CHAPTERS

MARKING IN FREE-RANGING SNOW LEOPARDS IN WEST NEPAL: A PRELIMINARY ASSESSMENT

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Little is known about the marking patterns of free-ranging snow leopards *Panthera uncia* (Schaller. 1977; Mallon, 1984; Fox et al.. this volume). Wemmer and Scow (1977) described the basic marking behaviors by captive snow leopards, with additional information from captivity being published in recent years by Freeman (1983), Reiger (1978 and 1980), and Blomqvist and Sten (1982). However, marking activities are likely to be strongly influenced by the artificial conditions under which cats are housed and managed.

In recent decades increased emphasis on studying free-ranging populations has added to our information base on marking in communal as well as solitary felids. For example, among solitary species, papers concerned with marking behavior have appeared on the tiger (McDougal. 1977; Schaller, 1967; Smith. 1984; Sunquist, 1981). on Jaguar (Rabinowitz and Nottingham, 1986, Schaller and Crawshaw, 1980), and mountain lion (Seidensticker et al.. 1973). Few researchers have been able to provide in-depth quantitative data. The role that marking may play in the more solitary carnivores is of particular significance as more knowledge accrues on their land-tenure systems. The possible functional significance of marking has been reviewed by Johnson (1973). Rails (1971), Wemmer and Scow (1977), and Gosling (1982).

PRIMARY OBJECTIVES

The primary objectives of this study were to:

1. Define marking patterns in a free-ranging snow leopard population.
2. Determine the extent to which snow leopards select specific locations and habitat features as marking sites.

3. Determine if marking occurs at a constant frequency with respect to time.
4. Examine the extent to which individuals mark in response to each other.

The data presented in this paper provides an overview of the typical marking patterns and trends observed for snow leopard in the Langu Valley of west Nepal. Results are based on data from the first of two years of monitoring permanent transects. Marking in relation to season, terrain and topographic (habitat) features and the temporal and spatial use of habitat by snow leopards are considered. For a description of the study area, see Jackson and Ahlborn (1986).

METHODS

Permanent Sign Transect

A permanent and repeatable transect, totalling 4,908m in length, and bisecting the ranges of five radio-tagged snow

leopards was established in December. 1983. It was divided into four segments ranging in length from 624m to 1.861m. and located through relatively homogeneous habitat from an elevation of 2,980m to 4,500m. The lowest segment paralleled the Langu River for 740m, then ascended a major ridgeline along the confluence of the Tillisha Gorge with the Langu River.

When transects were conducted, a thorough search was made within a 10m wide belt for the following snow leopard sign: scrapes. feccs. rock-scents and tree-rakes. Each marked site was assigned a number and documented by tagging a nearby bush; scrapes in "visual contact" or not more than 5m apart were assigned the same site number. A 10 cm bamboo stake was placed in the geographic center of each site. In addition, each scrape was given its own number, and a detailed sketch was made for each site,showing the position of all sign, except for pugmarks. as well as identifying bushes or rocks, so that all sign could be positively identified and monitored over long time periods. Linear distances between sites were estimated by pacing.

Recorded for each scrape, were its size [greatest length and width), substrate type, visibility on a relative scale of 0 to 4 (very fresh scrapes were assigned a 4 and just recognizable scrapes a 0). and placement in relation to other sign.

The type of sign left by snow leopards along permanent transects were assigned to various categories based on the presence/absence of specific types of marking (e.g., scrape, feces, etc.) and combinations of associated marks (e.g., scrape with urine, site with scrape and feces. etc.). Sign variables were defined in terms of sites (a discrete grouping of marks) and as individual marks (regardless of their grouping). Sites with scrapes were further classified as "relic" or "non-relic", according to the perceived relative age of the site. Relic (traditional) sites appeared to be older than non-relic sites, as judged by sculpturing of the substrate, growth of grasses and other vegetation in scrape depressions or on mounds. These sites usually consisted of several to many scrapes of various ages (i.e. visibilities). Non-relic sites usually appeared more transient in nature, lacking evidence of recurrent use.

After initial set-up, it was possible to accurately distinguish between two important types of scraping: new and rescraping. New scraping was defined as scraping that occurred at previously non-existing sites or in new locations at existing scrape sites; therefore, new scraping always results in an increase in the density of scrapes along a transect and the maintenance of site visibility; it may also result in an increase in the number of sites. By contrast, rescraping is scrape-specific remarking and results in the maintenance of existing scrapes and sites by increasing their visibility.

Transects were checked at intervals of about ten days, whenever a radio-tagged cat was known to have passed through the area, or whenever tracks of an unknown individual were found along the transect. Each time the transect was checked, it was noted for the presence, number, type and location of any new sign, and mapped for all new sites. Sign changes were attributed to a particular cat only when the authors were confident it had been left by the individual in question. The number of times when cat tracks were observed along a section of transect were designated as "known visits". The frequency of transect crossing by radio-tagged snow leopards was estimated by connecting each individual's consecutive locations with a straight-line, then counting the number of intercepts with the transect. Cat transect crossings were assigned to the appropriate transect replicate, and were used as an index of "suspected" visitation. Known and suspected visits were compared with the frequency and numbers of sign type changes to estimate the likelihood and intensity of marking during two seasons, as well as throughout the entire period monitored.

Two seasonal periods were delineated for the first year of monitoring: the first coincided generally with cat O4's pre-estrous and estrous period (28 Dec. 1983 to 31 Mar. 1984. N=104 days, 28 transect replications), and the second with her post-estrous (1 Apr. to 28 Jun. 1984. N=89 days. 41 transect replications). Changes in sign variables by season were weighted by the number of replicates per season, while the frequency of marking in each season was weighted by the number of days per season. Chi-square goodness-of-fit was employed to test whether frequency distributions of marking, crossing of transects by radio-tagged cats, and the number of tracks found on transects were proportionately distributed with season. The dependency and association of sign changes and intensity of marking on season, cat tracks and cat transect crossings were assessed using a log-likelihood statistic (G test, Sokal and Rohlf. 1981) and Yule's Q measure of association; correction for continuity was made where necessary.

Cumulative frequency distributions for visitation, sign variables and independent variables [number of days monitored) were compared using the Kolmogorov-Smirnov two-sample test to assess similarities and differences in shape and location.

Single Replicate Transects

In addition to the repeatable sign transects. 49 "one-time only" transects were conducted in various parts of the study area to investigate the hypothesis that density of sign is related to snow leopard density and differentially associated with various landscape and terrain types, as well as specific topographic features. Each time snow leopard sign was encountered along the transect, the type of sign (scrape, feces. tracks, rock-scent and tree-rake), as well as its abundance and location were noted. The visibility of each scrape was noted and sites with scrapes were judged to relic or non-relic. Transect lengths and distances between marked sites were determined by pacing.

Three hundred and twenty-one systematic sampling plots, located at 200m intervals, were used to characterize terrain and topographic features along each transect (Jackson and Ahlborn. 1986). Each systematic sampling plot and marked site was assigned to a hierarchical landform classification system, using three descriptors: (1) terrain type = cliffs, distinctly to moderately broken slopes, even or undulating slopes, river beds, or riverine terraces and bluffs; (2) topographic feature = knife-edge ridge, other ridge, cliff, riverine terrace, riverine bluff, smooth slopes, river-bed, gully/landslide; and (3) feature marked = promontory, cliff face, rock outcrop or boulder, or none. Information systematically gathered along the one-time transects was assumed to represent availability of terrain types and topographic features. These were compared with data collected at marked "selected" sites along the same transects, and used to assess preferential use of habitat components. The chi-square statistic was used to test the null hypothesis that attributes of sites marked by snow leopard are proportional to their availability. Bonferroni confidence intervals were subsequently used to identify which attribute(s) were used significantly more or less than expected by chance alone, thus indicating preference or avoidance respectively (Miller. 1966; Neu et al., 1974: Byers et al.. 1984).

Forty-nine one-time and four repeated sign transects were assigned to one of four landscape categories, to characterize marking density in each and to relate this to snow leopard use of habitat. The four landscape classes were defined as follows: (1) Confluence = transects

beginning or ending at the confluence of perennial streams, with no point along the transect further than 1 km from a stream; (2) Major ridge = transects that could not be classified as confluence and that were located along well defined ridgelines that divided perennial stream watersheds; (3) Ridge = transects that could not be classified as either confluence or major ridge, but were located along ridges; and (4} Other = all other transects.

Density of sign variables (number/kilometer) were tested for deviations from normality using the Kolmogorov-Smirnov one sample test (Siegel, 1956) and for homogeneity of variance with Bartlett's test (Sokal and Rohlf, 1981). When excessive deviation from normality and homogeneity of variance was detected, or when sample size was small, the Kruskal-Wallis one-way analysis of variance was used to test the null hypothesis that mean density of sign were the same among classifications. If the null hypothesis could be rejected, a non-parametric multiple comparison test (Daniel, 1979: 211-214) was used to find which means were different.

Scented Rocks

Scent-sprayed sites were detected by their characteristic odor, especially during winter and spring when most scent spraying activity apparently occurred. Accompanying evidence of leopard use included discoloration of the marked face by urine, pugmarks showing where the cat had backed up to a boulder, facial hair attached to the spray surface indicating cheek rubbing, and rarely, claw marks where it had reached up to investigate the scent. However, because we often located seemingly appropriate sites showing surface stains, the definitive criteria used for site determination was the presence of odor.

Scented rocks were characterized and described at two levels: first, the area proximate to and including the site was characterized. and second, attributes of the marked feature and spraying were quantified. Twenty-five spray-sites were permanently marked and mapped, and visited at regular intervals to quantify visitation. Only a brief summary of scent-sprayed sites is presented in this paper.

RESULTS

Marked Sites and Type of Marking

The permanent sign transect sampling effort is shown in Table I. In the first year of monitoring (1983-1984). 101 marked sites (scrapes and/or feces) were tallied during initial characterization of 4 permanent transects. At conclusion of monitoring. 129 sites existed, an increase of 28%. Eighteen of the 28 new sites (64%) resulted from scraping at previously unmarked locations. 29% from renewed scraping at relic sites (traditional sites judged to have been unmarked for at least six months), and 7% from the deposition of feces not associated with a scrape site. Thus, scraping was the predominant (93%) marking behavior associated with the formation of new sites.

TABLE I. Repeated **snow** leopard **sign** transect **sampling** effort, 1983-1985.

Transect	Length (m)	No. of times monitored	Total distance (km)	Dates monitored	No. of days monitored

1983/1984					
A2	**740**	**17**	**12.58**	**18-Dec to 18-Jun**	**193**
AB	**1,683**	**21**	**35.34**	**04-Jan to 26-Jun**	**174**
AM	**624**	**19**	**11.86**	**10-Feb to 26-Jun**	**137**
AU	**1,861**	**11**	**20.47**	**10-Mar to 16-Jun**	**98**
Subtotal	**4.908**	**68**	**80.25**		
1984/1985					
A2	740	19	14.06	05-Dec to 14-Jun	191
AB	1. 683	18	30, .29	08- Dec to 13-Jun	187
AM	624	17	10, .61	11 -Dec to 12-Jun	183
AU	1, 861	9	16 .75	10- Dec to 06-Jun	178
Subtotal	4 .908	63	71 .71		
TOTAL		131	151 .96		

When a cat was known to visit a transect, new sites were established 50% of the time, at a rate of about 0.8 sites/visit. We found that approximately 55% of the sites with scrapes (117) were reused during the period monitored. Of the sites reused, about 73% were classified as relic, 17% as non-relic and 9% were sites established during monitoring.

Scrapes occurred at sites_solitarily or in groups of up to 24 individual scrapes of varying ages (x=2.8; 1.134 scrapes at 410 sites). Although sites with solitary scrapes were encountered frequently (47%). only 15% of all scrapes occurred at these sites. A similar trend was found for the number_of feces (x=1.6: 226 feces at 140 sites) and sign (scrapes and feces) (x=3.1; 1,355 sign at 444 sites) at marked sites.

Measurements of new and rescrapes were recorded during two years of conducting permanent transects. _ Average scrape length (N=524) ranged from between 13 to 38 cm (x=24.5) and scrape width from between 9 to 38 cm (x=20.4).

Scrapes were the most abundant type of mark recorded on the permanent sign transects and the one-time transects; scraping oc curred at a greater frequency than all other marking combined. This was also found in captivity (Freeman, 1983). Approximately 77% of the total changes to sign observed on permanent transects were at tributable to scraping. The maximum number of scrapes recorded was 235/km. Scrapes averaged 72/km on permanent transects and 28/km on one-time transects.

TABLE II. Observed vs. expected use of five scrape visibility classes by snow leopard for re-scraping.

Visibility Classes[1]	**Expected usage (freq)**	**Observed usage (freq)**	**Observed Proportion of usage (Pi)**	**Expected**[2] **Proportion of usage (Avail able)**	**Index of Electivity**[3]	
0	**29**	**7**	**0.090**	**0.375**	**-0.6141**	**SO-**

1	15	10	0.128	0.186	-0.1839	NS
2	13	14	0.179	0.165	0.0410	NS
3	12	25	0.321	0.154	0.3509	SD +
4	9	22	0.282	0.119	0.4054	SO +

N=78; X^2=49.8; df=4; P<0.001

1 Scrape visibility classes indicate the relative "freshness" of scrapes from 0, barely visible to 4, very visible.

2 Expected proportion based on 78 rescrapes located along 4 sign transects.

3 Index of electivity (Ivlev 1961) = (obs - exp)/(obs + exp), values range from -1 to +1.

4 SD indicates that observed proportion usage (Pi) of the category is significantly (P < 0.05) greater "+" (preference) or less "-" (avoidance) than expected by chance and NA indicates no difference. Bonferroni's simultaneous confidence intervals were used (Miller. 1966; Neu et al.. 1974).

The decline of all scraping activity during spring and early summer resulted in a corresponding deterioration of scrapes (and sites) that is reflected by the relative proportion of scrapes in visibility classes greater than 1 (Figure 1). Chi-square analysis indicated that the relative visibility (viz, age) of scrapes was an important factor in the selection of marks for rescraping (x^2=49.79, df=4. P<0.05) (Table II). Scrapes in the more visible classes (3 and 4) were rescraped significantly more (P<0.05) than low visibility classes, while the oldest scrapes were avoided (P< 0.05) (Figure 2).

Forty-three percent of the scraping observed on permanent transects was rescraping and 57% was new scraping. The majority of scraping (77%) occurred at sites that existed at initial set-up. Nearly 86% of these scrapes were made at relic sites, only 14% occurred at non-relic sites ($\%^2$=17.42. df=l, P<0.001). Scraping occurred on about 86% of the occasions that a snow leopard was known to have visited a transect. During these events, approximately 2.1 rescrapes per visit and 2.8 new scrapes per visit were recorded.

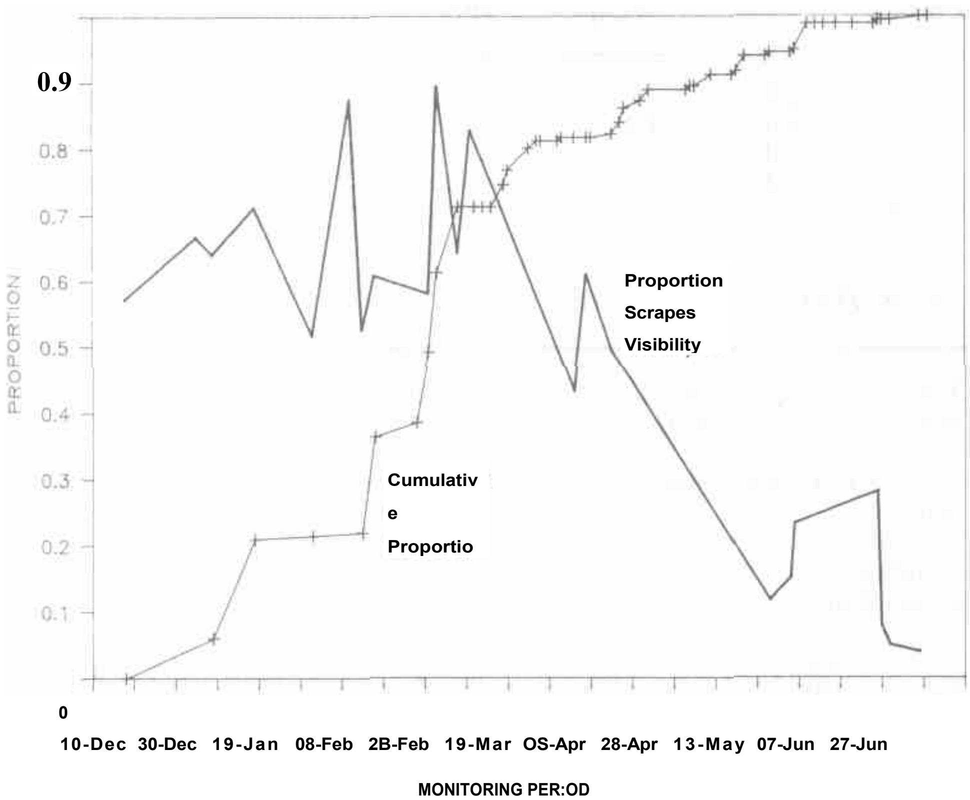

FIGURE 1. Seasonal relationship between cumulative proportion of scraping and the proportion of scrapes with a visibility greater than 1.

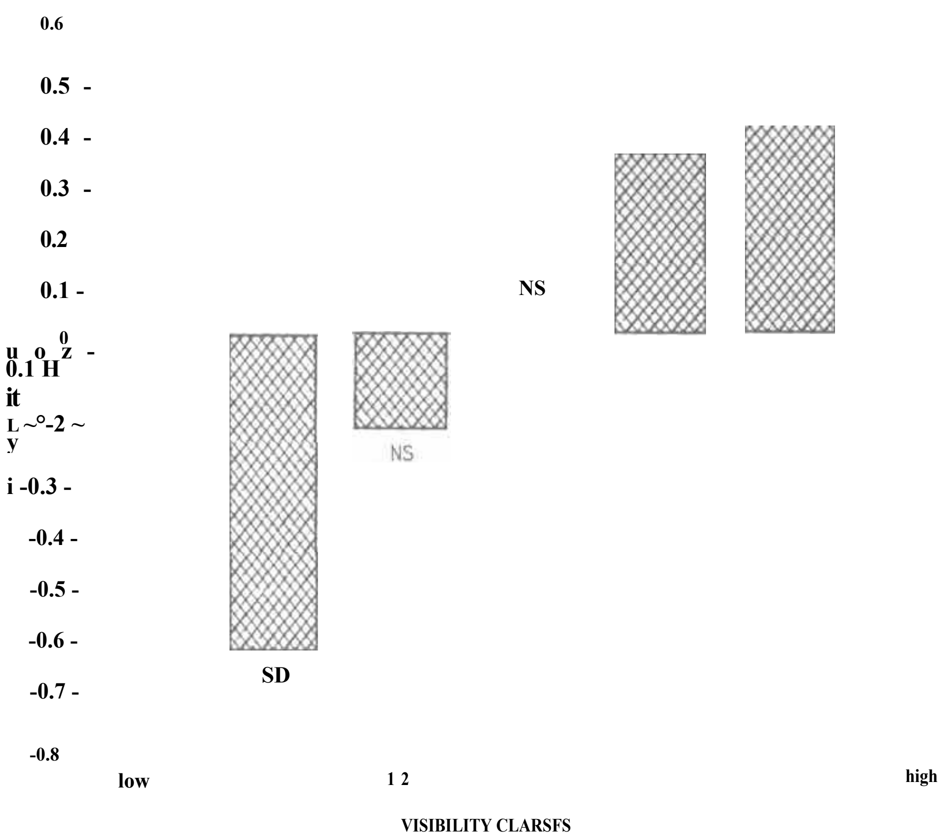

FIGURE 2. Preference Indices for the rescraping of scrapes of five visibility classes.

Seventy-seven .feces, almost 16 per km. were tallied along permanent sign transects. Feces were associated (i.e., in the scrape depression or on the scrape pile) with seven (4%) of the scrapes. In addition six (3%) scrapes were marked with "token" feces, defined as small feces containing much less than the normal amount of fecal material (Schaller 1967. Sunquist 1981). Sixty-five feces. about 84%, were recorded at scrape sites, and almost 74% of these were found at relic sites. The pattern of feces accumulated along transects indicated a strong tendency for snow leopards to deposit fecal material at scrape sites rather than randomly along travel routes.

Urine and/or anal gland marking of scrapes was detected at 33 of 181 scrapes (18%). Because the presence of urine was difficult to detect at scrapes, it is probably more common than the data indicate.

Snow leopards used the overhanging, usually protected surfaces of boulders, rock outcrops and cliffs to scent-spray. Eighty-eight sprayed sites were located in the study area; detailed data characterizing sites are discussed in Jackson and Ahlborn (1986). Boulders or rock outcrops comprised nearly 86% of the features marked, and cliff faces the remaining 14%. Scrape sites were found at 73% of the scented rocks. We were able to detect odor on scented rocks even after more than 60 days following spraying.

Many sites were repeatedly resprayed by different individuals. On occasion, snow leopards appeared to deviate from their line of travel to investigate a sprayed site. Not all visits resulted in the deposition of scent: snow leopards may cheek-rub without spraying or scent without cheek-rubbing. Some would scrape as well. In addition, 10 sites were found where cats had raked their claws on standing or fallen tree trunks, or where they had mouthed or chewed bushes.

Marking in Relation to Visitation and Season

Twenty-seven sets of snow leopard tracks (about one known visit per seven days) were found on sign transects during 22 of 64 (34.4%) of the replications. On the 22 occasions when tracks were found, 14 (64%) of these could be assigned to radio-collared individuals. Without the aid of radio-telemetry, it is estimated that only about half as many sets of tracks would have been observed during monitoring. Crossings of permanent sign transects (suspected visits) by radio-tagged cats totalled 46 (about one visit per four days) and occurred during 28 (44%) of the transect replications.

Seventeen known visits (63%) occurred during estrus (season 1) and 10 (37%) during post estrus (season 2). Twenty-three suspected visits (50%) were calculated for each season. Neither the presence/absence by transect replication or the total number of suspected or known visits to permanent sign transects were found to be different (P>0.05) between seasons.

The likelihood of change occurring to individual marks at sites (e.g. new scraping, rescraping, fcces. etc.) was generally greater during season 1, but seasonal differences were not found. The intensity of change occurring to sites (all sites, non-relic sites, and relic sites), was significantly greater during estrus (season 1). Frequency distribution of sign variables with respect to sites and individual marks was found to differ between seasons. The relative percent of marking that occurred during estrus was consistently about 80%. Figure 3 shows the cumulative proportion distribution for marking intensity and cat crossings per day. and the presence of marking per replicate.

The frequency distribution of marking for the first and second year of monitoring appear to be very similar in shape and location, except that during the first year a greater amount of marking occurred during season 1, when cat 04 was in heat. She gave birth to a litter in early June. Judging by the absence of vocalizations, none of the known

females using the core study area were in estrus the second year of monitoring. We suspect that a substantial portion of marking observed the first year may be attributable to males responding to the presence of a female in heat, as well as increased marking by the estrous female. Analysis of data to reveal intersexual differences in marking behavior have not vet been performed.

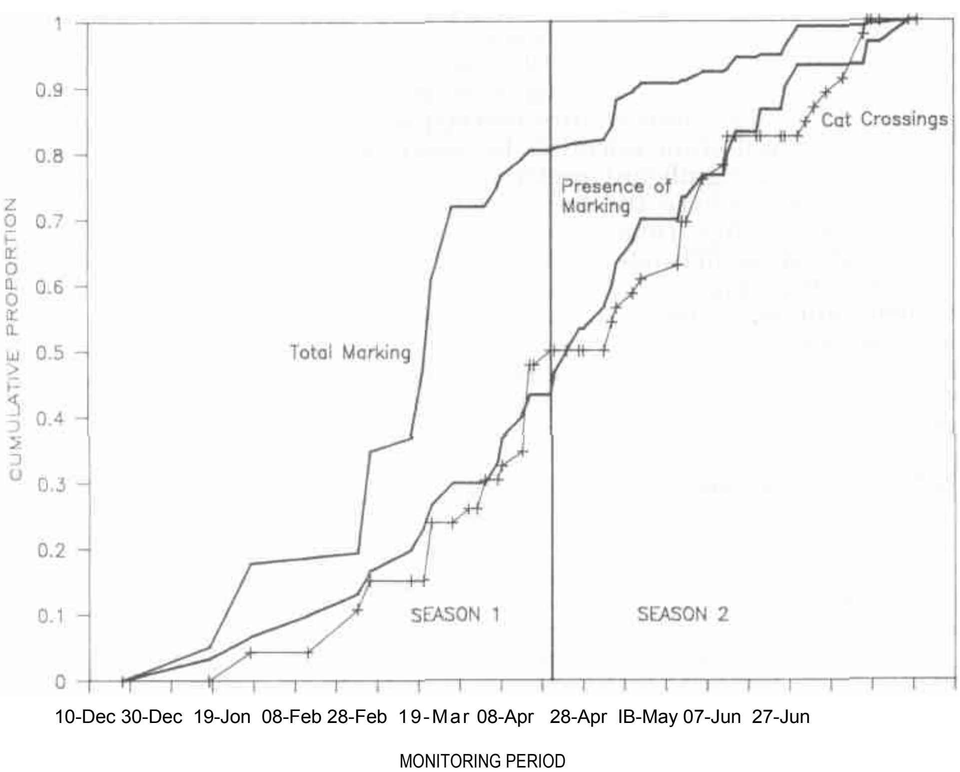

FIGURE 3. Seasonal relationship for cumulative proportion of all marking, cat crossings and presence of marking along four repeated sign transects.

Site Selection

Sites marked by snow leopard were found throughout the study area in a wide variety of substrates, vegetation and terrain types, and were associated with many different topographic features. While most marking was made beside upright boulders (Figure 4) or at the base of rock outcrops and cliff faces, or atop promontories and knolls, some were made in the open and a few at the base of pine trees. Others were situated near the edge of riverine terrace/bluffs or on cliff ledges, exposed on the crests of ridges, and even in landslides or on river gravel and sandbars.

Analyses for marking selectivity were conducted using the number of scrapes per site, which essentially weighted each site by the number of scrapes found there. We believe the number of scrapes rather than the number of sites {regardless of the number of scrapes at each) is probably a more sensitive indicator of initial marking and intensity of remarking at a specific location. Comparisons between the frequency distributions for available vs used scraping site terrain, local topographic feature and feature marked strongly suggested disproportionate use. and thus selection for marking sites (Table III). These data indicate a significant preference for scraping atop promontories or below cliffs, where the local topographic feature is cliff, riverine bluff or knife-edge ridge, and the terrain is a cliff, riverine terrace/bluff, or moderately to distinctly broken slopes (Figure 5). In contrast, areas where terrain and local topographic features are poorly defined, and where the features do not form abrupt structural changes or edges, were significantly under-utilized. Although scrape sites were found at locations where no dominant feature could be defined, it was a rare event, and as shown by analysis, marking under these conditions was strongly avoided.

Regional Selection

Snow leopard sign were found along 46 of 53 (87%) of all sign transects. All confluence (N=10) and major ridge [N=6) transects had sign present, while 89% of the ridge transects (N=18) and only 74% of the other transects (N=19) had sign present.

The density of different sign was significantly different (Kruskal-Wallis =26.8. P<0.001) among transects classified as confluence, major ridge, ridge and other. Confluence transects were found to have the highest density of sign, followed progressively by major ridges, ridges and other. Differences were significant (P<0.05) for comparisons between all categories except for ridge and other (Table IV).

This pattern was consistent ("or all sign variables, except sites with feces only. Sites with sprayed rocks, with tracks, and with tree rakes were excluded from the analysis.

Density of sign on transects (N-6) in three confluence regions on the south side of the Langu River were compared with the amount of sign found on the Tillisha confluence transects (N=4), located in the overlap zone for four radio-collared snow leopards. Sign density did not differ significantly (Kruskal-Wallis=0.87. P>0.832) among confluence areas. Furthermore, density of sign in the three south-side areas did not differ (Mann-Whitney U=16, P>0.394) from the Tillisha confluence sample.

FIGURE 4. Researcher examining and tagging an overhanging boulder face that was repeatedly scent-sprayed by snow leopards [Photo by Darla Hillard).

FIGURE 5. Major stream confluence In the Langu valley showing local topographic features strongly preferred by snow leopards for marking (a. major ridge line; b. terrace/bluff edge; c. base of cliff] (Photo by Rodney Jackson].

TABLE HI, Observed versus expected use of terrain, local topographic feature and features used for marking by snow leopards. The type of terrain or feature In each category is ordered from most to least preferred.

	Expected usage (freq)	Observed[1] usage (freq)	Observed Proportion of usage (Pi)	Expected[2] Proportion of usage (Available)	Index of Electivity[3]	
TERRAIN						
Cliffs	**96**	**219**	**0.256**	**0.112**	**0.3915**	**SD +**
Riverine Terrace /Bluffs	**48**	**79**	**0.093**	**0.056**	**0.2452**	**SD +**
Distinctly Broken Slope	**122 223 93**	**163 275**	**0.191**	**0.143 0.262**	**0.1423**	**SD + SD +**
Moderately Broken Slope River		**48**	**0.322**	**0.109**	**0.1034 -**	**SD-**
Bed			**0.056**		**0.3197**	
Smooth /Undulating Slope	**271**	**70**	**0.082**	**0.318**	**-0.5899**	**SD-**
N=854 $x^2=$ .4, df=5. P<0.001						
LOCAL TOPOGRAPHIC FEATURE						
Cliff (base, ledge)	55	153	0.183	0.065	0.4743	SD +
Riverine Bluff	31	63	0.076	0.037	0.3379	SD +
Knife-edge Ridge	210	310	0.372	0.252	0.1913	SD +
Ridge	200	211	0.253	0.240	0.0266	NS
Gully/Landslide	23	22	0.026	0.028	0.0305	NS
Riverine Terrace	31	23	0.028	0.037	-0.1509	NS
Smooth Slope	184	37	0.044	0.221	-0.6659	SD-
River Bed	99	15	0.018	0.118	-0.7362	SD-
N=854		df=7				

FEATURE MARKED

Promontory Cliff (rock face)	**108 123 241 256**	**257 169**	**0.354**	**0, 0,**	**.148**	**0.0. 4101**	**SD + SD +**
Rock Outcrop/Boulder No	**X^2=381.5, df=3.**	**245 56**	**0.232**	**0**	**.169**	**0.-0. 1580**	**NS SD-**
Feature		**P<0.001**	**0.337**	**0.**	**.331**	**0090**	
N=727			**0.077**		**.352**	**,6410**	

[1] Observed frequency based on the number of scrapes found along 53 sign transects.

[2] Expected proportion based on 321 sampling plots located along 53 sign transects.

[3] Index of electivity (Ivlev 1961) = (obs - exp)/(obs + exp), values range from -1 to +1.

[4] SD indicates that observed proportion usage (Pi) of the category is significantly (P<0.05) greater "+" (preference) or less "-" (avoidance) than expected by chance and NS indicates no difference. Bonferroni's simultaneous confidence intervals were used (Miller, 1966; Neu et al., 1974).

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TABLE TV. Density (number/kilometer) of sign variables left by snow leopards along 49 one-time sign transects and 4 repeated sign transects (S.E.= standard error of the mean, C.V.= coefficient of variability).

LANDSCAPE CATEGORY	Sites with scrapes or feces	Relic sites	Non-relic sites	Sites with scrapes	Tolal # of scrapes Siles feces. and only	sprayed with rocks, tree feces rakes tracks	Tolal number of scrapes and feces	Total number of scrapes	Tolal number of feces
CONFLUENCE (N=10)									
Mean[1]	25.53 A	14.68 A	8.67 A	24.42 A	1.07 A	99.03 A	99.03 A	83.24 A	12.34 A
S.E.	4.18	3.50	2.23	3.80	0.52	24.57	21.99	9.65	4.74
C.V.	0.52	0.75	0.81	0.49	1.52	0.70	0.72	0.75	1.21
MAJOR RIDGE (N=6)									
Mean	19.63 B	11.99B	4.77B	18. SOB	1.13 A	60.86 B	62.23 B	52.81 B	9.44 B

S.E.	5.86	3.76	1.65	5.53	0.58	18.93	15.27	13.08	2.44
C.V.	0.73	0.77	0.85	0.73	1.25	0.62	0.60	0.61	0.63
RIDGE	(N=18)								
Mean	6.47 C	3.79 C	1.36C	6.05C	0.43 A	19.02 C	17.93 C	15.68 C	2.25C
S.E.	1.34	0.75	0.50	1.21	0.29	4.30	4.23	3.50	0.87
C.V.	0.88	0.83	1.56	0.85	2.85	0.96	1.00	0.95	1.65
OTHER	(N=19)								
Mean	5.23C	1.97C	2.04C	4.50 C	0.74 A	14.03 C	13.41 C	10.24 C	3.16C
S.E.	1.50	0.58	0.77	1.34	0.50	4.07	4.08	3.48	1.39
C.V.	1.25	1.29	1.65	1.30	2.98	1.27	1.33	1.48	1.92
TOTAL	(N=56)								
Mean	11.11	6.12	3.37	10.37	0.74	33.56	36.05	30.68	5.29
S.E.	1.65	1.07	0.66	1.55	0.23	6.45	6.53	5.73	1.20
C.V.	1.08	1.28	1.43	1.09	2.29	1.34	1.32	1.36	1.65

Means with the same capital letter within the same column are not significantly different **(P>0.05)**

Comparison between the density of sign variables along six transects approximately located within 30% isopleths (snow leopard core-use areas) (Jackson and Ahlborn. in prep.), and 28 transects located in other parts of the home ranges showed significantly (Mann-Whitney U=151. P<0.002) more sign in core-areas. For example, the density (number/km) of most sign [e.g., sites, scrapes etc.) in these zones was about four times greater than the amount found elsewhere in the home ranges.

DISCUSSION

In free-ranging snow leopard, both sexes (including s^ibadults aged about 1.5 years) mark intensively, leaving sign in prominent locations. as first reported by Schaller (1977). Markings consist of scrapes, feces. urine and/or anal scent (often deposited on or adjacent to scrapes), scent-sprayed rock, and claw-raked tree trunks. Snow leopards marked along a complex system of frequently used travel routes which included ridge-tops, riverine bluff/terrace edges, cliffs, riverbeds, wild ungulate trails, and open slopes.

Marked Sites **and** Type of Marking

Scraping was the most abundant type of marking in snow leopards: 77% of the total change observed along permanent transects consisted of new and rescrapes. A notably large proportion (43%) consisted of rescraping of an existing scrape, and most scraping occurred at sites defined as "relic" or those that appeared to have been repeatedly used over long periods of time. Approximately 55% of the sites were remarked during the six months of monitoring. While sites with solitary scrapes were more common, only 15% of the 1.134 scrapes catalogued occurred singly.

Snow leopard display a remarkably high rate of re-marking of existing sites and scrapes. This tendency may reflect the high degree of spatial association observed in the Langu Valley population, and the necessity for animals to continually assess and re-evaluate their own status, as well as that of others around them. Initial selection of a sheltered location for marking, and the frequent recurrent use probably allowed "traditional" scraping areas to develop.

Evidence indicated that the likelihood that a site or scrape would be remarked was partially dependent on the number of scrapes per site and the relative visibility of individual scrapes. Scrapes with a high visibility are significantly more likely to be rescraped than those with a low visibility. Since high visibility scrapes are also the freshest (i.e. made most recently), they are presumably more likely to contain chemical information. The relative value of visual and olfactory cues is poorly understood, though Klelman and Etsenberg (1973) **noted** that felids rely more on visual cues than canids.

While Intersexual patterns of marking have not been analyzed, preliminary evidence indicates that both male and female snow leopards scrape frequently. Seidensticker et al. (1973) estimated that mountain lions in Idaho reused only 12.8% of 86 scrape sites; nearly all of the scrapes were made by resident adult males. According to Sunquist (1981) both sexes in tiger scrape, but he found no evidence that scrape sites were reused. This, and other evidence suggests that snow leopard scrape mark more Intensively than other solitary felids, like the tiger. Jaguar and mountain lion.

Feces were directly associated with about 7% of the scrapes along the permanent transect. These included "token" scats, similar to those described by Schaller (1967) and Sunquist (1981) for tiger. About 84% of all feces along the permanent transects were located at scrape sites. Mallon (1984J. working in Ladakh, found feces at about 20% of the scrapes. Like tiger, snow leopards made no attempt to cover their feces.

Scent-marking appears to be strongly related to periods of sexual activity and may be due, In part, to increased frequency of female spraying (Rieger, 1978). While both sexes scent-spray, we were unable to confirm if male snow leopards spray more than females, as has been reported for captive cats (Reiger, 1978; Freeman, 1983).

Marking in Relation to Visitation and Season

The rate and number of suspected and known visits by snow leopards to permanent transects and the likelihood that a cat would mark (regardless of the intensity) remained relatively constant in relation to season. However, during periods of time generally corresponding to pre-estrus and estrus, the intensity of marking (amount of marking per visit) far exceeded that found during the post-estrus period. Thus, seasonal differences in marking within core-use areas seem to be related to increased marking intensity rather than differential visitation.

Site Selection

Snow leopards show a consistent preference for travelling and marking along strongly defined terrain edges. Given any set of terrain and topographic conditions, leopards will invariably focus their marking efforts where their movement is channelled, impeded or somewhat directed by physical barriers. The majority of these "edge" situations also provide an unobstructed field-of-view in at least one direction. Koshkarev (1984) suggested that "movement along predominant relief points is one of the most important adaptations of the animal (snow leopard) to life in the high mountains." He pointed out that the primary advantage of this travel pattern is a greater potential for detection and successful approach of prey.

Seidensticker et al. (1973) observed that.mountain lions tended to scrape In areas where "the lay of the land dictated easy passage," such as the mouths of canyons, in draws, and on ridges. Reused sites were in situations where topography "molded a convenient runway or pass." Donaldson (1975) found more than

50% of mountain lion scrape sites on ridgetops.

Disproportionate use of topographic habitat components by snow leopards for marking should be viewed as, at least, a fourth-order selection process (Johnson. 1980). Marking of travel routes within a home range indicates that a considerable number of prior selections have already been made by the individual. Selection of a marking site becomes a question of where an individual should mark along its travel route to most efficiently and effectively communicate with conspecifics.

Regional Selection

Leyhausen and Wolff (1959) suggested that "marking might act 'like railway signals' to minimize encounters between individuals by signalling how recently an animal has passed." Gosling (1981) considered marking and the time spent marking to be a "limited resource" and suggested that "marking should be done economically." He predicts that marking should occur in areas that maximize the probability of encounter by conspecifics, and that the chance of inspection could be increased by making marks conspicuous (i.e., placing them adjacent to prominent objects. Increasing their number) and advertising their presence.

Seidensticker et al. (1973), working on mountain lions in Idaho, reported that marking occurred most frequently along the edges of territories or in the region of overlap rather than toward the center. Hornocker (1969) considered scraping to be important visual and olfactory cues facilitating the spatial and temporal separation or "mutual avoidance reaction" (Hornocker, 1967) of individual mountain lions.

In Belize, Rabinowitz and Nottingham (1986) found that sign left by jaguars was concentrated and considerably more abundant than that reported by Schaller and Crawshaw (1980) in Brazil. They attributed the differences to a greater density of Jaguars and sharing of home areas by Jaguars in Belize, These authors also stated that "If density and distribution of prey are favorable, it is reasonable that large solitary felids can share limited areas . . . if encounters leading to physical aggression are avoided." Davis and Houston (1984) considered sharing of common area an economically efficient strategy in situations of resource abundance.

Sunquist (1981) concluded that tigers maintained intrasexual territories with little overlap. Smith (1984) found that "tiger marking was clumped at contact zones where major travel routes approached territorial borders." He concluded that the clumped pattern of mark ing found in tiger in Chitwan National Park was more a function of a higher frequency of marking along adjacent home ranges.

No evidence was found to indicate that snow leopards in the Langu Valley occupy exclusive home ranges (Jackson and Ahlborn, 1986). In fact, extensive spatial overlap of use-areas by male and female cats was indicated. Marking activity was found to be concentrated in regions where snow-leopards spent the majority of their time and where the relative density of individuals was greatest (i.e, overlapping preferred use areas). In the Langu. these areas were consistently associated with the confluences of permanent drainages (Figure 4). In Ladakh. Mallon (1984) may have encountered a similar situation: "the greatest concentrations of sign occur in the beds of deep gorges which cut across part of the central mountains."

Concentrating marking in mutually used areas, where the probability of encounter with conspecifics is greatest, makes good sense with respect to communication. The potential for transfer of information among individuals is maximized, while the effort invested by an individual in transferring information is minimized. Indeed, this type of marking pattern may be an important prerequisite for the development and maintenance of an extensively overlapping land-tenure system, as observed for snow leopards in the Langu valley. We would expect that in areas where essential resources, especially food, are less abundant, home ranges would be larger and mutually used areas further apart and/or more poorly defined. Consequently, the density of sign in concentration areas should be less and the distance between areas should be greater.

Application of Findings

Conducting sign surveys to determine the presence and relative abundance of snow leopards is the most efficient means of providing valuable information on the status and ultimately the conservation of the species. Standardized, objective surveys are necessary to provide reliable results and allow for valid interpretation and inter-regional comparisons. We discuss several considerations for survey design here, based on research in the Langu Valley, in an attempt to facilitate standardization of methods. More detailed information on survey design, analysis and interpretation of snow leopard sign data are presented elsewhere (Ahlborn and Jackson, in prep.).

The value of sign left by snow leopards as an index to their abundance is not fully understood; however, data indicated several pertinent differences among the relative value of various types of sign. The differences in density (number/km) of sign variables located within four landscape categories can be extremely useful for assessing the relative effort required for detecting different sign types left by snow leopard in various landscape conditions. The relative effort, expressed as the number of transects (sample size) required for given interval estimates on the mean (±10, 20. 30%) at the 90% confidence level is **shown in Table V. Effort (sample size) was calculated based on the mean density and variance of sign tallied along permanent and one-time transects. Within a landscape category and at a given percentage of the mean, the types of sign with smaller sample sizes indicate less variability and thus, greater relative sampling efficiency. For example, considering all categories of transects (Total), the approximate sample size required to give a ±20% estimate on the mean number of sites with scrapes and tracks is 80 and 356 transects, respectively.**

In the Langu Valley sign was found on 87% of all transects. On transects where sign was found. 98% had scrapes. 70% had feces. 39% had scent-sprayed rocks, 31% had snow leopard tracks and 11% had claw-raked trees. By using the presence of marking activity and leopard tracks located on transects, a minimum of 38 visits by snow leopards to permanent sign transects were known to occur (marking activity (35) + leopard tracks (22) - concordant pairs (19) = 38 minimum visits). Scraping activity successfully predicted about 87% of these visits, while finding tracks predicted from 29% to 60% of the visits. Although all types of sign left by snow leopard should be considered when conducting sign surveys, it is suspected that the number of sites with scrapes and the total number of scrapes might provide the most reliable index for determining presence and relative abundance of local populations. Scrapes are a relatively abundant, stable and easily detected form of marking. By categorizing scrapes based on their relative visibility, the level of recent snow leopard activity can be assessed. Evidence suggested that scrape density and the pattern of areas with high concentrations of sign were strongly associated with snow leopard density and spatial patterns of habitat use. In contrast, snow leopard tracks, like scent-sprayed rocks, are inherently difficult to detect and extremely ephemeral in nature. Detection of tracks is primarily dependent on the recent passage of a leopard through the area (usually less than 1 week) and local weather and substrate conditions rather than cat density.

In the Langu Valley the average distance travelled along survey transects before encountering sign was about 204m+71. and

the average distance between marked sites was about 70m±13 (mean+95% CI). Approximately 75% of all marked sites and scrapes were found along transects within a distance of 700m and 650ni. respectively.

A reasonable approach for conducting surveys to determine the presence and relative abundance of snow leopard would be to initially optimize the probability of finding sign by locating transects in preferred marking habitat {e.g., river confluences, major ridges). If sign is found additional transects should be located in a restricted stratified random manner in representative habitats. Effort should be made to stratify transects in relatively homogeneous units.

Data from the Langu suggests that surveys should be conducted using many short transects (250m to 800m) rather than a few longer ones. Transects of shorter length are more efficient, manageable. provide data with lower relative variability, and allow investigators to

TABLE V. Effort or sample size (number of transects) required to estimate the mean (number of sign per km of transect) with a 9O% confidence interval for various types of sign left by snow leopard along 49 one-time sign transects and 4 repeated sign transects.

Number of Sites with							Number of Marks		
Landscape Category	Any sign	Scrapes	Feces	Scent sprays	Tracks	Tree rakes	All	Scrapes	Feces
Confluence		X=786m)	1 1.07	3.16	0.99	0.51	99.O3	83.24	12. 3 4
(N=10: Mean		24,42							
±1O%[2]	73	66	626	177	554	1119	133	151	399
±20	18	16	157	44	139	280	33	38	100
±30	8	7	70	20	62	124	15	17	44
Major Ridge (N=6·		X=904m)							
Mea	1963	18.5O	1.13	NA[3]	NA	NA	60.86	52.81	9. 4
±10	144	145	424	NA	NA	NA	105	100	109
±20	36	36	106	NA	NA	NA	26	25	27
±30	16	16	47	NA	NA	NA	12	11	12
Ridge	(N=18; X=883m)								
Mea	6.47	6.05	0.43	0.37	0.72	NA	19.02	15.68	2 2
±10	210	193	2201	1195	560	NA	249	243	737
±20	52	48	550	299	140	NA	62	61	184
±30	23	21	245	133	62	NA	28	27	82
Othe r	[N=19; X=970m(								
Mean	5.23	4.5O	0.74	0.31	0.09	0,09	14.03	10.24	3 ,1
±10	421	459	2406	1118	2915	5172	434	595	998
±20	105	115	602	279	729	1293	108	149	249
±30 %	47	51	267	124	324	575	48	66	111
Total	(N=53; X=900m)								
Mea	11.11	10.37	O.74	0.77	O.46	0.12	33.56	30,68	5.29
±10	315	321	1423	1118	1089	4789	489	499	734
±20	79	80	356	279	272	1197	122	125	183
±30 %	35	36	158	124	121	532	54	55	82

[1] **N = number of transects; X= mean transect length.**
[2] **90% confidence level; for interval estimate on the mean** of ±10. **20. and 3O%. respectively.**
[3] **NA indicates** that no sign was **found.**

delineate the spatial patterns of marking activity and determine the density of sign In and among concentration areas. Winter and early spring Is probably the optimal period for undertaking surveys because marking activity is greatest and weather (i.e., rain) or human disturbances (e.g., livestock grazing) are reduced (Fox et al. this volume).

The authors suggest that characterization of habitat components important to snow leopards be conducted in conjunction with sign surveys. These components should not only include vegetation, topographic and physiographic variables, but also human-wildlife interactions, especially livestock grazing and hunting of leopards and their prey. The value of sign survey data would be greatly enhanced in the context of information on available and used habitat. This approach would facilitate identification of human-wildlife conflicts and help clarify our understanding of snow leopard ecology (Jackson and Ahlborn 1984).

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