CONSERVATION OF THE MARKHOR IN KASHMIR

Yash Veer Bhatnagar, PhD, ISLT India Program & Nature Conservation Foundation Charudutt Mishra, PhD, ISLT India Program & Nature Conservation Foundation Riyaz Ahmed Peerzada, Field Officer, Wildlife Trust of India

Pranav Trivedi, Head, Education & Outreach, ISLT India Program

R. Raghunath, Scientific Officer, GIS, Nature Conservation Foundation

Rahul Kaul, Director, Wildlife Trust of India

Nature Conservation Foundation, 3076/5, 4th Cross Gokulam Park, Mysore 570002, Karnataka, India, Tel: +91 821 2515601, Fax: +91 821 2515601, Email: yash@ncf-india.org, Website: www.ncf-india.org

Abstract

Markhor (*Capra falconeri*) is a globally threatened species with very few remaining populations. Its population may number merely 300 in Kashmir, its only habitat in India, where it is confined in three or four small populations. The largest of these is in the Kaj-i-nag range that is in the western part of Kashmir, on the northern bank of the Jhelum and adjacent to the disputed border between India and Pakistan (along the Line of Control or the LoC). The species, in spite of its conservation significance, hasn't yet received its due in terms of research and conservation inputs. We thus initiated this project to obtain factual information on the species in Kaj-i-nag in order to find the critical requirements in terms of space, habitat and diet. We also attempt to document the species' ecology in general and identify the extent of its threats and means of mitigating them. The ultimate aim of the project is to use this scientific information to prepare and implement an effective species recovery program.

We used observational methods such as regular monitoring along trains and vantage points so as to maximize coverage to obtain information on markhor and livestock. We obtained information on the local people and the nomadic herders and their dependence through interviews and official records.

We estimated 63 ± 19 markhor in the Limber catchment with a preponderance of females year round (2: 50% in all seasons). Adult males formed a low proportion of the population but increased slightly to *c.* 20% during the rutting period. The Limber catchment thus appeared to be especially important for females. Our data suggests that the sexes remained separate in all-male and female-young groups year round, although some mixed sex groups formed during the winter rutting period. There was little spatial overlap in the 50% core zones calculated for the all-male and female-young groups during all seasons, and especially during summer, when the males spread out into other areas. The females were largely confined to the security of steep slopes and proximity of cliffs (escape terrain) in relatively open canopied areas of the Rambra cliffs in the Viji nala all through the year. Males however used areas somewhat farther from cliffs and on less steep slopes, but used areas with higher canopy cover. There were no clear differences in the use of shrub cover, grass cover and elevation between the sexes. Males got more difficult to locate during summer but making extra effort at tracing them showed that some of them moved into the adjacent catchments of Lacchipora and Naganari that were more disturbed with human activities.

The alpine and sub-alpine parts of Limber catchment are used by 15 *bakkarwal* households who rear close to 7,000 sheep and goats during summer. Looking at the annual range and especially the summer range of markhor and the zone of influence of these *bakkarwals,* it is apparent that the markhor are excluded from the sub-alpine and alpine tracts not only in the productive summer season, but during the rest of the year also. An important part of our future study will include further quantification of the mechanism of this exclusion.

Preliminary information on the socio-economic profiling of the local inhabitants suggests that over half of their income was from non-timber forest produce such as mushrooms and medicinal plants, which was followed by collection of walnut. Agricultural produce was primarily for sustenance. This illustrates the multi-pronged threats to the small region that houses the best population of markhor, which may be the only option to save the species in the state and country. There are tremendous pressures from the nomadic herders throughout summer and the local villagers depend on the region for extraction of precious produce and other biomass for consumption. The episodes of insurgency related activities also causes significant disturbance in the area and as discussed elsewhere, the fencing erected at the Line of Control between India and Pakistan has bisected markhor habitat in Kaj-i-nag. While it may be difficult to address the national security issues in this project we aim to find means of alleviating threats from herders and biomass extraction in the near future. We also intend to set up awareness programs for the army and local population to forge a better understanding of the issues of the region among these critical stakeholders. Some interaction with these groups is already underway.

Background and Introduction

Markhor is a highly endangered species (IUCN Red List (2000), Schedule 1 of the Indian Wildlife (Protection) Act (1972) (Anon., 2002)) occurring in the rugged tracts of the Hindu-Kush-western Himalaya, with a very small remnant population left in Indian controlled Jammu and Kashmir where the 'Pir Panjal type' (*Capra falconeri cashmiriensis*) is reported. No information on the species was available since late 1940's, when it came primarily from British hunting records. Citing local informants Schaller and Khan (1975) suggested that close to 200 markhor may be surviving in Kashmir but Roberts (1997) suggested that markhor may have gone extinct in Kashmir. However, based on a brief survey Sohail and Baba (2002) confirmed that markhor are present in south Kashmir, however details of status and exact occurrence were still not available. An important reason for this absence of information was the *c.* 15 years of political unrest that halted even developmental work in the state. With improving political climate our team took the very first opportunity to initiate a collaborative survey in 2004- 05 that included the state's Wildlife Department and the Indian Army, to document the range-wide status and distribution of the markhor (Ranjitsinh *et al* 2005). Markhor are found in three Wildlife Sanctuaries (WS) and one Conservation Reserve (CR), in all covering *c.* 252km^2, a range reduction of *c.* 33% since 1947. Our surveys found relatively large markhor populations only in the Hirpura and the Limber WS. These and other parts of the Kajinag range (Lacchipura and Naganari) are where close to 200 markhor are tenuously surviving (Ranjitsinh *et al.* 2005). A variety of threats to the species were identified, foremost among which were competition with livestock and insurgency related disturbances to the area. The other threats being faced by markhor in J&K were identified as - continued poaching for trophy and meat, increasing fragmentation of the population due to the new fencing that has come up at the Line of Control (LoC) with Pakistan, and lack of awareness among locals and officials. Recognizing the immediate threat to the survival of the markhor, we proposed to start a conservation program in J&K to ensure its survival. The first among these steps was to document the basic ecology of the species and undertake targeted awareness programmes.

In strife torn Kashmir, wildlife conservation had taken a back seat for many decades. However, with improving political situation, conservation efforts are again gathering pace. Markhor is certainly an apt flagship species for catalysing conservation in the mountain tracts that will help not only the species, but the entire range of wildlife of the region that includes the western tragopan, musk deer and brown bear. We believe that the Kaj-i-nag range is the last hope for the species and a thorough understanding of the species' habitat and diet selection, relationship with local human usage and threats from poaching and the military operations will be a critical link in formulating a thorough conservation strategy for this area, and in fact for any chances of a recovery in its erstwhile range.

Our work has thus three components – 1) focussed research on the species 2) awareness programmes for the local population, policy makers and military and 3) formulation of interventions and a Species Conservation Action Plan. While the research aspect is the primary focus during the first two years of the project along with some headway on the awareness programmes, the interventions and action plan shall be initiated during the third year.

Apart from the remoteness and previous lack of development, the area suffered substantially during the earthquake that rocked PoK and parts of J&K in 2003-04. Following the earthquake and with returning peace in the Valley, developmental pressures are increasing drastically. A classic example is the high powered approval, against environmental concerns, of the Mughal Road though the Hirpura WS. This road, that will connect Srinagar to Rajouri, will most likely result in the final extinction of the small population of markhor in Hirpura, which doesn't number more than 50 at present. There is tremendous developmental pressure in Kaj-i-nag too for roads, and especially limestone mining. Under such circumstances, it is important to know the present seasonal occurrences of markhor, and especially the areas that may be critically important for them, so that these are afforded the highest legal protection and kept out of the burgeoning exploitation of the area. The important aspects that thus need further investigation are seasonal markhor distribution, especially if there are any seasonal 'core' or critical areas, habitat and food requirements, the levels of local use by pastoralists and villagers and the level of extant threats. It is also important to have a clearer understanding of the potential range of the species based on its present habitat and identify other potential areas and corridors that can support markhor. An understanding of all these factors will be essential in preparing a conservation program designed to allow continued existence of markhor. Based on these needs the objectives of the present phase of the study are stated as:

1. To study the seasonal occurrence and habitat usage of markhor.
2. To study the degree of competition between livestock and markhor in terms of use of space, habitat and forage.
3. To identify other potential areas for initiating markhor conservation work using spatial analyses.
4. To develop and implement focussed awareness programs for locals, migratory herders (*Gujjars* and *Bakerwals*), policy makers and the military.

Study Area

The study was conducted in Jammu and Kashmir that has three geo-political regions – the southern Jammu, the northwestern Kashmir and the northeastern Ladakh region. Our study sites consist of a vast stretch of Himalaya from Pader- Kishtwar to Poonch in Jammu region and Hirpura (in south Kashmir) to Kaj-i-nag and Shamshabari (in north Kashmir) in the Kashmir region (Fig 1). This region lies in the North-West Himalayan Bio-geographic zone (2A) (Rodgers & Panwar 1988). The vegetation in general is Temperate Coniferous and Sub Alpine Forest (Champion & Seth 1968).

The Pir Panjal Range roughly runs from south Kashmir to north Kashmir and separates Poonch and Rajouri in the Jammu region from the Kashmir region. The Poonch and Bhaderwah-Kishtwar lie on the southern slopes of this range in the Poonch and Doda districts, respectively, while the other areas are in the Kashmir region, on the northern slopes of the Pir Panjal. The Kaj-i-nag and Shamshabari are on the northern banks of the Jhelum. Poonch is connected with Hirpura of district Pulwama in south Kashmir through the Mughal road that passes over the Pir Panjal and it is also connected with Gulmarg in district Baramullah of north Kashmir.

Temperature varies from a minimum of -10^0 C in winter to a maximum of 30^0 C in summer. The precipitation is mainly brought by Westerly disturbances during winter and falls largely as snow, and is undoubtedly a factor of importance in determining the type

of forests in these tracts. The four distinct seasons in the region are: Spring (March to May), Summer (June to August), Autumn (September to November) and Winter (December to February).

The selection of the study area was based on a survey done by our team in 2004-2005 (Ranjitsinh *et al.* 2005), which was the first such assessment since independence. This work drew heavily on earlier surveys in the area (Burrard, 1925; Stockley, 1936) and specially an antique *shikar* map of the Kashmir Valley (Survey of India, 1947). We identified six blocks to survey in the vast Pir Panjal range of the state covering *c*. 400km from, east to west. The six survey blocks were Poonch, Hirpura, Gulmarg-Bonyar, Kaj-i- nag, Shamshabari and Bhaderwah-Kishtwar (See Ranjitsinh *et al.* 2005 for maps and other details). In all we counted 155 markhor, bulk of which (85%) were sighted in the Kaj-i-nag range, thus we selected this as the site for further intensive studies.

Kaj-i-nag Range:
Kaj-i-nag occupies the north bank of Jhelum and consists of three Protected Areas, from west to east - the Lachipora WLS, Limber WLS and Naganari Conservation Reserve (Figure 1), that served as our study areas. The Kaj-i-nag ridge separates these sanctuaries from the Hundwara – Shamshabari area towards the north. The area is *c.* 70 km to the west of Srinagar along the Jhelum River.

Limber WLS:
Limber WLS was notified in 1987 and encompasses an area of *c.* 44 km^2. It is bounded to the north by Bhurji forest in Langet Forest Division, south by the River Jhelum, east by Katha Forest and west by Islamabad nala. Along the west, it is connected with the Lachipora WLS and along the east with Naganari Conservation Reserve. Limber WLS is fed by three main nallahs, Gamalitter, Mithwani (or Viji nala) and Grat nar, which form the Limber nallah below the Babgail village, which in turn drains into River Jhelum (Fig 1). The area consists of steep and moderately steep slopes broken by rocky cliffs at many places.

Lacchipora WLS:
Lacchipora WLS, which is about 93km^2 in extent was also notified in 1987 and lies immediately west of the Limber WLS. It is bounded in the north by Kakua Forest in Langet forest division, south by Maidan Forest, southeast by River Jhelum, west by the cease-fire line (LoC) and east by Bagna and Limber forests. Three main nalas, from east to west, that drain this Sanctuary are the Gujjar nallah, Malangan nallah and Ghoretal nallah. It encompasses the catchment of Katha Nilang, which flows into the River Jhelum. The entire area is steep and broken by precipitous cliffs. The Lacchipora Village is very large both in terms of its population (176 households) and spread.

Naganari Conservation Reserve:
Naganari Conservation Reserve is about 20km^2 and lies to the east of the Limber WLS and the topography is also similar.

Security concerns due to militancy pose a major hurdle in our working; however we are managing with close liaison with the Indian Army about our movements in the field. Access into the Lacchipora area is very restricted as most of this valley is right on the disputed LoC with Pakistan. We try to maximize our coverage of this valley as and when allowed by the Army. The Limber valley thus formed our intensive study area.

The Vegetation types in Kaj-i-nag covering the three sub-blocks were Western Mixed

Coniferous Forests (12/C1d), West Himalayan Sub Alpine Birch/Fir Forests (14/C1b), Deciduous Sub Alpine Scrub Forests (14/1s2) and Sub Alpine Pastures (14/DS1) (Champion & Seth 1968). The dominant species in temperate coniferous forest were spruce (*Picea smithiana*), fir (*Abies pindrow*) and *kail* pine (*Pinus wallichiana*) with occasional deodar (*Cedrus deodara*) in lower slopes. Birch (*Betula* sp.) is the dominant species in sub alpine forest and juniper (*Juniperus* spp.) in the sub alpine scrub. Other plant species include walnut (*Juglans regia*), rose (*Rosa macrofolia*), *and Viburnum grandiflorum*. Lachipora was in general more open canopied compared to Naganari and Limber.

People and their livelihoods

The people in the study area are primarily Muslims. Most of them are agriculturists and the main crop is maize. Paddy is also cultivated in lower hills and plains. Livestock consisting of sheep and goats, buffaloes, horses, oxen and cows are reared as an important source of income. Walnut is one of the main cash crops grown here, while apple is also important in places. There are numerous *Gujjars* and *Bakkarwals*, traditional pastoralists, who come into various parts of the area with their livestock during summer. The *Gujjars* primarily herd buffaloes and the *Bakkarwals* herd sheep and goats.

Kashmir has a human population of 5,441,341 and a large proportion live in the Baramulla district (1,166,722) (Anon. 2003). There is no clear estimate of the number of families or the population of migratory herders coming into the area. The local villagers and forest staff reported that the number of the latter has increased over the years in the region as with militancy monitoring by various departments had stopped and areas were occupied by the herders.

Methods

Markhor and livestock were observed from 13 trails (1-5km), 5 vantage points and 3 vantage trails (a series of vantage points) spread in the study area in a manner so as to maximize coverage. These were repeated at least thrice every season during the period of maximum activity in early morning and evening [Seasons identified were spring (1 April – 15 May), spring-birth (16 May – 15 June), summer (16 June – 31 August), autumn (1 September – 31 November) and winter (1 December – 31 March)]. All observations were plotted on a map and data was recorded on the group composition and habitat in a 30m radius circle around the point of maximum aggregation of the group as given on Table 1. Each trail took 2-4 hours to walk. Vantage points along some trails were set up at places that offered a vast view. In these places *c.* 20 minutes was spent to look for sightings of wildlife and livestock.

During the summer of 2007 an added effort was made to locate males that were rarely sighted during this season in 2006. Locating male markhor after segregation (see below) becomes difficult as the group size becomes smaller and they seem to use denser areas. We hence surveyed most of the Kaj-i-nag area (Limber WLS, Lachipora WLS, and Naganari CR) more intensively through transects (trails) and vantage points to locate males. In all 25 transects and 10 vantage points were laid covering most of the study. Twenty of the transects and 8 of the vantage points were repeated four times whereas the other 5 transects and 2 vantage points were visited only twice. We spent about 468 hrs on the transects and vantage points to scan the area.

Further, features such as elevation, aspect, slope and ruggedness were calculated for each sighting from the Digital Chart of the World Digital Elevation Model (DEM). Aspect being a

circular variable, was converted into a continuous one based on the deviation from north, where each aspect value would reflect the distance, in degrees, from due north. The full set of transformed values would thus range from 0 to 180 (Jenness 2007). This option has the advantage of maintaining a constant interval between units, such that the difference in direction between 0 and 1 degree is the same as the difference between 90 and 91 degrees and to some extent reflects the degree of insolation received at a site. Ruggedness was estimated as Slope and Aspect Ruggedness Index (SARI) (Jepsen *et al.*, 2005). SARI combines the attributes of slope and aspect (terrain) heterogeneity to give high index values where the terrain is simultaneously rugged (heterogeneous) and sloping, intermediate values in rugged and level areas and lowest index values in flat terrain and very steep (but less heterogeneous) slopes. From the digital maps we obtained two raster grids of slope and aspect. Based on the slope raster we calculated slope heterogeneity as the standard deviation (SD) of slope (SLSD) in all 8 pixels adjacent to the one being calculated. The integer values of the aspect grid were calculated in a similar manner as (ASPSD). Based on the SLSD and ASPSD raster layers we calculated SARI as ($SLSD_s$ * $ASPSD_s$)/ ($SLSD_s$ + $ASPSD_s$) following (Nellemann and Fry, 1995).

Table 1: Data recorded on markhor at each sighting. The same habitat variables were recorded at every livestock sighting too.

Variable	**Details & classes**
Age-sex composition	Male (Class I, II, III & IV), Adult female, Yearling, and kid
Coordinates (plot on a map)	Longitude and Latitude in decimal degrees read off from the mapped location
Vegetation type	Physiognomic vegetation types
Terrain type	Based on topographic features of slope smoothness or ruggedness
Vegetation cover	For the tree, scrub and ground layers as % estimate in the 30m radial plot
Slope	In degrees (5°interval)
Aspect	In 8 directions as N, NE, E, SE, S, SW, W & NW
Distance (and direction) to escape terrain	In meters. Direction of availability of the cliff w.r.t. the sighting noted in any of the 8 directions as top, top-right, right, etc
Altitude	In meters read off the map

Spring is a time when the area is still snow covered and markhor are mostly confined on the lower southern slopes, and thus is an ideal time for monitoring their numbers. In the spring of 2007 we conducted a census of markhor in the Mithwani nala of the Limber catchment dividing it into two blocks – the Safed Frash-Chemb and the Dragen-Pahal Pather blocks. Teams of two monitored these blocks on three consecutive days to obtain mean counts of animals in the area.

Analysis

Descriptives were used to study population size and structure. Proportions were used to study seasonal occurrences of group types (all male, female & young and mixed sex groups) and seasonal differences were identified using chi square tests. Principal Component Analysis (PCA) was used to explore use of variables by markhor and livestock in a multivariate scenario. For continuous variables groups were compared based on univariate tests and for ordinal variables, chi square test was used.

We adapted the 'Home Range' concept to look at seasonal ranges of categories of sightings

such as for the all-male groups and female-young groups. The 50% and 90% polygons were generated for each category using Kernel method in ArcView®. The overlap index between a pair of such groups was calculated using the formula: $(A_o/(A_f+A_m))X100$, where A_o is the area of overlap, A_f is the area of the female polygon and A_m is the area of the male polygon. Further, using these polygons we extracted the attributes – elevation, slope, aspect and ruggedness (SARI) for each of these polygons. For each season then the 50% polygon of each group type were compared using the binary logistic regression in SPSS. This suggested the characteristics that separated the seasonal ranges of the group types under discussion.

Results

Population size and structure

During the 3-day census in April 2007 in Limber, we obtained a mean estimate of 63.5 ± 19.5 markhor in the catchment (Table 2). Adult females dominated in the area with 36.2 adult males to every 100 females. However given that this was a post-winter period, there were relatively high female to young (82.8 young to 100 adult females).

Table 2: Population estimate for Limber catchment in spring 2007 based on block counts. The observed age-sex composition is also given.

Block				**Males**							
	Females	**Kids**	**Yearlings**	**CI**	**CII**	**CIII**	**CIV**	**Total**	**Mean**	**SD**	**SE**
Safed fresh - Chemb	43	26	5	0	3	4	2	83	27.7	5.5	3.2
Dragen-Pahal Pather	15	8	9	3	0	6	3	44	14.7	9.3	5.4
Overall	58	34	14	3	3	10	5	127	63.5	27.6	19.5

Seasonal Population Structure

Between April 2006 and August 2007, 1505 markhor were sighted in 321 groups. Of these 1472 could be classified yielding a female biased population - 29 adult males to 100 adult females. There were further 65.6 young to every 100 adult females. Looking at the seasonal age-sex structure (Table 3) also it is evident that the area primarily comprised of females with adult males largely absent from the area during all seasons, except autumn and winter, the period during and preceding the annual rutting season.

Table 3: Seasonal age-sex structure (in %) of markhor in the Limber-Lacchipora study areas during 2006-07. The number of classified animals in each season is given in parenthesis.

Age-Sex class	**SPRING (432)**	**BIRTH (326)**	**SUMMER (428)**	**AUTUMN (62)**	**WINTER (224)**
Adult female	50	56	50	63	49
Kids	25	31	30	10	18
Yearling	11	10	4	8	4
Adult males (unclassified)	0	1	0	2	0
Ad. Male Class I	1	1	7	2	1
Ad. Male Class II	4	0	6	3	9
Ad. Male Class III	5	0	1	10	13
Ad. Male Class IV	4	2	2	3	6

Markhor occurred in moderate sized groups (mean±SE, 4.69±0.25) overall. The largest groups occurred in summer (6.53±0.7), followed by spring (4.77±0.4), birthing (4.42±0.4), winter (3.63±0.48) and autumn (2.75±0.3) ($F= 5.29$, $p< 0.001$).

Sexual Segregation

Sexual segregation is seen at the level of spatio-temporal overlap, and proportion occurrence of single-sex groups. Similarly a high proportion of mixed-sex groups suggests a lack of segregation.

While males and females (& young) associated in single sex groups in all seasons, mixed groups were seen only during winter (38.7%) and few in autumn (2.2%) (Table 4). This suggests that there was aggregation of the sexes primarily in the rutting period (December-January) and the immediate period preceding and following it. During the remaining part of the year the sexes stayed apart.

Table 4: Seasonal proportion occurrence of group types in Limber study area (2006-07). Seasonal sample sizes are given in parenthesis.

Group type	**Spring** (91)	**Birth** (76)	**Summer** (68)	**Autumn** (24)	**Winter** (62)	**Overall** (321)
All Male	20.9	5.3	27.9	25.0	25.8	19.9
Female - Young	75.8	89.5	63.2	66.7	35.5	67.9
Mixed	2.2	0	0	0	38.7	8.1
Unclassified	1.1	5.3	8.8	8.3	0	4.0

Given the fact that segregation was prevalent throughout the year we looked at the seasonal ranges of these group types to identify whether the trend was true for the use of space too (Figure 2 a toe). This exercise also revealed that the 'core' of use of all- male and female-young was entirely different in summer, with merely a 1% overlap (Table 5), and the overlap in the other seasons was also low. This also revealed that during winter and autumn when mixed-sex groups also occurred, the all-male groups used areas where females occurred to a relatively higher degree. Females continue to use almost the same areas around the Rambra cliffs of Viji nala year round, while male groups separated out, into adjacent valleys especially in summer (Figure 2).

Table 5: Seasonal range used by all-male groups and female-young groups and their proportion overlap.

Season	50% Polygons (km^2)			90% Polygons (km^2)			Overlap @	
	Male	Female	Overlap	Male	Female	Overlap	50%	90%
Autumn	0.27	0.24	0.04	0.78	0.94	0.94	7.9	54.6
Spring	0.33	0.38	0.17	1.12	0.31	0.31	23.6	21.8
Birth	0.33	0.20	0.03	1.04	0.83	0.38	5.9	20.4
Summer	0.87	0.49	0.01	2.91	1.98	0.26	0.9	5.4
Winter	0.36	0.56	0.15	1.17	1.92	1.01	16.5	32.8

Since there was substantial spatial separation between male groups and female-young groups, we investigated whether they differed in habitat use trends also. Below we first describe the general seasonal trends in use by markhor and then compare the use by the all-male and the

female-young groups.

Habitat Use

PCA extracted 4 components that explained 65% of variation. As per the communality values, grass cover (0.783), followed by shrub cover (0.756) and elevation (0.690) were most important in explaining this variation. The other variables were in the following order – slope (0.668), distance to escape terrain (DTET, 0.653), aspect (0.614), tree cover (0.557) and ruggedness (0.527). The factor loadings of the variables on the four components suggests that the component 1 is the security component (with high loadings from slope, DTET and aspect), component 2 primarily denotes elevation, component 3 denoted the food axis (with high loadings for grass and shrub cover) and finally the component 4 that relates to tree cover and ruggedness (Table 6).

Markhor primarily used secure sites close to escape terrain (cliffs) which were steeper areas and on the southern slopes (higher transformed aspect values) during all seasons (Figure 3 a-c). During summer there were a small proportion of groups that descend to lower slopes and used areas that were not so steep and were far from escape terrain.

These areas were also on the northern slopes (Figure 3a). Use of higher ground cover and shrub cover was substantial year round, but was more so during the summer season (Figure 3b). The use of tree cover and ruggedness didn't vary much during the entire year (Figure 3c).

We will now look at the use by markhor in terms of actual values and classes of habitat used. Although seasonal differences were there (Chi sq, $p<0.05$), markhor consistently used areas with low tree and shrub cover, and high ground cover values year round (Table 7a).

Markhor occurred year round on steep slopes, close to cliffs on middle elevations (Table 7b). During spring, birthing and summer they tended to stay on steeper slopes closer to cliffs compared to the winter and autumn season, when they occurred farther from cliffs and on comparatively less steep slopes.

Table 6: Rotated Component Matrix for the PCA. These values relate to ordinations given in Figure 3 & 4.

Variable	Principal Component			
	1	2	3	4
Slope	**.755**	-.070	.104	.287
Aspect (transformed)	**.662**	.270	-.179	-.265
DTET	**-.565**	.518	.028	.254
ELEVATION	.002	**.829**	-.002	.055
Grass cover (SQRT)	-.026	.094	**.853**	.215
Shrub cover (SQRT)	-.012	-.142	**.723**	-.461
Tree cover (SQRT)	.041	.092	.004	**.739**
Ruggedness	-.201	-.487	.008	**.500**

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 13 iterations.

Seasonal differences:

Table 7: Seasonal use of habitat variables by markhor. (a) Seasonal use of the tree, shrub and ground cover by markhor.

		SEASON					Total
	Class (%)	AUTUMN	BIRTH	SPRING	SUMMER	WINTER	
Tree cover *Chi square = 19.23, p=0.01*	<20	62.5	72.4	68.1	50.0	72.6	65.7
	21-40	25.0	18.4	30.8	39.7	24.2	28.0
	41-100	12.5	9.2	1.1	10.3	3.2	6.3
	Total	*24*	*76*	*91*	*68*	*62*	*321*
Shrub cover *Chi square = 26.25, p=0.001*	<20	70.8	81.6	87.9	75.0	95.2	83.8
	21-40	20.8	18.4	12.1	17.6	4.8	14.0
	41-100	8.3			7.4		2.2
	Total	*24*	*76*	*91*	*68*	*62*	*321*
Ground cover *Chi square = 25.29, p=0.001*	<20	12.5	7.9	5.5	1.5	19.4	8.4
	21-40	20.8	17.1	14.3	5.9	21.0	15.0
	41-60	66.6	75.0	80.2	92.6	59.7	76.7
	Total	*24*	*76*	*91*	*68*	*62*	*321*

Table 7(b): Seasonal mean (SE) for some habitat variables.

Season (N)	Slope (°)	DTET (m)	Elevation (m)
Spring (91)	54.7 (1.9)	19.2 (3.8)	2707.8 (19.3)
Birthing (76)	60.3 (1.7)	15.3 (4.1)	2766.4 (20.8)
Summer (67)	56.0 (2.1)	27.7 (5.7)	2754.9 (20.2)
Autumn (25)	51.0 (2.2)	77.8 (16.7)	2744.2 (33.9)
Winter (62)	47.5 (2.2)	88.7 (15.7)	2787.1 (27.9)
Overall (321)	54.6 (0.9)	38.0 (4.1)	2749.6 (10.4)
F & p value (1-way ANOVA)	*5.568,<0.001*	*14.998, <0.001*	*1.953, 0.101*

Differences in use by the sexes

With the above background of seasonal differences, we return to look at the patterns of use between the sexes using the same PCA analysis (Table 6), now ordinating based on the group types. A large proportion of all sightings of both sexes, year-round were concentrated in the steep, southern aspects closer to cliffs (Figure 4a). However, all- male groups show some dispersion towards less steep areas, on northern aspects and farther from cliffs at lower elevations. The use of high shrub and ground cover was common to the sexes (Figure 4b), however males clearly tended to use areas with greater tree cover that were more rugged (Figure 4c). They also moved out of the Limber catchment during the peak of segregation in summer into the adjacent areas that clearly had greater pressures.

These trends are clearer when we look at the use of actual values and categories. All groups predominantly used areas with lower tree and shrub cover, and higher ground cover (Table 8a). All-male groups however used areas with moderate tree cover relatively more than the other group types.

The female-young groups were mostly confined to steeper slopes closer to cliffs (Table 8b) compared to the all-male groups. The mixed sex groups occurred farther from cliffs compared with both other group types.

Table 8: Use of habitat variables by different group types of markhor (a) Use of the tree, shrub and ground cover by markhor group types.

Group Type (N)	Tree Cover (Chi Square=13.6,			Shrub Cover (Chi Square=4.51, p=0.34)			Ground Cover (Chi Square=9.68, p=0.05)		
	< 20	21 - 40	41 -	< 20	21 - 40	41 - 100	< 20	21 - 40	41 - 100
All-Male (64)	53.1	43.8	3.1	79.7	20.3	0.0	14.1	6.3	79.7
Female-Young	68.8	23.9	7.3	83.9	13.3	2.8	6.0	16.5	77.5
Mixed (26)	80.8	19.2	0.0	88.5	11.5	0.0	11.5	23.1	65.4
	66.6	27.6	5.8	83.4	14.6	1.9	8.1	14.9	76.9

Table 8(b): Seasonal mean (SE) for some habitat variables.

Group Type	Slope (°)	DTET (m)	Elevation (m)
All-Male (64)	45.2 (1.9)	70.6 (9.9)	2766 (28.1)
Female-Young (218)	57.7 (1.1)	21.3 (3.4)	2739 (11.6)
Mixed (26)	47.5 (3.8)	107.9 (28.9)	2830 (43.3)
Total	54.2 (0.9)	38.9 (4.3)	2752 (10.8)
F & p value (1-way ANOVA)	*17.24, (<0.001)*	*26.57,(<0.001)*	*2.97, (0.05)*

Comparison of seasonal ranges of all-male and female-young groups

Spatial overlap between the all-male groups and female-young groups was least in summer, followed by birth and autumn (Table 5). Here we compared their 50% ranges in terms of four habitat attributes (elevation, slope, aspect, and ruggedness) to identify which of these variables contributed most to separate the two groups (Table 9). In all seasons, elevation, ruggedness and aspect predicted the all-male and female-young groups with high degree of accuracy, the classification for summer and birthing season was especially efficient.

Table 9: Logistic regression coefficient values in seasonal comparison of all-male and female-young groups using 'Forward: Wald' method. The step in which the variable was entered is also indicated.

	Logistic Regression Coefficient (b)				**Predicted Correct %**		
Season	**Elevation**	**Ruggedness**	**Aspect**	**Slope**	**Male**	**Female**	**Overall**
Summer	-0.03 (Step1)	-2.365 (Step3)	0.258 (Step2)	-	97.4	95.4	96.7
Autumn	-0.01 (Step1)	-	0.113 (Step2)	-	72.2	79.4	75.7
Winter	-	1.206 (Step1)	-	-	51.1	81.6	69.9
Spring	-0.01 (Step1)	-0.718 (Step2)	-	-	68.9	81.1	75.5
Birth	-0.01 (Step2)	-7.258 (Step1)	-	-	95.1	88.9	92.6

Interactions between markhor and livestock

The two types of herders grazing in Kaj-i-nag are the nomadic *Bakkerwals*, who come from Rajouri and Poonch districts of Jammu region and the other group that includes the locals. The migratory herders own and rear mainly goats but most of them also rear some sheep of the local people to earn additional cash. Bakerwals graze the livestock in the sub-alpine and alpine meadows. There are about 15 *bakkerwal* families with about 5000 goats of their own and about 2000 sheep of locals grazing mainly in Gammalitter and Thulthulan areas between June and early September. In Lachipora WLS, there were five families with about 2000 goats of their own and about 500 sheep of local people.

The zone of influence of the *bakkarwals* in Limber is limited to the alpine and sub-alpine tracts and is spread over *c.* 17km^2 (Figure 5) but houses about 7,000 sheep units (SU) for about three months or 37,059 SU/km^2 annually, an intensity that can potentially have serious consequences for the ecosystem.

In addition to the above, the local herders were of two types; one who rears mainly their own cattle, called *bahak wals* and the other, who rear mainly their own sheep in addition to some from other Kashmiris. These shepherds are called *chopans.* There are about four families of *choupans* and about 25 families of *bahak wals.* The *choupans* usually use the area from June to August, while the *bahak wals* from June to October.

Markhor seemed to avoid areas used intensively by livestock during all seasons (Figure 5). The 50% polygon of use by all markhor sightings had no overlap with the zone of influence of livestock and even the 90% polygon had merely a 1% overlap.

Socio-economy

There are *c.* 170 households in the four villages of the Limber Valley with an overall population of 737 (Table 10). They own in all about 1200 *kanals* of agricultural land where they grow maize, vegetables, rajmah (a type of beans used as a pulse) potato, fodder plants and some paddy. The villagers own a total of about 780 livestock of different types that mainly include cattle and some sheep, along with others.

Table 10: Demographic information of the main villages of the Limber Valley.

Village	**#Households**	**Adult Male**	**Adult Female**	**Children**	**Agricultural Land (*kanals*)**	**Livestock**
Babgail	56	49	42	67	335	170
Boodrali	17	42	35	35	352	135
Choolan	57	93	72	149	-	249
Limber	46	73	50	30	580	225
Total	**176**	**257**	**199**	**281**	**1267**	**779**

A preliminary analysis of the income in the area shows that most of the income comes from non-timber forest produce such as the *gucchi* mushrooms, medicinal plants and walnut, together accounting for 70% annually (Table 11). Animal products such as meat and milk products comes next, followed by employment. Agricultural produce contributes some amount to their income, and is primarily for self-use.

In terms of dependence of the people on Limber, it appears that NTFP extraction is the primary need along with some amount of grazing rights.

Table 11: Important sources of earning of the local population in the Limber Valley.

Source	**Overall (Rs)**	**USD**	**%**
NTFP	353,000	8,825	55
Walnut	93,825	2,346	15
Animal products	85,920	2,148	13
Employment	59,700	1,493	9
Rajmah	19,850	496	3
Maize	19,360	484	3
Potato	8,200	205	1
Paddy	4,800	120	1
Total	**644,655**	**16,116**	**100**

Exchange @ 1 USD = Rs. 40

Discussion

Our earlier range-wide work in 2004-05 had demonstrated that markhor had declined by over 33% in the past 60 years and now numbered < 300 animals in 3-4 small populations (Ranjitsinh *et al.* 2005). The largest population detected during the survey was in the Kaj-i-nag range, and the highest contribution to this estimate was from the Limber valley. Our spring monitoring in the area, when the markhor are more confined in distribution to the lower slopes on southern aspects, suggested that there are 63±19 markhor in the area. Further it showed that the adult female to young ratio was fairly healthy at 100F:83 young.

Another fact that emerged from this exercise as well as the entire study period was that the proportion of adult males in this population was very low (<20%) although it increases marginally around the rutting season in autumn-winter (Table 3). Of the 321 sightings 68% were of female-young groups and only 20% of all-male groups. This suggests two possibilities that are not mutually exclusive. One is that this is a male depleted population due to some sex-specific threat and the other is that the Limber valley is not an ideal 'male habitat' for most of the year. During 2006 security concerns had largely confined our study are to the Limber catchment. Our survey had shown that markhor also existed in the adjacent Lacchipora and Naganari catchments, due west and east of Limber. Unless a detailed survey of these tracts is completed it is difficult to say whether the population is male-depleted. However, we could address the issue of suitability of the habitat for males.

This leads to the issue of sexual segregation. Markhor, like most other temperate ungulates exhibits marked sexual dimorphism, with the males being almost double the size of females (Schaller 1977). The 'body-size hypothesis' (Main *et al.* 1996) would predict occurrence of segregation in markhor. Our data suggests that barring the winter period adult males and females didn't occur in mixed-sex groups (Table 4) and lived separately confirming segregation. The seasonal range maps of the group types also confirms that there was little spatial overlap between the all-male and female-young groups during all seasons, especially during summer. We thus looked at the relative habitat choice of the two group types. This analysis suggests that the all-male groups used areas with more gradual slopes, farther from cliffs and in areas with denser canopy than female-young groups (Table 8). Female-young

clearly used the security of cliffs on steeper slopes during all seasons, but especially during the parturition and summer season that followed (Table 8). The body size hypothesis for segregation also predicts that the males should prefer areas with higher forage availability, not necessarily higher forage quality. The variable on ground cover surrogates for forage quantity in our dataset, but this didn't show any differences between the group types.

Our analysis on the range attributes of the all-male and female-young groups created robust models that predicted with a high degree of accuracy. However, contrasting the actual data where elevation was not a factor separating males with females, this analysis consistently extracted elevation as an important variable along with ruggedness and aspect. We believe that the approach is very useful but needs to be carried out on data of a higher resolution than the present one where much of the heterogeneity of this extremely rugged area is lost in the 90m DEM.

The area is used intensively by a very large number of livestock as suggested by the extremely high intensity of use (37,059 SU/km^2 annually) by migratory herders. Spatially it appears that the markhor are confining to areas outside and below the zone of *bakkarwal* influence during the period of overlap (summer) as well as during all other seasons (Figure 5). The fact that the livestock grazing intensity is extremely high may have an influence not only in exploitation related exclusion of markhor in summer but also interference related exclusion due to the presence of shepherds and their dogs. The reported intensity can potentially change other habitat characteristics so as to make the area unsuitable for use during the rest of the year too. Our studies subsequently will look at the extent of competitive exclusion of markhor that may be occurring in the area.

Conservation Implications

Our findings so far illustrate the multi-pronged threats to the small region that houses the 'best' population of markhor, which may be the only option to save the species in the state and country. There are tremendous pressures from the nomadic herders throughout summer and the local villagers depend on the region for extraction of precious produce and other biomass for consumption. The episodes of insurgency related activities also causes significant disturbance in the area and as discussed in Ranjitsinh *et al.* (2005), the fencing erected at the Line of Control between India and Pakistan has bisected markhor habitat in Kaj-i-nag, thus fragmenting an already small and fragmented population. While it may be difficult to address the national security issues in this project we aim to find means of alleviating threats from herders and biomass extraction in the near future. We also intend to set up awareness programs for the army and local population to forge a better understanding of the issues of the region among these critical stakeholders. Some interaction with these groups is already underway.

Ongoing and future work

Ongoing work thus relates to strengthening research with additional data and to engage with the local community and the army in joint conservation exercises. Our research emphasis is now on expanding the area of study to include the Lacchipora and Naganari populations during all seasons; determine 'male areas' in the entire study area and find any additional populations of females; compare markhor sexes in terms of their diet and nutritional requirements so as to explain the mechanism of sexual segregation. Another area of research is to understand the entire range of impacts caused by livestock grazing in the region.

Acknowledgements

We are grateful to the funding agencies – The Rufford Foundation, the International Snow Leopard Trust and the Whitley Fund for Nature for providing the resources to carry out this study. The Chief Wildlife Warden, J & K, Mr. A.K. Srivastava and his officers, especially Mr. Parsa have been very helpful at all stages of the work. Mr. Md. Quyum, Forest Guard and other staff in the Limber WLS have always been there to help. The Field Assistants Md. Akbar and Rashid are gratefully acknowledged for all the crucial support they have provided. Villagers in the Babgail village where our base camp is located have also been very cooperative. Colleagues at NCF and WTI are also acknowledged for all their help.

References

Bhatnagar, Y. V. (2001) Species of the Trans-Himalaya and other Arid Tracts. *In.* Bhatnagar, Y.V. and Sathyakumar, S. (Eds.) ENVIS Bulletin: Wildlife and Protected Areas. Vol. 1 No. 1, 99-105

Burrard, G. (1925) Big game hunting in the Himalayas and Tibet. London: H.Jenkis.

Champion, H., and Seth, S. (1968) Forest types of India. Dehra Dun: Forest Research Institute.

Jenness, J. (2007). Some Thoughts on Analyzing Topographic Habitat Characteristics. http://www.jennessent.com.

Jepsen J.U., Madsen A.B., Karlsson M. and Groth D. (2005). Predicting Distribution and Density of European Badger (Meles Meles) Setts in Denmark. *Biodiversity and Conservation*. 14(13) 3235-3253.

Main, M. B., F. W. Weckerly and V. C. Bleich (1996). Sexual segregation in ungulates: New directions for research. *Journal of Mammalogy* 77(2): 449-461.

Prater, H. (1965) The book of Indian mammals. Bombay: Bombay Natural History Society.

Ranjitsinh, M.K. (1981) Himalayan fauna. In. Lall, J.S. (Ed.) The Himalaya: Aspects of Change. Oxford University Press, New Delhi. pp. 64-76.

Ranjitsinh, M.K., Seth, C.M., Ahmad, R., Bhatnagar, Y.V. and Kyarong, S.S. (2005). Goats on the border: A rapid assessment of the Pir Panjal Markhor in Jammu and Kashmir: Distribution, status and the threats. Wildlife Trust of India, New Delhi.

Roberts, T.J. (1997). The mammals of Pakistan. Karachi: Oxford University Press.

Rodgers, WA (1991) Techniques for wildlife census in India: a field manual. Wildlife Institute of India, Dehra Dun.

Rodgers, WA and HS Panwar (1988) Planning a protected area network in India. Vol.1. Wildlife Institute of India, Dehra Dun.

Schallar, G. (1977) Mountain monarchs. Wild sheep and goats of the Himalaya.

Chicago: University of Chicago press.

Schallar, G.B. and S.A.Khan. (1975) Distribution and status of markhor (*Capra falconeri*). *Biol.Conserv*. 7:185-198

Shackleton, D.M. (ed.) and the IUCN/SSC Caprinae Specialist Group .(1997) Wild sheep and goats and their relatives. Status survey and conservation action plan for Caprinae. IUCN, Gland, Switzerland and Cambridge, UK.

Stockley, C. (1936) Stalking in the Himalayas and northern India. London: Herbert Jenkins.

Suhail, I. and Baba, M. (2002). A report on annual animal census. Department of Wildlife Protection, Govt. of Jammu and Kashmir.

PLATES

Plate 1: A view of the Limber Valley showing the upper fir-spruce forests, sub-alpine zone and alpine meadows.

Plate 2: Sub-alpine birch-juniper forests

Plate 3: Alpine meadows in the upper Limber catchment

Plate 4: Most of the area is extremely rugged with steep cliffs

Plate 5 & 6: Bakkarwals at their camp at close to 3,000m in the sub-alpine zone.

Plate 7: Choupan or local herders at one of their camp sites

Plate 8: Areas around camps are often more intensively grazed. Here note the large number of cattle trails.

Plate 9: Bakkarwal sheep and goats in the alpine areas

Plate 10: The herders apparently suffer heavy losses to brown bear depredation, an aspect we are now investigating

Plate 11: Our field researcher, Riyaz Ahmad

Plate 12: Observing markhor in Limber

Figures

Figure 1: The study area in the Kaj-i.nag range showing the Limber (intensive study area), Lacchipora and Naganari areas. The base camp is in Babgail village.

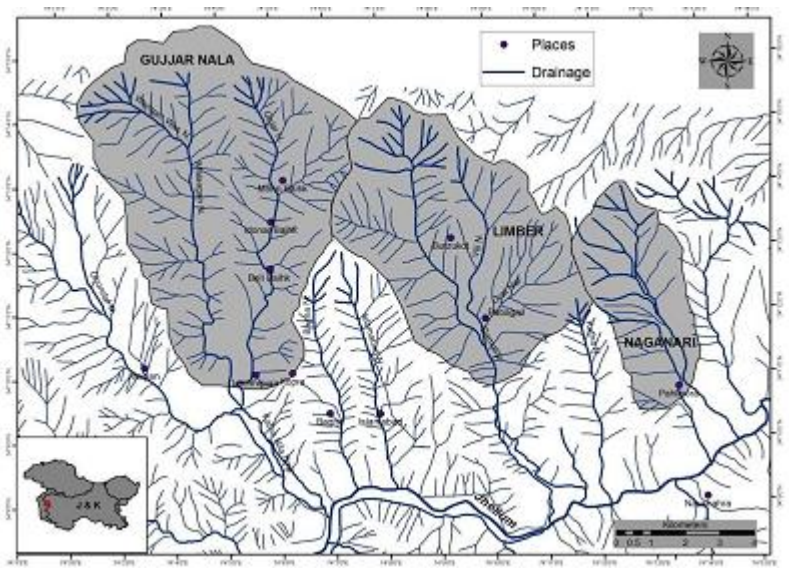
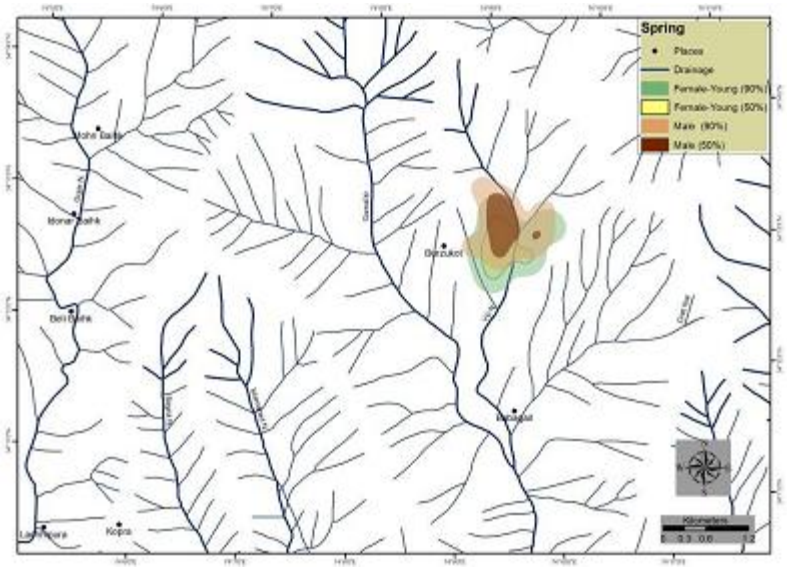
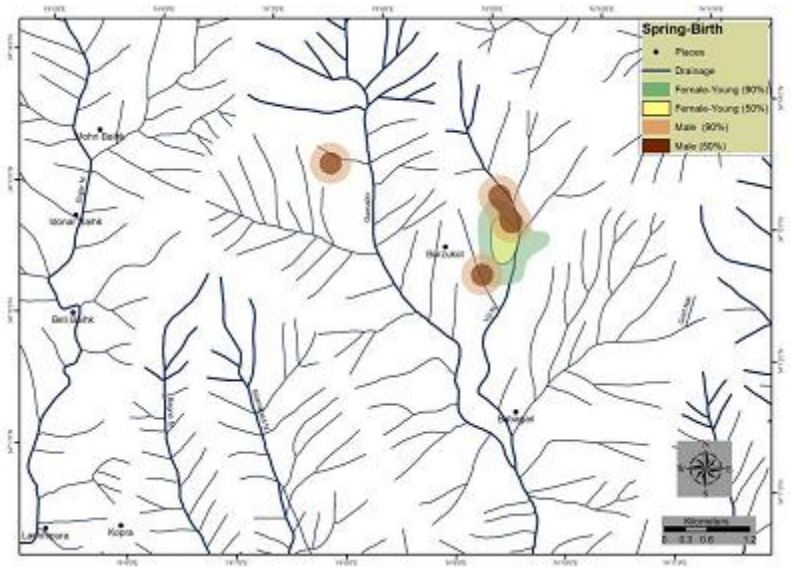


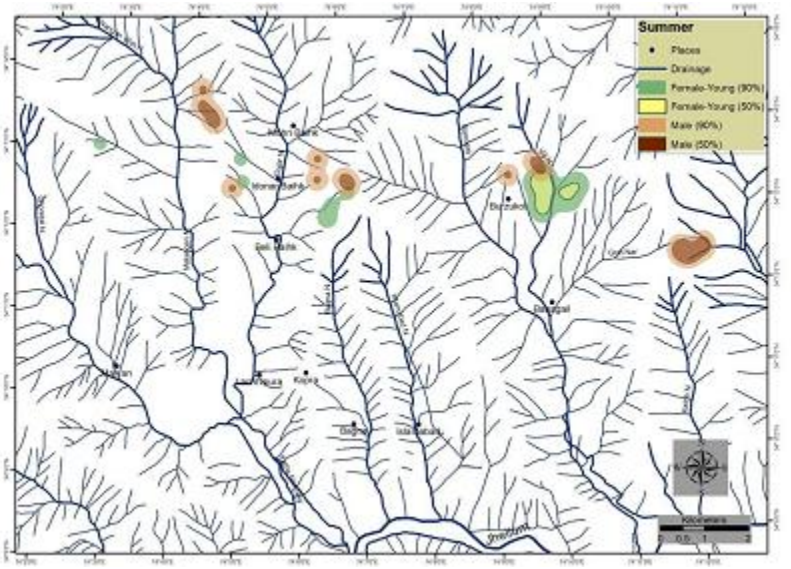
Figure 2: Seasonal ranges of males and females in the study area. The 50% polygon suggests the 'core zone' of the seasonal distribution while the 90% polygon includes much of the seasonal range. -\) Spring



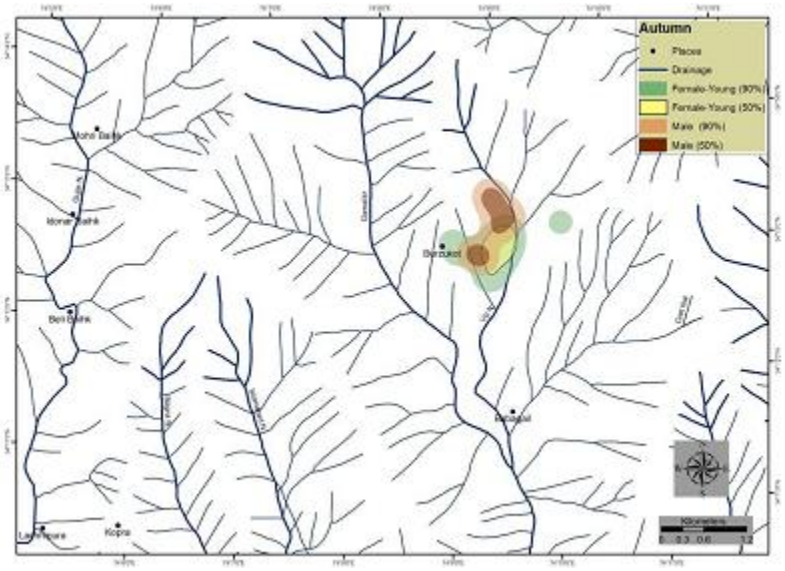
b) Birthing



c) Summer



d) Autumn



e) Winter

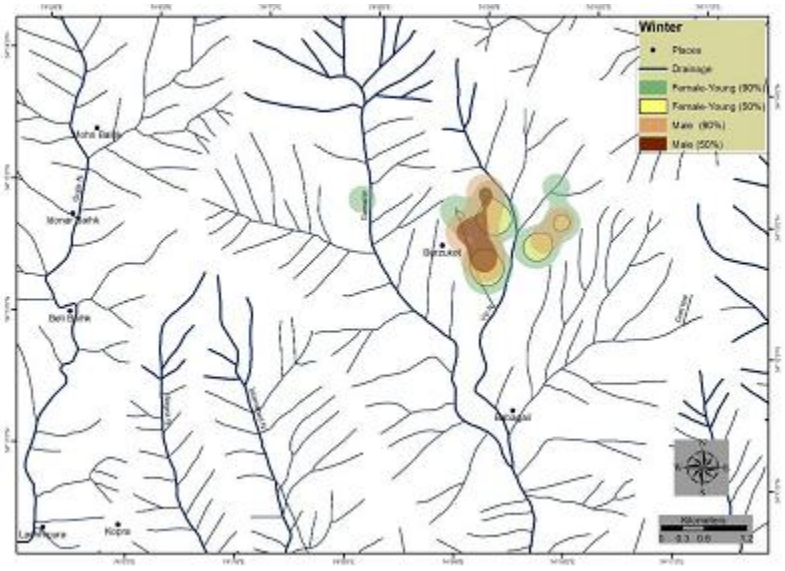
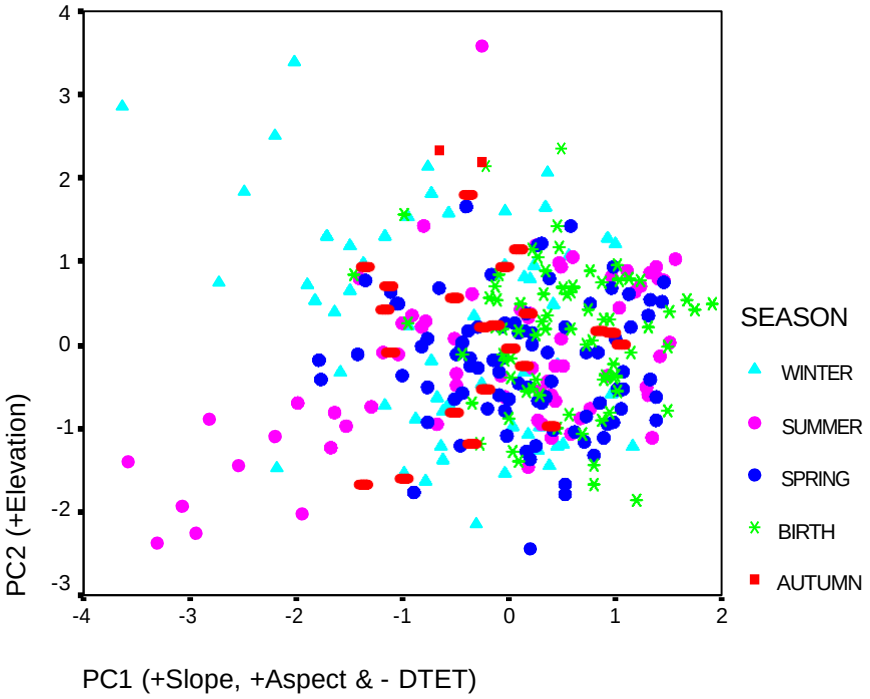
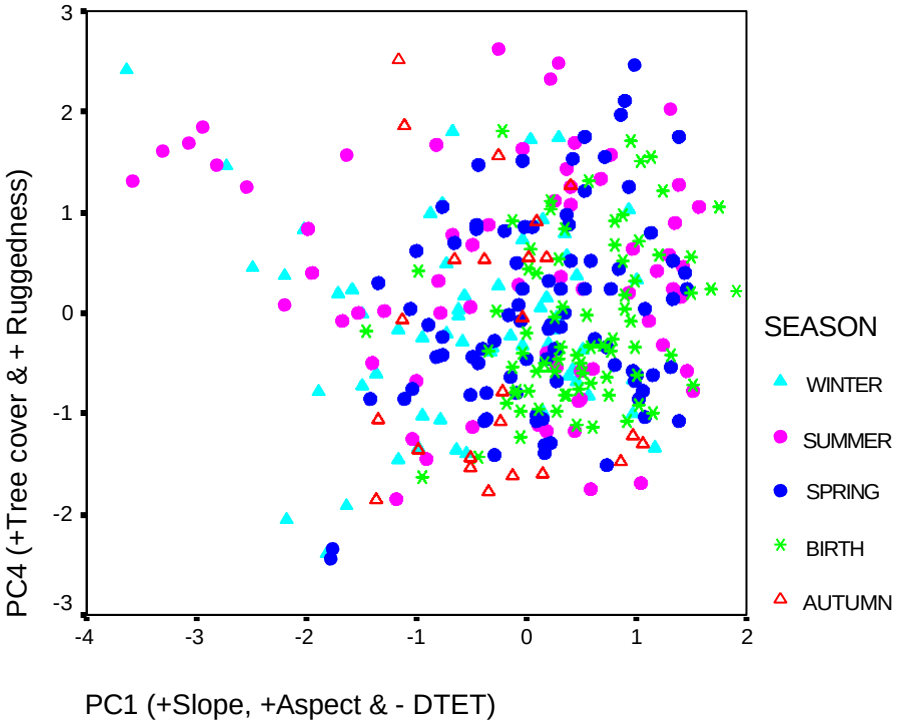


Figure 3: Co- ordination comparing seasonal use by markhor in the Limber study area



a)

b)



c)

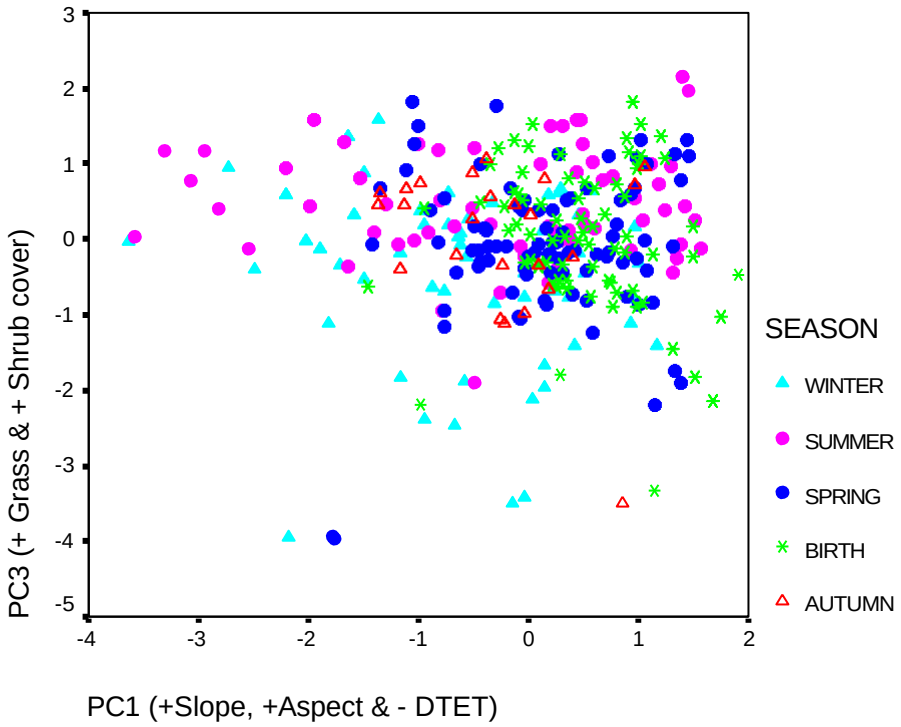
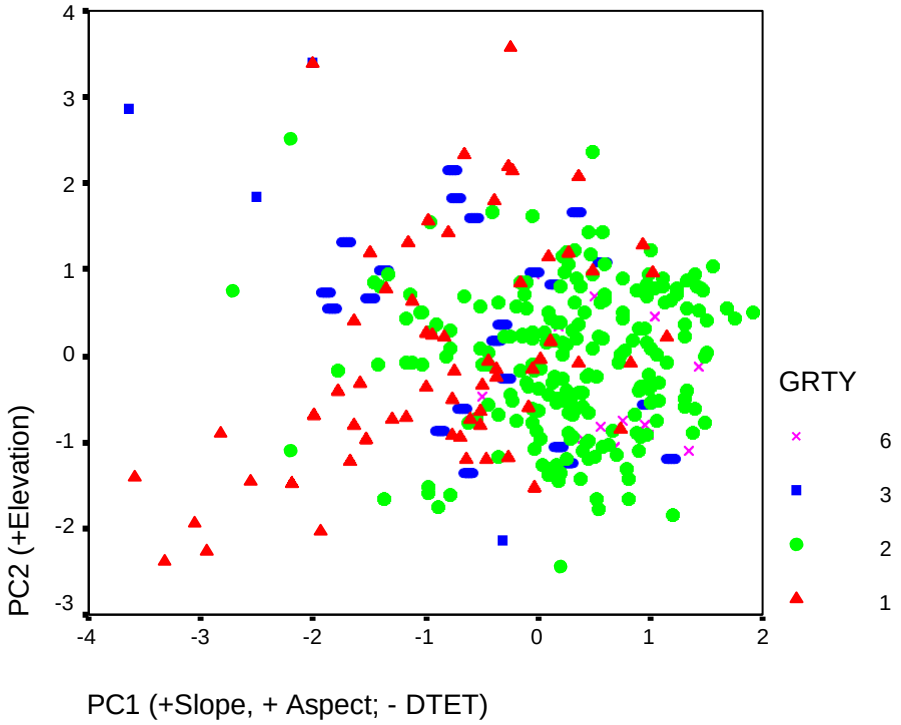
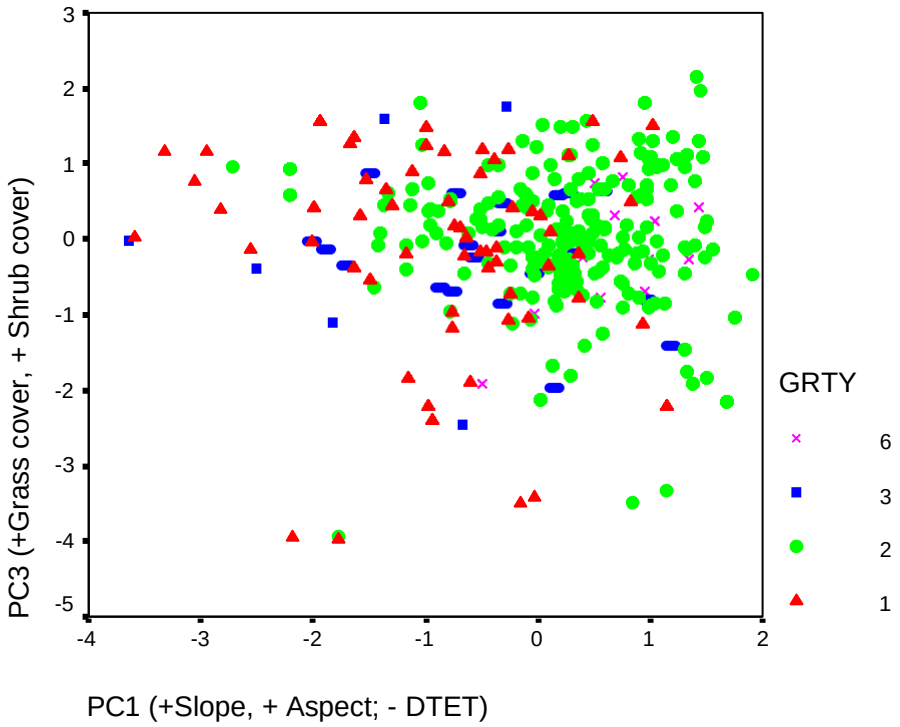


Figure 4: PC-\ ordination comparing use by markhor group types in the Limber study area

a)



b)


PC3 (+Grass cover, + Shrub cover)
3
2
1
0
-1
-2
-3
-4
-5
-4
-3
-2
-1
0
1
2
PC1 (+Slope, + Aspect; - DTET)
GRTY
6
3
2
1

c)

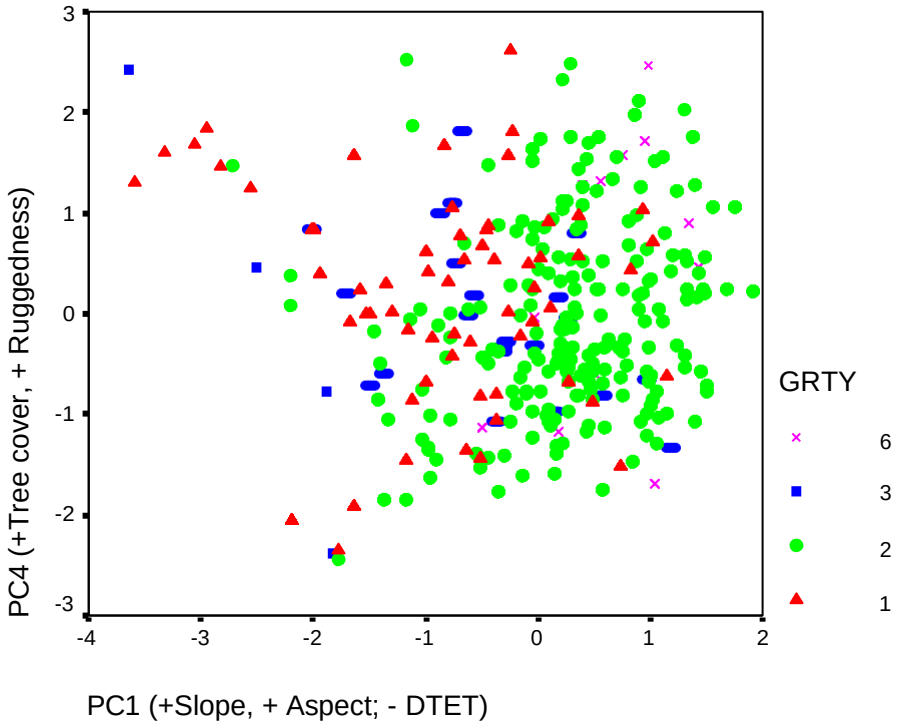
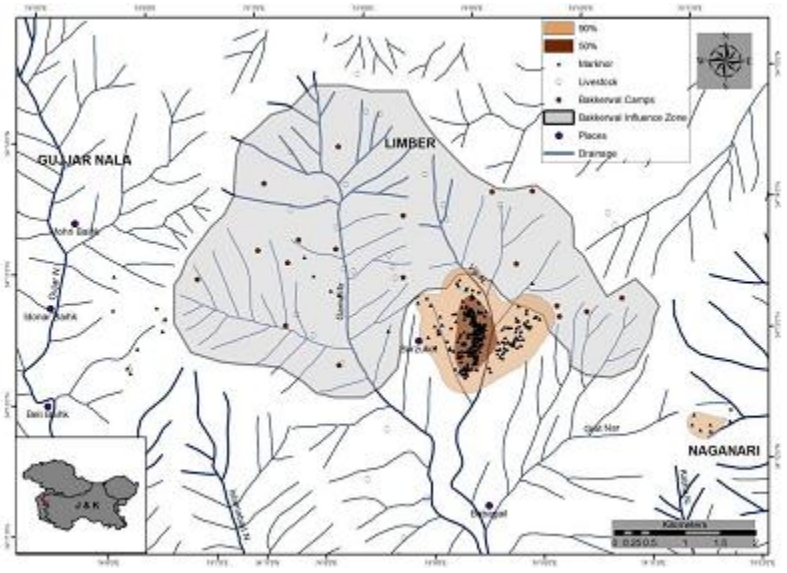

PC4 (+Tree cover, + Ruggedness)
3
2
1
0
-1
-2
-3
-4
-3
-2
-1
0
1
2
PC1 (+Slope, + Aspect; - DTET)
GRTY
6
3
2
1

Figure 5: The zone of influence of the bakkarwa!s (alpine and sub-alpine areas) in Limber and relation with (a) all markhor sightings and (b) during summer. a)



b)