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CHAPTER 13

MARKING SITE SELECTION BY FREE RANGING SNOW LEOPARD (*Uncia uncia*)

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ABSTRACT

Marking plays a major role in social communication of solitary carnivores. For the snow leopard (*Uncia uncia*), a sparsely distributed, solitary top predator of the high altitudes mountains in Asia, communication is very important for maintaining the social structure. Snow leopards leave a variety of signs in their habitat, with scrape marking and scent marking the two most predominant types of sign. We investigated the marking site selection by free ranging snow leopards in Hemis High Altitude National Park, Ladakh, India. We walked 15 trails and encountered 107 scrape sites and 43 rock scent sites and recorded their habitat attributes. We also sampled 99 random sites and 65 randomly selected rocks for quantifying the habitat availability. Logistic regression identified the height of the overhang of rock face, slope of the overhang of rock face and slope of the terrain to classify sprayed and unsprayed rocks with 91.6% classification accuracy. The stepwise discriminate function analysis resulted in 78.3% accuracy in classifying scrape sites and random sites, based on substrate, landform ruggedness, dominant topographic feature, rangeland use and openness of the terrain. For scent marking snow leopards preferred rocks of a particular size (100 cm modal width and 100-150 cm modal height) with a prominent overhang (70-85 cm modal height) and a slope of 40° (modal value) for the marked rock face; and for scrape marking, a substrate with soil and shale. Snow leopards seemed to prefer gentle to moderate slopes for leaving scrape marks, while scent marks were mostly left on steeper slopes. ‘Highly broken terrain’ was selectively used for both scraping and scent marking. Rolling terrain was preferred for scrape marking, while cliffs were preferred for scent marking. In the use of the dominant topographic features for leaving scrapes, snow leopards selectively used the ‘river terrace’, ‘riverside buff’ and ‘valley bottom’, while for scent marking they preferred ‘hill slopes’ and ‘valley bottoms’. Snow leopards appeared to clearly avoid the areas under greater levels of land use disturbance. Our study results could be used for more effective sign-survey designs, for population monitoring of snow leopards. It also gives an insight about marking pattern and mark placement strategy adapted by snow leopards for the efficient and effective dissemination of olfactory information, which is often useful for their communication. This study could also help in developing enrichment facilities for captive snow leopards.

Key Words: Kashmir, marking, population monitoring, snow leopard.

INTRODUCTION

Olfactory signals play an important and essential role for socio-ecological communication in carnivores, and more so in solitary carnivores (Ralls 1971; Eisenberg & Kleiman 1972; Macdonald 1980, 1985). They help in maintaining social structure, individual and kin recognition, intra-population and inter-population communication, sex recognition, mate selection, advertisement of reproductive status and various moods including stress, locating and marking of food resources, and territory establishment and maintenance (Gosling 1982; Gorman & Trowbridge 1989; Gorman 1990).

The role of scent marking as a tool for olfactory signaling in the social communication of mammals is widely variable, because the function of scent marking may vary with different ecological and social conditions (Miller *et al.* 2003). Gosling (1990) suggests three general mechanisms by which information is transferred by olfactory signals: individual identity based on the signal; intrinsic meaning for a particular stage like age, sex or reproductive status, and scent matching based on previously perceived olfactory signals. Johnston (1983) proposed the reproductive advertisement hypothesis for olfactory signals. These signals may also help in spatio-temporal separation of neighbors by signaling the temporal and historical record of an individual's movements by acting similar to 'railway signals' (Leyhausen & Wolff 1959). It has also been suggested that marking may reduce the chances of intra-population clashes, which might prove harmful to the individuals, through the establishment of individual recognition or social status assessment systems (Gosling 1982). Marks provide information about the probability of encountering another individual, information on the time elapsed since the site was last marked (White *et al.* 2003), and the direction of travel by the use of a concentration gradient (Alberts 1992). In this way an individual could assess the risk of potential injury and energetic cost involved in encounters by assessing a given area of the local odour field (Smith *et al.* 1989). Another theory relates the marking to resource dispersion and foraging efficiency, where it has been suggested that marking behavior is used by an individual to advertise its feeding location, resource availability and use to others, thus enabling resource partitioning and foraging efficiency (Henry 1977; Kruuk 1995). An olfactory signal also allows a receiver to assess certain parameters of its social environment very specifically, and it has advantages over visual and auditory cues because chemical cues persist longer in the environment (Eisenberg & Kleiman 1972). Marking as means of communication is thought to be adaptive, and the information conveyed by a mark contributes to the inclusive fitness of the marker (Gosling 1981), because the whole process of communication is subject to the process of natural selection (Eisenberg & Kleiman 1972).

Marking behavior also requires a significant investment of resources and energy (Gosling 1981), and it has been suggested that there is a logarithmic relation between signal strength and perceived signal intensity (Mozell 1972). To minimize energetic costs, the species should employ strategies to increase signal detectibility other than those involving an increase in signal strength (Alberts 1992). This involves the placement and distribution of signals (marks) in a way that increases their chance of being discovered by the intended receive, hence achieving the objective and maximizing the benefits of producing those marks (Gosling 1981). Marking posts are compared to ‘bulletin boards’ where signals are ‘posted’ and ‘read’, so the placement of these bulletin boards are important (White *et al.* 2003).

Among the carnivores several analytical field studies have been done on marking behavior related to olfactory communication, including on stoats and ferrets (Erlinge *et al.* 1982; Clapperton 1989), mongoose (Rasa 1973; Gorman 1976), European badger (Kruuk *et al.* 1984), Honey badger (Begg *et al.* 2003), otters (Trowbridge 1983; Mason & Macdonald 1986; Macdonald & Mason 1987; Kruuk 1992, 1993, 1995; Rostain *et al.* 2004), giant panda (Schaller *et al.* 1985; Swaisgood *et al.* 1999, 2000, 2002; White *et al.* 2003), aardwolf (Richardson 1990, 1991; Sliwa & Richardson 1998), hyenas (Mills *et al.* 1980; Gorman & Mills 1984; Mills & Gorman 1987; Mills 1990; Woodnansee *et al.* 1991; Christine *et al.* 2002; Drea *et al.* 2002), canids (Peters & Mech 1975; Henry 1977; Jorgenson *et al.* 1978; Macdonald 1979; Harrington 1981; Wells & Bekoff 1981; Brown & Johnston 1983; Gese & Ruff 1997; Sillero-Zubiri & Macdonald 1998), and felids (Hornocker 1967; Schaller 1967; Hornocker 1969; Schaller 1972; Seidensticker *et al.* 1973; Bailey 1974; Sunquist 1981; Smith *et al.* 1989; Mellen 1993; Feldman 1994; Bothma & le Richet 1995; Molteno & Richardson 1998).

The snow leopard (*Uncia uncia*) is a large solitary cat species sparsely distributed in high altitude regions of the Himalayas and central Asia (Schaller 1977, McCarthy & Chapron 2003). Their solitary nature coupled with large home ranges and semi-arid resource-scarce habitat requires an efficient communication system amongst individuals. Studies on the marking pattern of captive snow leopards have been done by Wemmer & Scow (1977), Reiger (1978, 1980), Freeman (1983), and Blomqvist & Sten (1982), but since marking patterns in captivity are strongly influenced by the artificial situation of housing and management, these studies do not provide much information about marking behavior in the wild and thus the social communication of free ranging snow leopard population (Ahlborn & Jackson 1988). Studies on marking behaviour of free ranging snow leopards have been done by Schaller (1977), Mallon (1984), Ahlborn & Jackson (1988), and McCarthy & Munkhtsog (1997). Schaller (1977) describes that both sexes (including sub-adults aged about 1.5 years) mark intensively and also leave their marks at permanent locations. Mallon (1984) reports the same results from his study on free ranging snow leopards in Ladakh, India. Ahlborn & Jackson (1988) present a detailed quantitative account of marking behavior of snow leopards in Nepal, and their study also provides some information about marking site preferences. McCarthy and Munkhtsog (1997) report the relationship between various habitat attributes and snow leopard marking patterns. All of these studies provide information that snow leopards mark along a complex system of frequently traveled routes in their mountainous habitat which includes valleys and their confluences, largely along with other features like ridges, riverside bluffs and terraces, cliffs, river-beds, wild ungulate trails, and some times open slopes. Snow leopards deposit various types of signs along their travel routes, which could also be a means of their social communication, by the aid of visual or olfactory cues. These signs are scrapes, scent spraying, scat deposition, claw raking, urination, and tracks (Jackson & Hunter 1996). Amongst these, scrapes and scent spraying are two of the most frequently-used marking signs (Ahlborn & Jackson 1988). Scrapes are characteristic ‘V’ shaped marks made by snow leopard by raking the available substratum (soil, snow, shale, and vegetation), using their hind legs. Sometime scrapes have urine and scat deposited on top. Scent spraying on overhangs is another frequently-used marking pattern used by snow leopards. The scent marking by an animal is defined as the application of its urine mixed with glandular secretion to the features in its environment (Macdonald 1980).

Though some information is available on the functional role of marking patterns in snow leopards, and also about qualitative attributes of the habitat features favoured by snow leopards for marking, no study had previously quantified the habitat attributes selected by snow leopards for displaying their marks at a finer scale. Here we describe the marking site selection (particularly associated with scrape and scent spraying) by free ranging snow leopards. We investigated how the snow leopards select sites using the various habitat attributes available in their area of occupancy, for depositing their marks, in a way to maximize their efficiency and use. The information obtained by this study has a potential in use for refining the designs of sign-surveys for snow leopard population monitoring.

Study area

We conducted this study in Rumbak valley of the Hemis High Altitude National Park in India. Hemis is located about 40 km southeast of Leh, within the Ladakh district of the state of Jammu and Kashmir. It is named after Hemis Gompa, a famous monastery situated inside the park boundaries. Hemis (*c.* 3,000 km^2) was gazetted as a national park in 1981 with the purpose of conservation and protection of representative flora and fauna of Trans-Himalayas. It lies on the west bank of the Indus River and comprises the catchments of Markha, Rumbak and Sumdah tributaries at 33°43'-34°11'N, 77°00'-77°38'E (Fig. 1). The rugged terrain in the area is spread between 3500 and 6930 m (Fox & Nurbu 1990).

The terrain surrounding the park is rocky and covered with a thin layer of soil, which supports a poor vegetative growth. Dry alpine pastures are found in sheltered locations, and the grass growth is relatively rapid during the summer season after the snow melts from the region. The Markha and Rumbak valleys of central Ladakh are located at high altitude, and are characterized by sparse grassland and herbaceous vegetation on mountain slopes, with shrub-lands and patchy forest in the valley bottoms.

Hemis protects to some 11 threatened species of Trans-Himalayan mammals, most of which are threatened elsewhere in their range. These include snow leopard, Tibetan wolf (*Canis lupus chanco)*, Pallas' cat (*Felis manul)*, wild dog (*Cuon alpinus*), lynx (*Lynx lynx*), Himalayan ibex *(Capra ibex sibrica)*, bharal (*Pseudois nayaur*), Tibetan argali (*Ovis ammon hodgsoni*) and Ladakh urial (*O. orientalis vignei*). There is substantial interaction between local people and wildlife in terms of competition between domestic livestock and wild herbivores for food (Namgail *et al.* 2004). Another conflict situation is depredation of livestock by snow leopard and other large carnivores (Bhatnagar *et al.* 1999).

Our intensive study area was located in the Rumbak valley (*c.* 100 km^2) which was situated in the western most part of Hemis and runs in south-north direction to eventually meet the Indus river. There are four villages in the Rumbak valleys, with 15 households and a total population of *c.* 70 people. The steep side valleys of Rumbak gorge -- named Husing, Tarbung and Kahrlung -- and the portion of Rumbak gorge connecting these valleys, was the primary sampling region.

Study method

We carried out this study during the peak of winter (January - March 2004), which coincides with the mating season of snow leopards, when their movement and marking frequency increases. This is also the time that they descend down to relatively lower elevations due to heavy snow in upper region. Winter coincides with a decrease in livestock grazing and related human disturbance activities (Ahlborn & Jackosn 1988; Fox & Chundawat 1995; Jackson & Hunter 1996). All these factors made winter the ideal season for conducting a study on snow leopards signs.

After an initial reconnaissance to identify the intensively used areas of snow leopards, we selected 15 trails of varying lengths for data collection on marking site selection. Most of these trails were laid in the side valleys of the main gorge, which were seen to be most intensively used by snow leopards. We searched especially for scrape and scent sprays, which are the two most prominent and frequently marked signs types. Snow leopards tend to deposit their signs on land form edges and more intensively where there is a confluence of two used trails (Schaller 1977; Mallon 1987; Ahlborn & Jackson 1988; Fox 1989), so we searched for both the sign types on the either side of the trails and at the junction of valleys.

Scrapes are distinct marks made by snow leopards on ground, and they are quite often found in groups at relic sites, which are most frequently marked and where the scrapes are usually remarked. These sites have scrapes marked during various time periods. There non-relic scrapes are more transient and lack evidence of recurrent use (Ahlborn & Jackson 1988). Scent sprays are usually made on the faces of upright or overhanging boulders and the bases of cliffs. In the snow leopard habitat sprayed rocks can be detected by sniffing them for the conspicuous odour of snow leopard scent sprays. Accompanying evidence to confirm the spray marking on rock are presence of other signs (scrape, scats, claw marks, and footprints) at the base of the rock and sometimes the presence of facial hair attached to the sprayed rock face indicating cheek rubbing and discoloration of sprayed rock faces (Ahlborn & Jackson 1988). Some rocks were recurrently used by snow leopards for spray marking.

For each sprayed rock found on the trails, we measured width of the rock face, height of the rock, height and angle of the overhang of the sprayed rock face along with recording the habitat features such as slope (in degrees), aspect (direction) and elevation (in meters) of the terrain where rock is located, Landform Ruggedness (LFR), Dominant Topographic Feature (DTF), Rangeland Use (RLU) and Openness of the landscape following Jackson and Hunter (1995). For each scrape site we measured the habitat features given above along with recording the substrate type on which the scrape was made. LFR characterizes the smoothness of the earth’s surface and the degree to which the surrounding terrain is broken by features like cliffs, drainages and rock outcrops. DTF is the topographic feature dominating the entire landscape of a given area present at the marking site. RLU describes the landuse in terms of grazing and the associated level of human disturbance in the proximity of the sign site. Openness describes the level of landscape surface associated with amount of area in a particular landscape open to the sky.

To assess the availability of the various habitat attributes in the study area, we randomly selected a few sites on each trail for assessment of finer scale selection, as well as in the areas which did not have any signs or very low intensity of snow leopard signs for assessment of higher scale selection of habitat attributes. We also selected unsprayed rocks randomly in these areas to assess why some rocks are preferred over the other available rocks for scent marking. These random site data would be used to assess availability of habitats with specific attributes.

We used exploratory data analysis for assessing the dominance of various measurements taken from the sprayed rocks. Stepwise Discriminant Function Analysis (DFA) and Logistic Regression analysis were used for analyzing the data. We applied Ivlev's Electivity Index (modified by Jacobs 1974) for assessing selectivity for the habitat attributes. Ivlev’s selectivity index $D = (r - p) / (r + p - 2rp)$, where r is the proportion of habitat attributes used and p is its proportion available in the habitat. Ivlev’s selectivity index ranges from –1 (total avoidance) through 0 (no selection) to +1 (maximum positive selection). All statistical analysis was done on SPSS 10 (SPSS Inc.) statistical software program.

Results

We walked 15 trails totaling 9.5 km with an average length of the trail 0.63 km and trail length ranging from 0.23 km to 1.07 km. We found 107 scrape sites, including both relic and non-relic sites, and identified 43 scent-sprayed rocks. We sampled habitat attributes of 99 random sites for comparison with the scrape site, while 65 rocks were sampled as random unsprayed rocks for analysis with the sprayed rocks and sites.

After an interpretation of histograms of width and height of the rock, height and slope of overhang for sprayed rocks as well as unsprayed random rocks, we found that the mean width of rocks was 252 cm (SD = 139.6 cm, n = 42), the mean height was 190 cm (SD = 118 cm, n = 42) , the mean height of overhang of sprayed rock face was 72.4cm (SD = 13.1 cm, n = 42), and the mean slope of overhang of sprayed rock face was 36° (SD = 13.6°, n = 43). The same information for random unsprayed rocks was as follows: the mean width of unsprayed rocks was 191 cm (SD = 97.3 cm, n = 61); the mean height was 113 cm (SD = 100 cm, n = 61); the mean height of overhand of exposed rock face was 44 cm (SD = 35.4 cm, n = 61); the mean slope of overhand of rock face was 21° (SD = 16.3°, n = 65).

An analysis of various measurements of sprayed rocks indicates that the mode value for each measurement for the sprayed rock differs from the average measurements. The mode values for each measurement class was as follows: width of the sprayed rock = 150 cm (31% of all measurements in that category); height of the rock = 100 and 150 cm (60% cumulatively of all measurements); height of overhang = two modal values -- 70 cm and 85 cm (38% cumulatively of all measurements); and slope sprayed rock face = 40° (40% of all measurements). These mode values for each measurement class provides a clue about the preferred morphometric dimensions used by snow leopards for depositing scent spray marks on the rocks. Stepwise DFA results for analysis of factors responsible for selection of rock and habitat attributes had 86.1% accuracy in classifying sprayed and unsprayed random rocks by using just three variables (height of the overhang of rock face, slope of the overhang of rock face and slope of the terrain) in the classification equation. Logistic regression reconfirmed the same results with 91.6% classification accuracy, and here again the same three variable were selected for classification.

Analysis of scrape sites found that 41% of scrapes were made on a substrate of soil + shale, while other substrate (pebbles, pebbles + shale, shale, fine soil, soil + vegetation) were equally used. The Stepwise DFA resulted in 78.3% accuracy in classifying scrape sites and random sites and the habitat attributes selected for this classification were substrate, LFR, DTF, RLU and Openness.

Further analysis on selection of various habitat attributes using Ivlev's Electivity Index indicates that some habitat attributes are preferred over others for both scrape and scent marking site selection (Tables 1 and 2).

Gentle and Moderate slopes were preferred for scrape marking, while for placing scent marks scent rocks placed in areas with higher slopes were preferred. Though the sign sites were almost equally distributed among all aspect categories, there was a preference for North and West aspect category for scent marking and scrape placement, while South and East aspects were avoided. Shale + soil was the most preferred substrate category for leaving scrape marks, while substrate with pebbles, pebbles + shale and shale only, was not preferred but sometimes used for the scrape marking. Highly broken terrain and rolling terrain were preferred for scrape marking, while cliffy and highly broken terrain were preferred for scent marking. Among dominant topographic features, the river terrace, riverside buff and valley bottom were preferred for scrape marking, while hill slopes and valley bottom were preferred for scent marking. In Range land use categories, the areas which were minimally used by people and livestock were preferred for scrape marking, and areas with minimal and moderate use were preferred for scent marking. There was a clear avoidance of high land use areas. Amongst openness categories, moderately open areas were preferred for scrape marking and it was also the maximum represented class (83%). But the moderately open class was not preferred for scent marking even though being highly represented (84%), while the very close and very open terrain was preferred. It was also interesting to note here that we found more sprayed rocks compared to scrapes in areas of high disturbance (high RLU), which could be due to some specific reason by the snow leopards.

Discussion

For the snow leopard, a sparsely distributed, solitary top predator of high altitudes, communication needs are especially important, and thus marking is expected to play a more important role in its social interaction than among most other felids. Indeed, it was found that snow leopards mark more frequently than any other large felid (Ahlborn & Jackson 1988). Amongst a variety of sign types used for communication, snow leopards have been seen using scrapes and scent sprays predominantly for communication. Snow leopards place their mark along their trails on various types of features (Jackson & Hunter 1996). It has also been suggested that given any set of terrain and topographic conditions, snow leopards will focus their marking effort where their movement is hindered or channelised by physical barriers or edges, and it was inferred that these edges aid in providing an unobstructed field of vision in one direction (Ahlborn & Jackson 1988).

In our study we found that snow leopards place their scrape and scent spray marks on visually distinct places. Previous studies also suggest that the signal information of a marking type increased if it contains visual components (Alberts 1992). The evolutionary advantage of retaining the chemical component of signals that are localized visually may be in their relatively high information content (Bossart & Wilson 1963). So the strategies suggested for promoting the visual localization of range mark includes deposition of signals near obvious landmarks, especially vertical objects such as tree stumps, rocks etc. (Eisenberg & Kleiman 1972), as seen in case of scent spray marking on rocks by snow leopard. These also include making a mark conspicuous in appearance by shape or size (Hornocker 1969; Brown & Macdonald 1985), as happens in the case of snow leopard scrapes which are distinct in shape and may have some chemical information content in them related to olfactory communication (Ahlborn & Jackson 1988). In our study we found that snow leopards prefer rocks of a particular size (100 cm width and 100-150 cm height) with a prominent overhang (70-85 cm in height and a slope of 40° for the marked rock face), which is optimal for placing their scent spray marks, along with slope of the terrain where the rock is placed. These distinct features are important in maximizing the communication effort made by snow leopards by making the site more visible and approachable. It was seen that deposition of scent marks well above the ground facilitates in diffusion of the odour by wind, and increases the evaporating surface as the marking liquid trickles down, thus strategic positioning of small quantities of scent marks on many different objects increases the total effectiveness of the amount deposited (Sillero-Zubiri & Macdonald 1998). The height and angle of the rock-overhang is also important, because it makes the scent spot approachable and at the same time it increases the chances of longevity of the scent mark by protecting it from sun and snow. A similar phenomenon has been observed in tigers, where they prefer to leave their scent marks on those trees which have some lean and a particular girth. They usually mark on the underside of these trees where the scent is protected from rainfall (Smith *et al.* 1989).

It has also been suggested that orientation to certain chemical traces may be based on vision as well as olfaction (Eisenberg & Kleiman 1972), and in various vertebrates the chemical signals are the first to be detected but approached through visual cues (Alberts 1992). We found that the snow leopards do deposit some urine on scrape mounds, but the percentage of this type of scrapes is less than 5%. We also think that the scrapes are used more as a visual cue and less as an olfactory cue. The evidence of this could be the re-scraping of the scrapes with high visibility, which is done quite often by snow leopards. High visibility scrapes are also usually the fresh ones, and they presumably are more likely to contain chemical information. Kleiman and Eisenberg (1973) suggested that felids rely more on visual cues than canids, but we think that the effective area covered by an olfactory signal, scent spray in the case of snow leopard, is more than the visual cue as olfactory signals can disperse faster and further, and they also remain for long time (almost 60 days in case of snow leopard). These olfactory signals are made conspicuous by their placement and association with other visual cues, such as the scrapes of snow leopards.

Smith *et al.* (1989) found that tigers use various marking types interchangeably depending on the habitat situation. They leave more scrape marks in open grasslands, compared to thick forest where numbers of scent marks are higher. This could be due to low detectibility of scrapes in thick forest and lack of marking trees in grasslands. In our study we found that areas with higher rangeland use have scent sprays as the predominant marking type rather than the scrape. There could be two plausible reasons for this. First, these maximum use areas are usually open and the chances of detectibility of olfactory signals are more due to a large odour field in an open area than the visual cues which have a less ocular field, so it would be economical for an individual to leave a mark type which increases the chance of conveying the message. A second reason is that these areas are usually more disturbed due to livestock and anthropogenic activities, so chances of persistence of scrapes are less than for scent marks. The relative importance of visual stimuli and olfactory stimuli in orienting an animal to an odour site is an area that needs investigation (Eisenberg & Kleiman 1972), along with the role of snow leopard scrapes in signaling olfactory messages. We also found that though the marking sites were more or less equally distributed in all aspect categories, north and west aspects were preferred while south and east aspects were avoided. To explain this selection for the scent marked rocks we hypothesize that if the scent marking is done on rocks on the northern slopes, the scents would last longer as they would be protected from sun as compared to the marked rocks on southern slopes. This hypothesis needs further investigation.

In DFA analysis of scrape site selection we found that substrate is one of the fine level habitat attributes classifying the selection. We found snow leopard scrapes in various types of substrate but a major portion (41%) were made on a substrate of soil and shale. The conduciveness of soil and chances of durability due to shale might be the leading factors for choosing this kind of substrate for scrape marking. Other factors selected in the DFA analysis were LFR, DTF, RLU and Openness, which are major scale habitat attributes. Further interpretation of these results using Ivlev’s selectivity index indicates that snow leopards select less disturbed sites for marking. Proportionately more sign sites were located in highly broken terrain and areas of minimum to moderate disturbance and they were also the preferred sites. Riverside bluffs have more scrape sites than spray rocks while valleys have more spray rocks than scrapes. These results also correspond with those of McCarthy and Munkhtsog (1997), who found 65% of scent sprayed rocks in valley bottom. They also found that 54.3% of sign sites were in non-grazed areas, reiterating our results that snow leopards prefer less disturbed areas. But their study found that 76.6% of the scrape sites were on ridges. Our study had less sampling effort in ridge areas, but snow leopard in our study area were also found to be using valley bottoms more often than ridge tops for travel during winter. We explain the variations in results of our study with that of McCarthy and Munkhtsog (1997) in terms of difference in the proportion of LFR in the entire habitat and area of intensive habitat use by snow leopards in their study site in Mongolia compared to our study site in Ladakh. Studies have shown that marking behavior and preference for marking sites vary seasonally and geographically, and that flexibility of marking behavior between geographically isolated populations of different areas is a response to different environmental condition (Smith *et al.* 1989). This calls for comparative studies of snow leopard marking behaviour in various areas of its range.

It was also found that snow leopards select marking sites disproportionately to the available habitat (Ahlborn & Jackson 1988), and to judge the preference for the habitat selection a detailed habitat mapping of the study site is required to assess the availability. We suggest that studies similar to ours on marking behavior and sign site selection be carried out at various sites in conjunction with habitat mapping using remote sensing and GIS technology along with collection of habitat usage data by direct (radio-telemetry) and indirect (sign based) methods. Our study also gives a direction for selecting appropriate places for sign-transact (where chances of sign encounter rates would be more), for the objective of assessing relative abundance of snow leopards at a spatio-temporal scale. In snow leopard sign surveys, it is still unclear that sign density is a reflection of true abundance or just a measure of habitat utilization. We suggest that based on the habitat attributes preferred by snow leopards provided by our study results, sign transacts should be laid in a stratified portion of available habitat, and if the goal of sign transact is to assess the relative abundance, then their frequency should be increased in the areas where chances of obtaining snow leopard signs are greater. These areas can be selected by following our study results. Another possible use of our study results could be to enhance the enrichment facilities for captive snow leopards by providing them suitable substrate for scrape deposition and rocks of suitable size and overhang for scent spray marking.

CONCLUSION

A continuing investigation of marking behaviour in snow leopards could also be efficiently used as an aid for developing a monitoring protocol because snow leopard signs have been used to assess their population status (Jackson & Hunter 1996). It is likely that the frequency of markings may vary with gender, age-class, and social and reproductive status of the snow leopard. Therefore, understanding the function of marking patterns may provide valuable information for correcting population estimates based on sign surveys, and thus could be of help in the conservation of snow leopards.

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Table 1: Observed vs expected use of various habitat attributes and their selection by snow leopard for scent marking.

Habitat attributes	Expected usage (frequency)	Observed usage (frequency)	Expected usage (proportions)	Observed usage (proportions)	Ivlev's Selectivity Index
Slope of terrain					
0-10	14	3	0.33	0.05	-0.81 **Avoided**
11-30	21	24	0.49	0.38	-0.22 **Avoided**
31-40	4	9	0.09	0.14	0.24 **Preferred**
> 40	4	27	0.09	0.43	0.76 **Preferred**
Aspect					
North	11	19	0.26	0.29	0.09 **Preferred**
East	10	14	0.23	0.22	-0.05 **Avoided**
South	11	13	0.26	0.20	-0.16 **Avoided**
West	11	19	0.26	0.29	0.09 **Preferred**
Landform ruggedness					
Cliff	0	4	0.00	0.06	1.00
Highly broken terrain	23	39	0.53	0.60	0.13 **Preferred**
Medium broken terrain	6	8	0.14	0.12	-0.07 **Avoided**
Rolling terrain	14	14	0.33	0.22	-0.28 **Avoided**
Dominant topographic feature					
stream bed	4	6	0.09	0.09	0.00 **Used proportionately**
hill slopes	10	23	0.23	0.35	0.29 **Preferred**
riverside terrace	0	2	0.00	0.03	1.00
bluff	18	19	0.42	0.29	-0.27 **Avoided**
valley	4	6	0.09	0.09	0.00 **Used proportionately**
gulley	7	9	0.16	0.14	-0.09 **Avoided**
ridge	0	0	0.00	0.00	
Rangeland use					
1 -minimum use	10	15	0.23	0.23	-0.01 **Avoided**
2 - moderate use	20	33	0.47	0.51	0.09 **Preferred**
3 - maximum use	13	17	0.30	0.26	-0.10 **Avoided**
Openness					
veryclose	1	4	0.02	0.06	0.47 **Preferred**
moderately open	40	55	0.93	0.85	-0.42 **Avoided**
very open	2	6	0.05	0.09	0.35 **Preferred**

Table 2: Observed vs expected use of various habitat attributes and their selection by snow leopard for scrape marking.

Habitat attributes	Expected usage (frequency)	Observed usage (frequency)	Expected usage (proportions)	Observed usage (proportions)	Ivlev's Selectivity Index	
Slope of terrain						
0-10	43	63	0.43	0.59	0.30	**Preferred**
11-30	33	37	0.33	0.35	0.03	**Preferred**
31-40	20	4	0.20	0.04	-0.73	**Avoided**
> 40	3	3	0.03	0.03	-0.04	**Avoided**
Aspect						
North	24	30	0.24	0.28	0.10	**Preferred**
East	30	27	0.30	0.25	-0.13	**Avoided**
South	20	16	0.20	0.15	-0.18	**Avoided**
West	25	34	0.25	0.32	0.16	**Preferred**
Substrate						
pebbles	28	14	0.28	0.13	-0.45	**Avoided**
pebbles + shale	18	14	0.18	0.13	-0.19	**Avoided**
shale	11	8	0.11	0.07	-0.21	**Avoided**
shale+ soil	29	44	0.29	0.41	0.26	**Preferred**
fine soil	13	14	0.13	0.13	0.00	**Preferred**
soil + vegetation	0	13	0.00	0.12	1.00	
Landform ruggedness						
Cliff	29	0	0.29	0.00	-1.00	
Highly broken terrain	46	61	0.46	0.57	0.21	**Preferred**
Medium broken terrain	14	11	0.14	0.10	-0.18	**Avoided**
Rolling terrain	10	35	0.10	0.33	0.62	**Preferred**
Dominant topographic feature						
stream bed	6	4	0.06	0.04	-0.25	**Avoided**
hill slopes	39	26	0.39	0.24	-0.34	**Avoided**
riverside terrace	5	11	0.05	0.10	0.37	**Preferred**
bluff	22	29	0.22	0.27	0.13	**Preferred**
valley	14	28	0.14	0.26	0.37	**Preferred**
gulley	13	6	0.13	0.06	-0.44	**Avoided**
ridge	0	3	0.00	0.03	1.00	
Rangeland use						
1 -minimum use	27	34	0.27	0.32	0.11	**Preferred**
2 - moderate use	64	65	0.65	0.61	-0.08	**Avoided**
3 - maximum use	8	8	0.08	0.07	-0.04	**Avoided**
Openness						
veryclose	18	6	0.18	0.06	-0.58	**Avoided**
moderately open	34	89	0.34	0.83	0.81	**Preferred**
very open	47	12	0.47	0.11	-0.75	**Avoided**

Fig 1: Map of Rumbak valley and associated drainage channels situated in Hemis High Altitude National Park, Ladakh, India.