OBSERVATIONS **ON** THE **ECOLOGY OF SNOW LEOPARD** IN WEST NEPAL

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Almost nothing is known about the endangered snow leopard *Panthera uncia* in the wild because its secretive habits, low numbers, sparse distribution and inaccessible habitat have discouraged attempts at study. Knowledge of snow leopard behavior and ecology is primarily anecdotal (Guggisberg, 1975; Schaller, 1977). More information has been published in recent years, but it mostly concerns captive snow leopards. This is the first successful attempt at in-depth study of this elusive carnivore.

His Majesty's Government (HMG) took far-sighted action in approving the application to study snow leopards in Nepal's Langu Valley in cooperation with biologists of the Department of National Parks and Wildlife Conservation (DNPWC) in October 1981. Field work was conducted between January 1982 and June 1985.

PRIMARY OBJECTIVES

Primary objectives of the four-year study were to examine, to the extent possible, snow leopard activity and movement patterns, home range size and configuration, habitat utilization and predator-prey relationships (food habits and basic ungulate prey population dynamics). We specifically attempted to answer the following questions:

1. Does the snow leopard's home-area and land tenure system resemble other large solitary cats such as the mountain lion and tiger?
2. How do individuals utilize their home-range space with regard to resources?
3. What are the patterns of movement shown by individuals relative to each other, and what mechanisms operate in spacing behavior?
4. Is sign (tracks, feces and scrapes) a reliable Indicator of relative population abundance?
5. What conservation measures are necessary to protect the species?

The study area supported a dense, undisturbed snow leopard population, with sympatry between snow leopard and common leopard *Panthera pardus* being limited to a small section of the valley, so that sign could be reliably attributed to snow leopard in the core study area. The Langu population represents optimal conditions, rather than the typical situation applying in most of the cat's range.

This paper provides a summary of study findings with emphasis on home-range, movements, habitat use. and activity patterns. Ahlborn and Jackson (this volume) review marking patterns, while Nepalese counterpart Karan B. Shah will report on associated prey species studies, as part of his Ph.D. program at Tribhuvan University, Kathmandu. Detailed results will be presented in Jackson's Ph.D. dissertation (University of London), and forthcoming papers.

STUDY AREA

The deeply dissected Langu River gorge (longitude 82°, 33' to 41' E; latitude 29°, 30' to 35' N) is located in the Shey-Phoksundo National Park in west Nepal. Described as among the most forbidding terrain in the Himalaya (Tyson. 1969), elevations in the study area range from 2,700m to about 6.800m. It is situated In the "Inner Valley" semi-arid climatic and vegetation zone of Stainton (1972). a regime resulting from the rain-shadow effect of the Kanjiroba Himal. The climate is temperate, with relatively little winter snowfall, most of which occurs in January-March. Total annual precipitation is estimated at 500-1,000 mm, with more than half occurring during the monsoon (July-September). Snowfall rarely remains more than a few days on south-facing slopes, in contrast to northerly slopes which retain their winter snow cover for up to several months. Aspects are primarily southerly.

A steppe scrub community dominates the northern side of the Langu Gorge between elevations of 2.800m and about 3.900m. Equivalent to communities of Dobremez's steppe zone (1976) and Stalnton's (1972) Dry Alpine Scrub, dominant species include juniper *(Juniperus* indictis), *Caragana gemrdiana. Lonicera spp., Abelia triflora, Rabdosia pharica, Cotoneaster spp., and Artemesia spp. Rosa, Berberis. Ribes* and Jasminum occupy rocky sites, while Prunus *mtra* occurs in gully bottoms and some talus slopes. Above 3,700m Caragana uersicofor and *Potentilla fruticosa* assume greater importance, with a wider variety of herbaceous species. Prostrate Juniper (J. squamata) largely occurs above 3,800m. Shrubs stand between 0.3 - 1.5m in height and are usually widely spaced. Typically only one to three species dominate any particular site. Ground cover is extremely variable depending upon slope steepness, moisture, aspect and soil development.

Barren areas (less than 10% ground cover) occupy about 49% of the north Langu slopes, with alpine grassland covering about 17%, and scrub all but 4% of the remaining vegetative cover types. Small isolated stands of *Pinus wallichiana* occur in most large tributaries, with birch *Betula utilis* on some higher, moist north-facing ledges and slopes. Alpine grassland (dominated by a sedge) occurs on the more evenly sloping and less rocky mountain slopes above about 3,900m, as well as narrow glacial bowls and high cliff ledges. The upper limit of grassland is about 4.800m. A few hardy succulents grow on screes as high as 5,200m.

In contrast to semi-arid conditions north of the Langu River, the cooler, moister north-facing slopes to the south support open forests of Pinus *wallichiana,* interspersed with a few Abies specfabilis and Picea smithiana trees. Above the discontinuous forest belt, at about 3,500m there is a dense zone of birch forest and scrub. Much of the forest has been destroyed by fire, so that dense successional stands of *Cotoneaster, Caragana* and Rosa shrubland occur. In lower, more open areas *Artemesia* predominates.

No permanent human habitations occur above the village of Dolphu, situated at about 3,500m. Livestock are unable to penetrate the gorge further than 4 km upstream, while humans visit the gorge to hunt wildlife and collect various plants. Hunting of snow leopard and muskdeer Moschus chrysogaster has been pervasive in recent years (Jackson. 1979).

METHODS

Capture and Immobilization

Snow leopards were captured using leg-snare traps (Novak. 1980) placed along frequented trails. All individuals were immobilized with ketamine hydrochloride, administered using a jabstick (Figure 1) or Telinject blowpipe, with a dart propelled by a Vario air-pistol (Jackson, Ahlborn, and Shah, in prep.). Animals were weighed, measured, tattooed in the inside of one ear with an identifying number, and fitted with a motion-sensitive radio-collar (Telonics, Inc., Mesa. Arizona).

Cats were sexed and classified according to three age-classes based on size, weight and dentition: (1) Cubs: 0 to <12 months of age; (2) Juveniles and subadults: >12 to *<36* months old: and (3) Adults: >36 months old.

Radio-tracking Procedures •

Attempts to relocate each radio-tagged snow leopard were made daily from the ground using triangulation by two or more observers and homing techniques (Cochran, 1980) (Figure 2). Bearings were taken using a hand compass and plotted on a 1:24,000 topographic map. Each location was classified to an area class. Good, fair and poor locations were those where we placed the cat within areas of less than

FIGURE 1. Immobilizing an adult male snow leopard (cat 01) using a jab stick. Animal had been trapped with a leg snare (Photo by Darla Hillard).

FIGURE 2. Rodney Jackson radio tracking snow leopard in the Langu **Gorge (Photo by Gary Ahlborn).**

25 ha. 25-50 ha and more than 50 ha respectively. Except for locations with visual confirmation, we judged the minimum error polygon to be about 3.2 ha.

Home range size and configuration was calculated using the minimum area polygon method (Mohr, 1947). Centers of activity were calculated using the method described by Dixon and Chapman (1980), as modified by Spencer and Barrett (1984). Core area use was quantified according to Samuel et al. (1985). The day-after-capture locations were excluded from the home area analyses. The cumulative area curve was used to determine what constituted an adequate sample. It was derived by computing the area within cumulative two-weekly minimum area polygons defined by connecting the outermost locations.

An index of movement was obtained by measuring the straight-line distance between the first location of radio-tagged individuals on successive days. Same-day movements were derived by computing the linear distances between repeated locations made during a single day-Distances moved were tested 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 Mann-Whitney U test (Daniel. 1978) was

used to test the null hypothesis that the distances moved by male and female snow leopards were similar.

Activity Patterns

The activity patterns of snow leopard were examined by monitoring their activity at consecutive five-minute intervals throughout the day and night. Determination of activity was based on transmitter pulse rate and changes in signal strength during the monitoring interval. The following categories were recognized: (1) active (travelling): active pulse rate with frequent and usually wide fluctuations in signal strength; (2) active (locally): active pulse rate with less frequent and more weak deviations in signal strength; and [3| inactive (resting): Inactive pulse rate of constant strength.

A chi-square test for independence was conducted to determine if activity was independent of sex. A chi-square good ness-of-fit was employed to test whether the frequency distributions of activity were proportionately distributed with respect to time of day. according to four intervals (night=2000 to 0355 hours; dawn=0400 to 0755 hours: day=0800 to 1555 hours: and dusk=1600 to 1955 hours).

Social Interaction Patterns

The degree to which snow leopards socialize was studied by computing straight-line distances between individuals located on the same day, and by interpretation of sign (pugmarks, scrapes, scats, scent-sprays and claw rakes) (Ahlborn and Jackson, this volume).

Linear distances between individuals on the same day were computed using the first location for each individual on that day. The Kruskal-Wallis one-way analysis of variance was used to test the null hypothesis that distances between individuals of the same and different sexes on the same day did not differ. If the null hypothesis could be rejected, a non-parametric multiple comparison test (Daniel, 1978) was used to determine which mean was different.

Habitat Characterization and Classification

Classification of landform was based primarily on the degree of land-surface ruggedness, using the contour-intercept method described by Beasom et al. (1983). This classification is designed to quantify the relative structural diversity of land surfaces due to drainages, ridges and slopes, and aspect and elevation changes. Four basic landform types were distinguished, while a set of azonal or linear landforms (river bluffs, terraces, river-beds and landslides) typified snow leopard travel lanes (Table I).

Vegetation types were classified on a combination of life-form and dominant species into seven types, ranging from non-vegetated (barren or <10% plant cover) to types dominated by grasses and sedges, shrubs or trees.

Vegetation and landforms were visually mapped from prominent ridgelines, onto a topographic base-map. No units less than 3.0 ha in size were mapped.

Habitat parameters were characterized at 130 randomly located sites, which were in approximate proportion to the occurrence of landform and vegetation cover types in the core study area (Jackson and Ahlborn. 1986). A 100 square meter plot was placed with one side parallel to the dominant aspect. Five one meter-square subplots were designated, one in each of the four corners with the remaining one in center of the large plot. The dominant elevation, slope, aspect, landform and vegetation type, and topographic feature was recorded. We characterized vegetation by recording percent life-form composition (Mueller-Dombols. 1974) and percent canopy cover (six cover classes) in the central meter square subplot. For each of four cardinal compass sectors (NW, NE, SW, SE) we measured the distance from the geographic center of the plot to the nearest shrub at least 1m in height, and the nearest boulder at least 1m high and 1m across, and located within the 100m square plot.

It was hypothesized that visibility may be a factor in the snow leopard's selection of different habitat types. Measurement of horizon distance provided a means of assessing visibility under different terrain ruggedness conditions. Distances were measured by standing at the center point of each plot and looking upslope, downslope and in either "across-slope" direction, using a rangefinder. The horizon was considered to be the nearest visual obstruction as viewed from the observers eye-level (2m). In effect this usually consisted of a gully or ridge edge, cliff, or rock outcrop. We visually estimated distances in excess of 120m.

TABLE I. Description of landform types.

Landform Unit No.	Ruggedness Index	Percent Occurrence	Type of Landform
Zonal types			
2	2	14.24	Terrain moderately to strongly broken by rocky outcrops, drainages (gullys) and ridges.
3	3	13.62	Very heavy broken cliffy terrain with interrupted ridgelines
4		40.25	Smooth, relatively even-sloped, gently rolling terrain with few rock outcrops
1			
		28.79	Cliffs (slopes generally **exceed** 50 degrees)
Azonal types			
6	na		**Landslides and rockfalls**
8	na		River bluff
9	na		River or major stream bed
10	**na**		Riverine terrace
Total		100.00	

* Combined percent occurrence of types 6, 8, 9 and 10 = 3.10% (na = not applicable). Derived from 174 random points, using landform map prepared in the field.

Zonal types = non-linear landform categories (see text). Azonal types = predominantly linear landform features (see text). Ruggedness index = degree of land-surface ruggedness (structural diversity), ranked from 1 (low) to 4 (high) according to Beasom et al. (1983).

Ungulate sign (by species) was noted by tallying the number of pellet groups in each of five one-meter square subplots, while the number of beds lying at least 50% within the 100m square plot were recorded. The absence or presence of fresh tracks was noted.

Habitat Use

Habitat use was determined by matching the grid coordinates of snow leopard locations with the map of vegetation and landform types. Habitat use was compared to availability within the core study area, and preference or avoidance of particular types was determined by the method of Neu et al. (1974). Categories with few expected frequencies were combined to meet chi-square requirements and simultaneous confidence intervals were constructed using the Bonferroni method (Miller. 1966; Neu et al.. 1974; Byers et al., 1984).

The linear landform types were combined into a single category for analysis. The vegetation types subalpine scrub and mixed scrub were also combined, since these communities differed little in structure, while low expected frequencies of the three tree types (riparian, birch forest and conifer forest) necessitated their combination as well. Circular distributions such as aspect were analyzed according to Zar (1974).

Individuals were pooled by sex because of the small sample sizes. For each parameter, chi-square tests of homogeneity (Daniel. 1978) were made to determine if the sexes differed significantly: if no difference was reported at $P<0.05$, data from both sexes were combined. If a significant difference was found, the samples were not combined. We tested the hypothesis that snow leopards use available habitat categories in proportion to their occurrence. We Judged the data met the assumptions of (1) that all snow leopards had an opportunity to select any of the habitat categories deemed available, and (2) that the relocations were collected in a non-biased manner.

In conducting the tests, it was necessary to combine some categories because of low expected proportions of usage. Important requirements are that (1) categories are mutually exclusive; (2) there is at least one expected observation in each habitat category; and (3) that no more than 20% of all categories contain less than five expected observations. Bonferroni simultaneous confidence intervals were constructed to determine which categories the cats used significantly more (over-utilized or "preferred") or less (under-utilized or "avoided") than expected by chance alone. The terms "under-utilized" and "over-utilized" are preferable to "preferred" or "avoided".

Food Habits

Food habits will be studied through the analysis of scats. Few kills were examined because the extremely rugged terrain precluded access to most suspected kill sites.

Snow leopard scats were identified on the basts of size, color, associated sign and location. Scats will be prepared according to Johnson and Aldred (1982); identification of prey items will be made by examining hair scale patterns (Weingart. 1973) with those of a reference collection of possible prey species.

Scat contents will be reported as frequency of occurrence (% of total scats in which an item was found) and percent occurrence (number of times a specific item was found as percentage of all items found).

RESULTS

The trapping effort totalled 3.899 nights, with an overall trap success of 0.26%. We trapped cats 23 times, but in 13 instances the animals escaped prior to immobilization. Five snow leopards (three males and two females) were radio-tagged (Table II).

Contact with male 01 was lost before males 02 and 03 were radio-tagged. The latter may have been litter-mates, though they were not recorded travelling together; they were judged to be nearly three years old at capture. Cats 02. 03, 04, and 05 were tracked over a common time period, although contact with male 03 was lost at the time the first female was collared. Cat 05 is the presumed daughter of adult female number 04 as they associated for three days, a month before 04 gave birth to a litter of at least two cubs. The daughter's age at capture was estimated at 18-22 months. Cat 04 was Judged to be at least four years of age, and nipple coloration and size indicated she had previously given birth.

Radio - tracking

The five snow leopards were relocated a total of 711 times using radio-telemetry (Table III). Eighty-two percent of the relocations were assigned within an area of less than 50 ha (good and fair locations) and the remaining 18% to fixes in excess of 50 ha. Except for 01. we tracked each Individual over two successive years.

Movements

Snow leopards were found in a different place on 72% of all consecutive days located (N=232, data from five leopards pooled).

The mean minimum distance (straight-line) moved between consecutive days ranged from 0.85-1.61 km (Table tV), excluding stationary locations (i.e., individual at a known or presumed kill-site, or one that otherwise remained stationary). Males moved slightly further than females, but the difference was not significant (Mann-Whitney U=7547; P>0.057).

Table n. Snow leopards captured in the Langu Valley.

Cat No	Age /Sex	Weight (Kg.)	Body Length (cm.)	Tail Length (cm.)	Capture Date
0 1	Adult M	50-55 (Est)	na	96	3 Apr 82
02	Subadult M	28	114	98	15 Dec 82
03	Subadult M	34	102	90	1 May 83
04	Adult F	39	113	96	23 Mar 84
05	Subadult F	21	96	69	30 Apr 84

na = not measured

Table m. Radio-location data of tagged snow leopards.

Cat No.	Age/Sex	No. of locations	No. of days located	Mean Interval (days) between locations	Percent days contacted
01	Adult M	36	28	3.61	27.7
02	Subad M	222	199	1.77	56.3
03	Subad M	75	69	2.70	37.1
04	Adult F	245	206	1.47	68.0
05	Subad F	133	109	2.43	41.1
Total		711	611		

Males moved an average of 1.16 km during the same day (N=13; S.E.=±0.40 km; min=0.20: max=5.65; all males pooled), and females an average of 0.64 km (N=27; S.E.=±0.10 km; min=0.22; max=2.25: both females pooled). No differences in same day movements between the sexes was found (Mann-Whitney U=803; f>0.300). The average distance moved by a snow leopard of either sex was 0.81 ±0.15 km (N=40). Several observations of tagged and untagged cats indicates that actual distances moved are considerably greater, because snow leopards follow a *zig-zag* route in travelling about their home range.

Home Ranges

Table V shows the home range size and dimensions for the five radio-tagged snow leopards, based on the minimum area polygon method of Mohr (1947). Home range size varied widely between the five individuals, from about 12 to 39 square kilometers. Actual home range size for snow leopard 01 is definitely substantially greater than our estimate shows, but the estimates for cats 02 and 04 appear reasonably accurate.

The ranges of the five cats overlapped almost entirely, both between and within sexes (Figure 3). In early 1984. two young adult males (02 and 03). a subadult female (05) and at least one adult female (04) shared the central part of the study area; the presence of pug-marks indicated the presence of at least one and probably two or three uncollared subadults. as well as at least one large, but apparently widely roaming adult male. The two young males (02 and 03) shared a common range for about a year, until one (03) presumably left the area.

Using the Dixon-Chapman algorithm, we computed 75% and 30% activity isopleths for four cats, based on the entire period they were monitored. Figure 4 illustrates the home area polygon, activity isopleths, and all loci in relation to the Langu River and permanent streams for cat 02. In all cats, a relatively large number of locations were concentrated into a relatively small part of the home range. None of the radio-tagged leopards was located south of the Langu River, although it would have been possible for them to cross during winter.

The 30% isopleth (activity contour) best defined the core area of use. and these overlapped extensively between individuals of the same and different sexes (Figure 5). A relatively high percent of home range use (42-60%) occurred within the 30% isopleth, which encompassed only about 14-24% of the total home range. Although these areas overlapped greatly among the cats, use was temporally separated. The harmonic mean activity centers of the four snow

leopards were located within a distance of two km of each other, and were situated near the confluence of the Tillisha gorge with the Langu River-an area of abundant snow leopard sign with a relatively high prey population. Differing patterns of core area use were related to reproductive condition and age (Jackson and Ahlborn, in prep.).

TABLE IV. Linear Distance between locations of radio-tagged snow leopards on consecutive days

Cat No.	Sex	N	Mean Distance + S.E. (km)	Mm	Max
01	M	12	1 .61 + 0 .31 . - 5	0 .30	3 .37
02	M	68	1 .31 + 0 .13	0 .21	4 .74
03	M	19	0 .95 ± 0 .13	0.22	2 .15
04	F	88	1 .09 ± 0 .11	0 .22	6 .72
05	F	45	0 .85 ± 0 .09	0 .24	2 .35
	Males	99	1 .27 ± 0 .10	0 .21	4 .74
	Females	133	1 .01 ± 0 .08	0 .22	6 .72
	All cats	232	1 .12 ± 0 .06	0 .21	6 .72

N = number of consecutive day locations.
S.E. = standard error; stationary locations (<200m) are excluded.

TABLE V. Home range size of five snow leopards In the Langu Valley, based on the minimum area method of Mohr (1947).

Cat No .	Sex	Minimum Area (km^2)	Length (km)	Width (km)	Ratio width to length	No. of Locations
01	M	11.7	8.8	1.5	5.9	26
02	M	22.7	8.1	3.9	2.1	143
03	M	11.7	6.4	2.6	2.5	51
04	F	38.9	10.8	5.7	1.9	167
05	F	19.7	9.7	2.6	3.7	99
Mean ± S.E.		20.96 ± 4.98	8.76 ± 1.34	3.26 ± 1.47	3.21 + 1.35	

Mean based on all cats: S.E. = standard error

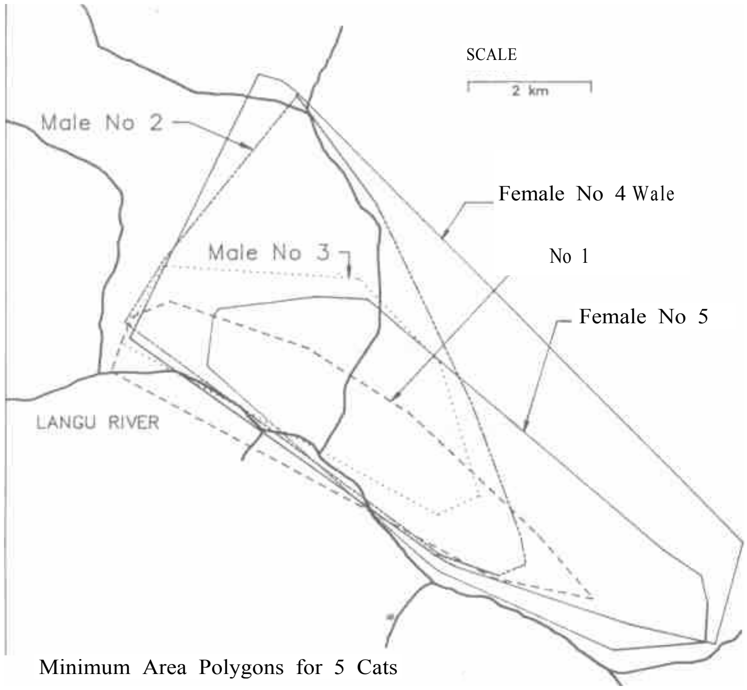

FIGURE 3. Minimum area polygons for five radio-tagged snow leopards.

Sociality

Although snow leopards utilized a common space, they were separated tempo rally, confirming the species' solitary social structure.

Figure 6 shows the frequency distribution for mean linear distance between cats of the same and different sexes on the same day. A significant difference was detected in distances between the same or different sexes (Kruskal-Wallis=8.91: df 2; P<0.012).

Vocalizations ("yowling") were heard on seven occasions, primarily in winter (January-March), the presumed mating season. The calls carried long distances, over the roar of the Langu River. Yowling was more frequently heard in 1984. when 04 was in estrus, suggesting it plays a role in enabling mating pairs to locate one another. Most yowling occurred in the late evening (especially 7-10 p.m.) and around midnight. In one three-hour period, 25 yowls were heard, apparently made by an adult male. In another instance, cat 02 yowled, followed by another individual shortly afterwards. The incidence of yowling was greatest in late February.

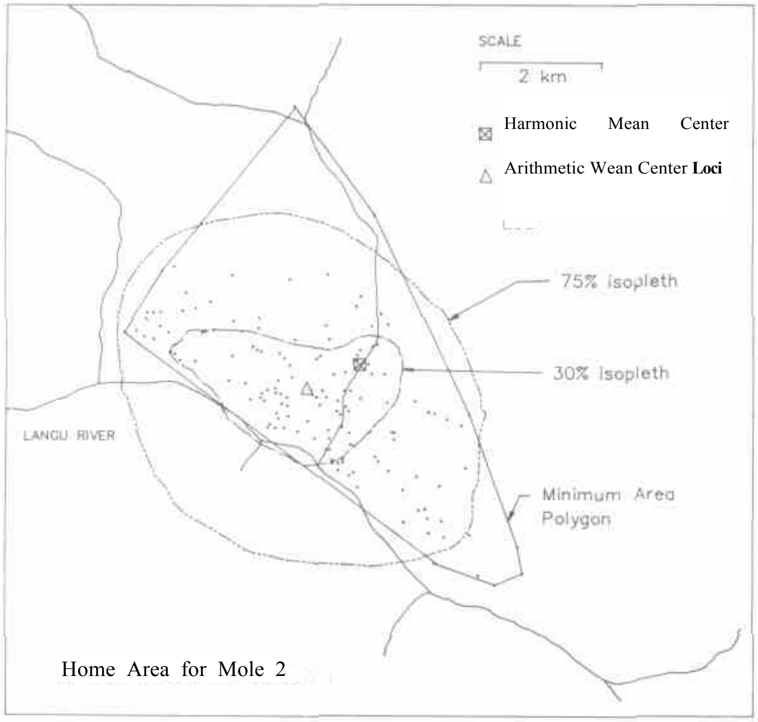

FIGURE 4. Home area for male 02. showing all loci, minimum area polygon, activity centers and perennial streams.

Activity Pattern

The Langu snow leopards are primarily crepuscular, being most **active** around dawn until 9 or 10 a.m., and then again in the late afternoon and early evening. However, activity during midday is not infrequent. Male activity (x^2=36.231; df=3; P<0.001) was significantly different from expected for the four time intervals, **with** greater than expected levels of activity during the dawn and dusk periods and **less** than **expected** during the daytime **interval. Female** activity **(X^2=l 1.223; df=3;** P<0.005) differed **only** for the dusk period, when **they were** more active than expected. **Over** the 24-hour period, males were active for 45.6% and females for 55.9% of the time. Some seasonal differences may exist, but this awaits further analysis.

Preferred bedding sites are located on or near ridges, cliffs and other sites with good vistas. While the cat often selected prominent features, **such** as a large rock outcropping, it seemed to rest at the **base** rather than on the top. These features, promontory in nature,

provided shade as well as a close-by vantage point from which the cat could survey the area after it became active. Snow leopards also rested under low Juniper bushes or the edge of low outcropping rock strata.

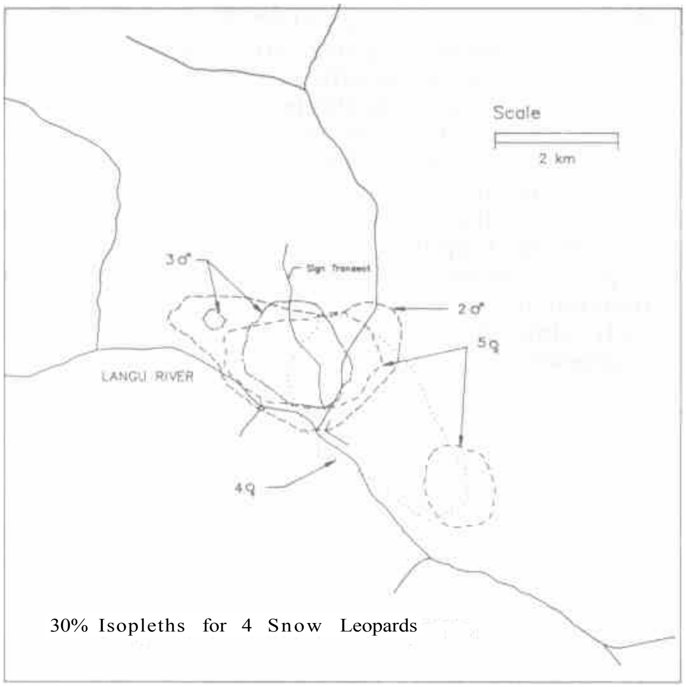

FIGURE 5. Overlapping core areas for four snow leopards, showing perennial streams and the permanent sign transect.

Food Habits

Bharal are the primary large prey of snow leopards in the Langu, although Himalayan tahr are taken as well. Subadult snow leopards, weighing an estimated 20 kg are known to kill fully grown male bharal weighing over 55 kg. indicating that snow leopard can subdue prey up to nearly three times their weight. Preliminary scat analysis indicates that they also consumed small rodents and plkas, as well as game birds.

Four hunts were observed, all unsuccessful. Three involved a bharal and one a tahr as Intended victims. Only 12 kills were found (excluding domestic stock kills), which could be reasonably attributed to snow leopard: five tahr and seven bharal. All but two were adults,

and of a sample of ten, six were males and four females. Forty-five percent of the kills were made in relatively cover-poor, even terrain. with the remainder about evenly distributed between cliffs (landform type 5), broken (type 2) and other landform types (types 9. 10) (Table I). Snow leopards kill with both nape and throat bites. After eviscerating their kill, they seem to start feeding on the rump. No evidence was found of snow leopards covering the remains of their kill, as has been reported for mountain lion. While an adult bharal provides sufficient food to keep a single cat occupied for three to five days or more, cat 04 and her two cubs consumed an adult female bharal in less than 48 hours. There is circumstantial evidence to suggest that bharal are more easily approached from above and that bachelor male herds are less wary than herds with females and young. Not only is the snow leopards' camouflage superb, but they are remarkably adept at concealing themselves despite poor cover. Given their short, muscular limbs, it is reasonable to presume that they must have to approach relatively closely before launching their final attack if they are to be successful.

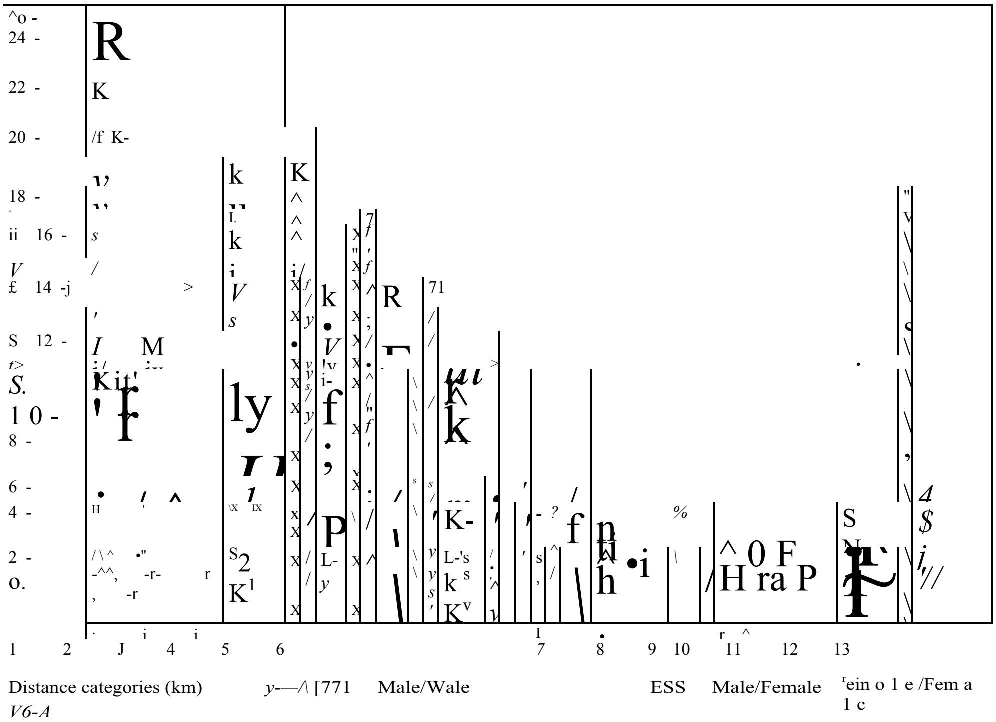

FIGURE 6. Frequency distribution (percent) for linear distances (km) between male and female snow leopards on the same day.

Habitat Use Patterns

The null hypothesis that snow leopards used habitat components in proportion to their availability was rejected. Both sexes showed a significant under-use or avoidance of less steep slopes (<35 degrees) and an over-use or preference for slope categories in excess of 40 degrees, a trend most pronounced in females. Snow leopards significantly over-utilized cliffs (landform type 5) while under-utilizing even-surfaced terrain [type 4). Levels of use increased as the brokenness of the terrain increased from type 4 through types 2 and 3 to type 5. clearly reflecting the snow leopard's preference for bedding in broken areas (Figure 7). This trend was more marked in females, but there was no significant difference between the sexes.

Males and females seemed to select bedding sites where the closest landform type consisted of a landslide, rockfall. river bluff or terrace and river bed more frequently than expected by chance alone. A significant under-utilization of cliffs in this case reflects the likelihood that the leopards are already using a cliff within the immediate area.

Snow leopards appear to show a strong affinity for terrain and vegetative edge situations; they occurred within 25m of an edge significantly more than expected by chance alone, while significantly under-utilizing all categories further from an edge.

When not bedded on a cliff, they tended to occur within 50m of such a landform type significantly more than expected by chance alone, further attesting to their preference for edge situations and broken terrain. Sites where the nearest cliff was more than 125m (females) and 150m (males) away, were significantly under-utilized. When not bedded in even terrain (landform type 4), male and female snow leopards occurred within 25m of such a type significantly more than expected. Females significantly under-utilized sites that were more than 125m from the edge, with males

under-utilizing sites more than 150m away.

Both sexes significantly under-utilized areas with northerly aspects (NW through NE). while over-utilizing sites with a south-westerly aspect. Use of elevations above 4,200m was significantly less than expected by chance in both males and females; both sexes showed significant use of the lower elevational categories (below 3,600m).

DISCUSSION

Snow leopards of the Langu Gorge inhabit extremely precipitous, rugged terrain characterized by a diversity of surface ruggedness types or landforms, and a high amount of available habitat edge and juxtaposition. Surface ruggedness and structural diversity increases progressively from slightly undulating through moderately broken terrain with distinct ridges and gullies to cliffs. Numerous small cliffs are well in-

terspersed with large expanses of undulating or broken terrain. Throughout the study area there were more linear landforms, such as river or stream-beds, riverine bluffs and terraces, and rockfalls or landslides.

All radio-tagged cats showed a significant preference for cliffs and areas with slopes in excess of 40 degrees. They occurred within 25m of a terrain or vegetation edge significantly more than expected by chance alone. Use of sites increased as the degree of terrain bro-kenness increased, clearly reflecting the cat's preference for broken areas. Use of elevations in excess of 4,200m was significantly less than expected, with most use occurring below 3.600m. In the Langu, cliffs are frequently located above or beside even surfaced terrain preferred by bharal. the principal prey of snow leopard. Such a spatial relationship presumably offers benefits to snow leopard in terms of the detection, stalking and killing of prey. These areas are characterized by improved visibility, generally adequate cover in the form of rocks and/or shrubs, and an increased probability that bharal may be bedded or feeding nearby [Jackson and Ahlborn, unpubl. data).

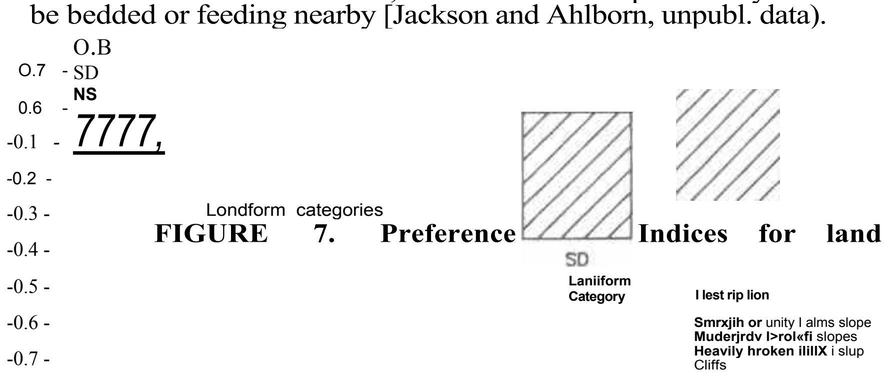

FIGURE 7. Preference Indices for land form types used by snow leopards in the Langu Gorge (NS=not significant; SD=slgnificantly different, P<0.05).

Snow leopards are highly mobile, changing their locations from one day to the next, unless on a kill. Given the precipitous terrain, it is hardly surprising that they tended to move an average of only a kilometer or less (straight-line distance) between consecutive days; nonetheless, they were able to cover linear distances of nearly seven km in a single night and morning. Actual distances moved are greater than the data indicate, as all cats often travelled circuitous, *zig-zag* routes.

While the Langu leopards were primarily crepuscular, they not infrequently shifted their bedding site several times during the daytime. Preferred bedding sites tended to be located on or near ridges, cliffs and other sites with good vistas. Freeman (1975) reported that captive snow leopards prefer to rest in elevated sites. A high proportion of bedding sites were situated along repeatedly travelled corridors: all radio-tagged individuals showed a strong preference for moving along major ridgelines, bluff edges, gullies and the base or crest of broken cliffs. Most social marking also occurred along these linear topographic features (Ahlbom and Jackson, this volume).

Home range size averaged 21 km^2, with considerable variation between individuals. These estimates fail to account for surface area due to substantial topographic relief, which likely increases the actual home range size by 20-30%. Langu snow leopards occupy notably smaller home ranges than those reported for the puma *Felis concolor.* another solitary felid of mountains (Anderson, 1983; Seidensticker et al., 1973). The total yearly home areas are roughly comparable to those reported for the common leopard Panthera pardus in Kenya (Hamilton, 1976). Sri Lanka (Eisenberg and Lockhart, 1972), Zimbabwe (Smith, 1978) or Nepal (Seidensticker et al.. 1985).

Home areas of four collared snow leopards overlapped almost entirely between individuals of both sexes, in contrast to the generally exclusive male ranges shown by other large solitary cats like the leopard, tiger or jaguar. Although the male sample was comprised largely of individuals just entering adulthood when collared, they used the same area over the two-year period that they were monitored (Figure 6).

There is no evidence from this study that snow leopards are territorial. Resident cats visited most parts of their ranges at intervals of a few days to two or more weeks; on rare occasions, they crossed their ranges in a single 24-hour period, while at other times they remained in small areas for a week or more. Typically, they remained in a general area for several weeks before shifting to another part of their home area. Rabinowitz and Nottingham (1986) reported a similar pattern in Jaguar. The collared snow leopards did not occupy distinct winter or summer ranges. Some authors (for example Novikov, 1962 and Roberts. 1977) have reported seasonal movements in snow leopard occupying more severe climates, like the Tien Shan of the USSR and the mountains of Pakistan. Fox et al. (this volume) suggested that some leopards in India may move to regions of low snowfall during

winter. Since bharal do not exhibit significant winter-summer movements, there is no need for snow leopard to shift their range seasonally. Winters in the study area were relatively mild with little accumulation of snow on the primarily southerly aspects.

On a typical day, Individual snow leopards were nearly two kilometers or more apart. Further evidence of the species' essentially solitary nature accrued from pugmark tracking. Data from this study do not confirm the observations of Dang (1967) and others that pairs regularly hunt together.

Despite their solitary nature, the Langu snow leopards shared activity centers with conspecifics of both sexes: however, occupancy was staggered temporally. Mutual avoidance appears to be facilitated by scent-marking, scraping and the deposition of other sign, which presumably identifies the particular snow leopard, its sex, relative age and reproductive status, and thereby possibly conferring some home area "ownership right" over periods of time. Judging by the intensity of use of core-areas, the large amount of overlap between different individuals, and the relatively small total home areas, it is remarkable that the tagged cats managed to remain on average more than 2 km apart. These observations suggest the Langu snow leopards were actively avoiding one-another. While all showed a special preference for the area around the confluence of the Langu River and Tillisha stream. visitation was temporally separated. It is probably no coincidence that significantly more markings were observed in the overlapping core area (Ahlborn and Jackson, this volume).

Different home range and land-tenure patterns may be found in snow leopard populations inhabiting areas where terrain, habitat, prey abundance and seasonal availability, and level of human disturbance differ from our study area. For example, studies in less favorable habitats may indicate greater spatial separation between individuals.

The Langu snow leopard population is a dense one, suggesting that it represents prime habitat for the species. We estimated that the study area supported at least five to ten cats per 100 km^2, excluding cubs. This compares very favorably with estimates of 0.66 per 100 km^2 in Ladakh (Mallon, 1984) and 1.2 per 100 km2 in Shey (Schaller, 1977), both more arid and higher areas inhabited by man and wolves. The degree of co-existence and sharing of habitat shown by the Langu snow leopards is presumably only possible because of the relatively dense bharal population, the brokenness of the terrain and the fact that snow leopards tend to use common areas at different times.

If any observation is striking, it is that the Langu snow leopards found enough food. Preliminary indications suggest that snow leopards are opportunistic predators. Presumed bharal kills (derived from stationary locations of more than two days) are separated by relatively long time periods, suggesting that the use of supplementary prey may be important in meeting the cats' overall energy requirements. We are presently examining the hypothesis that prey availability is greatest in core areas, which provide an optimal combination of foraging areas.

cliffs, broken terrain, increased edge and juxtaposition of habitat types.

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