Have snow leopards made a comeback to the Everest region of Nepal?

Progress report

for

the International Snow Leopard Trust

by

Som B. Ale, UIC, Chicago, USA

(*Photo*: S. B. Ale)

February 2005

Contents:

Executive summary

In the 1960s, the endangered snow leopard was locally extirpated from the Sagarmatha (Mt. Everest) region of Nepal. In this Sherpa-inhabited high Himalaya, the flourishing tourism since the ascent of Mt Everest in 1953, has caused both prosperity and adverse impacts, the concern that catalyzed the establishment of Mt. Everest National Park in the region in 1976. In the late 1980s, there were reports that some transient snow leopards may have visited the area from adjoining Tibet, but no biological surveys exist to confirm the status of the cats and their prey. Have snow leopards finally returned to the top of the world? Exploring this question was the main purpose of this research project.

We systematically walked altogether 24 sign transects covering over 13 km in length in three valleys, i.e. Namche, Phortse and Gokyo, of the park, and counted several snow leopard signs. The results indicated that snow leopards have made a comeback in the park in response to decades of protective measures, the virtual cessation of hunting and the recovery of the Himalayan tahr which is snow leopard's prey. The average sign density (4.2 signs/km and 2.5 sign sites/km) was comparable to that reported from other parts of the cats' range in the Himalaya. On this basis, we estimated the cat density in the Everest region between 1 to 3 cats per 100 sq km, a figure that was supported by different sets of pugmarks and actual sightings of snow leopards in the 60 km2 sample survey area. In the study area, tahr population had a low reproductive rate (e.g. kids-to-females ratio, 0.1, in Namche). Since predators can influence the size and the structure of prey species populations through mortality and through non-lethal effects or predation risk, snow leopards could have been the cause of the population dynamics of tahr in Sagarmtha, but this study could not confirm this speculation for which further probing may be required.

Introduction

In the early 1970s in east Nepal, the endangered snow leopard *Uncia uncia* was locally extirpated in what is now Sagarmatha (Mt. Everest) National Park (E 86^0 30' 53" to E 86^0 99' 08" and N 27^0 46' 19" to N 27^0 6' 45"; area 1,148 km^2; figure 1). In 1987, Ahlborn and Jackson (1987) reported some signs probably made by transient cats from Tibet in the Gokyo area of the park. After almost three decades of effective protection measures, the virtual cessation of hunting and the recovery of the endangered Himalayan tahr *Hemitragus jemlahicus* (and musk deer *Moschus chrysogaster*) in the park since its establishment in 1976, snow leopards seem to have made a comeback to the world's highest national park. The Sagarmatha National Park (or Khumbu) lies in the Solu-Khumbu district of the northeastern region of Nepal and encompasses the upper catchment of the Dudh Kosi River system.

One of the objectives of this research project is to assess whether snow leopards have established resident populations in the park. How far have they expanded their range? What is the status of their main prey? Answering these questions will be the main purpose of the project (part I). Achieving this will form the basis to explore some ecological questions associated with the larger project on the snow leopard and the Himalayan tahr in Sagarmatha (part II). For management purposes, information on local megafauna such as the snow leopard is crucial not only for the overall management of the park, but also to expedite the trans-boundary landscape conservation, an effort that is currently being undertaken in Nepal and its neighboring countries. Because no protected areas in Nepal are large enough to contain viable populations of snow leopards and other large predators, the establishment of trans-frontier conservation areas at landscape level with neighboring countries may facilitate genetic exchanges between individuals ensuring their long-term survival (Soule 1987, Jackson and Ahlborn 1990, Green 1994). Qomolongma Nature Preserve (Tibet, China), and Langtang, Makalu-Barun and Everest National Parks in Nepal form the largest trans-frontier conservation area covering approx. 40,000 km^2 in the Himalayan region.

Here we have summarized some findings of part I, with a note on issues akin to local landuse practices that may have relevance to wildlife conservation. A detailed (technical) report will be submitted later. We have also estimated the relative abundance of snow leopards although this assessment is preliminary, and is subject to changes as more information will be collected in coming years. Snow leopards leave marks in the form of scrapes, scent sprays, feces and pugmarks (Rieger 1978, Ahlborn and Jackson 1988) which can be indexed to derive information on abundance using standardized methodology called the Snow Leopard Information Management System (SLIMS) (Jackson and Hunter 1996, see also Connor et al. 1983, Van Dyke et al. 1986, for other species).

Sign surveys were conducted in three valleys using SLIMS in habitats with high vs. low human activity (Namche, Phortse and Gokyo). Transect routes were plotted on available 1:50,000 topo maps, most being along landforms where snow leopard sign is likely to be found, such as ridgelines and cliff edges. To minimize within-transect variability, transects were short and rarely crossed habitat (i.e. forest, shrubland, scrubland and grassland) boundaries. Transects were walked by a pair of observers and all sign recorded as to type and number. At each site where snow leopard sign was found, habitat attributes within a 20 m radius were determined including elevation, slope, aspect, vegetative cover, dominant topographic feature, landform ruggedness, and land use. Of these attributes, landform ruggedness was the most subjective which included rolling, broken, very-broken, and cliff. Cliffs in this case were defined as being surfaces of 50^0 or steeper over an area of at least 100 m^2 (McCarthy 2000).

On each transect a number of random sites (at least one per 100 m) were selected and all habitat attributes were recorded to allow comparisons with sign sites (cf. McCarthy 2000). The attributes of sign sites and random sites were used to compare use and availability. The frequency with which leopards used sites of various habitat attributes was compared to the availability of such sites using a Chi-square goodness-of-fit test. Sign placement was considered an indicator of habitat use by leopards. Sign density, expressed in sign/km of transect was calculated for each transect, for each survey area, and for the whole area. To test for differences in mean density of sign sites between valleys, Kruskal-Wallis one-way analysis of variance was employed.

For Himalayan tahr, fixed-point counts from ridgeline vantage points were conducted using the methods detailed by Jackson and Hunter (1996). Survey blocks were outlined on maps and observation sites identified. Each block was scanned and all tahr counted and assigned to sex and age class when possible (see Schaller 1977). Opportunistic observations on tahr and other prey species of snow leopards were also made along snow leopard sign transects which provided supplemental data to fixed-point counts of tahr.

A sample of 20 adult males was darted, weighted, aged, eartagged, and their blood samples were collected, as part of the Ev-K2-CNR project. A study on Himalayan tahr was carried out with the following expected results: minimum population distribution, size and density of tahr in selected areas of the park, assessment of sex ratio and assessment of reproductive rate. Observations on the foraging behavior of tahr were also made, and findings will be reported later in the final report.

Local herders and key residents were interviewed about wildlife numbers and abundance. They were also questioned on landuse practices such as grazing.

Results

Between October and November 2004, sign surveys were conducted in three valleys (figure 2-5). Altogether, 24 transects were walked covering 13.4 km in length. Thirty three (10 relic and 23 non-relic) snow leopard sign sites and 56 signs were counted (table 1). No relic signs were discovered in Gokyo valley, but in Phortse and Namche. Scrapes (59%) were by far the most common sign type, which together with feces (32%) constituted over 90% of signs encountered (table 2).

Table 1: Site and sign density

Location	Transect (km)	Sign sites	Mean site/km	Sign (all)	Mean sign/km	Scrapes	Mean scrape/km
Phortse	5	25	4.77	43	8.20	26	4.96
Gokyo	5	5	1.10	6	1.32	6	1.32
Namche	4	3	0.84	7	1.95	1	0.28
Total	13	33	2.46	56	4.18	33	2.46

Table 2: Signs encountered in three valleys

Block/valley	Scrape	Feces	Hair	Scent mark	Pugmark
Phortse	26	14	0	1	2
Gokyo	6	0	0	0	0
Namche	1	4	1	1	0
Total	33	18	1	2	2
Total	58.93	32.14	1.79	3.57	3.57

Snow leopard sign density/km of transect was not equal across valleys (table 1). Phortse valley had a higher mean density of snow leopard sign site/km of transect when compared to Namche and Gokyo (F=5.64, df=2, p=0.011). More statistical analysis will eventually carried out in 2005 and 2006, when more data will be collected. Variation in mean sign density between summer and winter may be expected.

Sign sites were not found in habitats of varying in features in proportion to occurrence, except in case of vegetation cover (table 3). Altogether, 170 sites, including 33 sign sites and 137 random sites, were characterized to compare use and availability of these sites by snow leopards. Following features (all categorical) were tested using Chi square goodness-of-fit: terrain ruggedness, primary topographic feature, aspect and vegetative cover. All other features (continuous variables) will be analyzed later. On average, snow leopard signs were located at the altitude of 4032 m (SE = ± 46.6) and in sites with slopeness angle of 47 degree (SE = ± 2.5).

Table 3: Habitat characteristics of snow leopard sign sites and random sites.

	% sign sites (n=53)	% random sites (n=137)	Chi2	Remark
Landform ruggedness				
	O	E		
Broken	32.85	20.75	7.044973	
Cliff	10.95	32.08	13.91505	
Flat	2.19	1.89	0.048655	
Rolling	28.47	13.21	17.63049	
Very broken	25.55	32.08	1.328589	
	100.00	100.00	39.96776	df=4, significant*
Dominant topographic feature				
Boulder	23.36	16.98	2.394432	
CLIFF	16.06	50.94	23.88854	
Hill	28.47	11.32	25.96991	
Ridge	22.63	18.87	0.749218	
Stream	6.57	0.00	0	
Talus	2.19	0.00	0	
Valley	0.73	1.89	0.709319	
	100.00	100.00	53.71142	df=6, significant*
Aspect				
E	19.71	7.55	19.59496	
EW	4.38	1.89	3.293367	
NW	2.92	13.21	8.013572	
S	17.52	13.21	1.406934	
SE	24.82	30.19	0.955635	
SW	21.17	24.53	0.460383	
W	9.49	9.43	0.000322	
	100.00	100.00	33.72517	df=6, significant*
% Vegetation cover				
1-25	16.73	24.73	2.588567	
26-50	46.39	43.01	0.265159	
51-75	35.36	32.26	0.298516	
76-100	1.52	0.00	0	
	100.00	100.00	3.152241	df=3, non-significant

* significant: [**$p < 0.05$**]

A total of 86 (n=744) sightings of tahr were recorded during the study period in Namche, Phortse and Gokyo valleys, with the average group size of 8.6 (SE= ± 0.76) individuals. Table 4 shows the population structure in Phortse and Namche valleys based on **(1)** the known numbers (repeated total counts and classification), and **(2)** all tahr seen daily in the study area.

The results derived by the two methods show close match. Young to female ratio was 0.4 (Phortse) and 0.1 (Namche). Adult females outnumbered males (male to female ratio: 0.2 in Namche; 0.6 in Phortse), but male to female ratio in the rutting season was 1.2 when more males joined the group making the total number of males to 31 (mean 30.9, SE = ± 3.7) (table 5), based on individually recognizable tahrs through eartags (mark-resight index). Our total count of tahr indicated that tahr density in Phortse valley was approximately 3.2

individual/km and in Namche 5.1 individual/km (8.4 individual/km by the end of November 2004, rutting period: refer to table 5).

Table 4: Tahr population structure based on known number of different tahr and all animals tallied.

	Known number		All animals tallied		Known number		All animals tallied	
Himalayan tahr	No.	%	No.	%	No.	%	No.	%
Female	29	44.62	172	42.79	26	65.00	189	59.43
Yearling	8	12.31	43	10.70	5	12.50	15	4.72
Kid	12	18.46	70	17.41	3	7.50	24	7.55
Total Yearlings and kids	20	30.77	113	28.11	8	20.00	39	12.26
Male 1	3	4.62	16	3.98	0	0.00	5	1.57
Male 2	5	7.69	24	5.97	1	2.50	8	2.52
Male 3	8	12.31	35	8.71	5	12.50	40	12.58
Unidentified male	0	0.00	5	1.24	0	0.00	4	1.26
Total males	16	24.62	80	19.90	6	15.00	57	17.92
Unidentified (all)	0	0.00	37	9.20	0	0.00	33	10.38
Total	65	100.00	402	100.00	40	100.00	318	100.00

Table 5: Male tahr population size in Namche based on mark-resight index (marked = 20)

Date	Total males sighted	Re-sighted marked males	Total size
27-Nov	21	11	38
28-Nov	14	10	28
30-Nov	16	12	27
Mean	17	11	31

Human-snow leopard interactions

Interviews to herders in Phortse (with traditional/conservative animal husbandry practices) indicated that the mean herd size for all domestic stock was 8.05 (SE = ± 0.93) animals per household. Losses to snow leopards in the year 2004 were only 9 head of stock, or about 0.15 head per household (table 6). Overall, 1.9% of total livestock number was lost to snow leopards, with total mortality of all causes being 7.5%. Six families actually lost stock (2/3 of them cattle), for an average of 1.5 head per loss. No loss to other predators was reported during the same period. The attitudes of herders who responded were indifference towards snow leopards. Most (87%) did not see how the presence of snow leopards (and Himalayan tahr) are related to overall biodiversity maintenance, but virtually nobody suggested persecution of snow leopards for killing their livestock.

Table 6: Livestock type and mortality in Phortse

Livestock type	**Number**	**% loss (n=36)**	**% loss to SL (n=9)**
Yak	138	5.07	1.45
Nak	238	6.72	0.42
Jom	38	2.63	0.00
Jopkyo	12	0.00	0.00
Cow	46	19.57	10.87
Ox	3	100.00	33.33
Total	**475**	**7.58**	**1.89**

Discussion

The presence of snow leopards in all three Namche, Phortse and Gokyo valleys, as determined in this study, varies from what has been reported previously by Ahlborn and Jackson (1987) who recorded sign possibly made by (transient) cats from Tibet only in Gokyo (including Thagnak) valley in 1987. Apparently, snow leopards have expanded their range in Sagarmatha because of three decades of protection afforded by the Department of National Parks and Wildlife Conservation since 1976. We located signs in 58% of transects conducted (n=24), with 2.5 sites/km and 4.2 all signs/km (2.5 scrape/km), in contrast to the previous survey (13% of the 31 transects had signs, with 0.7 sites/km, and 2.6 all signs/km, and 0.5 scrapes/km). In Sagarmatha, snow leopards have actually increased in abundance. Apparently, now they are resident here.

The sign density was comparable with that reported from India (2.1 scrapes/km, with one cat/100 km in central Ladak: Fox et al. 1991; 2.5 scrapes/km, with approx. 3 cats/100 km in upper Indus valley: Fox and Chundawat 1997) and from the trans-Himalayan part of Nepal (2.8 all sign/km: Fox and Jackson 2002). On this basis, cat density in Sagarmatha may be **1-3 snow leopards/100 sq km**, ignoring differences of use of terrain by snow leopards. The Langu valley of west Nepal with snow leopard density of 8-10 cats/100 km, one of the densest populations, had 11 sites/km, 36 combined signs/km with 11 scrapes/km, where scrapes predicted 87% of snow leopard use of an area (Ahlborn and Jackson 1988). However, judging from their different pugmarks (two different individuals sighted and their pugmarks measured on the spot), we got evidence of 4 snow leopards using a minimum area of 60 km^2 of Namche, Phortse and Gokyo valleys (figure 1 and 2), which suggests a higher density, i.e. 6-7 per 100 sq km, than the estimate based on sign density alone. Sign density on transects may be a function of more than cat density. The abundance of scrapes, as well as tracks and scats, may provide a rough index of relative numbers, but counts of scrapes as a measure of abundance must take into account differences in use of terrain by snow leopards, from area to area (Schaller 1998), differential sign longevity and how it is influenced by seasonal changes in livestock disturbance, weather, flooding, and animal behavior, and different topography (primarily differential presence of valley bottom cliffs and ridge top outcrops), general topography as well as livestock density (Jackson 1996, Fox and Chundawat 1997, McCarthy 2000). Clearly, there are difficulties in comparing sign densities to draw inferences, but even rough estimates are better than a “wild guess” for conservation of rare and endangered species as the snow leopard (Schaller 1998). If limitations are recognized and addressed, sign density as a predictor of leopard density may provide the best available and easily applied method to assess relative snow leopard densities.

Informal interviews in other valleys, e.g. Thame (upper Bhote Kosi) and Pangboche (Imja Khola) revealed that snow leopards are more than a rarity there. A survey covering additional valleys in the park is recommended for the year 2005 to find their total range. Jackson and Ahlborn (1990) crudely speculated a potential habitat of 30,000 km2 for Nepal, with estimated numbers at 300-500 individuals, but surveys are urgently needed to confirm this rough guess. A GIS-based model of potential snow leopard range across Asia (Hunter and Jackson 1997) could be useful to predict snow leopard distribution for conservation planning, provided that it considers actually suitable habitat parameters e.g. elevation, distance to cliff, slope, land ruggedness and vegetation type (cf. in west Nepal, Jackson 1996; and in Mongolia, McCarthy 2000). Multiyear data points with snow leopard signs are required to draw a conclusion for Sagarmatha for immediate management purposes.

The density of tahr was greater in Namche than Phortse, during October and November 2004. Young to female ratio was very low both in Phortse and Namche. Apparently, adult females outnumbered males, in contrast to most ungulate species which show 1:1 ratio. Such low male to female ratio is not surprising outside the rutting season, when males wander widely while females are localized in small home ranges (cf. Schaller 1973). The male to female ratio of tahr populations in Annapurna was 0.61 (Gurung 1995). As the rutting season advanced, male to female ratio increased favoring males (1.2 in Namche, at the end of November) when males from neighbor areas may have joined the female groups.

In both valleys, tahr showed a low reproductive rate (kids-to-females ratio). It was worse in Namche, 0.1, i.e. just 1 female out of 10 produced a kid in 2004 there. Such an alarmingly low reproductive rate of tahr has regularly been reported from the area since 1992 (Lovari 1992, Sandro Lovari, pers. comm.). 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). Standard reproductive rates in stable populations of ungulates oscillate around 0.5-0.6, and reproductive rates in growing populations may exceed 0.7, on average. Such an alarmingly low reproductive rate in Sagarmatha may depend on predation or disease, factors which are currently under examination. Is predation by snow leopards responsible for the low reproductive rate of the Himalayan tahr population in Sagarmatha? This is an interesting question that needs further probing. Unlike other Caprins (sheep and goats and their relatives) that show a short synchronized birth period (thus there is predator satiation), the birthing season for tahr seems to stretch (but further data are necessary) over almost a period of 4 months, from June to September, which makes their young exposed to predation probably because no “predator swamping” occurs. This speculation needs to be validated. The following research topics have been identified and planned for the coming years: a study of snow leopard diet; observations of tahr during the birthing season (June through August, 2005/2006); additional observations on feeding behavior (June to November, 2005/2006). A disease, e.g. brucellosis, affecting the fertility of females may be another cause of the Namche population crash. Current analysis of blood samples from 20 adult male tahr and as many local cattle were sampled in November 2004 to assess whether disease, if any, was responsible.

Namche with its higher density of Himalayan tahr revealed a lower snow leopard sign density than Phortse. This is surprising, but it is too early to draw a conclusion. Fox and Jackson (2002) reported a similar questionable inverse relationship between snow leopard density and blue sheep *Pseudois nayaur* in trans-Himalayan Nepal (blue sheep 2-4/km2 and 2.8 snow leopard signs/100 km of sign transect) and in Bhutan (blue sheep 4-6/km2 and 1.2 snow leopard signs/100 km). It has been shown that density of prey alone cannot predict predator abundance. Ibex *Capra ibex* density does not appear to be a particularly good predictor of snow leopard sign density in Mongolia (McCarthy 2000). Biomass of all available prey, including livestock and small mammals, may prove a better predictor, but such a value is not easily obtained. Such difficulties indicate that perhaps different models should be used to predict large predator habitat use and abundance (e.g. models based on foraging theory). Behaviors of prey species (here Himalayan tahr) may be modeled to identify suitable habitats of snow leopards, as a part of the larger project. It is quite likely that, because of fear responses through vigilance and habitat choice, the distribution and density of prey species may be a poor predictor of predator habitat use and abundance.

If there is recovery of prey, snow leopards could make a comeback. Alternative prey species for snow leopards in Sagarmatha may include musk deer, pika and pheasants, but no effort was made to record their abundance. Snow leopards show little fear of humans and will approach established human dwelling sites to prey on livestock. Secondary impacts of grazing, particularly reductions of wild prey through competition, may negatively influence snow leopard range use. Although no data were recorded on competition between livestock and Himalayan tahr, they maintain distance between them (308 m, SE = ± 42; n = 29). Is there any competition for forage between livestock and Himalayan tahr? This is another research question that should be addressed sometime in the future. Elsewhere, the issue of competition between livestock and wild herbivores has remained contentious. Mishra (2004) compared forage availability and blue sheep population structure between rangelands differing in livestock density in India and reported that, in the intensively grazed rangeland, blue sheep density was 63% lower and their population showed poorer performance (lower young:adult female ratio). Most livestock removed large amounts of forage from the pastures (Bagchi 2004), otherwise available to native prey.

Anecdotal reports that common leopards occur in lower Namche could not be verified. Neither we encountered any sign that indicated the presence of grey wolf *Canis lupus* throughout the survey area, but there was evidence of other predators such as golden jackal *Canis aureus*, red fox *Vulpes vulpes*, martens and weasels in the area. Unlike elsewhere, complaint against livestock predation by snow leopards is almost non- existent in the region (although they lost 1.9% of their total livestock to snow leopards, the mortality rate which is not very different from that reported from other areas, see Oli et al. 1994, Jackson et al. 1994, Mishra 1997). This is positive sign for the long-term survival of snow leopard population here in Sagarmatha. Unlike in other parts of Nepal and the Himalaya, interestingly, the snow leopard is one of the mountain deities for Sherpa people who believe that snow leopards kill their livestock only upon their negligence to appease any of these deities. On the other hand, herders both feared and hate wolves that are capable of subduing even large yaks. Today, wolves are absent in the rugged mountains of the Mt. Everest ecosystem. Stevens (1993) claimed that the last Khumbu wolf met his end in 1986. When villagers discovered that a pair of wolves had apparently crossed from Tibet into the upper Bhote Kosi and produced a litter there, they asked the national park to exterminate the animals. But when this request was refused, they took matters into their hands. But there exist reports that claimed the existence of wolves in the early 1990s (Fleming, undated, quoted in Lovari 1992). We inquired at an old local herder from Thami, one of the five permanent settlements in Khumbu, located on the way that leads to Nagpa-La, "where have all the wolves gone?" They went back to Tibet, he joked. Nagpa-La, a high pass over 5,700 m, perhaps serves as a migration and dispersal route between Nepal and Tibet, for wolves and snow leopards (see Ahlborn and Jackson 1987). In this part of Tibet (Qomolongma Reserve), snow leopards have long been reported to occur "widely but sparsely" (Jackson et al. 1994). That wolves have not returned to Sagarmatha for a along time may indicate that they have become scarcer in adjacent areas. This needs confirmation. One day, wolves will perhaps return to this side of Mt. Everest. Most of the upper parts of Mt Everest consist of rolling undulating terrain suitable for coursing predators like wolves, but these valleys are sparsely vegetated and consist of barren glacial moraines, devoid of large ungulates. The lower portions of Mt. Everest are V-shaped rugged valleys that are much more vegetated and teeming with abundant prey species, thus more hospitable for snow leopards (stalking predator) than wolves. Snow leopards and wolves are sympatric in much of their range, e.g. northern districts (Dolpo, Mustang and Manang) of west Nepal, Ladak (India) and Tibet (China), to name a few.

For centuries Khumbu has not only supported arrays of wildlife species but also for 3,500 Buddhist Sherpa people and their approx. 3,000 livestock (as well as perhaps thousands of transhumant sheep and goats from nearby lower valleys outside Khumbu before 1960). For many generations, knowledge about land use such as livestock grazing and the impact of such practices has been of fundamental importance to livestock, wildlife, rangelands and agriculture. Its impact is evident in lifestyles in Khumbu today. In a landscape of marked relief, where cultivable ground is scarce, cropping for direct human consumption certainly takes precedence over cultivation of fodder. Although summer grazing is luxuriant, it is only possible for a few months, then begins a harsh winter that almost always exhausts the stored supplementary feed. This essentially means that animal numbers must be in balance with winter feed limits. In Khumbu the response of pastoralists to this has been to create a detailed set of social rules and regulations for grazing. Seeking to limit risks, the pastoral production system is based on flexible strategies, which allow people to take advantage of the seasonal rangeland condition. Apparently, community imposed restriction of access to common lands is an important strategy that has played a crucial role in maintaining the sustainable use of the available forage resources. Such indigenous practices may explain the continued existence of ungulates in Khumbu.

Along with subsistence farming and animal husbandry, for a considerable time Khumbu Sherpa made regular excursions via the Nagpa-La into Tibet to trade grain from lower Solu for Tibetan salt, wool, jewelry and cattle. When the Chinese took full control in Tibet, the flow of trade over the Nagpa-La soon dried up, disrupting economic life in Khumbu. The rupture of centuries old trading relation with Tibet coincided with the advent of tourism, since the ascent of Mt. Everest, that built a stronger tie with Kathmandu. Sherpa reinvested their capital in the establishment of tourist lodges and shops in Khumbu, as well as in trekking agencies in Kathmandu. Visitors increased from about 1,400 in 1972/1973 (Jefferies 1984) to 7,492 in 1989, and over 20,000 today, exceeding the local population by a factor of six. As anticipated, increased affluence from tourism particularly since 1970s may have resulted in pressure on local resources. There have been many publicized accounts on post–1950 land use changes and perceived landscape degradation in Sagarmatha National Park, claiming that large-scale vegetation and geomorphic changes have occurred in the park. The loss of forest cover in the region began some 500 years ago with the arrival of the first Sherpa settlers and, more recently, this has been accelerated by the influx of thousands of Tibetan refugees accompanied by thousands of their livestock during 1959-1961 and the large-scale growth of trekking and mountaineering, all considerably stressing local systems. This scenario on the top of the world was heralded as prime example of environmental degradation in the seventies in the Himalayas, producing a copious literature linking population pressures with increased deforestation, soil erosion, landslides, and siltation of watercourses (see Eckholm 1976).

In the 1980s and early 1990s, the studies by Bjonness (1979, 1980, 1983), Byers (1986, 1987), Brower (1990, 1991) and Steven (1993) brought forward new insights. With the assessment of soil profiles, pollen analysis of stratified soil samples, and 14C dating of charcoal samples found at various soil depths, Byers (1987) suggested that man may have been frequenting and modifying the Khumbu landscape considerably longer than the 400-year period generally assumed, and that substantial climatic change has occurred during the past 4,000 years. Since the 1950s, far less forest removal and geomorphic damage has occurred in the Khumbu, thereby invalidating previous claims of serious landscape degradation in the region. Reports also suggested that most shrub/grassland and forested slopes below 4,000 m are stable, but high soil loss occurs in degraded Alpine summer settlement areas because of continued shrub harvesting for fuelwood, grazing pressures, and natural freeze-thaw processes. Much of what we observe today in Khumbu has been there since the first settlers, thus showing that traditional land-use practices of Sherpa people may be environmental friendly. The Shinga nawa - a system of forest guardians traditionally responsible for controlling use of forest resources – may be the key behind this (Sherpa 1987). The same system also controls pastoral practices of the region to the benefit of people and resources alike. Evidence of both the cultural resiliency of Sherpas and wisdom acquired over many generations of residence in Khumbu suggest that revitalization of traditional conservation systems may offer an answer to recently increasing problems of environmental deterioration (Brower 1990), essentially suggesting to promote local level institutions to enhance proactive environmental management at the local level (see also Nepal 2003). However, Stevens (1993) cautions not to romanticize too much the possible harmonious relationship between Sherpa and their high valleys. Although Sherpas have historically demonstrated both the depth of their local environmental knowledge and the degree to which they have carefully patterned their land use and management practices on the basis of this knowledge, their forest and pasture management had shortcomings from an environmental standpoint, as expected when the resource management is driven by efforts that maximize yields, minimize risk and promote conservation. Identification of these shortcomings and addressing them at times with minimal outside intervention may be the best conservation strategy at present.

Snow leopards have re-colonized Sagarmatha or Khumbu. The local Sherpa residents are beginning to realize the presence of snow leopards in their lands, to date fortunately not as a threat to their livelihood. However, the picture may not remain the same forever particularly when cats will start supplement their diets with livestock beyond the level tolerable to local herders. This is a typical scenario in areas with depleted prey populations, not sufficient to maintain local predators. Unlike elsewhere, Himalayan tahr may be the main prey species of snow leopards of Sagarmatha. Although blue sheep are the primary prey, Himalayan tahr are the second most important part of the Langu Valley's snow leopards food base, constituting 10% of their diet (Jackson 1996). A predation rate of about 10% of a population represents a limiting equilibrium state for large predators and large mammalian prey (Emmons 1987). Jackson (1996) assumed that an adult snow leopard may require 20-30 blue sheep annually, i.e. 150-230 blue sheep are needed to support a single adult snow leopard (harvesting rate 13%). Schaller (1998) suggested a similar figure, i.e. a blue sheep population with 150-200 animals and an annual increment of 15% could support one wolf or one snow leopard if the population lacked other mortality causes such as poaching.

How many Himalayan tahr do snow leopards require on the top of the World? Where are the biodiversity hotspots in Sagarmatha, from the perspective of snow leopard conservation? Are there pastures or habitats that can be temporarily closed to grazing to improve productivity, beneficial both to native and domestic ungulates? These are some of the ecological questions to be answered and translated into management suggestions, before a management plan for Mt. Everest National Park may be drafted.

References

Ahlborn, G. and R. Jackson. 1987. A survey of Sagarmatha National Park for the endangered snow leopard. Department of National parks and Wildlife Conservation, and King Mahendra Trust for Nature Conservation. Unpub. Report, 18 pp.

Ahlborn, G. and R.M. Jackson. 1988. Marking in free-ranging snow leopards in west Nepal: a preliminary assessment. Pages 25-49 In: H. Freeman (ed.). Proceedings of the Fifth International Snow Leopard Symposium, Int. Snow Leopard Trust and Wildlife Institute of India. 269 pages.

Bagchi, S., C. Mishra, C., Y. Bhatnagar. 2004. Conflicts between traditional pastoralism and conservation of Himalayan ibex *Capra sibirica* in the Trans-Himalayan mountains. Animal Conservation 7: 121-128.

Bjonness, I.M. 1979. Impacts on a high mountain ecosystem: recommendations for action in Sagarmatha (Mount Everest) National Park. Unpublished Report. 38 pp.

Bjonness, I.M. 1980a. Animal husbandry and grazing, a conservation and management problem in Sagarmatha National Park. Norsk Geogr. Tidskr. 33: 59-76.

Bjonness, I.M. 1980b. Ecological conflicts and economic dependency on tourist trekking in Sagarmatha National Park, Nepal. An alternative approach to park planning. Norsk Geogr. Tidskr. 34: 119-138.

Bjonness, I.M. 1983. External economic dependency and changing human adjustment to marginal environment in the high Himalaya, Nepal. Mountain Research and Development 3: 263-272.

Brower, B. 1990. Range Conservation and Sherpa Livestock Management in Khumbu, Nepal. Mountain Research and Development 10: 34-42.

Brower, B. 1991. Crisis and Conservation in Sagarmatha National Park, Nepal. Society and Natural Resources 4: 151-63. Bulletin 11:146-152.

Byers, A. 1986. A Geomorphic Study of Man-Induced Soil Erosion in the Sagarmatha (Mount Everest) National Park, Khumbu, Nepal: Report on the Activities of the UNU/MAB (Nepal) Mountain Hazards Mapping Project, Phase II. Mountain Research and Development 6: 83-7.

Byers, A. 1987. Landscape Change and Man-Accelerated Soil Loss: The Case of the Sagarmatha (Mt. Everest) National Park, Khumbu, Nepal. Mountain Research and Development 7: 209-16.

Connor, M. C., R. F. Labisky, and D. R. Progulske. 1983. Scent-station indices as measures of population abundance for bobcats, raccoons, gray foxes, and opossums. Wildlife Society Bulletin 11:146-152.

Eckholm, E. P. 1996. Losing ground: Environmental stress and world food prospects. New York: worldwatch institute/Pergamon.

Emmons, L. 1987. Comparative feeding ecology of felids in a neotropical rain forest. Behavioural Ecology and Sociobiology 20: 271-283.

Fleming R. L., Jr. (undated). The natural history of the Everest area. A summary*. Background paper for heart of Himalayas Conserv. Progr*.: 1-30.

Fox, J. L. and R. M. Jackson. 2002. Blue sheep and snow leopards in Bhutan and trans-Himalayan Nepal: recent status evaluations and their application to research and conservation. In: Proceedings of the International Snow Leopard Survival Summit, pp 64. International Snow Leopard Trust. Seattle, USA.

Fox, J. L. and R. S. Chundawat. 1997. Evaluation of snow leopard sign abundance in the upper Indus valley. Pages 66-74. In: R. Jackson and A. Ahmad, editors Proceedings of the Eighth International Snow Leopard Symposium, Islamabad, Pakistan. International Snow Leopard Trust, Seattle, WA.

Fox, J., S. Sinah, R. Chundawat and P. Das. 1991. Status of the snow leopard in northern India. Biological Conservation 55: 283-98.

Green, M. J. B. 1994. Protecting the mountains of central Asia and their snow leopard populations. In: Proceedings of the Seventh International Snow Leopard Symposium, J. L. Fox and D. Jizeng (eds), pp 223-237. ISLT, Seattle.

Gurung, J. B. 1995. Population, habitat selection and conservation Himalayan tahr in Annapurna sanctuary, Nepal. M. Sc. thesis. Agricultural university of Norway.

Jackson, R. 1996. Home range, movements and habitat use of snow leopard *Uncia Uncia* in Nepal. Ph.D. Thesis, University of London (External Programme), London, United Kingdom. 233 pages.

Jackson, R. and G. Ahlborn. 1990. The role of protected areas in Nepal in maintaining viable population of snow leopards. Intl. Ped. Book of Snow Leopard 6: 5169.

Jackson, R., Wang, Z. Lu, X., and Chen, Y. 1994. Snow leopards in the Qomolongma Nature Preserve of the Tibet Autonomous Region. In Proceedings of the Seventh International Snow Leopard Symposium, ed. J. Fox and J. Du, pp. 85-95. Seattle, ISLT.

Jackson, R. and D. O. Hunter. 1996. Snow leopard survey and conservation handbook. International snow leopard Trust and U. S. National Biological Service.

Jackson, R. M., G. Ahlborn. M. Gurung, and S. Ale. 1996. Reducing livestock depredation losses in the Nepalese Himalaya. R. M. Timm and A. C. Crabb (eds.). Proceedings of the 17th Vertebrate Pest Conference. University of California, Davis, pp 241-47.

Jefferies, B.E. 1984. The Sherpas of Sagarmatha. In: McNeely, J.A. and Miller, K., National Parks, conservation and development. Smithsonian Institution Press, Washington DC. pp. 473-478.

Lovari, L. 1992. Observations on the Himalayan tahr and other ungulates of the Sagarmatha National Park, Khumbu Himal, Nepal. Oecologia Montana 1: 51-52.

McCarthy, T. M. 2000. Ecology and conservation of snow leopards, Gobi brown bears, and wild Bacterian camels in Mongolia. Ph D dissertation. The university of Massachusetts, Amherst.

Mishra, C. 1997. Livestock depredation by large carnivores in the Indian trans-Himalaya: Conflict perceptions and conservation prospects. Environmental Conservation 24: 338-343.

Mishra, C., S. Van Wieren, P. Ketner, I. Heitkonig and H. Prins. 2004. Competition between domestic livestock and wild bharal *Pseudois nayaur* in the Indian Trans-Himalaya. Journal of Applied Ecology 73: 344-354.

Nepal, S. K. 2003. Tourism and the management: perspective from Nepal Himalaya. Himal Books and STUDIENVerlag Insbruck-Wien-Mucnchen.

Schaller, G. B. 1998. Wildlife of the Tibetan Steppe. The Univ. of Chicago Press.

Schaller, G.B. 1973. Observations on Himalayan tahr *Hemitragus jemlahicus*. J. Bombay Nat. Hist. Soc. 70:1-24.

Schaller, G.B. 1977. Mountain Monarchs: wild sheep and goats of the Himalaya. Univ. of Chicago Press.

Sherpa, L.N. 1987. A proposal for forest research and management in Sagarmatha (Mt. Everest) National Park, Nepal. Working Paper No. 8. East-West Center, Hawaii. 47 pp.

Soule, M. E. 1987. Viable populations for conservation. Cambridge University Press.

Stevens, S.F. 1993. Claiming the high ground: Shrepas, subsistence, and environmental hange in the highest Himalaya. Motilal banarsidass, Delhi.

Van Dyke, F.G., R.H. Brocke, and H.G. Shaw. 1986. Use of road track counts as indices of mountain lion presence. J. Wildl. Manage. 50:102 - 109.

Figure 1: Sagarmatha (Mt. Everest) National Park

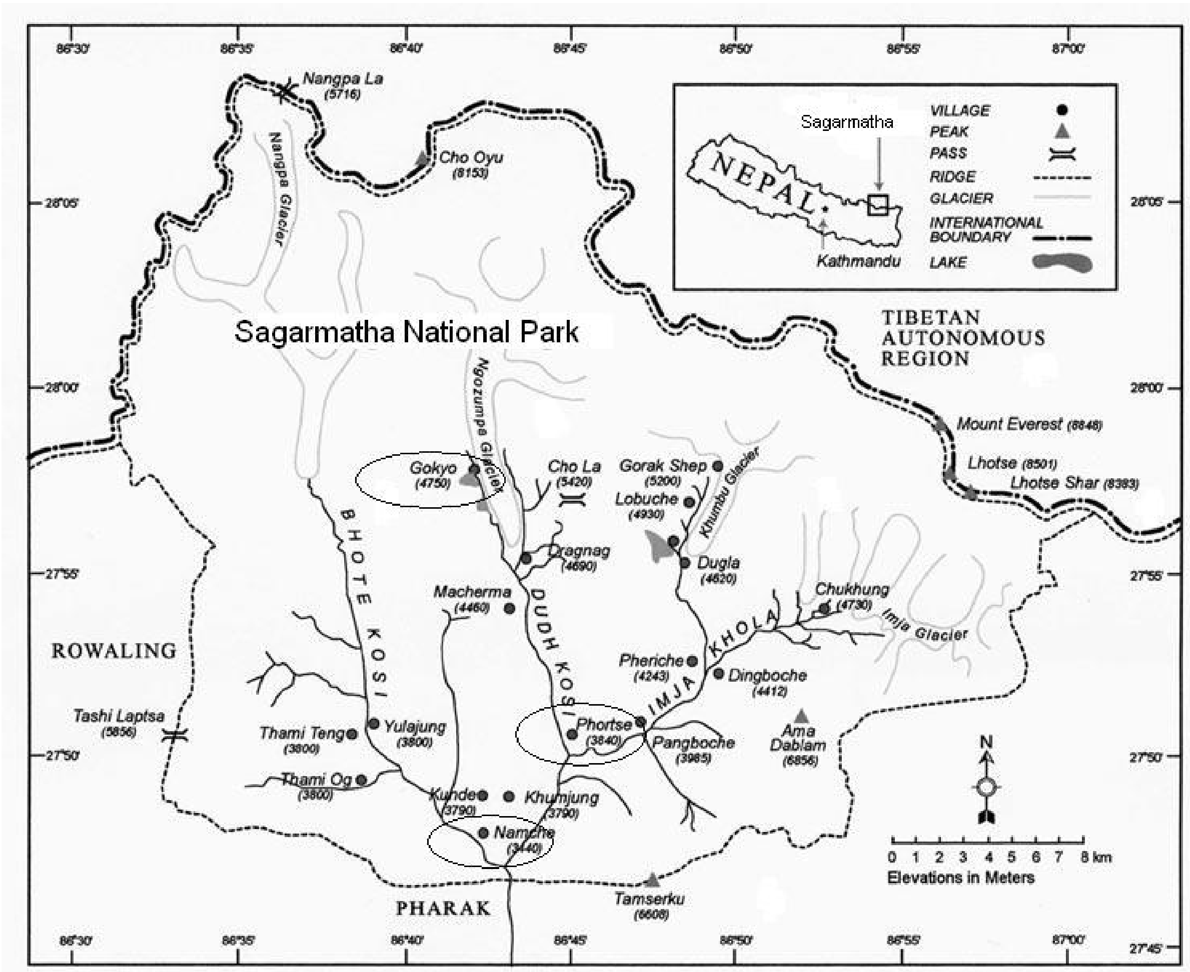
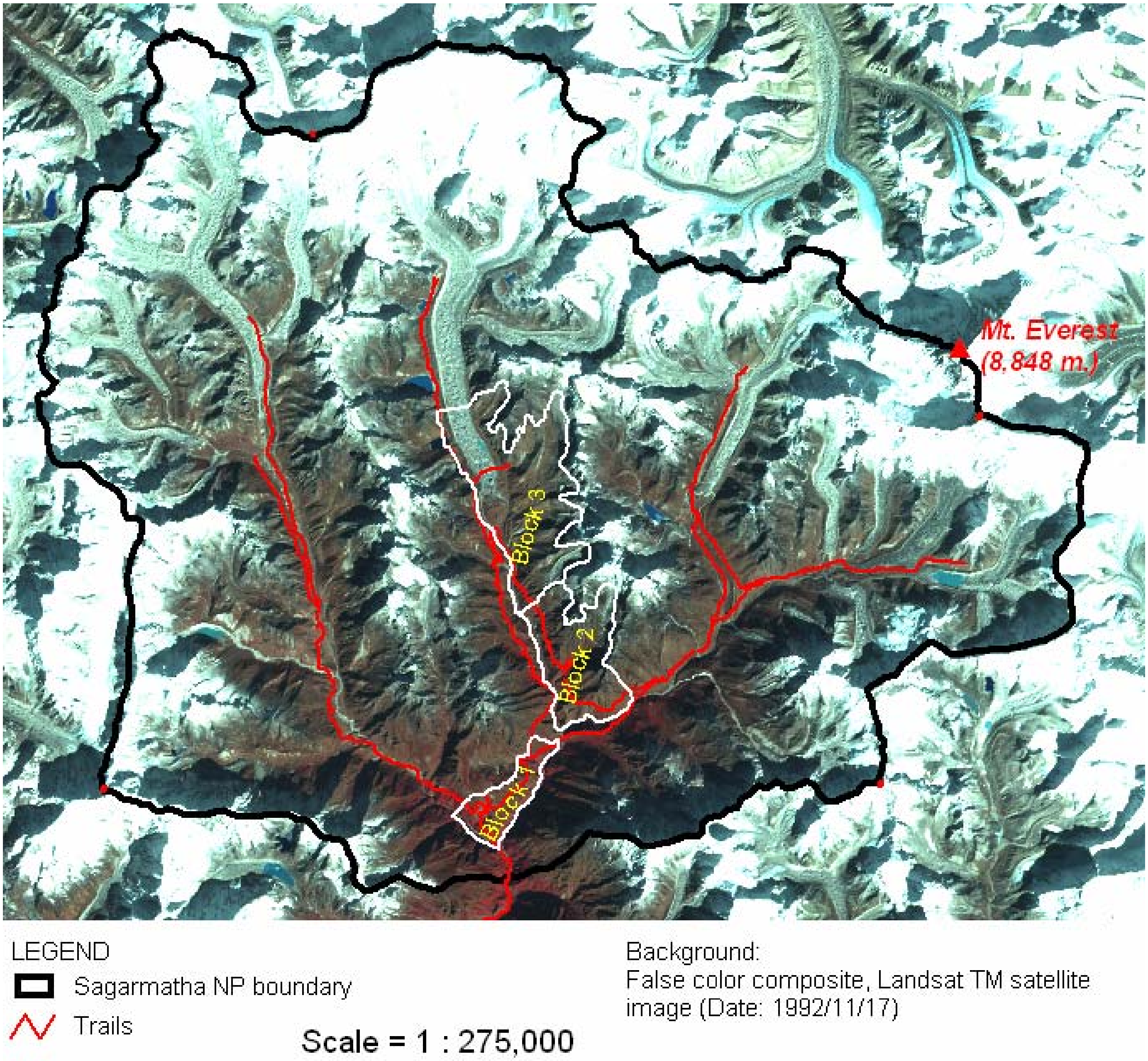


Figure 2: Location of survey blocks/valleys in Sagarmatha National Park



Area of different survey blocks

Block	Area (sq.km.)
1	7.87
2	18.27
3	33.15
Total	59.28

Figure 3: Locations of transects and signs recorded in Block 1

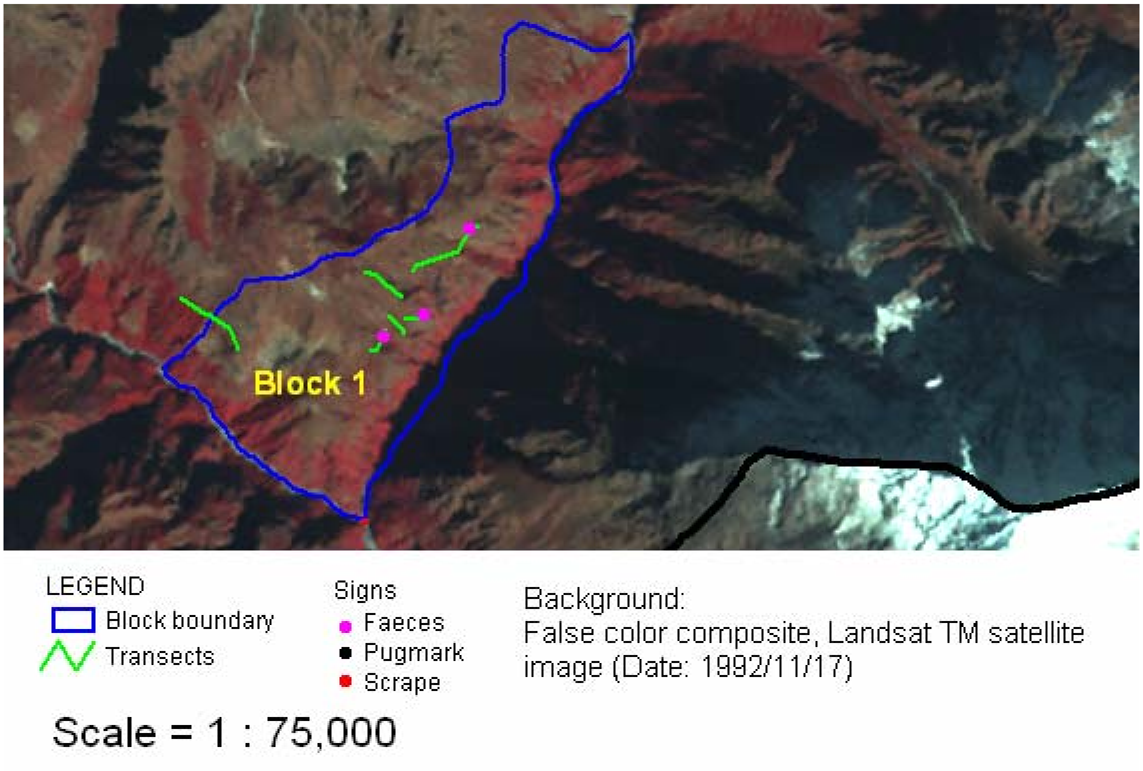


Figure 4: Locations of transects and signs recorded in Block 2

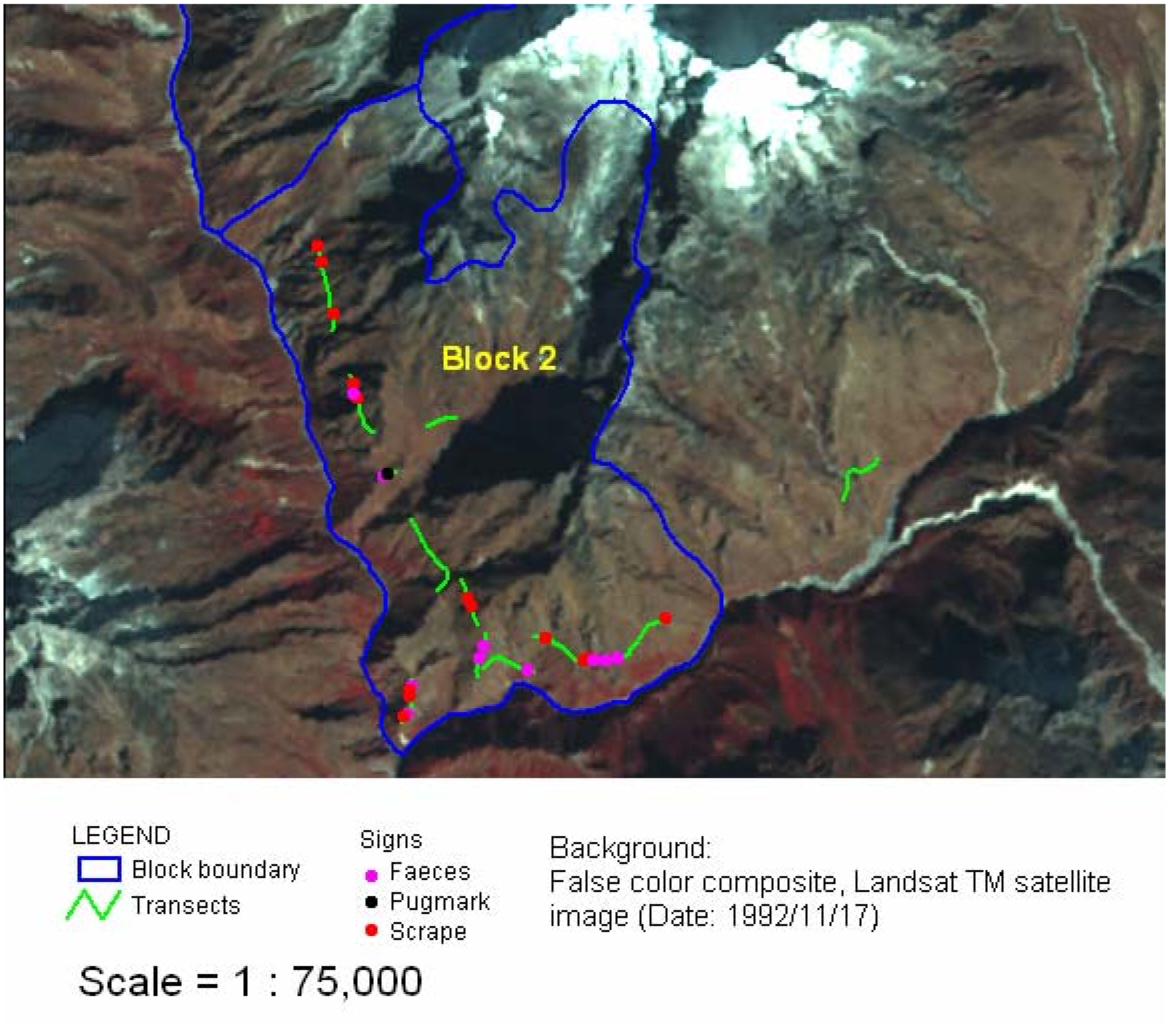


Figure 5: Locations of transects and signs recorded in Block 3