Evaluation of Snow Leopard Sign Abundance in the Upper Indus Valley

Introduction

A rare, sparsely distributed and secretive animal such as the snow leopard (Uncia uncia) presents significant difficulties in assessing its abundance in the isolated and rugged terrain of its typical range. Efforts to determine the distribution and abundance of snow leopard therefore rely in large part on indirect sign such as tracks and markings (Fox et al. 1991b, Jackson and Hunter 1995). Large-scale surveys have used the frequency of snow leopard sign, especially scrape markings, as a basis for estimating the relative abundance of these animals in different regions (e.g., Schaller et al. 1988, Fox et al. 1991b). The rationale for use of such sign as a basis for measuring relative abundance is founded on assessment of snow leopard scrape and spray marking numbers analyzed in association with the monitoring of known individuals (Ahlborn and Jackson 1988), which showed that the density of snow leopard markings along their travel routes is strongly associated with population density. Ahlborn and Jackson (1988) have recommended that surveys of snow leopard relative abundance utilize many short transects covering a variety of physiographic types (e.g., river confluences and ridges) within a specific locality. Such comprehensive techniques, however, are not always feasible over large areas, especially when significant distances need to be covered in a short period and other monitoring tasks must also be performed.

We conducted surveys to investigate the constraints associated with such rapid monitoring during summer, and to assess their practical value in documenting snow leopard relative abundance. We know that in the study area snow leopards make substantial use of valley-floors in their home range movement patterns (Chundawat 1992). We therefore have chosen an area where valley-floors contain significant amounts of typical marking habitat (i.e., cliff bases), and which can be surveyed rapidly. Such mid-summer transects along valley-floors are the most practical and rapid type of surveys to conduct, but they present drawbacks due to their timing and siting that increase the influence of disturbance by humans and their pastoral activities, and the potential for effects of flooding. We relate sign abundance to overall physiography, terrain and substrate characteristics, as well as to season and degree of natural and human-related disturbance. In one watershed we compare the summer results with a late winter survey (earlier the same year) of the identical area and, using data from detailed investigations of snow leopard ecology in the Rumbak valley (Chundawat 1992), we relate sign frequency to the estimated number of adult snow leopards. While working with inexperienced personnel in some of the surveys, we assessed the accuracy of their observations.

Study Area

The Ladakh district of India's state of Jammu and Kashmir is a high, arid mountainous region bounded to the north by the Karakorum Range and to the south by the main Himalaya. Our central Ladakh study area (34o N, 76-78o E) is dominated by the Transhimalayan Zanskar Mountains, located north of the main Himalaya and bounding the upper valley of the Indus River (Figure 1). Annual precipitation in the Indus Valley at Leh is about 100 mm, increasing somewhat southwestward and altitudinally to 500-1,000 mm in valleys at the northern base of the Himalaya (Hartmann 1983). Monthly mean temperatures at Leh vary from 7.5oC in July to -6oC in January with recorded extremes of 34oC and -

28oC (Hartmann 1983). The vegetation is predominantly high elevation steppe (Kachroo et al. 1977) characterized by grasses, subshrubs and herbaceous vegetation on the mountain slopes, with patchily distributed shrublands and forest in the narrow valley floors. Snow leopards in Ladakh are sympatric with wolves (Canis lupus) throughout the region, and patchily so with lynx (Lynx lynx), dhole (Cuon alpinus) and brown bear (Ursus arctos). The major wild prey of snow leopard include wild mountain ungulates such as blue sheep (Pseudois nayaur) and Asiatic ibex (Capra [ibex] sibirica), and smaller mammals such as marmot (Marmota spp.) and hare (Lepus oiostolus) (Chundawat 1994). In some areas domestic livestock constitute a substantial component of snow leopard prey (Fox et al. 1991b, Chundawat 1994).

Our surveys were conducted in four small tributaries to the Indus river within the Zanskar Mountains on the south side of the Indus valley just south of Leh (Figure 1). Each of the four tributaries flows through portions of highly deformed bedrock associated with the "Indus molasse" along the Indus-Tsangpo Suture Zone (Frank et al. 1977), and the vertically tilted conglomerates and other sedimentary formations here result in areas of extremely rugged terrain. These include steep-sided canyons with substantial portions of the valley floors bordered by vertical or near-vertical cliffs, features that provide ideal marking habitat for the snow leopard (Ahlborn and Jackson 1988, Fox et al. 1991b).

Methods

Our surveys were carried out in the Shang canyon during July 1988, the Matho canyon in June 1989, the Stok canyon in July 1989 and in Rumbak canyon in January/February and July of 1989. We examined both sides of the valley floor adjacent to the mountain slopes, and recorded and mapped the location of all sign of snow leopard (scrapes, spray marks, scats, tracks). Valley-floor cliff bases were paced to measure the linear extent of these features, and their location was sketched onto the detailed maps. The surveys were divided into one kilometer sections (valley, canyon) to provide a measure of variability that could be used in statistically comparing results from the different canyons. Following confirmation of a poisson distribution to the scrape count data, we tested (Zar 1984: 415) for difference between study site or season. In the Stok and Rumbak canyons cliff-bases were further divided into categories of substrate type (e.g., gravel, sand, vegetated) and condition (wet, dry) which reflect suitability for scraping and retention of scrapes over time. In the Rumbak canyon, surveys were conducted in both winter and summer to provide a seasonal comparison of sign frequency. Original surveys of the Shang and Rumbak canyons, with which we make some comparisons, were conducted using similar methods in January and March of 1986 as part of large-scale snow leopard surveys (Fox et al. 1991b). Marking sites were located on computer drawn maps based on Survey of India 1:50,000 topographic sheets, and all map-based measurements of length and area were performed using the digitized computer mapping program AUTOCAD. Following initial training in sign identification, portions of the surveys in Shang, Matho and Stok were carried out by inexperienced assistants, with spot checks by the first author to assess accuracy.

Results and Discussion

The location of valley-floor cliffs along the four canyons studied is concentrated in the central portion of each drainage, with the exception of additional cliffs in the lowest parts of the Rumbak stream (Figures 1 and 2). The total valley stream length within the 8 km-long study area rectangle (Figure 1) and the portion that could be characterized as canyon in each drainage were as follows: Shang 9.1 km, 4.5 km; Matho 11.7 km, 7.7 km (includes bifurcation); Stok 8.7 km, 6.7 km; Rumbak 9.4 km, 7.2 km. The portion of each of these canyons that were bounded by valley-floor cliffs (both sides of valley) was: Shang 2,160 m, Matho 3,530 m, Stok 3,720 m, Rumbak 5,725 m. Thus, the percentage of canyon-floor bounded by cliffs was Shang 48%, Matho 46%, Stok 55%, and Rumbak 80%. This is a measure that combines the cliff-bases on both sides of the valley-floor, thus giving a potential maximum of 200% bounded by cliffs. These measurements compare favorably with the visual five-kilometer valley section estimates of 40% for Shang and 70% for Rumbak used in Fox et al. 1991b, thus supporting the accuracy of those original rough estimates.

As shown in Figure 2, we located 12 scrapes and two spray sites in the Shang canyon, 20 scrapes and three spray sites in the Matho canyon, 20 scrapes and two spray sites in the Stok canyon, and 28 scrapes and nine spray sites in the Rumbak canyon. Only scrape counts were of sufficient quantity and accuracy (see below) to warrant statistical comparison, and as expected they proved to be poisson distributed. The frequency of scrapes ranged from 1.3 - 2.9 scrapes per km of riverbed within the rectangular sections surveyed (Figure 1) in each of the four valleys (Table 1), but this was not a statistically significant difference ($P > 0.05$). The range was even less different when only the canyon portions of the valleys were considered, 2.6 - 3.8 scrapes per km, again not statistically different ($P > 0.05$), and providing an overall mean of 3.0 scrapes per km. Scrapes per km of valley floor cliff-base were also not different among the various canyons ($P > 0.05$) (Table 1), reflecting in part a relatively constant relationship between canyon length and length of cliff-base. If in Rumbak we include only the central canyon portion of the valley (excluding the area adjacent to the Indus), which is more comparable to that present in the other canyons and more centrally located within the core of snow leopard home ranges there (Chundawat 1992), the scrape frequency along cliff-base (5.2 per km) is virtually the same as in the other canyons.

Table 1. Snow leopard sign frequency in four Indus tributary canyons of central Ladakh.

	Scrape frequency per			Spray-mark frequency
	km valley*	km canyon	km cliff-base	per km canyon
Summer				
Shang	1.3**	2.7**	5.6	0.4
Matho	1.7	2.6	5.7	0.4
Stok	2.3	3.0	5.4	0.3
Rumbak	2.9	3.8	4.7	1.3
Total	2.0	3.0	5.2	0.6
Winter				
Rumbak	5.1	6.7	8.9	1.3

*8-km straight-line section shown in Figure 2 ** both sides of valley or canyon

To account for the inclusion of both sides of the valley floor in our current presentation, the figure of 1.3-2.9 scrapes per km of valley floor must be halved to 0.7-1.5 scrapes per km (mean 1.0 per km) for comparison with our previously reported scrape frequency average of 1.2 scrapes per km in central Ladakh from summer surveys (Fox et al. 1991b). We must also note, however, that these earlier reported scrape frequencies are slightly inflated (ca. 15%) compared with those presented here because of more conservative estimates of valley length that did not account in detail for all valley-floor meanderings as we have done here. Two late winter surveys in the Rumbak canyon revealed totals of 41 and 45 scrapes above the first confluence (shown in Figure 2), giving an average scrape frequency of 5.1 per km of valley and 6.7 per km of canyon, which is significantly different ($P < 0.05$) from the 3.4 per km found the same canyon during the summer survey. Again, for comparison with previous valley surveys on one side of the valley-floor, this must be halved to 2.5 per km, which is similar to the mean result of 2.1 per km in this same region of central Ladakh from winter surveys in 1986 (Fox et al. 1991b), but lower than the ca. 4.5 per km scrape frequency in a dense snow leopard population of western Nepal (Ahlborn and Jackson 1988).

The late winter results show a scrape frequency of 8.9 per km of cliff-base, or the equivalent of 9.4 per km in what during summer remains as cliff-base, and approximately double the frequency actually found in summer. The stream is much lower during winter and many acceptable scraping locations at that time of year become inundated with water during spring and summer. Other scrapes become trampled by livestock, so that the relationship between the original amount of scrape marking and that found during mid-summer surveys depends on both the degree of stream flooding and the amount of livestock traffic. In this way, the number of scrapes found in summer is a function not only of current snow leopard activity but also of scrape placement height above stream level, substrate composition, protection from precipitation (e.g., under rock overhangs), and level of human-related disturbance. But, unless there is severe flooding (flash floods can occasionally occur), scrapes under overhangs and away from the main valley trails (e.g., opposite side of stream) can persist through the summer. In Rumbak, it is known that the lower summer sign frequency is a function not only of water and human disturbance destroying late winter sign, but also a somewhat decreased frequency of use of the canyon floor by snow leopards that have increased their ranges in summer to include portions of the upper valley (Chundawat and Fox, in prep.).

Only three percent of the valley-floor cliff-base substrate was vegetated. Of the remainder, 37% was wet sand or gravel or rock, and 60% was dry sand or gravel. Dry gravel or sand substrate provided the best and longest lasting sites for marking with 96% of all scrapes being found on this substrate. Wet substrates indicated a high potential for flooding and consequent obliteration of scrapes. As indicated above, in all canyons combined, the frequency of scrapes during the mid-summer surveys was 5.2 per km of cliff-base. In more detailed surveys in Stok and Rumbak canyons (9.4 km of cliff-base), the scrape frequency was 7.9 per km on dry (gravel/sand) cliff-base, and moist or vegetated cliff-bases had only 3 scrapes in the 3,936 m (0.8

per km) of this type surveyed. This indicates that along the surfaces most commonly used for scrape marking (dry cliff-bases) the frequency of scrape markings found in summer was, on average, one every 120 m of such cliff-base.

We found that our inexperienced assistants could quickly learn to consistently identify snow leopard scrapes, but that spray markings were difficult for them to recognize. The frequency of spray marks was therefore low in those canyons partially surveyed by inexperienced personnel, and a detailed assessment of their quantitative use in assessing snow leopard abundance was abandoned. The constant disturbance by livestock of the dusty tracking substrate permitted no consistent measure of snow leopard tracks and is therefore not reported here. Given these constraints, it appears that the use of scrape markings provides the most reliable measure of snow leopard relative abundance under the conditions present with rapid, valley-floor surveys in summer using newly-trained personnel.

There are two primary reasons for the difference in scrape frequency between late winter and mid-summer. First, snow leopards mark most intensively during the late winter (January through late February to early March) mating season (Ahlborn and Jackson 1988). Second is the effect of physical disturbance to the marking substrate, and with the beginning of summer two major changes take place in the patterns of such disturbance. Spring snowmelt causes the stream level to rise and occasionally there is minor flooding. Very occasionally, but not in the study area of this investigation, there is major flash flooding associated with rainfall events that can completely resurface the valley floor, thus destroying all scrape markings. The traffic of people and livestock up and down the canyons also greatly increases with the onset of summer. Although, unlike the other valleys, Stok and Matho do not have permanent settlements up-valley from the canyons, and winter human disturbance is clearly less, during summer the movement of people and livestock up and down the canyon was apparently comparable in all canyons and proved quite destructive to snow leopard sign.

As an indirect test of the likely effects of differential disturbance, we made brief surveys of two little-disturbed side-canyons, one in Matho where we found six scrapes along a kilometer section of valley-floor with 30% cliff-base, and one in Stok where we found 19 scrapes along a kilometer section of valley-floor with 70% cliff-base. This suggests a greater density of scrapes in less disturbed valley-floors and again points up the tenuousness of a quantitative use of this method in comparing different areas without accounting for disturbance levels.

Implications of the Study

It is clear that, in these valley surveys, the frequency of snow leopard scrape markings is highly correlated with the abundance of valley-floor cliffs, and thus it may be more appropriate to compare surveys on the basis of scrapes per kilometer of cliff-base, rather than simply on the basis of valley-floor traversed. Or, one should at least identify "canyon" areas with high proportions of cliff-base for comparison. For example, the physiography of the Manang Valley in central Nepal, with a dense population of snow leopards (Oli 1994), does not lend itself (J. L. Fox, pers. obs.) to the type of valley-floor surveys conducted here. It is, however, more amenable to ridgeline transects of the type conducted in western Nepal (Ahlborn and Jackson 1988). In comparing results between areas, there are thus difficulties associated with terrain features, vegetation cover, seasonal animal behaviour, precipitation patterns, and patterns of human-related disturbance (Jackson and Hunter 1995). All of these factors make the quantitative interpretation of sign data as indices of snow leopard abundance very difficult. Nevertheless, in regions where narrow valleys are common, the overall valley-floor figures do assume some known relationship to abundance in such habitats and may be important, for example, in evaluating livestock risk to predation in such areas. Under the International Snow Leopard Trust's SLIMS (Snow Leopard Information Management System) protocol, standardized techniques have been formulated for the design of comparative surveys in different physiographic regions (Jackson and Hunter 1995). These will be refined as more information becomes available.

If we do take the survey results at face value, a reasonable prospect given the similarity of conditions, they indicate that snow leopard abundance is essentially the same among the four valleys surveyed along the northern slopes of the Zanskar Mountains, and there are no obvious physiographic or human-utilization differences from one valley to another to discount such a conclusion. Minimum population estimates indicate relatively similar prey densities for the major snow leopard wild prey species, blue sheep, (1.9 per km2 in Shang, 1.5 in Matho, 1.8 in Sto, 2.0 in Rumbak) across all catchments (Fox et al. 1991a, Chundawat 1992, J. L. Fox, unpubl. data). Livestock densities and use patterns are similar among all valleys. In the Rumbak catchment four or five adult snow leopards made consistent use of the central canyon areas through the years 1988 - 1991 (Chundawat 1992), but it is probable that individual snow leopards have home ranges that include areas in more than one canyon. If such activity is consistent across all canyons, we are dealing with a population of perhaps 8 - 12 adults in the overall 350 km2 study area. This represents a relatively dense snow leopard population, considering the overall estimate of one cat per 100 km2 throughout central Ladakh (Fox et al. 1991b), but is less dense than the 6 - 8 snow leopards per 100 km2 reported in areas of western and central Nepal, where prey populations are also denser (Jackson and Ahlborn 1986, Oli 1994).

Conclusion

In conclusion, summer surveys of snow leopard sign can give definite information on presence, and less reliable indications of relative abundance. More accurate evaluations of relative abundance will benefit from late winter-early spring survey timings and should address factors such as season, weather and livestock use. Although late winter immediately following the period of highest snow leopard marking activity is apparently the best time for conducting surveys, it can be a time of difficult access to many mountain areas, and in many regions surveys of snow leopard sign will therefore be concentrated in the summer period. It is thus important to realize the limitations of surveys during this time of year and the potential problems with making direct comparisons with results from other areas and from different seasons. Detailed comparisons between the results of different canyon surveys such as those performed here can be appropriate because the various factors that affect sign permanence are similar. Comparisons between areas of different physiography and climate can be problematic.

Acknowledgements

The studies reported here were carried out with support from several organizations; work in Matho, Stok and Shang was supported through programs associated with The School for Field Studies (Beverly, Massachussetts, USA) and we would especially like to thank David J. Stone, Nelson A. Rowe, and Chris E. Watson for their enthusiastic help. The Wildlife Institute of India supported R. S. Chundawat during his PhD studies in the Rumbak valley and some of the work reported here was performed during a joint field visit to the Rumbak study area arranged through a U.S. Fish and Wildlife Service (Office of International Affairs) - Wildlife Institute of India Cooperative Exchange Program.

Figure 1. Study area location, along the south side of the Indus valley south of Ladakh's main town of Leh. Specific canyon areas of intensive survey (shown in Figure 2) are numbered according to drainages as follows: 1) Rumbak, 2) Stok, 3) Matho and 4) Shang.
Figure 2. Intensive study sites for snow leopard sign in four tributary canyons of the upper Indus valley in central Ladakh, as shown in Figure 1. The rectangles represent areas of 2.5 km by 8 km and include the most rugged portions of canyon for each drainage. Cliffs bordering the valley floor are represented by the thick lines adjacent to the stream, whereas scrape locations are shown as circles (o) and spray sites as asterixes (*).

1) Royal Bardia National Park; 2) Khaptad National Park; 3) Lake Rara National Park; 4) Shey-Phoksundo National Park; 5) Dhorpatan Hunting Reserve; 6) Proposed Annapurna Conservation Area; 7) Langtang National Park; 8) Sagarmatha National Park; 9) Makalu-Barun National Park and Conservation Area;
10) Parsa Wildlife Reserve; 11)Royal Chitwan National Park.
SLIMS: An Information Management System for