepal) in the Sagarmatha National Park in 2003 (DNPWC/TRPAP 2006). This may be because yaks and naks are moved to high pastures in spring and during the monsoon months, and returned to settlements at lower altitudes in summer and winter, and this study was done during the summer season.

5.5.2 Habitat Selection by Himalayan Tahr and Livestock

Himalayan tahr and livestock prefer to occupy similar habitats, with similar aspects and to some extent slopes (Table 5.3). Both tahr and livestock were found in rugged areas at middle altitudes with a southern aspect and slopes of 31°–60°. Tahr, however, can be found in more rugged and very steep areas at low altitudes and livestock in rolling, flat areas at high altitudes. Livestock is regularly observed feeding in areas more than 150 m from escape terrain, whereas tahr is almost consistently seen only in areas less than 100 m from escape terrain. A similar overlap in habitat is recorded for ibex and livestock in other trans-Himalayan protected areas, with ibex changing its grazing habitats during the season, which reduces competition.

5.5.3 Food of Himalayan Tahr and Livestock

In terms of species composition, the diets of livestock and tahr are similar, but not in the relative proportions of individual species. The proportion of woody plants (*Rhododendron* and *Cotoneaster*) was higher, and that of grasses and sedges lower in the diet of livestock than in that of tahr. This may be because livestock graze in the vicinity of villages, where other species of plants are scarce due to harvesting or overgrazing.

Parkes and Thompson (1995) found grass in the rumens of 48–65% of 253 tahr shot in the Southern Alps, particularly snow tussocks; they claim that tahr more often includes herbaceous than woody plants in its diet. In this study, the percentage of woody plants, like *Cotoneaster microphyllus* and *Rhododendron lepidotum,* was higher in the tahr's diet, but nevertheless they still eat more soft and herbaceous plants, compared to livestock, which often eat woody plants like *C. microphyllus* and *R. lepidotum*. According to Forsyth and Tustin (2001) males of tahr prefer herbaceous and woody plants to grasses and sedges in the period when the males and females are segregated. This study was also done during this period (July-August) and tahr grazed more on woody plants than is reported by Forsyth and Tustin (2001). The percentage of woody plants may, however, be overestimated, as they are difficult to digest and therefore more likely to be found in the faeces.

In this study, the tahr's diet consisted of 47% herbaceous plants and shrubs, 28% grasses and 25% sedges, which is similar to the yearly averages reported by Green (1979) for tahr in the Langtang valley (38% herbaceous plants and shrubs, 34% grasses, 21% sedges, 4% ferns and 4% mosses). According to Green (1979), however, there are seasonal differences in these percentages, e.g., in winter tahr supplements its diet with small amounts of mosses and ferns, presumably because other food is less readily available. The previous results differ from those of Parkes and Thompson (1995) who record that their diet is made up of 16.3% herbaceous plants, 55.7% grasses, 26.6% woody plants and 1.1% ferns.

5.5.4 Palatability

Herbivore diet depends not only on the abundance of vegetation, but also on the palatability of individual species. There are conflicting opinions about plant palatability in the literature. Species like *Rhododendron, Cotoneaster, Anaphalis contorta, Carex* sp. and *Bistorta affinis* are often considered to be unpalatable (Bauer 1990; Koirala and Shrestha 1997; Buffa et al. 1998). However, Schaler (1973) reports that tahr eats small quantities of *Rhododendron*, Sharma (2000) that blue sheep include *Anaphalis contorta* and *Cotoneaster microphyllus* in their diet, Awasthi et al. (2003) that ungulates in the Himalayas include *Carex* sp. in their diet and Wangchuk (1995) that both blue sheep and yak eat *Carex* sp.*, Bistorta* sp., *Anaphalis* sp. and *Cotoneaster microphyllus*.

5.5.5 Niche Breadth and Food Overlap

Body size is the most important factor determining the metabolic rate and food requirements. Large-bodied mammals have higher food requirements, since they have higher cost of maintenance and production compared to small species (Geist 1974). Thus small-bodied ungulates tend to be limited by forage quality and large-bodied ungulates by forage quantity (Hanley 1982). Small animals tend to be more selective not only in terms of the number of plant species they eat, but also in terms of their diversity and have a smaller niche breadth.

In this study, livestock, which is larger than tahr, grazed more plant species than tahr and have a larger niche breadth. Thus, tahr is more selective feeder than livestock. There is also a large overlap in the diets of tahr and livestock expressed by the Morisita index ($C_H = 0.83$). However, the fieldwork was carried out during the monsoon season, when net primary productivity is high and forage quality very good. During winter, the yak herders interviewed reported that yak eats any plant matter, including shrubs and tree bark. The same might hold for tahr. Consequently, dietary overlap might be 100% during winter.

Shrestha (2006) and Buffa et al. (1998) suggest that the spatial overlap in the habitats of tahr and livestock can lead to competition, which is not always the case (Squires 1982) as is well illustrated by the interactions between ungulates in the Serengeti National Park in East Africa (Krebs 1994). The present study also indicates there is a partial, but not a complete spatial overlap between tahr and livestock. However, there is a good availability of forage on both rangelands. In addition, tahr, which is more agile than livestock, is able to reach the vegetation growing in steep and rocky areas and therefore spatially separated from livestock. Therefore, strong competition for food is unlikely.

There were more individuals of tahr at Phortse than at Mongla, where forage diversity and availability are lower. Tahr is often observed grazing together with livestock (Gurung 1995) and sometimes even at low altitudes. This might be how it avoids predators like snow leopard. A similar phenomenon is reported by Basnet

(2002) for blue sheep, which graze together with livestock that protect the blue sheep from predators or attackers by chasing them away.

The worrying fact is, however, that the signs of overgrazing, such as bare and eroded pastures, are becoming increasingly noticeable in the SNP. This is a warning for the future, because if this trend continues, tahr will become an endangered species in this area.

5.5.6 Comparison of the Difficulties Associated with Direct Observation and Micro Histological Techniques

Direct observation is a simple, cheap and easy way to determine the food habits of both livestock and tahr, as neither is shy. Livestock is clearly used to the presence of man; males of tahr escape very quickly when encountered, while females with juveniles do not, as they seem to be used to the presence of man. Thus tahr was often observed from a distance of about 50 m. The problem with direct observation is in defining and quantifying the species of plant being grazed, and how much of a plant is consumed. It is difficult to differentiate between freshly and earlier eaten plants and even those that have only been trampled (Holechek et al. 1982).

Histological analysis is the most commonly used method for evaluating herbivore food habits (Holechek et al. 1982). The problem with faecal analyses is that the material has to be examined under a microscope in order to identify the plant fragments (Fitzgerald and Waddington 1979). The grass and sedge species are usually overestimated and herbaceous plants underestimated (Vavra and Holechek 1980; Gyawali 1986). In the present study, most of the fragments of grasses were very characteristic: *Avena* sp. has a very distinct trichome and inter-stomatal cell structure, which is clearly seen in faecal samples. The microstructure of other species, like *Carex* sp., Cyperaceae sp., *Trisetum spicatum* is, however, very similar and difficult to distinguish. *Ephedra, Saxifraga brachypoda* and *Potentilla* sp. have distinct characters and are easy to recognize.

5.5.7 Floristic Composition

Species diversity was higher at Phortse than at Mongla, which may be explained by their different altitudes. The range of most high altitude plants in the Northwest Himalayas is 3,600–5,500 m, sometimes only 3,900–4,200 m (Mani 1978). The rangeland at Mongla is at 3,400–3,800 m and at Phortse 3,600–4,200 m. Therefore, that at Phortse is in the transition zone between shrubland and grassland, in which vegetation diversity tends to be high. It is reported that the peak number of species occurs at 4,250 m (Gurung 1995). The floristic composition however, is also affected by slope and aspect.

The dominant shrub species on both rangelands are *Rhododendron lepidotum* and *Cotoneaster microphyllus*. Their dominance seems to be increasing (Bauer 1990) and they are rapidly colonizing new areas (Buffa et al. 1998). Bushes of *R. lepidotum* and *C. microphyllus* sometimes form very dense growths, especially on gentle slopes. Some grass and sedge species, like *Avena* sp. and *Carex anomoea* are almost uniformly distributed on both rangelands. The species diversity was highest, where the terrain is not rugged and the vegetation least disturbed on steep slopes.

5.5.8 Effect of Predation by Snow Leopard on Himalayan Tahr and Livestock

The snow leopard has re-colonized the Everest region. An analysis of its scat indicates that Himalayan tahr is its most important food, closely followed by livestock. Our sample size is too small to reach a definitive conclusion, but certain indirect factors indicate that snow leopards depend on tahr as food throughout the year. These include the low kid-to-female ratio in tahr, for which snow leopard might be responsible.

Ale (2006) reports that snow leopard started killing livestock in 2004. Our study also indicates that because snow leopard is quite rare, it does not kill many livestock. In addition, most villagers have a spiritual belief that animals should be respected. However, they may change their mind in the future, especially if the numbers of snow leopard increase and those of tahr decrease, which will result in snow leopard's supplementing their diet with livestock, beyond the level tolerable to local herders. This is typical of areas with depleted prey populations that are insufficient to sustain the local predators and can lead to a serious conflict interest.

5.6 Conservation Recommendations

Based on this study, it is recommended:

1. The tahr populations should be monitored regularly and any changes in population structure (mortality, fecundity), prevalence of diseases, reproduction, general health and other factors associated with the well being of populations recorded.
2. Trends in the productivity and carrying capacity of the tahr's habitat should be closely monitored and action taken if the decline in productivity continues.
3. An in-depth predator-prey population study based on monitoring the abundance of snow leopard, tahr, livestock and vegetation is needed.
4. As both snow leopard and tahr need protection and there is currently no serious competition between livestock and tahr for food, the main threat now comes from the decline in plant productivity in the region due to overgrazing. This trend

could seriously change the situation, as tahr and livestock would then compete for food.

5. The most effective way of reversing this trend is to introduce measures that limit the amount of grass that is harvested for feeding livestock during winter, which is rapidly increasing.
6. Delivery of hay from low altitude areas for feeding livestock during winter should be subsidized, so that it becomes economically attractive for the farmers not to use the overgrazed areas for hay production.

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Annexes

Annex 5.1 Floristic composition of the vegetation at Mongla (see text for notation)

Plant species	*D*	*f*	*RF*	*RD*	*A*	*RA*	*IVI*
Anaphalis contorta	4.6	52.4	4.5	3.5	8.8	2.1	10.1
Anaphalis triplinervis	0.6	9.5	0.8	0.5	6.5	1.5	2.8
Androsace sarmentosa	5.4	52.4	4.5	4.2	10.4	2.5	11.1
Avena sp.	19.4	90.5	7.7	14.9	21.4	5.1	27.7
Bistorta affinis	2.1	19.1	1.6	1.6	10.7	2.5	5.7
Briza media	1.0	4.8	0.4	0.7	20.0	4.7	5.9
Buplerium sp.	0.6	4.8	0.4	0.5	13.0	3.1	4.0
Carex anomoea	11.5	66.7	5.7	8.8	17.3	4.1	18.6
Cheilanthus sp.	0.3	4.8	0.4	0.3	7.0	1.7	2.3
Compositeae	0.1	4.8	0.4	0.0	1.0	0.2	0.7
Cotoneaster microphyllus	6.2	81.0	6.9	4.8	7.7	1.8	13.5
Cyperaceae sp. I	0.5	4.8	0.4	0.4	10.0	2.4	3.1
Cyperaceae sp. II	1.2	19.1	1.6	0.9	6.2	1.5	4.0
Cyananthus hookeri	8.4	38.1	3.3	6.4	22.0	5.2	14.9
Cyananthus microphyllus	9.2	57.1	4.9	7.1	16.2	3.8	15.8
Cypripedium himalaicum	0.8	14.3	1.2	0.6	5.7	1.3	3.2
Drosera peltata	3.1	47.6	4.1	2.4	6.6	1.6	8.1
Festuca sp.	0.3	9.5	0.8	0.2	3.0	0.7	1.7
Fragaria daltoniana	0.3	14.3	1.2	0.3	2.3	0.6	2.0
Gerbera gossypina	6.4	47.6	4.1	4.9	13.4	3.2	12.1
Gueldenstaedtia himalaica	4.1	33.3	2.9	3.1	12.3	2.9	8.9
Habenaria aitchisonii	0.1	9.5	0.8	0.1	1.5	0.4	1.3
Herminium josephii	3.6	38.1	3.3	2.7	9.4	2.2	8.2
Hieracium sp.	0.1	4.8	0.4	0.1	3.0	0.7	1.2
Iris sp.	0.3	4.8	0.4	0.3	7.0	1.6	2.3
Juniperus sp.	0.0	4.8	0.4	0.0	1.0	0.2	0.7

(continued)

Annex 5.1 (continued)

Plant species	*D*	*f*	*RF*	*RD*	*A*	*RA*	*IVI*
Leontopodium stracheyi	0.1	4.8	0.4	0.1	2.0	0.1	1.0
Microula pustulosa	0.4	4.8	0.4	0.3	8.0	1.9	2.6
Notholirion macrophyllum	1.6	19.0	1.6	1.2	8.5	2.0	4.9
Parnassia nubicola	0.1	4.8	0.4	0.1	2.0	0.5	1.0
Pedicularis siphonantha	0.0	4.8	0.4	0.0	1.0	0.2	0.7
Persicaria capitata	1.8	14.3	1.2	1.4	12.7	3.0	5.6
Poa sp.	1.1	23.8	2.0	0.9	4.8	1.1	4.1
Polygonatum hookeri	8.3	42.9	3.7	6.4	19.33	4.6	14.6
Potentilla sp.	7.0	19.0	1.6	5.3	36.5	8.7	15.6
Rhododendron lepidotum	5.4	71.4	6.1	4.1	7.5	1.8	12.0
Salvia hians	1.0	19.0	1.6	0.8	5.5	1.3	3.7
Satyrium nepalense	4.7	57.1	4.9	3.6	8.2	1.9	10.4
Saxifraga brachypoda	3.1	28.6	2.4	2.4	11.0	2.6	7.5
Saxifraga parnassifolia	2.7	57.1	4.9	2.1	4.7	1.1	8.1
Sedum sp.	1.9	9.6	0.8	1.5	20.0	4.7	7.0
Sedum sp.	0.0	4.8	0.4	0.0	1.0	0.2	0.7
Silene sp.	0.1	9.6	0.8	0.1	1.5	0.3	1.3
Trisetum spicatum	0.3	4.8	0.4	0.3	7.0	1.6	2.3
Unidentified gramineae (15)	0.2	4.8	0.4	0.2	5.0	1.2	1.8

Annex 5.2 Floristic composition of the vegetation at Phortse (see text for notation)

Plant species	*D*	*f*	*RF*	*RD*	*A*	*RA*	*IVI*
Allium wallichii	0.0	3.3	0.2	0.0	1.0	0.2	0.4
Anaphalis contorta	0.2	6.7	0.4	0.1	2.5	0.5	1.04
Avena sp.	9.0	96.7	6.4	5.8	9.3	1.8	14.1
Bistorta affinis	2.8	46.7	3.1	1.8	6.1	1.2	6.1
Campanula pallida	2.0	10.0	0.7	1.3	20.0	3.9	5.9
Carex anomoea	12.2	100.0	6.7	7.8	12.2	2.4	16.9
Cassiope fastigiata	1.7	10.0	0.7	1.1	17.3	3.4	5.2
Cheilanthus spp.	0.2	10.0	0.7	0.1	2.3	0.5	1.3
Compositeae	0.0	3.3	0.2	0.0	1.0	0.2	0.4
Cotoneaster microphyllus	1.9	43.3	2.9	1.2	4.5	0.9	5.0
Cyperaceae sp.	0.1	3.3	0.2	0.1	5.0	1.0	1.3
Cyananthus hookeri	8.4	63.3	4.2	5.4	13.3	2.6	12.2
Cyananthus microphyllus	5.2	50.0	3.3	3.3	10.3	2.0	8.7
Cyperus sp.	4.0	43.3	2.9	2.6	9.2	1.8	7.3
Cypripedium himalaicum	0.6	6.7	0.4	0.4	9	1.8	2.6
Dactylorhiza hatagirea	0.1	3.3	0.2	0.1	3.0	0.6	0.9
Drosera peltata	5.4	46.7	3.1	3.5	11.6	2.3	8.9
Dubyaea hispida	1.2	6.7	0.4	0.8	18.5	3.6	4.9
Ephedra gerardiana	0.2	6.7	0.4	0.1	2.5	0.5	1.0
Euphrasia himalayica	2.3	13.3	0.9	1.5	17.5	3.4	5.8
Fragaria daltoniana	2.9	56.7	3.8	1.8	5.1	1.0	6.6
Gentiana depressa	6.6	23.3	1.6	4.2	28.1	5.5	11.3

(continued)

Annex 5.2 (continued)

Plant species	*D*	*f*	*RF*	*RD*	*A*	*RA*	*IVI*
Gentiana sp.	1.0	23.3	1.6	0.7	4.4	0.9	3.1
Gerbera gossypina	7.2	73.3	4.9	4.7	9.9	1.9	11.5
Gueldenstaedtia himalaica	2.7	46.7	3.1	1.8	5.9	1.2	6.0
Halenia elliptica	1.5	20.0	1.3	1.0	7.5	1.5	3.8
Herminium josephii	0.3	6.7	0.4	0.2	5.0	1.0	1.6
Hieracium sp.	3.3	43.3	2.9	2.1	7.6	1.5	6.5
Leontopodium jacotianum	3.0	20.0	1.3	1.9	14.8	2.9	6.2
Morina nepalensis	3.5	36.7	2.4	2.3	9.6	1.9	6.6
Neottianthe calcicola	1.6	23.3	1.6	1.0	6.9	1.3	3.9
Notholirion macrophyllum	1.7	20.0	1.3	1.1	8.5	1.7	4.1
Parnassia nubicola	1.9	33.3	2.2	1.3	5.9	1.2	4.6
Pedicularis siphonantha	3.4	66.7	4.4	2.2	5.0	1.0	7.6
Persicaria capitata	5.6	36.7	2.4	3.6	15.2	3.0	9.0
Poa sp.	0.6	20.0	1.3	0.4	2.8	0.6	2.3
Polygonatum cirrhifolium	0.2	3.3	0.2	0.1	6.0	1.2	1.5
Polygonatum hookeri	29.7	56.7	3.8	19.0	52.4	10.3	33.2
Polygonum sp.	1.0	16.7	1.1	0.6	5.8	1.1	2.9
Polygonum sp.	0.4	3.3	0.2	0.3	12.0	2.4	2.8
Potentilla sp.	105.0	26.7	1.8	1.0	5.6	1.1	4.5
Primula sp.	2.2	6.7	0.4	1.4	33.5	6.6	8.5
Rhododendron lepidotum	3.1	60.0	4.0	2.0	5.2	1.0	7.0
Salvia hians	0.7	20.0	1.3	0.5	3.5	0.7	2.5
Satyrium nepalense	0.4	10.0	0.7	0.3	4.0	0.8	1.7
Saxifraga brachypoda	2.4	40.0	2.7	1.6	6.1	1.2	5.4
Saxifraga parnassifolia	1.4	36.7	2.4	0.9	3.7	0.7	4.1
Sedum sp.	0.2	13.3	0.9	0.1	1.7	0.3	1.4
Sedum sp.	0.6	6.7	0.4	0.4	9.0	1.8	2.6
Silene sp.	0.1	3.3	0.2	0.0	2.0	0.4	0.7
Thermopsis barbata	4.9	26.7	1.8	3.2	18.5	3.6	8.6
Thesium emodi	0.4	6.7	0.4	0.2	5.5	1.1	1.8
Trachyspermum ammi	0.7	13.3	0.9	0.5	5.2	1.0	2.4
Woodfordia sp.	0.1	6.7	0.4	0.1	1.5	0.3	0.8

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