RANGING AND HABITAT UTILIZATION BY THE HIMALAYAN IBEX (*Capra ibex sibirica*) IN PIN VALLEY NATIONAL PARK

THESIS SUBMITTED TO THE
SAURASHTRA UNIVERSITY, RAJKOT

FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN
WILDLIFE SCIENCES

BY

YASH VEER BHATNAGAR

WILDLIFE INSTITUTE OF INDIA
POST BOX 18, DEHRADUN
UTTAR PRADESH
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OCTOBER, 1997

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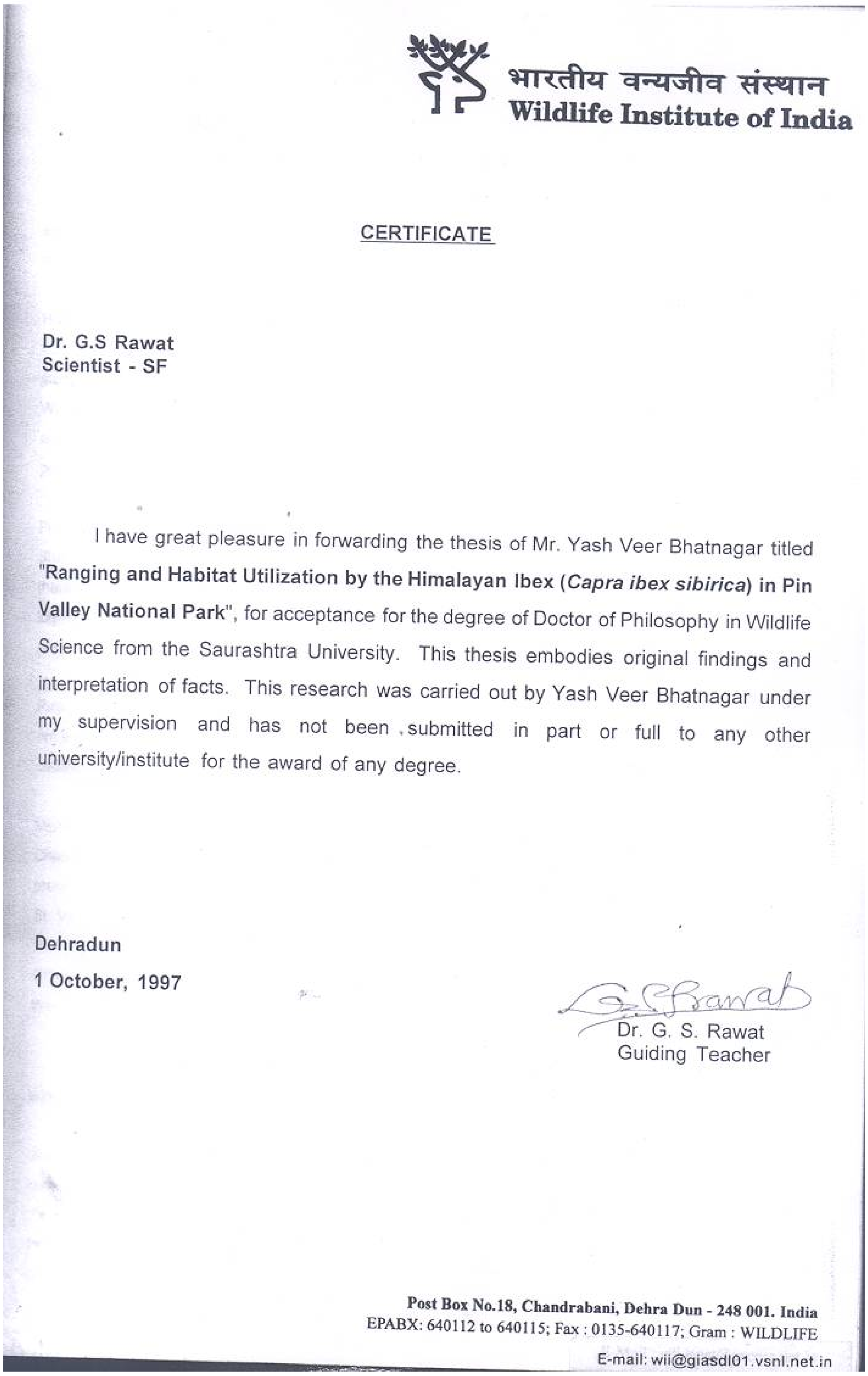

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

Dr. G.S Rawat
Scientist - SF

I have great pleasure in forwarding the thesis of Mr. Yash Veer Bhatnagar titled "**Ranging and Habitat Utilization by the Himalayan Ibex (*Capra ibex sibirica*) in Pin Valley National Park**", for acceptance for the degree of Doctor of Philosophy in Wildlife Science from the Saurashtra University. This thesis embodies original findings and interpretation of facts. This research was carried out by Yash Veer Bhatnagar under my supervision and has not been submitted in part or full to any other university/institute for the award of any degree.

Dehradun
1 October, 1997

G.S.Rawat
Dr. G. S. Rawat
Guiding Teacher

Post Box No.18, Chandrabani, Dehra Dun - 248 001. India
EPABX: 640112 to 640115; Fax : 0135-640117; Gram : WILDLIFE
E-mail: wii@giasdl01.vsnl.net.in

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YASH VEER BHATNAGAR

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CHAPTER 1: INTRODUCTION

"The high altitudes are a special world. Born of the Pleistocene, at home among pulsating glaciers and wind-flayed rocks, the animals have survived and thrived, the harshness of the environment breeding a strength and resilience which the lowland animals often lack. At these heights, in this remote universe of stone and sky, the fauna and flora of the pleistocene have endured while many species of lower realms have vanished in the uproar of the elements." So had the renowned wildlife biologist George B. Schaller ended his book on the 'Mountain Monarchs'. The Asiatic ibex (*Capra ibex sibirica* pallas) is one among the **Mountain Monarchs** that inhabit the high mountains of Central Asia and Himalaya and this thesis is about some aspects of its ecology. But first, a brief introduction to the Himalaya and associated mountain ranges where ibex live.

1.1**THE HIMALAYAN REGION**

The Himalaya stand north of the Indo-Gangetic plain spreading along a distance of *ca.* 3,000 km from the Nanga Parvat in the west to Namche Barwa in the east, and 80 to 300 km from south to north. It is bounded by the Salt ranges in the west and Indo-Burmese mountains in the east. These mountains are lower and have a north-south axis. Himalaya have a largely north-west to south-east orientation, and three parallel ranges are recognised. After the plains are the Shivaliks, foothills made of sandstone and boulders. North of this is the Middle Himalaya, consists of sedimentary, low grade metamorphic rocks. The Greater Himalaya is made up of mainly igneous rocks and is the highest mountain range in the world, with peaks such as Everest and Kanchendzonga, exceeding 8,000 m (Wadia 1967). At places the Greater Himalaya splits into more than one range as in case of the Pir Panjal range in western Himalaya. To the north-west of the Himalaya lie the Karakoram and the Hindu Kush ranges and the Tibetan plateau to the north. Some mountain ranges run parallel immediately north of the Greater Himalaya which are called the 'Tibetan Marginal Mountains' (Hagen 1970, quoted from Schaller 1977).

The Himalaya, the adjoining ranges and the Tibetan plateau have originated as a result of tectonic movements of continental plates. The Indian plate buckled under the Eurasian one giving rise to the Tibetan plateau that emerged from the bed of the Tethys sea. Crumpling of the Indian land mass gave rise to the Middle Himalaya and intrusions of magma between the continental plates formed the Greater Himalaya. Shivaliks were formed later by upheavals in the glacial debris of the ice ages (Wadia 1967). The mountain building process started in the late Cretaceous period and was intensified in the Pleistocene. It is said that the Himalaya are still growing due to continued tectonic movements (Wadia 1967).

With the formation of the Himalaya, new barriers and corridors formed which influenced the dispersal of flora and fauna. The Himalaya became the meeting point of three biogeographic realms, the Oriental, Palaearctic and the Ethiopian (Mani 1974). The high mountains provided new habitats that were occupied by newly evolved species (Schaller 1977). Most of the herbivore niches in this region were occupied by various caprinae. As a result the Himalaya and the associated mountain ranges have a rich diversity of caprinae. The region is home to 12 of 31 species (38.7 %) and 36 of 94 sub-species (38.3 %) of caprinae found worldwide, the richest in any part of the world (Shakleton 1997).

The trans-Himalaya is a vast region occurring in the rain shadow of the Greater Himalaya. The region is characterised by extreme cold and arid conditions, with stark seasonality and low plant productivity in most parts. Within India about 186,200 km² (*ca.* 2 % of geographic area) is classed under the trans-Himalayan region. This is considered to be the biogeographic zone with a minimum protected area (PA) coverage (Rodgers and Panwar 1988). Various mountain ungulates occurring in this region are specialised to survive in the highly seasonal and cold conditions. Species such as Tibetan argali (*Ovis ammon hodgsoni*), Tibetan antelope (*Panthelops hodgsoni*) and Tibetan gazelle (*Procapra picticaudata*) do not have a viable population in any Indian PA, Ladak urial (*Ovis orientalis vigni*) and Tibetan wild ass (*Equus hemionus kiang*) are found in only one PA (Rodgers and Panwar 1988). This, combined with the fragility of the trans-Himalaya, demonstrates the vulnerability of this region.

1.2 REVIEW OF LITERATURE

Few studies on *Capra ibex sibirica* exist, especially from the Himalayan region. Schaller (1977) and Fox *et. al.* (1992) have published some original work on ibex ecology in the Himalaya, and Heptner *et al*. (1966), in the Central Asian regions. Most other information eg.: Roberts (1977), Prater (1980), Sharma (1994) and Manjrekar and Bhatnagar (1997) are based on anecdotal information and museum studies. Pandey (1992) has reported ibex abundance from the Pin Valley National Park.

1.2.1 Systematic Position

Ibex (*Capra ibex*), a member of the family Bovidae, sub-family Caprinae and tribe Caprini, is a true goat species.

Simpson (1945, quoted from Schaller 1977) divided the sub-family Caprinae into 4 tribes and 14 genera. The number of species and sub-species remain disputed (Schaller, 1977). Lydekker (1913), Haltenorth & Trense (1956) (quoted from Schaller, 1977) and Heptner *et al.* (1966) recognise 9, 4 and 8 species of *Capra* respectively. Schaller (1977) has recognised 6 *Capra* species including the domestic goat, *C. hircus*. and five sub-species of *Capra ibex* (see Section 1.2.3).

1.2.2 General Characteristics

Ibex is a 'sturdy, thick-set goat' (Prater 1980). The face is short and broad with a long beard in males and a shorter one in females (Schaller 1977). It lives in precipitous terrain where it requires not speed but power. Hence they have stocky legs with robust fore limbs to climb and leap among rocks (Schaller 1977).

Ibex are sexually dimorphic and their pelage colour varies round the year. In winter adult males are a striking, dark brown with a white saddle and in some males whitish areas are also present on shoulders, abdomen, legs and thighs. A dark flank stripe is present in some animals. The whitish rump patch is surrounded by light coloured hair that extends down the back of the legs. In contrast, females have grey-brown coats with less conspicuous whites on their bodies (Schaller 1977, Roberts 1977, Prater 1980).

Ibex develop a dense under-fur of fine wool (*pashm*) during winter that enables them to withstand extremely low temperatures. Moulting occurs during spring and early summer (May - July) in most parts of it's range, after which ibex acquire a paler coat (Schaller 1977, Roberts 1977, Prater 1980).

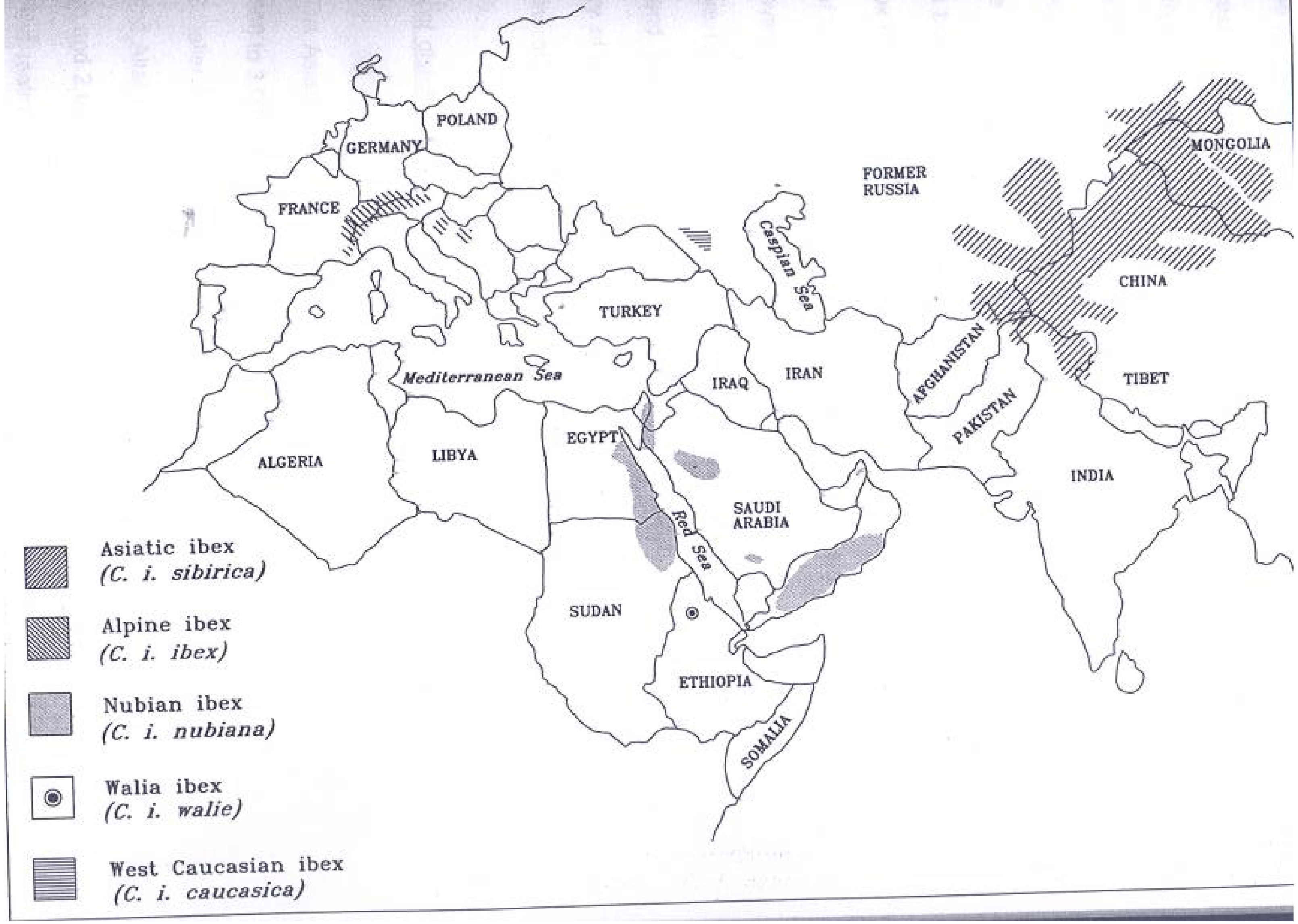
Ibex males have scimitar shaped horns with a relatively flat anterior surface, broken by prominent transverse ridges. Horns grow throughout their life, the annual horn increment declining with increasing age (Schaller 1977, Nievergelt 1981). Horns grow during spring and summer, and cease growth at the initiation of the rut. Each of the thus formed segments can be identified by a furrow which is most clear on all sides of the horn except the anterior. Usually 2 ridges or knobs are added each year on male horns between 2 and 9 years. Horn sizes of large adult males are reported to be larger in the Tien Shan region (mean 145 cm, max. 147 cm) than the Himalayan one (mean 128 cm, max. 140 cm) (Heptner *et al.* 1966, Schaller 1977). Female ibex have thin, straight or slightly diverging horns, nearly round in cross section, which lack distinct markings or ridges. They are reported to have the longest horns among *Capra* females with reports of up to 24 and 29 cm from the Himalaya and Tien Shan, respectively (Schaller 1977) and 31 cm from Pin Valley (*pers. observ.*).

An adult ibex male weighs roughly 1.5 to 2 times more than an adult female which weighs 50 to 60 kg. An adult male stands about 100 cm at the shoulder while an adult female has a shoulder height of about 70 cm (Heptner *et al*., 1966, Schaller, 1977, Prater, 1980). The weight of an ibex male head with horns may constitute *ca.* 6 to 8 % of it's body weight and the horn length is usually about 1.25 to 1.58 times longer than it's shoulder height (Schaller 1977).

Yearling males roughly equal adult females in body size and horn length but differ in having a thicker horn and a darker body. Yearling females are a little over half the size of adult females and have thin, short horns measuring *ca.* 10 to 15 cm (Schaller 1977).

Ibex, like all other *Capra*, have a potent body odour, callus on the knees and lack pre-orbital, inguinal and pedal glands. It's karyotype has a 2n chromosome number of 60 (Nadler *et al*. 1974, from Schaller 1977).

Figure 1.1: Distribution of subspecies of *Capra ibex*



1.2.3 **Status and Distribution**

Origin

Geist (1971), Schaller (1977) and Nievergelt (1981) suggest that the wild goat species, including ibex radiated from the east Mediterranean region, North Africa, and the Middle East region to other areas of the world during the Pleistocene 'ice ages'. Based on his 'Dispersal Theory', Geist (1971) postulated that *Capra ibex sibirica* is the most recent and advanced sub-species of ibex, owing to it's large body size, long horns and it's having penetrated deepest into the once glaciated regions of Central Asia. Bhatnagar (1994) has further discussed about the origin and distribution of caprini.

Geographical distribution

Five sub-species of *Capra ibex* recognised by Schaller (1977) are distributed discontinuously from the European Alps to North Western Himalaya. These occur in the Alps (*C.i. ibex*), the Ethiopian highlands (*C.i. walia*), North Sudan, parts of Egypt, Syria and Israel (*C.i. nubiana*), the Caucasus (*C.i. caucasica*) and the Central Asian mountains including the north-west Himalaya (*C.i. sibirica*) (Fig. 1.1).

The Asiatic ibex is separated by over 2000 km from the nearest Kuban ibex in the Caucasus (Schaller 1977). It's range extends from Afganistan's Hindu Kush in the west to Russia's Sayan mountains in the north and down to the Pir Panjal range in Himachal Pradesh, India, in the south. This range includes Pamirs, Tien Shan, Kara Tau, Tarbagtay and Altai mountains (Roberts 1977, Schaller 1977, Prater 1980). In India, the upper Shyok valley in Ladakh marks the eastern, and the Sutluj gorge the southern boundary for the species (Roberts 1977, Schaller 1977, Prater 1980, Mallon 1991, Fox *et al*. 1992, Sharma 1994). Ibex have also been recorded from the southern slopes of the Pir Panjal range in Kullu (Fox *et al*. 1992) district of Himachal Pradesh. It is believed that conditions to the east of the Sutluj gorge in Himachal Pradesh are not conducive for ibex, owing to higher precipitation (Schaller 1977). Although Prater (1980) and Sharma (1994) accept that the Sutluj gorge marks the south-eastern boundary of the sub-species, they still report its occurrence further south-east in the mountains of the Kumaon region of Uttar Pradesh.

Ecological distribution

The Asiatic ibex uses rugged mountains of cold arid regions, between the tree line (2,500 to 3,000 m) and the upper limit of vegetation (*ca.* 5,000 m) above mean sea level (Schaller 1977, Prater 1980). However, in it's more northerly range i.e. the Tien Shan and Altai ranges, it occurs as low as 500 m and mostly uses areas between 1,000 m and 2,000 m (Heptner *et al*. 1966).

The realm occupied by ibex mostly has 'Alpine scrub' (Champion and Seth, 1968) or 'dry alpine steppe' vegetation (Schweinfurth 1957, Puri *et al*. 1989). Such areas are characterised by scattered and open bush-land mainly with herbaceous and shrub species such as *Artemisia* spp., *Lonicera* spp. and *Caragana* spp. Also, such areas have a relatively low annual biomass production with a 'peak vegetation pulse' during summer when ibex regain body condition. They seasonally venture into sparsely forested slopes in lower parts of their range, as in northern Pakistan (Schaller 1977) and Central Asia (Heptner *et al.* 1966).

Sympatric species and predation

Ibex share their range with other mountain ungulates. In the lower parts of their western distribution, their range overlaps with markhor (*Capra falconeri*) and urial (*Ovis orientalis*). In the Pamirs and Karakorum range, they occur along with Marco polo sheep (*Ovis ammon polii)* (Roberts 1977, Schaller 1977, Petocz 1978). All along the south-west, west and northern fringe of the Tibetan plateau their range overlaps with different argali sub-species (*Ovis ammon*), and bharal (*Pseudois nayaur*) (Schaller 1977, Schaller *et al.* 1987, Mallon 1991, Fox *et al*. 1992). The Himalayan tahr (*Hemitragus jemlahicus*) and musk deer (*Moschus chrysogaster)* may occur sympatrically with ibex along the southern fringe of it's distribution in Lahul and Spiti, Kulu and Kinnaur districts of Himachal Pradesh (Fox *et al*. 1992).

In most areas, however, different levels of ecological separation occur between all species (Schaller 1977, Schaller *et al.* 1987, Mallon 1991). Ibex prefer steeper, more rugged terrain than all the *Ovis* and *Pseudois* species and usually occur higher than markhor and Himalayan tahr.

The primary predators of ibex are the snow leopard (*Panthera uncia*) and the Tibetan wolf (*Canis lupus chanko*) (Schaller 1977).

Status

Within it's range ibex is the most common ungulate along with bharal (Schaller 1977, Fox *et al*. 1991). Johnsingh and Mishra (1997) estimate the population in India at *ca.* 15,000 individuals. Ibex distribution is, however, patchy and up to 100 km may separate neighbouring populations due to unsuitable habitat and/or anthropogenic disturbances (Schaller 1977). Sporadic records on presence-absence and abundance from surveys exist from its range (Appendix 1). It is, however, difficult to compare studies owing to differences in methods used and the season sampled. Ibex occurs in low to medium densities (0.5 to 2.8 ibex per sq. km.) in it's entire range (Appendix 1). The relatively low densities may be due to the severe weather, limited plant productivity of its habitat and human disturbances.

1.2.4 **Habitat Use**

The range occupied by ibex has distinct seasonality, which reflects in the habitat use trends by ibex. Ibex are partial to rugged, steep terrain (Roberts 1977, Schaller 1977, Prater 1980). They have evolved to exploit the niche provided by high, rugged mountains and their life is closely associated with cliffs. They scale cliffs effortlessly and use this to an advantage for escaping predators (Schaller 1977, Fox *et al.* 1992).

Ibex select different altitudes seasonally. They mostly occur on upper slopes throughout the year, going highest during peak summer, and descending lowest during spring to take advantage of the new plant growth (Schaller 1977, Prater 1980, Fox *et al.* 1992).

Winter is usually long and severe in regions used by ibex. This is the *critical* or the *pinch* period, when forage is of low quality and is not easy to access through the snow cover. Ibex cannot move efficiently on snow (Schaller 1977) and have to bear considerable cost for feeding in deep snow conditions. Hence, they mainly confine to steep precipices on southern slopes which have less or no snow in this season (Schaller 1977, Fox *et al*. 1992).

Ibex take advantage of the delayed phenology of plants and use higher elevations during summer. Pregnant females retreat alone or in small groups into steep and unapproachable (for predators) terrain for parturition.

The day range length of ibex is *ca.* 300 m and they may occasionally travel 3 to 5 km or more in a day (Fox *et al*. 1992). Most ibex use the same general area all year round (Schaller 1977). Virtually no other information on movement and range use of ibex exists.

1.2.5 **Feeding Ecology**

Ibex mainly feed on grass, sedges and forbs and occasionally on shrubs such as *Ribes* spp. (Heptner *et al*. 1966, Schaller 1977). They report 80 and 14 species of such plants that were eaten by ibex in Russia and Pakistan respectively.

1.2.6 **Behaviour**

Aggressive

Schaller (1977) described 33 forms of behaviour in the caprine aggressive and courtship behavioural repertoire; 11 of these are overt or direct, and 22 are indirect forms. Of these, he observed 6 direct and 5 indirect forms of aggression in *C. i. sibirica* and was not too sure about the *shoulder push*. Many of the described forms occur in a kind of continuum and on occasions become difficult to distinguish. Ibex, like most other caprini have a male rank order based on absolute rank where males maintain a linear hierarchy. This may result from individual recognition and memory of past encounters in small populations. In fluid, large populations where individuals may not always recognise each other, animals instantaneously establish rank on their first encounter based on physical attributes (horn size, body size and striking pelage colours). This way direct confrontation which may cause injury may be avoided in most instances (Schaller 1977, Nievergelt 1967).

The repertoire for direct aggression observed by Schaller (1977) included *jerks, lunges, chases, jumps, butts* and *clashes* whereas indirect forms included *parallel walk, urine spray, penis mouthing, head shake* and *horning objects*. Schaller (1977) believes that among direct forms, *jerks, lunges* and *butts* are used for assertion of rank but *clashing* is used in testing situations to settle the respective ranks of the involved individuals, which on most occasions are of equal size.

Courtship

All females are passive during the rut and courting males have to test for oestrus females. Usually, mating is the prerogative of the dominant male in a group. A male usually approaches the female in the *low stretch* from behind, often *twisting* its head and *kicking* with its forefoot. The female ignores this gesture initially and may eventually comply to the persistent pursuits by urinating. The male then tests for oestrus by sniffing and curling it's lip (*flehmen*). A male repeatedly mounts a receptive female, a few seconds each time (Schaller 1977).

Some behavioural patterns such as *horning vegetation, head-shake* and *huddle* are difficult to classify both under aggressive or courtship related behaviour as they may occur in situations which may be neither (Schaller 1977).

Beside these visual signals, ibex also rely on olfactory signals. The secretion from the sub-caudal glands and the practice of spraying urine over the body helps in individual recognition and may enhance their physical attributes (Schaller 1977).

Play

Young often involve in play behaviour which seem to be mostly exaggerated aggressive or sexual behavioural forms. On occasions it also involves running with huge bounds, often with hind legs thrown up in the air and head waving from side to side. Some times even adults involve in such behaviour (Schaller 1977).

Escape Behaviour

As mentioned in Section 1.2.3, above, ibex have evolved in the rugged mountainous tracts where they require strength in the forelimbs to climb and jump on steep slopes and cliffs. Cliffs are one place where they can outsmart any land predator and ibex use this to their benefit in escaping predators. Being saltatorial animals, ibex cannot run fast over long distances but can climb steep slopes with ease (Schaller 1977). Cliffs are hence referred in literature as escape terrain (Fox *et al.* 1992).

Ibex respond to danger, especially large predators by issuing a high pitched whistle or chirp like a bird (Petzsch and Witstruk 1958, quoted from Schaller 1977, Prater 1980) before bounding off into escape terrain.

Activity pattern and feeding habits

Ibex mostly feed during early morning and evening but activity patterns vary seasonally (Prater 1980, Fox *et al*. 1992). Fox *et al.* (1992) reported that in November and December ibex had a bimodal pattern with a major activity peak around sunrise and a minor one around sunset. During mid-day, most ibex rested and after sunset they started bedding for the night. After heavy snow fall and drop in temperatures, limited observations by Fox *et al.* (1992) suggested that ibex had switched to a single mid-day activity peak, often remaining bedded till mid morning, followed by feeding and bedding again just before sunset.

1.2.7**Reproduction and Population Dynamics**

Reproduction

Ibex has a highly synchronised mating and calving period lasting two to three weeks each (Heptner *et al*. 1966). In the Russian Pamirs, ibex mate in December-January and after a gestation period of 170 to 180 days, usually one and rarely two young are born in June-July (Heptner *et al*. 1966). Schaller (1977) also got similar information from villagers in Pakistan but Prater (1980) reports the rut to start in October.

Ibex females may have young as early as in their second year but usually only after they are 3 years old (Heptner *et al*. 1966). Parturition is synchronised to occur about a month after the snow melts and green forage becomes available in the short plant growth season that follows. This enables the lactating females to replenish their reserves lost during the lean winter season and rear their young more efficiently (Schaller 1977).

Asiatic ibex females weighing around 50 kgs were reported to have young of 3.5 to 4.0 kgs (Heptner *et al*. 1966). Ibex females may cache their young for 2 to 3 days (Savinov 1962, quoted from Schaller 1977) after which the young *follow* their mother. A strong mother-young bond exists for about an year and may temporarily (in female yearlings) or permanently (in male yearlings) break during parturition (Schaller 1977).

Longevity

Based on horn characteristics, Schaller (1977) found ibex to be among the most long lived caprines as some animals had lived up to 15 years. However, most deaths in (male) ibex occurred during their prime years (4 to 10 years) with a mean of 8 years. This paradoxical situation is difficult to explain and is probably due to stressful conditions following a period of high activity, i.e. the rut, when males successful in mating have a higher chance of facing malnutrition in the following lean season i.e. winter (Schaller 1977).

Longevity in females is difficult to estimate due to obscure annual rings. Although most of Schaller's observations were on animals killed by predators, he feels that poor nutrition and disease may have a significant role in mortality.

Herding activities, population structure and composition

Ibex are group living animals and may occur in groups of adult females with young, all male groups and groups with both sexes (Heptner *et al*. 1966, Schaller 1977). Adult males and females associate throughout the year. The proportion of males in all male groups increases in summer (Prater 1980, Fox *et al*. 1992, Bhatnagar *et al.* 1997). Prater (1980) reported that males rejoin female groups in October, coinciding with the onset of the rut and stay with or close to the females until early summer.

Group size and composition varies considerably with season, forage availability and population density and there is much variation in the reports by different authors. Group size ranged from 3 to 50 in different reports (Heptner *et al*. 1966, Schaller 1977, Prater 1980, Sharma 1994) while Fox *et al.* (1992) reported a mean group size of 9.4 (median 11). Larger aggregations, up to 200 ibex have also been reported (Heptner *et al*. 1966, Schaller 1977). Ibex group sizes in Pin Valley were largest during the spring sprout (mean 15 and 21 in two years) while they were smallest during the lean months of winter (Bhatnagar *et al.* 1997).

The adult sex ratio of ibex, like many other caprines is usually 1:1 or slightly male biased (Schaller 1977). Fox *et al*. (1992) found a ratio of 91 adult males : 100 females : 33 yearlings : 78 kids (n=312) during winter and spring in Ladakh. Nath (1982) reports a rather skewed ratio of 20 to 30 adult males to 100 females (n=87) for the Suru valley, Ladakh.

1.3**CONSERVATION**

In India, ibex is catagorised as an endangered species and is included in the Schedule I of the Indian Wildlife Protection Act 1972 (Anon. 1992). It is poached/hunted in parts of it's range for trophy, meat and the high quality under-wool or *pashmina* (Schaller 1977, Mallon 1991, Sharma 1994). Schaller (1977) reported that much of the lower ibex range in his study area in Pakistan was overgrazed by livestock, and only 1 to 3 % of the plant species were eaten by ibex. Areas above 4,000 m were relatively free from human disturbance but the forage available there was very sparse.

At present one national park (NP) and six wildlife sanctuaries/game reserves (as in Jammu & Kashmir) in India fall within ibex range, covering an area of *ca.* 2,800 km² (Chundawat and Rawat 1994; *pers. observ.*). Although poaching may be very rare, there is a threat of habitat loss due to degradation in some areas. In Pin Valley, locals felt that the NP area is degrading and that now they need to go farther into the NP to collect shrubs for fuel wood. The practice of uprooting shrubs for this purpose may be hindering regeneration and hastening degradation (Bhatnagar 1995).

The future of ibex looks grim in the disputed areas along the Indo-Pakistan border due to continued aggression. We should take note of the caution sounded by Schaller (1977) while concluding his treatise on mountain ungulates, lest: "Just as we become aware of this hidden splendour of the past, we are in danger of denying it a future. As we reach for the stars we neglect the flowers at our feet. But the great age of mammals in the Himalaya need not be over unless we permit it to be. For epochs to come the peaks will still pierce the lonely crags and the last markhor has stood on a promontory, his ruff waving in the breeze, a spark of life will have gone, turning the mountains into *stones of silence* (Schaller 1977)."

1.4**AIMS OF THE STUDY**

The Himalayan ibex is an important prey species of the endangered apex predator of the alpine region, the snow leopard (Schaller 1977). There is an imminent threat to the trans-Himalayan areas in India due to increasing human activities. In this context I wanted to study ibex in a relatively safe population to learn about its habitat requirements and ranging behaviour. Some questions I wanted to address were:

1. What is the annual home range size required by ibex males and females? Are there any seasonal variations in their home range? How do ibex move about within their home ranges (seasonal rate of travel, migrations, etc.)?
2. What are the primary habitat requirements of ibex? Are there seasonal variations? What are the habitat use trends in the *pinch period* i.e. winter? Is escape terrain really important for ibex?
3. How many resident livestock use the study area? Do they compete for resources with ibex?

It is vital to answer the above questions to direct better conservation efforts for this species which will also benefit the snow leopard. Besides this, an understanding of various aspects of ibex behaviour and ecology will help in clarifying its relationship with other caprinae.

1.5**SELECTION OF STUDY AREA**

The need for such a study was realised by Dr. Michael Stüewe, Smithsonian Institution and Dr. A.J.T Johnsingh, Wildlife Institute of India. Subsequently, a collaborative project "Ecology and Genetics of *Capra ibex* in India" was launched by the Wildlife Institute of India, Dehradun and the Smithsonian Institution, Washington D.C. Based on the suggestion of late Mr. B. S. Negi (the then Director of the national park), Pin Valley National Park was surveyed in 1990. Pin Valley National Park had a relatively high ibex density (*ca.* 2.26 per km^2, based on census in 1989, Pandey 1992). The people inhabiting the region are Tibetan Buddhists who do not hunt or vex ibex. Ibex were thus quite tame and afforded relatively easy observation. Hence, this area was selected for the study.

1.6**ORGANISATION OF THE CHAPTERS**

The thesis is organised into six chapters. After a brief introduction to the study area (Chapter 2), the general methods are discussed in Chapter 3. The ranging patterns are discussed in Chapter 4, followed by habitat usage trends in Chapter 5 and finally ecological separation between ibex and resident livestock in Chapter 6. Specific methods and statistical analysis regarding the results is presented in each chapter separately. At the end of Chapter 6 a general discussion on the conservation threats to the study area is presented.

This thesis is primarily a documentation of some aspects of ibex ecology and does not attempt to give any management recommendations. This will however be presented in the final report on the project 'Ecology and Genetics of *Capra ibex* in India' to be submitted to the Wildlife Institute of India, the Himachal Pradesh Forest Department and the United States Fish and Wildlife Service.

CHAPTER 2.0: STUDY AREA

2.1 LOCATION AND TOPOGRAPHY

The study area is part of the Pin Valley National Park (PVNP; 31° 6' 40" to 32° 2' 20" N latitude and 77° 41' 21" to 78° 6' 19" E longitude), located in the South-East of the Lahul and Spiti district of Himachal Pradesh (Fig. 2.1). Pin valley is situated in the rain shadow of the Pir Panjal range and is classified under the trans-Himalayan zone 1 (biotic province B) according to bio-geographic classification by Rodgers and Panwar (1988). The region experiences extreme cold, semi-arid to arid conditions, has low plant productivity and a plant growth season of about two and a half months from mid-June to August.

The park was notified in January 1987, by the Government of Himachal Pradesh (Singh *et al.* 1990, Pandey 1991). Combined with the buffer zone (*ca.* 1150 sq. km.), it covers an area of *ca.* 675 km² and includes most of the Pin-Parahio catchments. The Pin river flows due North from the ridge bordering the district Kinnaur to meet the East flowing Parahio river near Sagnam village. Here on, the Pin river flows largely north-east to meet the south-east flowing Spiti river, a tributary of the Sutluj. The NP is flanked by the Bara Shigri glacier complex to the North, the Great Himalayan NP (Kullu district) to the west, and the Rupi Bhaba Wildlife Sanctuary (Kinnaur district) to the south. The buffer zone extends East of the NP till the Spiti river. Bulk of the NP lies in the Parahio catchment formed by five rivulets *viz.* Khaminger, Debsa, Killung, Kocho and Kidul Chu (Fig. 2.2). The lowest point of the NP is at about 3600 m near the confluence of Kidul Chu and Parahio rivers and the highest, 6632 m, is the Shigri peak in the North.

The road-head to Pin Valley is at Mikim about 34 km from the sub-divisional headquarters, Kaza, and 8 km down stream of the base camp at Gechang.

2.2 INTENSIVE STUDY AREA

The intensive study area (*ca.* 100 sq km) is located in the eastern part of the NP (Fig. 2.2) with altitudes ranging from *ca.* 3600 m to 5400 m and an average elevation of *ca.* 4420 m (SD 468 m). Most of the lower slopes are smooth with an inclination of 30° to 35° and often have a lower steep bank (old moraine) till the valley bottom. The middle to higher slopes are mostly rugged with a gradient over 40° with frequent rocky projections. Roughly equal proportions of northern and southern aspects occur in this expanse and about 7% is under permanent snow and glaciers. Only about 28% of the area has a plant cover of over 50% (see section 5.3.1 for more details).

2.3 CLIMATE AND SEASONS

Within a year temperatures vary more than 60°C, between a maximum of *ca.* 30°C in summer and a minimum of ca -40°C in winter. The daily minimum temperature remains sub-zero for over half the year (October to May) and even the daily maximum temperature drops below zero in January and February (Fig. 2.3). These variations result in stark seasonality. The area experiences severe winters with heavy snow from November/December to March/April. The total snow precipitation was usually *ca.* 300 cm during this period. Spring is characterised by patchy snow melt and sprouting between April and May/June. The peak vegetation pulse coincides with the peak summer beginning from July till September. This season also has a large number of cloudy days with occasional rain and snow and temperatures varying between a minimum of 4°C and a maximum of 30°C. Pin Valley has moister summers and winters compared to other parts of Spiti. With the onset of autumn there is a steady decline in daily temperatures. Dry conditions and senescence of most plants continue till snowing occurs in November/December. Table 2.1 summarises the different seasonal features.

Figure 2.1: Location of Pin Valley National Park and Kibber Wildlife Sanctuary in Himachal Pradesh, India

The approximate ibex distribution in the region is also shown

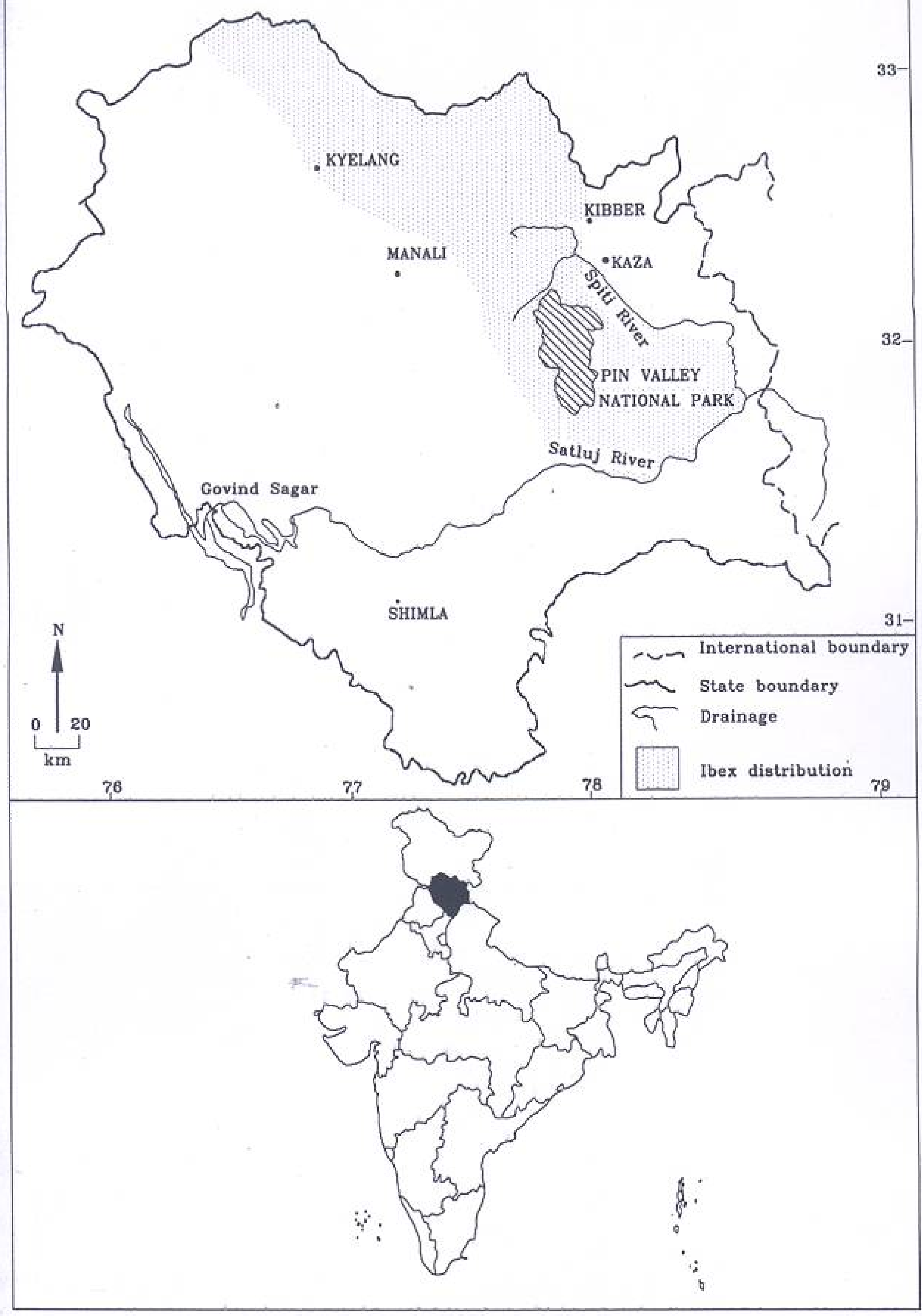
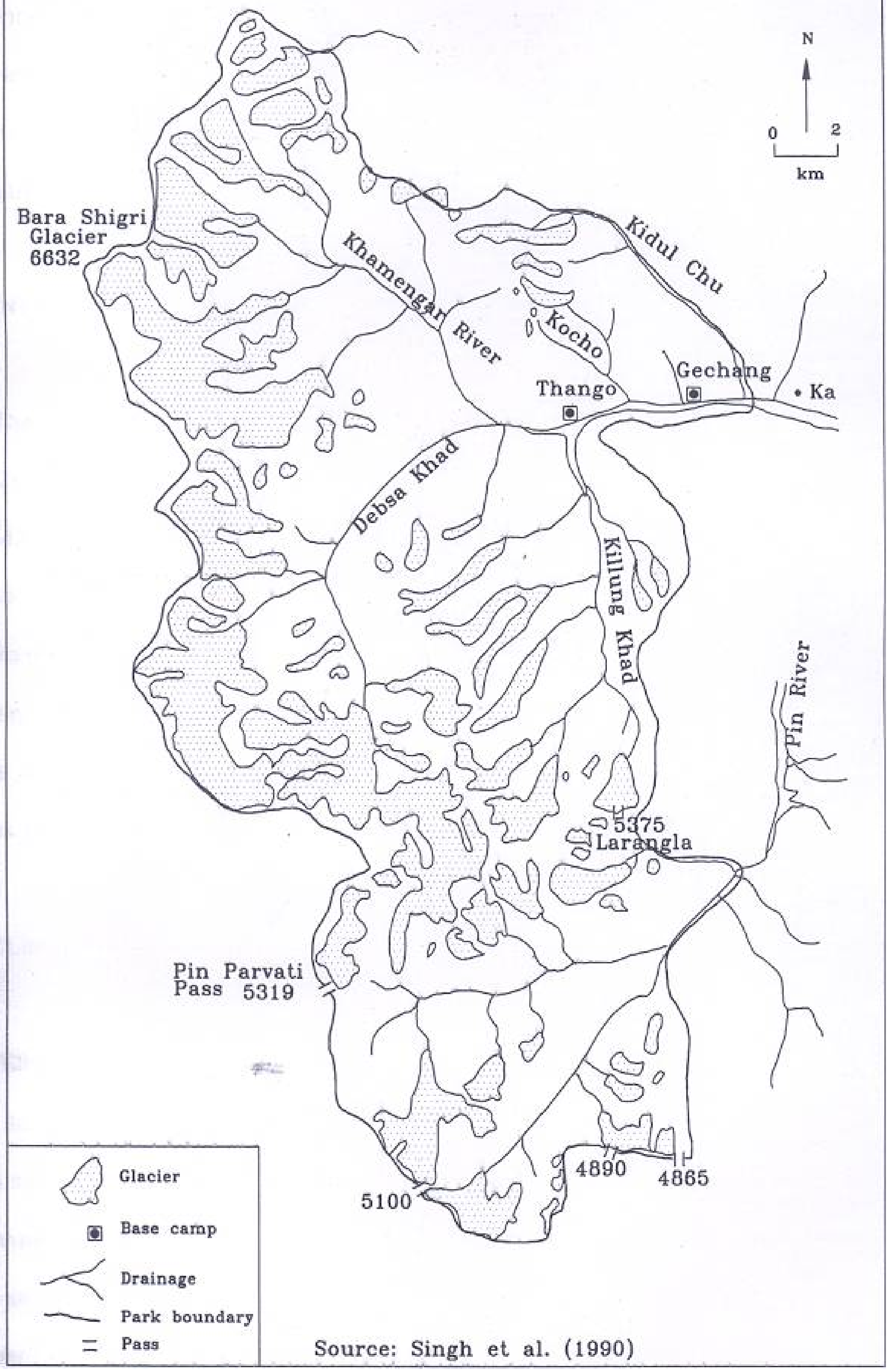


Figure 2.2: Pin Valley National Park showing the location of base camps at Gechang and Thango



Source: Singh et al. (1990)

2.4 **GEOLOGY AND SOILS**

The geology of Spiti is interesting owing to the almost complete sequence of exposed sediments from the Pre-cambrian era to the Cretaceous period (Wadia 1967). The area is characterised by sharp changes in a combination of quartzite, shales, limestones and conglomerates. Most of the area is rich in fossils, mainly brachipods, trilobites, ammonites, bivalves and also certain corals and algae, indicating its Tethyan past. The high altitude desert soils are predominantly sandy and shallow, derived mainly by mechanical disintegration due to marked diurnal and seasonal fluctuations of temperature. The avalanches and streams bring down enormous soil masses to the lower valleys and alluvial fans (Gupta 1994) making them particularly rich in plant cover. The soils are mostly silty loam to silty-clay loam in texture with a slightly alkaline pH, poor organic matter and water holding capacity. The soils are low in available nitrogen, phosphorous, potassium and carbon, however are better supplied in calcium (Gupta 1994).

2.5**FLORA**

Puri *et al*. (1989) classed the area as 'Dry Alpine Steppe' while Schweinfurth (1957) as '*Artemisia* Steppe and Meadows'. It is characterised by sporadic patches of trees (*Juniperus macropoda*, *Salix* spp. and *Betula utilis*, now mainly confined to inaccessible areas or those protected by religion) and sparse scrub, meadows and grasslands. Prominent shrubs are *Rosa* spp., *Lonicera* spp., *Caragana gerardiana, Ephedra gerardiana*, *Artemisia* spp.; herbs are *Lindelofia* spp., *Cicer microphyllum*, and *Cousinia* spp., and grasses such as *Festuca* spp., *Oryzopsis* spp. and *Poa* spp. The cliffs and steep rocky slopes have rare *Juniperus* spp., *Rosa* spp. and *Ribes orientale*. Moist tracts in the valley bottoms have patches of *Salix daphnoides ,* *Salix flabellaris*, *Myricaria elegans*, and *Hippophae tibetana*. Most *Ephedra* and *Rosa* scrub and meadows occur in the lower to middle slopes. Middle to higher slopes have *Caragana-Lonicera* scrub and patches of usually dense meadows dominated by herbs such as *Lindelofia stylosa, Potentilla atrosanguinea* and grasses like *Festuca* spp., *Oryzopsis* spp. and *Stipa* spp. A detailed list of plant species recorded in the region is presented in Manjrekar (1997).

2.6**FAUNA**

The large mammalian fauna is less diverse in this region compared to other trans-Himalayan areas as reported by Chundawat (1992) and Mallon (1991). The only large wild mammals recorded from the NP area are ibex, snow leopard and red fox. Besides, smaller carnivores such as stone marten (*Martes foina*), Himalayan weasel (*Mustela sibirica*) and pale weasel (*Mustela altaica*) with a variety of rodents and the mouse hare (*Ocotona* spp.) also exist (Bhatnagar 1993).

The golden eagle (*Aquila chrysaetos*), lammergeier (*Gypaetus barbatus*), Himalayan griffon (*Gyps himalayensis*), Himalayan snow cock (*Tetraogallus himalayensis*) and chukar partridge (*Alectoris chukar*) are among the *ca.* 60 bird species recorded from the study area (Manjrekar and Bhatnagar, *unpubl. data*).

2.7**PEOPLE AND THEIR DEPENDENCE**

The following account on people and their dependence on the Pin Valley National Park relies primarily on Bhatnagar (1996). All indigenous people of the area follow Tibetan Buddhism. There are 17 villages in Pin Valley , with ten of them in the vicinity of Sagnam about 7 km from the NP boundary. Of these, only the Sagnam village consisting of *ca.* 62 families is dependent on the NP for fuel, fodder, pastures and farming. Of the other 9 villages, 7 depend to a lesser extent on a smaller portion along the Eastern fringe of the NP. About 800 people reside in these villages with about 500 heads of livestock.

Ten families use 6 seasonal settlements, locally known as *dogries* located within the park. These families live in the *dogries* from March through December, tending cattle, collecting fodder and fuel and cultivating barley (*Hordeum vulgare* var.), peas (*Pisum sativum* var.) and potatoes (*Solanum tuberosum*). While other locals come in between late June and December for fuel (shrubs and cattle dung) and fodder collection and livestock grazing. These people camp at fixed sites for a few days each time.

People own yak, cows, yak-cow hybrids (locally called d*zo* (male), d*zomo* (female)), horses, donkeys, sheep and goats. *Dzomo*, sheep and goats are often accompanied by herdsmen to prevent crop damage and protect from snow leopard predation and are grazed close to the villages or *dogries* during the day. Young (<4 years), and pregnant horses are grazed at definite sites far from settlements and are herded into pens during nights by herdsmen. Whereas yak, d*zos* and older horses are directed into definite areas to be left free to graze. Between mid-December and the first major snow fall usually later that month the livestock is herded back to the villages by the *dogri* dwellers.

Coiniciding with the vegetation pulse, in late June, eight to nine groups of migratory herdsmen from the Simla and Kinnaur districts arrive, some covering a distance of over 200 km, with a total of over 5000 sheep and goats. These groups spread out into the upper catchments of Killung, Debsa and Khaminger till mid-August. These herders have used this area for generations, mainly to avoid the heavy monsoon of their native areas and avail the more nutritious forage of these parts. According to local sources, their sheep and goat population is increasing remarkably each year.

Currently the park management is executing an ecodevelopment plan under which schemes such as pasture development inside and around the NP, distribution of fuel efficient smokeless *chulhas* (stoves), making and improving trails and constructing of public toilets are prevalent. The Forest Department of Himachal Pradesh has undertaken *Salix* sp. and *Rosa* sp. plantations within the NP. The residents, with support from the Forest Department, have also raised small plantations of *Populus* sp. and *Salix* sp. within the NP and near their villages.

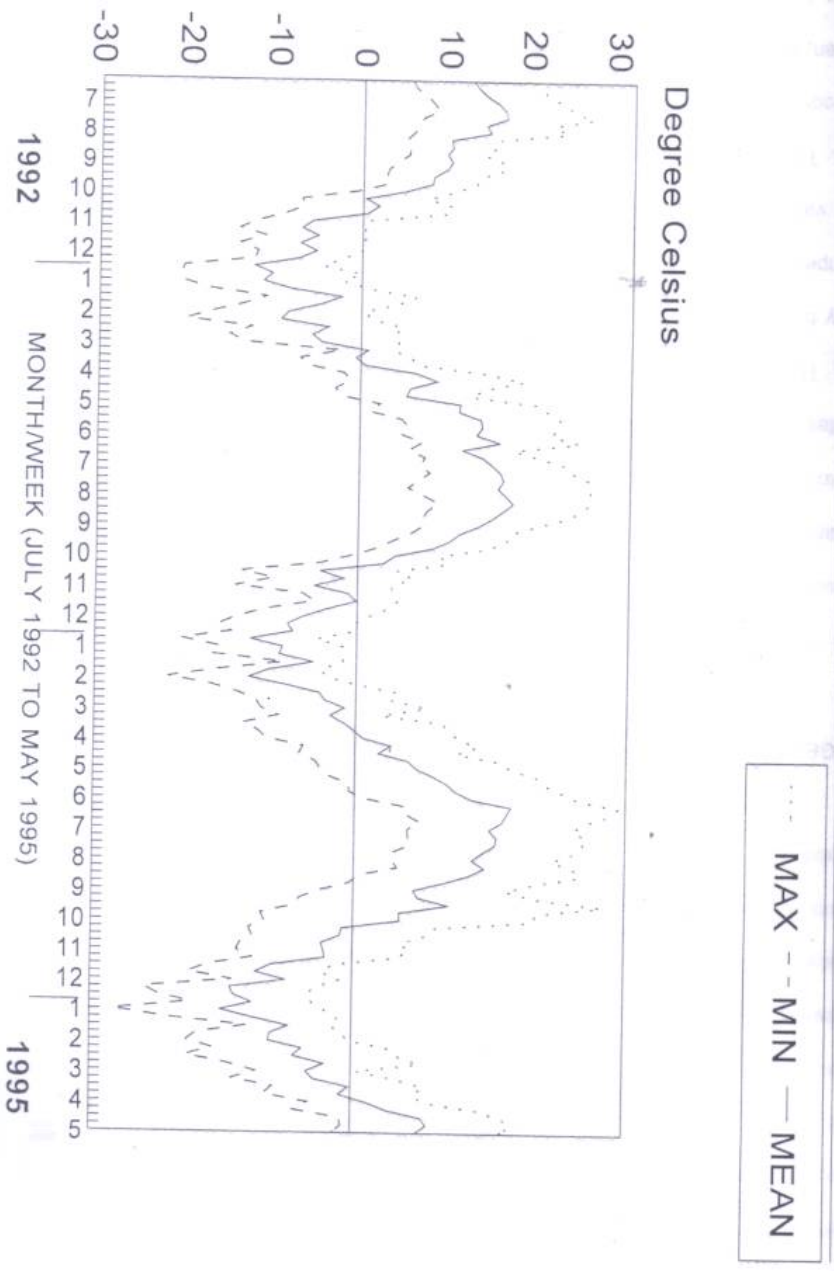


Fig. 2.3: Mean weekly temperatures at the Gechang Base Camp, Pin Valley N.P., between July 1992 and May 1995

Table 2.1:**A brief summary of seasonal snow, forage conditions and temperatures in the study area, Pin Valley National Park.**

ENVIRONMENTAL CONDITIONS	WINTER			SPRING (Apr./Jun)	SUMMER (July-Sept.)	AUTUMN (Sept.-Nov.)
	EARLY (Dec.)	PEAK (Jan.-Mar)	LATE (Apr.)			
SNOW	USUALLY THIN AND SCATTERED	EXTENSIVE, DEEP, AND SOFT	DEEP, USUALLY COMPACT WITH SOME THAWED PATCHES	THAWED PATCHES ON SOUTHERN SLOPES, RELATIVELY THIN	NO SNOW; SOME ON HIGH NORTHERN SLOPES AND ON GLACIERS	RARE, THIN LAYER
FORAGE QUALITY	LOWEST	LOWEST	LOWEST	HIGH	MODERATE TO HIGH; HIGH MAINLY ON UPPER SLOPES	LOW, ALTHOUGH LOCALISED, HIGH QUALITY FOOD AVAILABLE AS FRUITS
FORAGE QUANTITY	MODERATE TO LOW, MAINLY LIMITED BY SOME SNOW COVER	LOWEST, ACCESSIBILITY HEAVILY RESTRICTED BY SNOW COVER	LOW, VERY FEW MELTED SITES AND AVALANCHE PATHS WITH LESS OR NO SNOW	LOW, MOSTLY PATCHY AVAILABILITY AT LOW ALTITUDES, ESPECIALLY ON THE SOUTHERN SLOPES	HIGHEST ANNUAL AVAILABILITY, IN ALL ALTITUDNAL ZONES 'PEAK VEGETATION PULSE'	HIGH BUT DRY AND LESSER THAN SUMMER
RELATIVE NEED OF ESCAPE TERRAIN AND PREDATION RISK	NEED IS ALMOST CONSTANT THROUGHOUT THE YEAR, BUT NEED TO BE CLOSER TO ESCAPE TERRAIN IS PROBABLY HIGHEST DURING PEAK WINTER WHEN EXTENSIVE SNOW RESTRICTS EFFICIENT ESCAPE. DURING SPRING, THE POOR BODY CONDITION OF ANIMALS AND THE NEED TO EXPLOIT THAWING AREAS AWAY FROM ESCAPE TERRAIN MAY INCREASE PREDATION RISK					
IBEX BIO-CYCLE	RUT, FORAGING	RUT (Jan.) AND FORAGING THROUGH SNOW 'SURVIVAL'	FORAGING THROUGH SNOW 'SURVIVAL'	FORAGING ON SPROUT 'SURVIVAL'	KIDDING (July), FORAGING, REGAINING LOST RESERVES	FORAGING, REGAINING LOST RESERVES, PRE-RUT MALE-MALE AGGRESSIONS
TEMPERATURE - MIN.:	-10 TO -15	-20 TO -40	-10 TO -15	00 TO -05	06 TO 10	-15 TO 02
(°C) MAX.:	00 TO 05	00 TO -05	00 TO 10	05 TO 15	20 TO 30	05 TO 15

CHAPTER 3.0: GENERAL METHODS

3.1 INTRODUCTION

Data on ibex were collected based on trail monitoring in the first phase (November 1992 to May 1994) followed by telemetry during the second phase of the study (June 1994 to May 1995). As already mentioned in chapter 2.0, the study area is characterised by severe climatic conditions which on occasions hindered efficient data collection. Besides, there were some topographic and logistic peculiarities which made regular data collection through established methods difficult. These are discussed below (Section 3.2).

The study area was surveyed in November 1991 and the base camp was established. The winter of 1991-92 could not be spent in the study area owing to administrative and logistic difficulties. The period from May 1992 to June 1995 was mostly spent in the study area. During the first year (November 1991 to October 1992), direct and indirect methods of data collection on ibex habitat use, ranging and activity patterns were done. However information during this period of reconnaissance is not included and only the data collected by direct methods have been used in my thesis.

3.2 TRAIL MONITORING

Data on the use of habitat variables by ibex were collected along six trails from the base camp, walked between May 1992 and May 1994 covering a total distance of *ca.* 1200 km. These trails were, Debsa (*ca.* four km), Khaminger (*ca.* five km), Killung (*ca.* four km), Kocho (*ca.* four km), Kidul Chu (*ca.* five km) and Parahio (*ca.* six km). During the warmer period information was supplemented by a search of upper parts (>4200m) between mid-July to mid-September. Winter trails were limited to a set of two, three km trails and regular observations from vantage points. Some problems encountered using this method are mentioned below.

Whenever a group of ibex was encountered it was sexed and aged based on the recognized classification (Section 3.4) and habitat variables (Table 5.1) were noted at the center of activity i.e. where greatest aggregation was present.

For any livestock species encountered on trails, the same habitat variables were noted.

3.2.1 Problems Faced in Trail Monitoring

Trails were selected and walked along the six main valleys (Section 3.2), but some problems such as the following were encountered:

1. Owing to the extreme ruggedness of the middle and higher slopes, it was possible to miss out ibex groups in the limited time available during trail walks.
2. Trails were giving low output and the encounter rate of groups was low (1 to 2 sightings per 5 km walk).
3. The warmer periods (mid-July to mid-September) yielded very few sightings on the trails. It was therefore surmised that the ibex were using higher slopes (> 4200m). However, an intensive search in these parts did not yield encouraging results. The latter method was especially unrewarding due to the very little area visible on the slope being traversed and the enormous effort needed. Although opposite slopes were in good view, ibex sighting on those slopes during summer became difficult due to long sighting distances (> 2 km), their dull summer coat and small groups. These factors may have influenced sightings from trails too. The vegetation was at its maximum growth during this

period achieving a height of 0.5 to 1 m at places. This could also obstruct view, especially when viewing from below. These problems were confirmed later when ibex were radio tracked and located regularly in the same area in during the summer of 1994. After obtaining the peak arc of the signals, it often took (for two people) about one hour to locate ibex even when they were on open slopes. Hence, long sighting distances, usually viewed from below, dull coloration of ibex, small group size and tall vegetation at places resulted in the overall low 'detectability' of ibex during summer.

4. During winter it was not feasible to cover all the six valleys due to deep snow which hampered movement (after fresh snow the speed went down to *ca.* 1 km per hour) and the danger of avalanches

To partially overcome these problems more time was spent on the trails to scan rugged areas. In summer, this was done all along the trails and the surveys into higher slopes. During winter the trails were reduced to about 3 km each on either side of the camp along the valley and the frequency of walking the trails was increased. Data were complimented by observation from vantage points. This was particularly possible because each group could be monitored to a remarkable extent from the tracks left on snow. Ibex were in a dark coat and were easy to locate even from a far distance in rugged terrain. More details about data collection are given in Section 5.2.2.

3.3 HABITAT USE AND RANGING THROUGH RADIO TRACKING

Radio tracking was undertaken between June 1994 and June 1995. Fifteen ibex of various age-sex classes were captured using a 50 X 55 feet drop net at a salt lick close to my base camp, Gechang (Table 4.1).

Habitat selection by ibex was determined from observed usage in relation to the availability of various habitat variables. To determine the availability, Marcum and Loftsgaarden's (1980) method for quantifying habitat variables at random points in the study area was used. Two hundred random plots were laid for this purpose (Section 5.2.1).

3.4 POPULATION STRUCTURE AND GROUP SIZE

Females more than two years old were considered as **adults.** Ibex less than two years old were classed as young. **Kids** were individuals in their first year and had stubby horns while **Yearlings** were individuals in their second year with females having horn length usually < 5 cm and body size about 3/4th smaller than adult females. Yearling male horn length was usually < 20 cm, were laterally wide with one or two frontal knobs and body size was close to, but smaller than that of an adult female. They were relatively darker than adult females and yearling females. Kids and yearling males were clearly identifiable, but yearling females and young females were some times misclassified. Hence, there is a chance of a slight underestimation of females. Based on my observations and horn measurements from Schaller (1977) and Neivergelt (1981), four categories of males were recognised:

a. **Class I** (third year): Horn length *ca.* 35 cm. Horns short with little curvature. Animal usually did not develop dark brown markings on body during rut and winter.
b. **Class II** (fourth & fifth year): Horn length *ca.* 50 to 60 cm. Horns curved slightly backwards and dark brown markings with a distinct silvery 'saddle' that appeared during rut and winter.
c. **Class III** (sixth and seventh year): Horn length 60 to 70 cm. Horns curve back in a semi-circle and dark black coloration with silvery saddle appeared during rut and winters.
d. **Class IV** (> seventh year): Horn length more than 70 cm. Horns shape and body coloration similar to Class III which also curve outward.

Ibex **groups** were classified as **all male groups**, **female and young groups**, **female, young with class I males (sub-adult)** and **mixed groups** (groups that had adult males and females along with young).

3.5 **WEATHER DATA**

Daily records of the following were maintained:

1. Temperature (min.-max.) and highest wind speed in the preceding 24 hours (recorded with a Weather Pro system)
2. Relative humidity at 0900 hrs.
3. Cloud conditions (scattered or continuous - low, medium or high) and the duration of each during the day (eg. 1200 to 1430-continuous medium)
4. Wind speed [breezy (1 to 20 kmph), windy (21 to 40 kmph), strong wind (> 40 kmph)] and the duration of each condition
5. Rain as traces, moderate or heavy with duration of each condition
6. Snow as in case of rain with fresh snow fall in the preceding 24 hrs. (in cm).

In the winter of 1993-94, data on snow depth and temperature on the North, East, South and West aspects were simultaneously recorded twice every month. Snow depth was taken at 10 points and temperature was recorded 4 times at a gap of *ca.* 5 minutes in sun and shade respectively.

CHAPTER 4: IBEX MOVEMENTS AND HOME RANGE

4.1**INTRODUCTION**

Movement patterns and home range analysis yields spatial data useful in the study of animal ecology. Most studies relate to spatio-temporal use of the range by animals, while some relate to manipulative experiments, management implications or form part of a demographic study (Harris *et al.* 1990).

The home range concept has been defined and further improved by several authors since early 1940s (Burt 1943, Mohr 1947, Baker 1978, Dixon and Chapman 1980, Anderson 1982, Worton 1989). Home range consists of a more or less restricted area within which an animal moves when performing its ***normal*** activities of feeding, mating and caring for the young (Burt 1943, Harris *et al.* 1990).

As more sophisticated methods to determine home range size and shape are coming up, the number of related biases and problems with methods are also coming to the fore. White and Garrot (1990) argue that most often the actual location data can be of better use in hypothesis testing. Hence, in this study, due importance has also been given to the actual location coordinates to investigate animal movements.

This is the first study of its kind on the Asiatic ibex and the need for such an exploratory study is realised. Moreover, the limited sample size of the monitored individuals (Table 4.1) covering various age-sex classes permit mainly a descriptive approach of movement patterns and range sizes. A major part of the chapter is thus a description of the patterns of movement and home ranges, while another tests specific hypotheses.

Based on the optimal foraging concept, Veeder (1983), discussed the trade off between profitability of food items and search time. He suggested that when forage is scarce an animal should respond in either of these two ways: a) by feeding un-selectively on a larger spectrum of forage items, thus decreasing search time; or b) by travelling greater distances, at greater energetic cost, in order to obtain adequate quantity of better quality forage. The relationship between forage availability and quality with ibex mobility and home range size in the forage deficient period, winter, is emphasised.

The main questions asked in this study regarding ibex movements and home ranges are:

Rate of travel or Mobility

Do ibex use their home ranges at the same rate in different seasons? Are there any sexual differences in seasonal speeds? What is the relationship between speed and forage availability and quality?

Seasonal Migration

Do ibex migrate? When do they migrate? Where do they migrate?Why do they migrate?

Seasonal Movement Pattern

Are ibex movements concentrated or dispersed within their home range? Are ibex movements random or directional within their home range?

Home Range (HR) Sizes

Which home range estimation method is most appropriate for ibex? Are the seasonal home ranges asymptotic? What is the asymptotic sample size for each individual? What are the home range sizes for different age-sex classes in different seasons? Do home range sizes differ for age-sex classes within a season and between seasons? Are there any seasonal shifts in the home ranges? If so, why? Does forage availability and quality affect home range size? Does snow cover restrict movement and home range size?

4.2 METHODS

4.2.1 Study Animals

Fifteen ibex of various age-sex classes were captured using a drop net at a salt lick close to the base camp, Gechang in May-June, 1994 (Table 4.1). Radio tracking of these animals was then undertaken for 12 months from spring 1994 (June) to spring 1995 (May).

4.2.2 Field Methods

All locations were based on 'homing in' on the animal. In the narrow and rugged valleys of the study area the problem of signal 'bounce' was high which precluded the use of triangulation. The other objective of studying habitat utilization and group structure also required sighting the animals. Each location was plotted on a 1:50,000 Survey of India topographical map and all group and habitat variables noted as for the sightings from the transects (see Section 5.2.2). The open view and the presence of ample drainage and terrain features on the map aided in identifying sites, hence, the error in determining the exact location may not exceed 100 m.

Table 4.1:Some details of the captured ibex captured near Gechang, Pin Valley National Park in May-June 1994.

DATE OF CAPTURE	ANIMAL SEX & TAG #	APPROX. AGE AT CAPTURE*	BREEDING STATUS DURING STUDY PERIOD	PERIOD MONITORED
31 MAY, 1994	F 1 ^	10	PREGNANT, KID DIED AFTER PARTURITION	JUNE, 1994 TO MAY, 1995
	M 2	1		
	F 3 ^	5	PREGNANT, KID SURVIVED	--DO--
	F 4[1]	1		
	M 5	1		
	F 6[1]	4		
	F 7 ^	3		--DO--
	M 8	1		
	F 9	7	PREGNANT, KID SURVIVED	
2 JUNE, 1994	M 10	2		
	M 11 ^	9	BREEDING	--DO--

	M 12 ^	5	BREEDING	JUNE, 1994, DEC.,1994 TO MAY, 1995
	M 13 ^	4	SUB-ADULT	JUNE, 1994 TO MAY, 1995
6 JUNE, 1994	F 14	1		
	F 15 ^	4		JUNE, 1994 TO MAY, 1995

[*] Female age is a rough estimate because of the ambiguity of annual rings.
^ Radio-collared animals
[1] Died during the capture operation.

Animals were tracked every alternate day (56 % locations, n=452). At times (24 %), however, a greater interval was unavoidable due to shortage of radio-tracking equipment, manpower and weather constraints. Animals were on an average located 10 to 15 times each month (Appendix 2).

Very frequent telemetric locations may lead to auto-correlated data which violates assumptions for most home range analysis techniques. Swihart *et al.* (1988) elaborated on the concept of 'time of independence' (TTI), which represents the time interval at which an animal's current position was influenced only by its pattern of home range use and not by its position '*delta t*' minutes earlier. The rate of use of home range is a function of body weight. Swihart *et al.* (1988) found the following relationship between body weight (W) and TTI for grazers/browsers:

$$TTI = 336\ M^{0.17}$$

Based on a mean ibex female weight of 60 kg and male weight of 85 kg (Schaller 1977; *pers. observ.*), the TTI is 11.2 and 11.9 hours, respectively. Since the sampling interval was greater than 12 hours in all cases, the location data is taken to be independent. The mean seasonal sampling interval for the collared animals was never less than 43 hours (Appendix 3). However, the sampling for Female 15 and Male 12 could not be regular owing to equipment and logistic problems.

Data were collected between 0600 hours and 1800 hours, with most of the locations (60 %) taken between 1000 and 1300 hours.

4.2.3 **Analysis**

Locations from the topo sheets were digitised using GRASS to obtain the Universal Transverse Mercator (UTM) coordinates which were subjected to further analysis.

Animal associations

Animals were captured on 31 May and 2 June from one large group. The group captured on 6 June was also a part of the large aggregation which had continued to stay in the Gechang area while the others had moved further. The spring sprout in the south facing Gechang slopes attracted animals from a vast region. An association index (Sorensen's similarity index) (Magurran 1988) for each pair was calculated (Appendix 4). The association index (AI) was calculated as:

$$\mathbf{AI = 2\ AB/(A+B)}$$

where, A is the frequency occurrence of animal 'a', B is the frequency occurrence of animal 'b' and AB is the frequency occurrence of the animals together in the same group. AI, here, is taken as an index of the amount of spatio-temporal overlap between different radio-collared animals.

Home range analysis

The software CALHOME (Kie *et al.* 1994) was used for home range calculation. For home range size estimates the minimum convex polygon (MCP) (Mohr 1947, Southwood 1966) and the harmonic mean methods (HM) (Dixon and Chapman 1980) were used. Core areas were determined by the harmonic mean method, defined as the 55 % contour. Justification for the use of these methods is presented in Appendix 5.

The home range areas reported here are two dimensional and actual home ranges, after accounting for the slope would be larger. The bias is expected to be constant across seasons and animals. An important problem regarding range size comparisons between seasons was the different sample sizes for each biologically meaningful season whose durations differed. Summer and autumn were of similar durations (76 days) which were approximately 1.7 times longer than early, peak, late winter and spring (44-46 days). Such a bias may be expected to be less in comparisons using harmonic mean method (Harris *et al.* 1990).

Asymptotic sample sizes were determined after the study was completed to test whether the overall sampling was adequate. As indicated above, constraints such as equipment and manpower limited a more intensive sampling scheme. The animal range sizes had a tendency to plateau off between 40 and 60 locations (Appendix 6). This way most seasonal locations may not be strictly comparable.

Analysis of movement patterns

Distance travelled in a unit time as obtained from consecutive locations is a useful index of foraging patterns and its relation to environmental conditions (White and Garrot 1990). The day range length (meters per day) is used here as an index of seasonal mobility. However, there are some confounding factors such as:

- the varying sampling intervals between locations,
- the calculated distances being straight line distances, mostly underestimating the actual distance travelled by the animal,
- although no clear estimate is available, ibex could travel right across their home ranges ($\leq$ 5 km in most cases) in *ca.* 24 hours. Hence, any sampling, especially more than this interval could mean that the animal returned to the site after visiting a farther site.

However, these biases may be assumed to remain constant across individuals and seasons. Day range length (meters/day) has been used as an index of mobility. The day range values, thus, must be treated only for inter-animal and inter-season comparison within this study and not as absolute values of speed of travel. Also, this index of mobility may not be as robust as others such as 'steps/minute' commonly used in foraging studies (Goodson *et al.* 1991a, Goodson *et al.* 1991b, McCorquodale 1993).

Seasonal differences in the day range length between individuals and between the sexes was tested using Kruskaal-Wallis one-way ANOVA.

For this study long distance **migration** has been defined as a prolonged (at least 30 days) but temporary range shift of over five kilometres, when no location overlapped within the range of the previous time period. Range shift was distinguished from migration by a lesser distance moved and some amount of overlap in home range continuing to occur.

To test whether the animals moved randomly or in an oriented manner within their seasonal home range Rayleigh's z statistic was calculated (Zar 1974, White and Garrot 1990). Also, to test whether the range was used intensively, i.e., in a concentrated manner or in a dispersed manner, the measure of concentration, *'r'*, was calculated (Zar 1974, White and Garrot 1990). For a selected time period, angle of movement between consecutive locations (a_i) were calculated based on the difference in the Easting and Northing values using the formula:

$a_i = \arctan(Yi/Xi)(180/\pi)$ if $Xi>0$

$a_i = 180° + \arctan(Yi/Xi)(180/\pi)$ if $Xi<0$

$a_i = 90°$ if $Xi=0$ and $Yi>0$

$a_i = 270°$ if $Xi=0$ and $Yi<0$

Where, Xi and Yi are the differences between consecutive X and Y coordinate values, respectively.

The measure of concentration is:

$r = \sqrt{(Xbar^2+Ybar^2)}$

where, $Xbar = 1/n \sum^{n}_{i=1} \cos a_i$

$Ybar = 1/n \sum^{n}_{i=1} \sin a_i$.

To test the H_o that the sample angles (a_i) confirmed to a random distribution the Rayleigh's z statistic (Zar 1974, White and Garrot 1990) was calculated as:

$$z = nr^2$$

where n = sample size

If the z calculated was higher than the critical value given in Zar (1974), the null hypothesis was rejected in favour of the H_1 that movements were oriented.

There were consistent data on three adult females and three adult males whose range sizes were compared using the Mann-Whitney U test. Seasonal differences between range sizes of males and females were tested using the Kruskaal-Wallis one-way ANOVA. Differences were considered significant if $p \leq 0.1$.

Forage availability and quality

Forage availability (quantity), and quality in temperate/alpine areas vary greatly round the year. These may influence rate of travel and range sizes of ibex. Ideally, quantification for both these parameters for a given time period is desired from the entire range of the study animals. Biomass per unit area is a good index of availability while nutrients and anti-herbivory compounds can jointly influence quality. In the absence of such clear-cut indices for Pin Valley, I have subjectively ranked (Table 4.2) the forage quantity and quality of months and seasons based on literature for other temperate/alpine areas (Fox *et al.* 1989) and some cover and nutrient analysis data (Manjrekar 1997). Monthly ranking of relative availability and quality (Table 4.2) was related to the respective rate of travel for radio-collared animals using Spearman's rank correlation test (Sokal and Rohlf 1995). Relationship between range size and ranked seasonal forage availability and quality was also tested in a similar fashion. An explanation for the ranking in Table 4.2 follows:

Snow restricted forage availability drastically in January/February (peak winter) while due to some amount of thaw from March to mid-April there was a slight increase in availability. With continued increase in temperatures, snow-melt exposed more areas during spring (mid April to June) but this had low biomass being in the sprouting stage. By July further increase in temperatures initiated the peak vegetation growth phase which lasted till mid September. Senescence picked up in the second half of September after which there was a decline in net forage availability till the commencement of winter in December. Heavy snow from January further limits forage availability.

Crude protein (CP) levels were the highest during the spring sprout (Manjrekar 1997) suggesting high forage quality. However, this is also the period when anti-herbivory compounds such as alkaloids are reported to be high in forbs, thus causing a reduction in the palatability of such species (Robbins 1983). Grasses which lack anti-herbivory compounds in their growth phase, had high CP levels during spring. These were dominant and were selected by ibex during this season (Manjrekar 1997). Hence, forage quality during spring is considered to be the highest. The CP levels marginally declined during summer (Manjrekar 1997) and further reduced during senescence in autumn. The quality is further expected to decline by early winter (December) with greater drying, translocation of nutrients to roots (Hanley and McKendrick 1983, quoted from Fox *et al.* 1989) and reduction in the amount of fruits. The annual low in forage quality is reached in the snow covered months of January/February when leaching may cause further reduction in quality. There may be a marginal improvement in quality in late winter in some windblown areas or thaw in avalanche paths.

Table 4.2:Monthly subjective ranking (in ascending order) of forage quantity and quality.

Parameter	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul	Aug.	Sep	Oct.	Nov	Dec
Quantity	1.5	1.5	3	4	5	6	11.5	11.5	10	9	8	7
Quality	1.5	1.5	3	4	12	11	9.5	9.5	8	7	5.5	5.5
	PW		LW	SPRING			SUMMER		AUTUMN			EW
Quantity	1		2	4			6		5			3
Quality	1		2	6			5		4			3

*n.b.*EW: early winter; PW: peak winter; LW: late winter

It should be noted here that the ranking in Table 4.2 as defined above for winter and spring may differ between years due to variations in snowfall patterns.

4.3 RESULTS

4.3.1 Association Among Radio-collared Animals

The association index (AI) reflects the amount of spatio-temporal overlap between animals. Females 1, 3 and 7 were strongly associated, (AI varied between 0.631 and 0.703) while their association with female 15 was poor (AI < 0.200; Table 4.3). The two adult males were poorly associated with all animals while the sub-adult male 13 had moderate associations with all except female 15 and male 12. The sampling of female 15 was infrequent owing to constraints detailed in the Methods section (4.2.2). However, it is certain that its association with any other collared animal was minimal. Similarly, male 12 had migrated outside the monitored catchment for over 140 days, and even later, remained less associated with the other collared animals.

Table 4.3: Annual association matrix between radio-collared animals based on Sorensen's similarity index. Higher values (in bold) suggest greater spatio-temporal overlap.

	F1	F3	F7	F15	M11	M12	M13
F1		**0.631**	**0.684**	0.116	0.200	0.130	**0.424**
F3			**0.703**	0.096	0.210	0.104	**0.424**
F7				0.110	0.238	0.132	**0.497**
F15					0.183	0.126	0.067
M11						0.239	**0.424**
M12							0.218
M13							

Based on the frequency occurrence of animals together in one group they were clustered into two main groups as a) females 1,3,7 who were strongly associated and b) female 15, adult males 11, 12 and sub-adult male 13 (Fig. 4.1). The latter group had poor association amongst themselves.

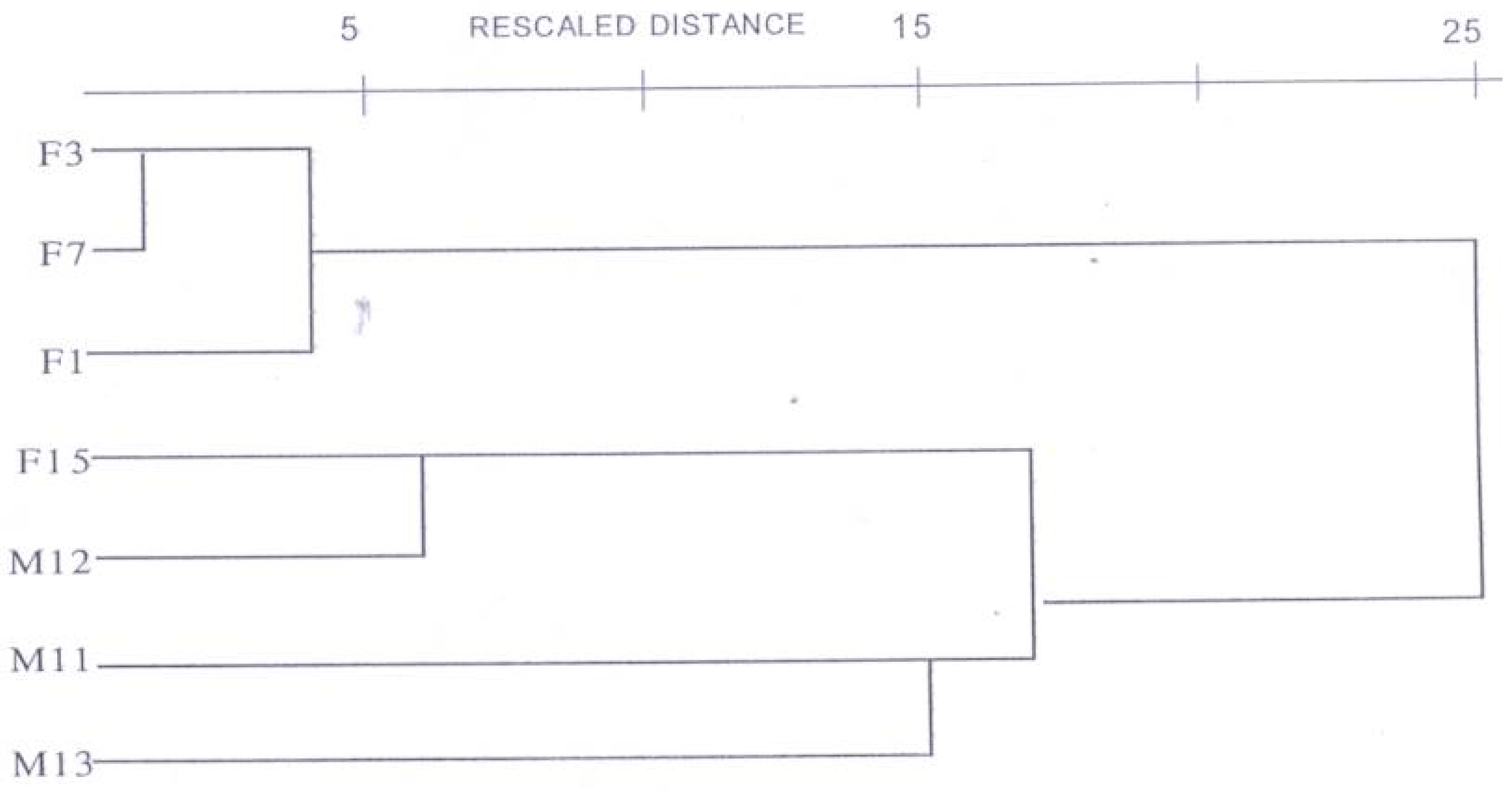
Association between females 1,3 and 7 remained high in all seasons (Appendix 4). The association between any given pair was usually highest during spring when animals aggregated at the sprout on the lower south facing slopes to feed on the sprouting vegetation.

4.3.2 Mobility

Seasonal mobility or day range length

Seasonal day range lengths differed for both, adult females (χ^2= 105.6, df=5, p<0.001) and males (χ^2 = 56.5, df=5, p<0.001). Female ibex covered greater distance (mean ≥ 1000 m/day) in the period with higher vegetation cover and succulence (July through September), followed by a sharp decline between October and December, the period of senescence, to the annual low (mean ≤ 400 m/day) in the deep snow months from January to March (Fig. 4.2a). The monthly trend of adult males confirmed to that of the females with one marked difference during December. The adult males covered greater distances daily during the pre and early rut period of December (1,489 m/day) (Fig. 4.2b) and also shifted their range to the left bank of the Kidul Chu river for the remaining rutting period in January, 1995 (Fig. 4.4 e,f,g) when their mean day range length

Fig. 4.1: Dendrogram showing association between radio-collared animals. (Cluster analysis on occurrence of radio-collared animals together in a group using 'average linkage between groups')



declined to below 350 m/day. Sub-adult male 13, however did not show any increase in speed of travel during the pre-rut, although it did quickly move to a different part of the area during peak rut (see Section 4.3.1).

Ecological correlates of mobility

Ibex tended to cover greater distances in periods with relative high forage quality and quantity (Table 4.4; Spearman's rank correlation, $p<0.05$). Their mobility was severely hindered during winter months (January/February) when heavy snow covered the forage and made travel difficult.

Table 4.4:Relation between monthly forage quantity, quality and monthly day range lengths (Spearman's rank correlation coefficient (r_s)) ('p' values in parenthesis).

Animal	Range length vs. Forage quantity	Range length vs. Forage quality
Adult Female (n=3)	0.835 (0.001)	0.731 (0.007)
Adult male (n=2)	0.554 (0.061)	0.657 (0.020)
Sub-adult male (n=1)	0.625 (0.030)	0.752 (0.005)

n.b.:*Male 12 had positive correlation but data was lacking for 5 months*

4.3.3 **Seasonal Home Range and Core Zone Size**

Trends in range sizes

The seven monitored animals have been divided into four groups based on their age-sex class. The four categories were: a) adult females 1, 3, 7, who had good sample size, b) female 15, who had low sample sizes, c) the two adult males (11, 12), and d) the sub-adult male 13. This is also the result of the 'association' analysis (Table 4.3; Fig. 4.1). Apart from low sample size, female 15's transmitter failed after January, 1995, after which the animal was only opportunistically spotted.

Table 4.5:Seasonal home range size estimates based on minimum convex polygon. Sex wise and overall seasonal sizes ± SE. Please see Table 4.6 for seasonal sample sizes.

ANIMAL	HOME RANGE AREA (km^2)							
	SUMMER 1994	AUTUMN 1994	WINTER 1994-95	WINTER^			SPRING 1995	ANN.
				EARLY	PEAK	LATE		
FEMALE 1	10.0	12.0	8.0	7.08	3.90	3.00	3.0	18.7
FEMALE 3	11.0	8.6	7.4	4.32	4.00	4.24	3.1	20.9
FEMALE 7	13.9	12.1	6.6	4.94	4.14	3.68	3.3	20.4
MEAN ± SE	11.6± 1.2	10.9± 1.2	7.3± 0.4	5.5± 0.8	4.0± 0.07	3.64± 0.36	3.1± 0.09	20± 0.7
FEMALE 15	25.9	15.6	8.8	-	-	-	0.4	34.4
MALE 11	18.5	11.7	28.5	14.29	11.7	11.72	2.6	40.4

ANIMAL	HOME RANGE AREA (km ^{2})							
	SUMMER 1994	AUTUMN 1994	WINTER 1994-95	WINTER^			SPRING 1995	ANN.
				EARLY	PEAK	LATE		
MALE 12	-	-	16.5	9.97	5.13	4.83	2.8	-
MEAN ± SE	-	-	22.5±6.0	12.1±1.4	8.4±3.3	8.3±3.5	2.7±0.1	-
MALE 13	23.0	8.5	34.7	9.63	8.46	2.79	3.3	47.2

^Winter has been divided into early (1 Dec.-15 Jan.), peak (16 Jan.-28 Feb.) and late (1 Mar.-15 Apr.)

n.b.Number of days covered in the seasons was summer and autumn, 76; early, late winter and spring, 46 and peak winter, 44 days; annual, 334.

Ibex had a mean home range size (MCP) of 30.33 ± 4.5 km^2. Males, (excluding male 12 who migrated outside the catchment in summer and autumn) had larger annual home ranges (43.8 ± 3.4 km^2) compared to females 1, 3 and 7 (20 ± 0.7 km^2), although the difference was significant only at $p = 0.08$ (Table 4.5). The oldest adult male 11 (9 years) had an annual home range of 40.4 km^2 while the home range of the younger male 12 (5 years) was probably more than double this value owing to its summer migration outside the Parahio catchment. The home ranges of female 1,3 and 7 averaged 20 ± 0.7 km^2 but that of female 15 was 1.72 times larger (34.4 km^2), owing to its more extensive summer movements. The sub-adult male 13 had a home range similar in geographical extent, to females 1,3 and 7 during spring and autumn but the range was much larger during summer and winter. Thus, its annual home range was large (47.2 km^2), being only second to male 12 in total size.

Among seasons, the spring home range for females 1,3 and 7 was smallest (3.1 km^2 ± 0.09) followed by a major range expansion of over four times in summer (11.6 ± 1.2 km^2) a slight contraction during autumn (10.9 ± 1.2 km^2) and a further decrease during winter (early: 5.5 ± 0.8, peak: 4.0 ± 0.07 and late: 3.6 ± 0.36 km^2) ($\chi^2 = 15.15$, $P < 0.01$). As an example of this trend for the female No. 1, see Fig. 4.3. Values differed, but the trend in home range sizes remained similar for female 15 (Table 4.5). Seasonal range sizes for males also differed ($\chi^2 = 10.19$, $p = 0.07$). Spring home ranges were smallest among seasons for the males, varying between 2.6 and 3.3 km^2 and were similar to female range sizes in this season. Summer home range for both male 11 (18.5 km^2) and 13 (23.0 km^2) far exceeded the female (1,3 and 7) home range sizes which varied between 10 and 14 km^2 (mean 11.6 ± 1.2 km^2). Entire winter home ranges for all three males (_11: 28.5 km^2, _12: 16.5 km^2 and _13: 34.7 km^2) were greater than the mean female (1,3 and 7) home range by 3.9, 2.3 and 4.8 times, respectively. Male home range sizes for early, peak and late winter were also approximately double their respective seasonal female range sizes. Males had larger early winter (rut) ranges compared to their autumn ranges as the size decreased during peak and late winter. Autumn home range sizes for males 11 (11.7 km^2) and 13 (8.5 km^2) were not very different from female home ranges (Table 4.5).

Trends in home range size obtained by the harmonic mean method were similar to MCP (Table 4.6). Animals had largest ranges in summer, while in early, peak, late winter and spring range sizes were smaller in case of females ($\chi^2 = 13.96$, $p = 0.014$) and to some extent, for males ($\chi^2 = 7.07$, $p < 0.10$) (Table 4.6). Males had slightly larger annual home range than females (excluding female 15) ($U = 0.0$, $p < 0.10$).

For females 1,3 and 7 core zone (harmonic mean 55 % contour) sizes (Table 4.6) were larger in summer than other seasons ($\chi^2 = 14.24$, $p = 0.01$). Core zone size trends for males were also similar but not significantly different ($\chi^2 = 8.57$, $p = 0.13$). Except for the adult male 11, whose annual core zone size was 6.85 km^2, all other sizes varied between 2.95 and 3.67 km^2 ($U = 0.0$, $p = 0.08$) (Table 4.6). The number of annual core zones did not exceed 4 for any animal although in some seasons, such as summer, up to 9 core zones were observed (Table 4.6).

Ecological correlates of range size

Female range sizes increased with forage availability (r_s=0.67, n=16, p=0.005). Summer had largest home ranges, followed by autumn, winter and spring. In case of males such a trend was lacking (r_s=-0.08, n=10, p=0.82), but on excluding winter range sizes, when large scale range shifts were observed, a positive trend emerged (r_s=0.94, n=7, p=0.001). There was a weak negative correlation between range sizes and forage quality for both sexes (r_s=-0.6, n=7, p=0.15 for males (excluding winter); r_s= -0.29, n=16, p=0.27 for females).

Ibex had smaller home ranges in periods with snow cover (winter and spring) (Table 4.5 & 4.6), although this may be the combined influence of forage availability and mobility through snow.

4.3.4 **Seasonal Movements - Range Shift and Migrations**

The fortnightly arithmetic mean locations for all the seven animals has been plotted in Fig. 4.4 (a to g) to show the movement patterns. Arithmetic mean can misrepresent centre of activity due to the outliers (Dixon and Chapman 1980, Koppel *et al.* 1985). Here, this estimator is used not as a measure of centre of activity *per se* but to represent fortnightly mean locations for comparisons between animals, between months or seasons. On examining the broad trends we find that female 1, 3 and 7 and sub-adult male 13 (Fig. 4.4 a,b,c,g) moved in a 'clumped' manner while the two adult males, _ 11 and 12 (Fig. 4.4 e,f) and female 15 (Fig 4.4 d) moved in a more dispersed fashion. In early summer all animals showed varying amounts of range shift. During July-August, female 1,3,7, male 11 and 13 moved approximately 2 km from their mean late June location, but occupied areas rarely visited in the rest of the year. Female 15 moved 4.6 km away in late June compared to its early June mean location and through summer (July - August), moved large distances (3.3 to 5.7 km) each fortnight. Male 12 moved over 20 km to an unknown site in late July. Between December-January, female 1,3,7 moved *ca.* 2 km west to their January range, adult male 11 moved the same distance to the east, while the sub-adult male moved *ca.* 8 km further to the east.

As mentioned above, barring male 12 and female 15, for all other animals two distinct outliers were seen in their fortnightly mean locations, one in January (peak rut/peak winter) and another in July/August (peak summer). There was a remarkable similarity in the distributions of the females 1, 3 and 7 through out the year (Fig. 4.4 a,b,c). The sub-adult male (13) also had a very similar distribution (Fig. 4.4 g) but shifted to a different area during the rut (January). The movement trends of male 12, 13 and female 15, the only ones who showed long distance migrations, are discussed in greater detail below.

The sub-adult male (13) was in the Gechang area with the three females (1, 3 and 7) during early rut and rapidly shifted range to the Chidang *nala* area, moving a straight line distance of over 8 km between two locations (within 9 days; 25/12/95 to 02/01/95) (Fig. 4.4 g, Fig. 4.6). The animal had most likely moved the entire distance to Chidang by 27th December itself when an attempt to relocate it was made. The area from one of my tracking points to Chidang has a straight line of sight, except for the last 2 km when a ridge blocks it. Therefore the migration, probably occurred in a single day (26 and 27 December). This shift coincided with the initiation of peak rut (increased courting and mating activity). Male 13 remained in the Chidang area till the cessation of rutting activities and returned to the Gechang region on 2 February, after an excursion of 37 days.

The adult male 12 and female 15 were the only two collared animals who showed summer migration in July. Male 12 migrated out to an unknown area between 11 July, 1994 and 18 December, 1994 (161 days) (Fig. 4.5, Fig 4.4 f). The animal was tracked in the entire Parahio catchment (from upper Khamingar R. and Debsa R. to Guling spanning a distance of *ca.* 25 km (Fig. 2.2) without any success. The animal had most likely migrated to a site in upper Ratang *nala*, *ca.* 20 km due north-west of the capture site, across a ridge (between 5,000 and 5,600 m). The upper Ula catchment, *ca.* 15 km due north of the capture site is another plausible site (Fig. 4.4d, Fig. 4.7). The animal again migrated out in July, 1995 when the main phase of field work was over.

Female 15 had migrated over a ridge (5,000 m high) to largely remain in the Ula river catchment, over 10 km from the capture site (Fig. 4.7). It also visited the higher parts of the left bank of Kidul Chu adjacent to Ula. Although there was a pronounced shift in the range during July-August, in the strict sense of the above definition (Section 4.2.3) this animal did not show migration since some locations overlapped with those of June.

Fig. 4.2: Mean day range (meters travelled/day with SE) for female 1,3 and 7 (a), adult male 11 & 12 (b) and sub-adult male 13 (c).

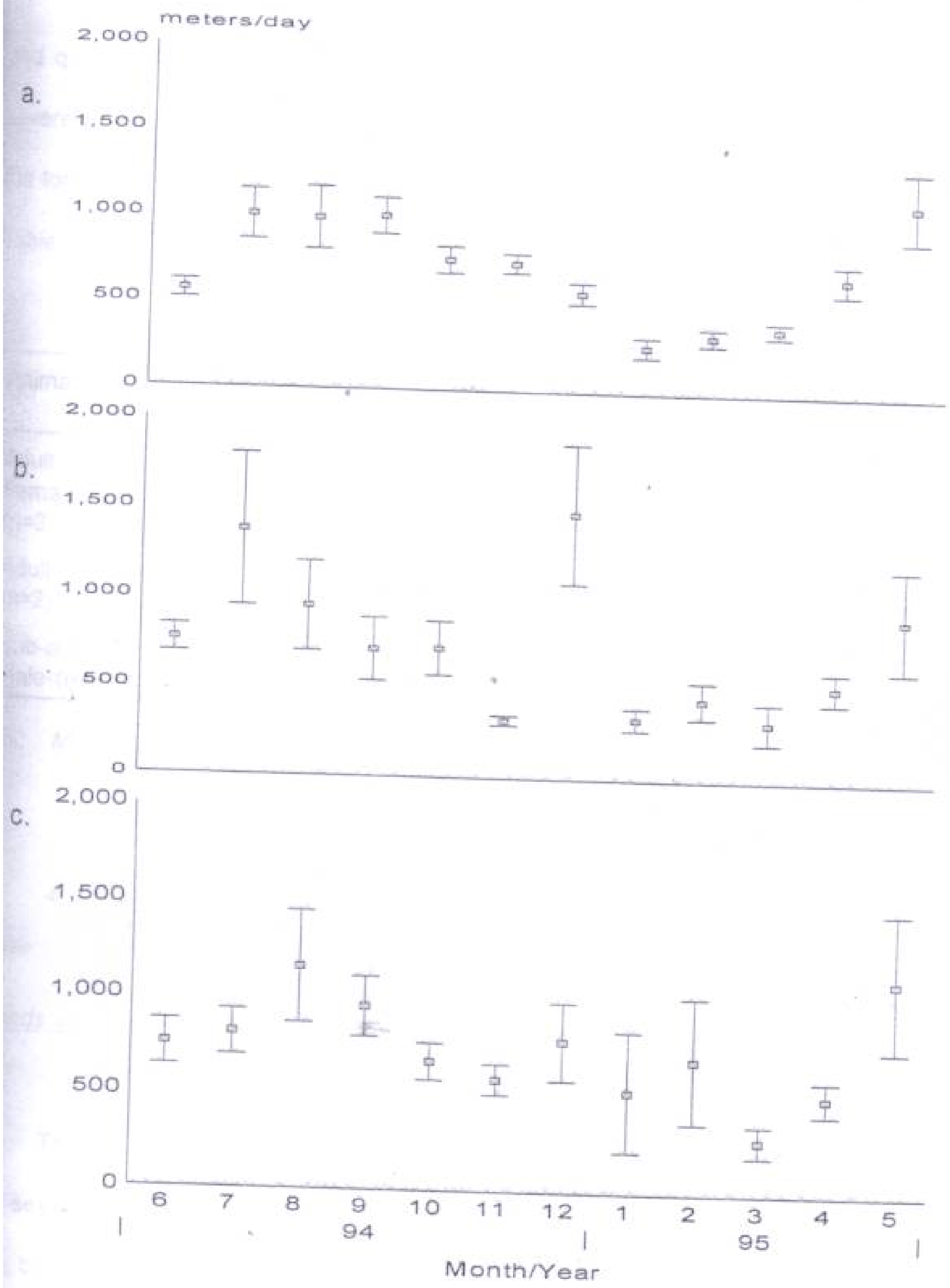


Fig. 4.3: Home range of female no. 1 in summer (SU), autumn (AU) 1994 and peak winter (PW), spring (SP)1995 in Pin Valley National Park. Home ranges based on minimum convex polygon.

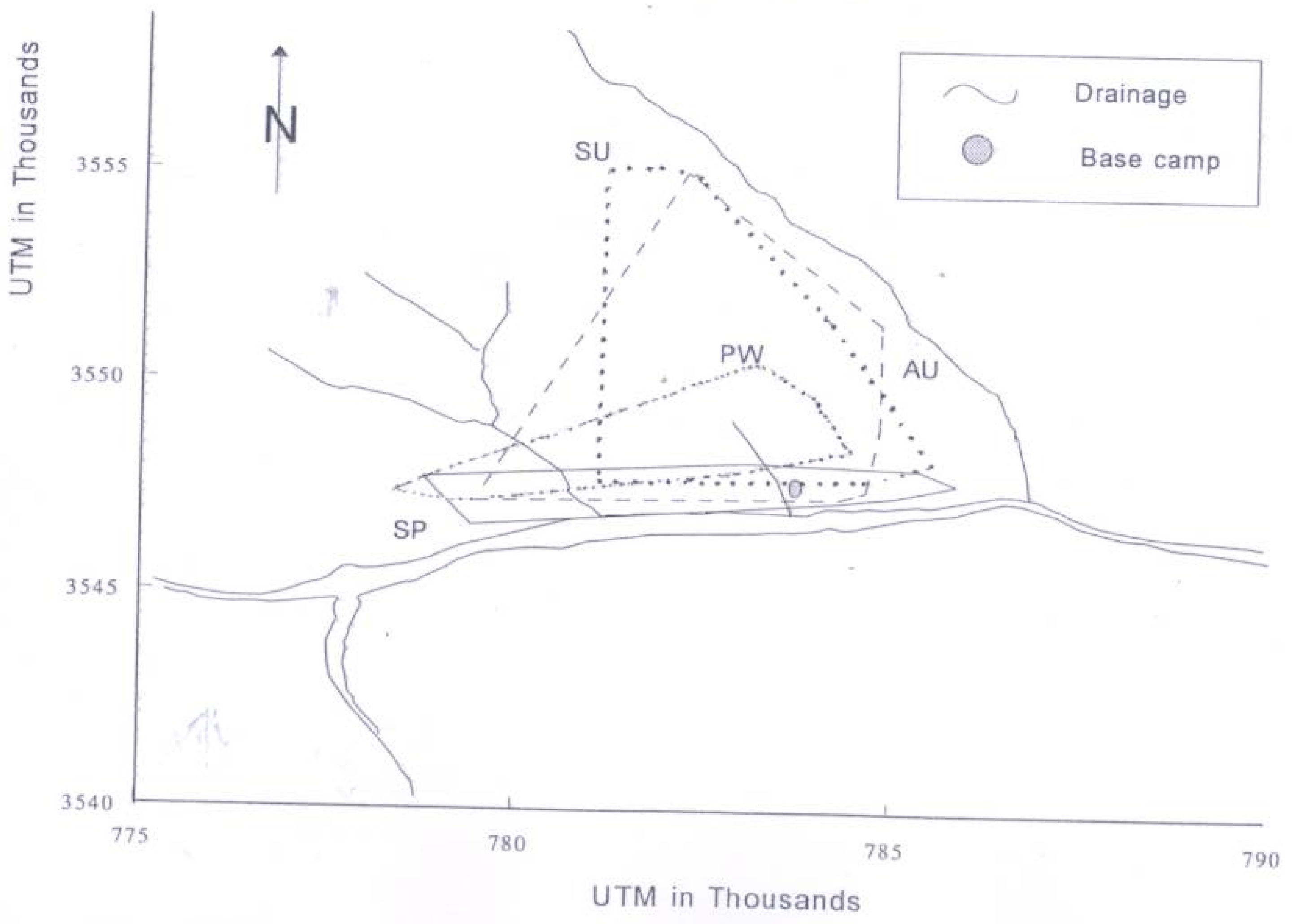


Fig. 4.4:Fortnightly arithmetic mean locations of males between June, 1995 and May, 1995 in Pin Valley NP. Each fortnight of a month is marked by the same no., eg. May by 5.

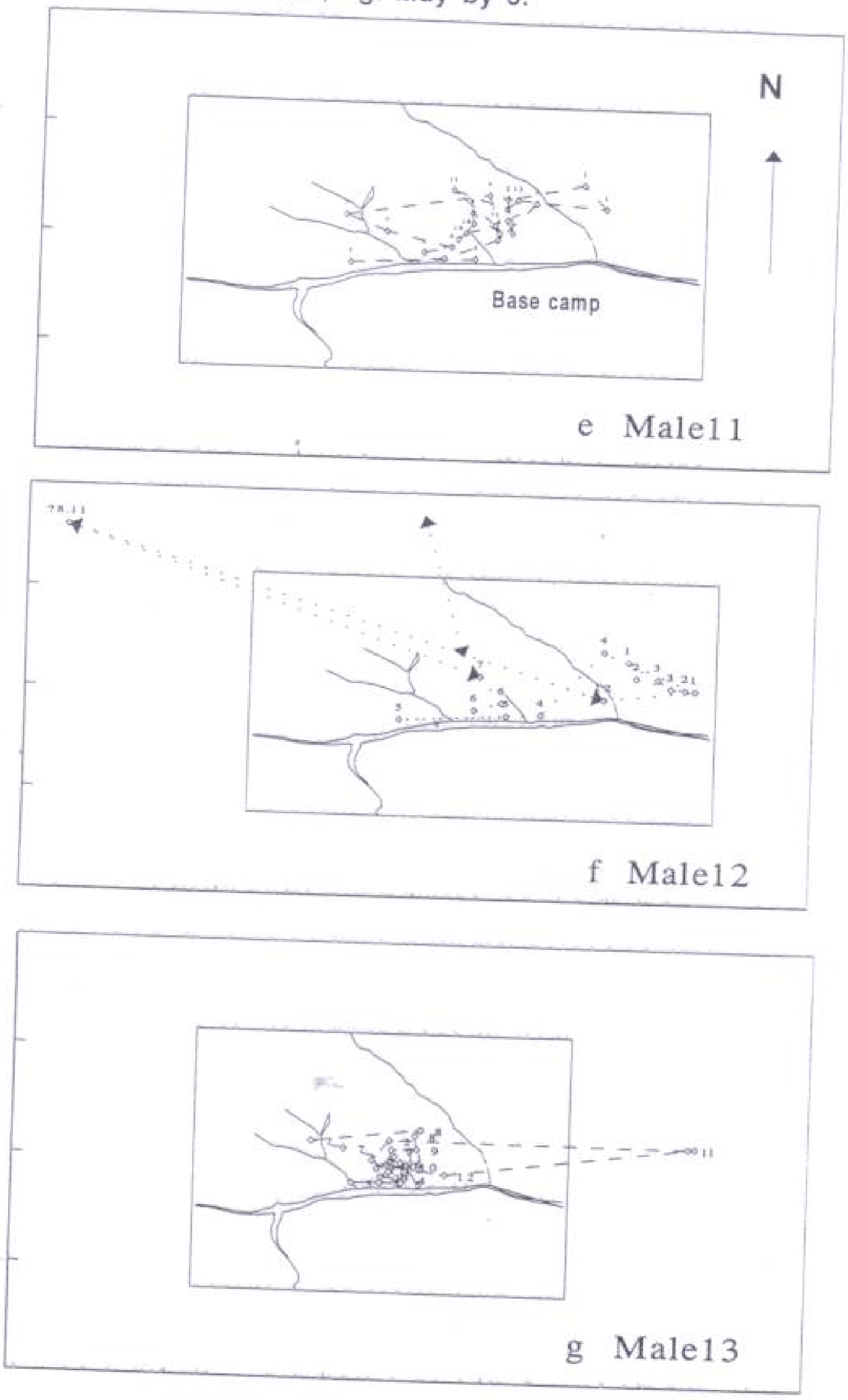


Fig. 4.4: Fortnightly arithmetic mean locations of females between June, 1994 and May, 1995 in Pin Valley NP. Each fortnight of a month is marked by the same no. eg. January by 1

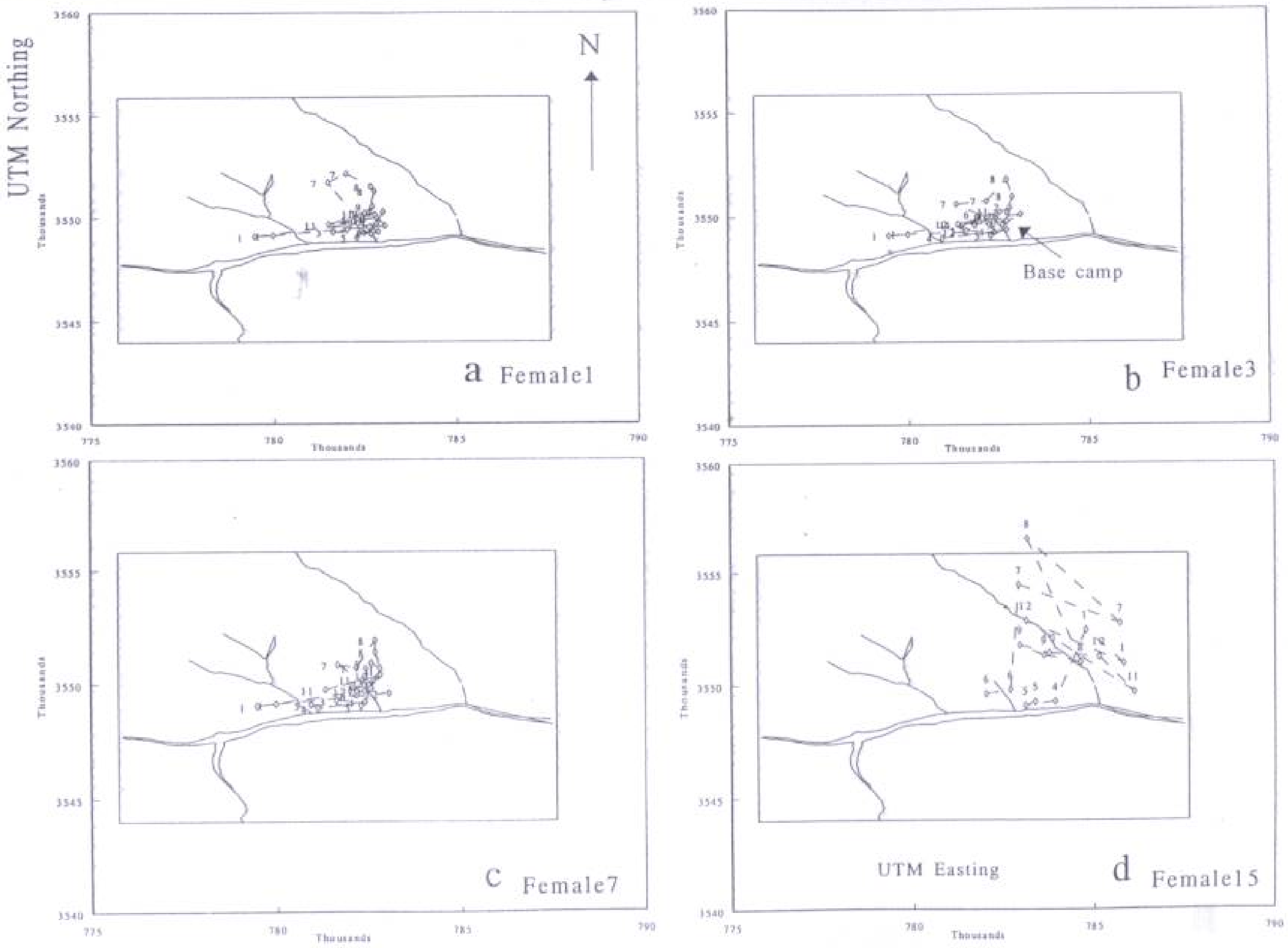


Fig.4.5:Migration by the adult male no.12 in July, 1994, to an unknown site, most probably in the upper Ratang river catchment. Figure shows the period between 15 June, 1994 and 31 January, 1995. Consequtive locations are connected by lines and the respective month and date are given.

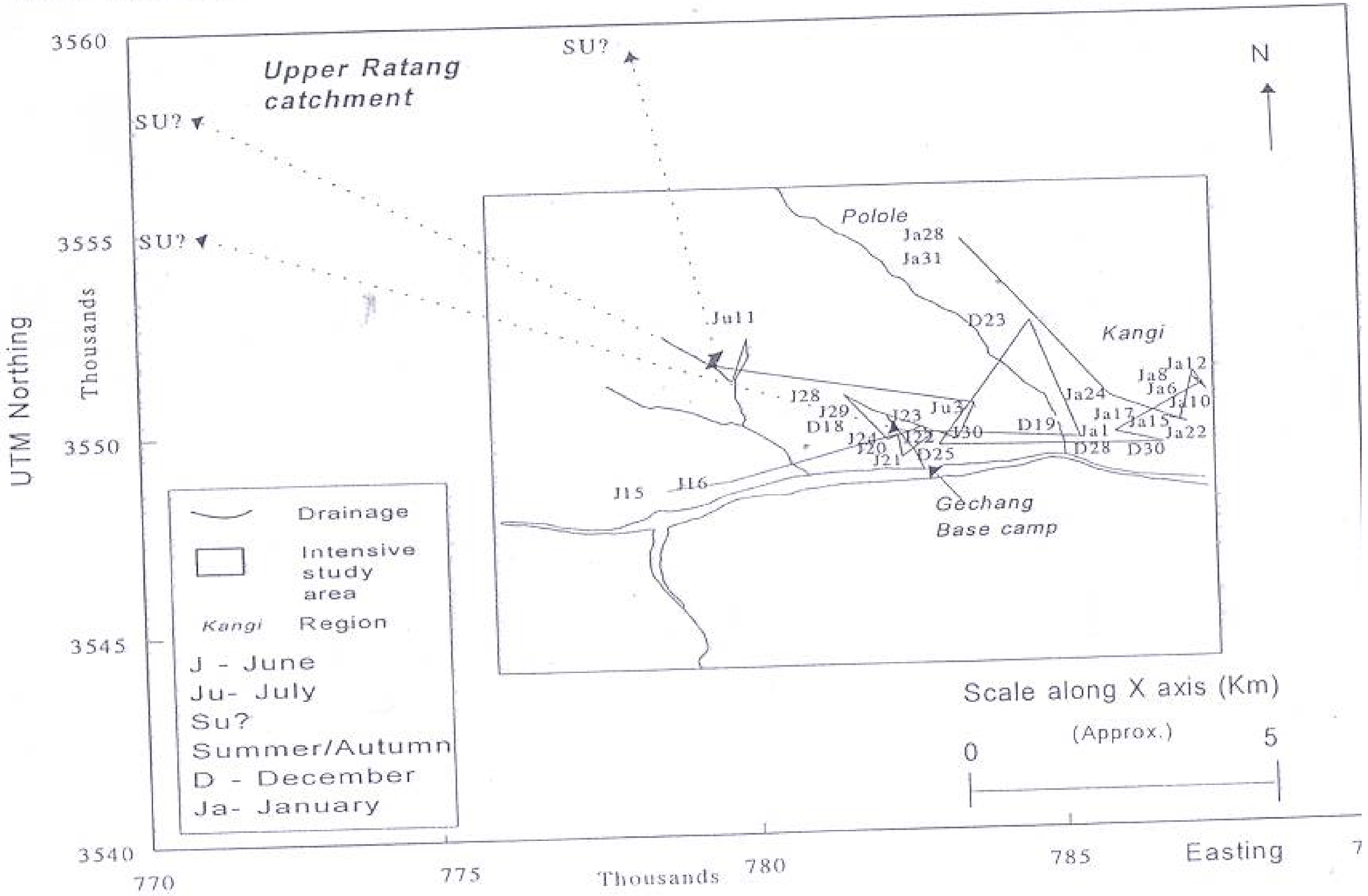


Fig.4.6: Migration of the sub-adult male no.13 during peak rut (January) and its return after the rut in February. Only locations between 15 Dec. and 15 Feb. are shown. Consequtive locations are joined by lines and their respective month and date are given.

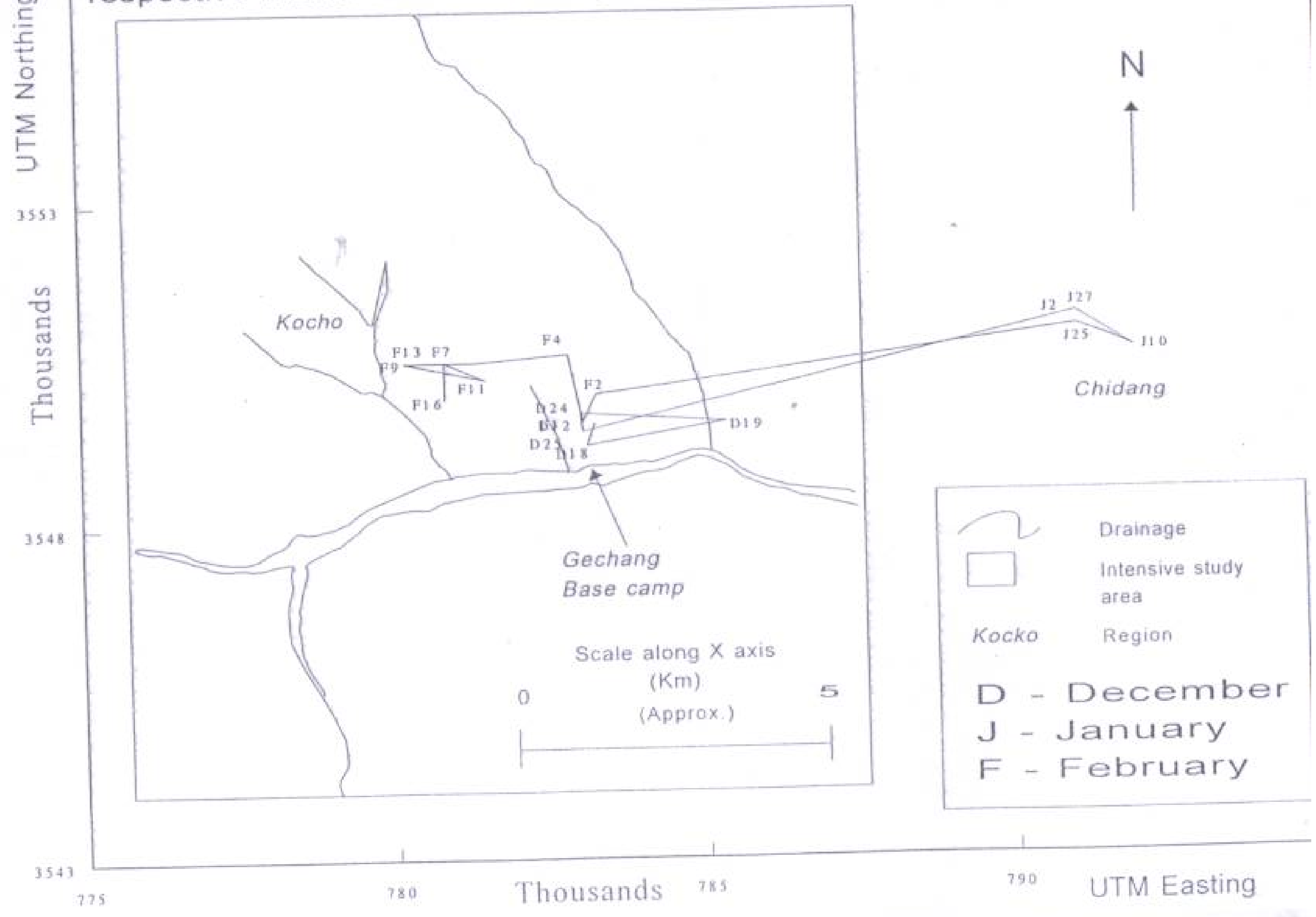
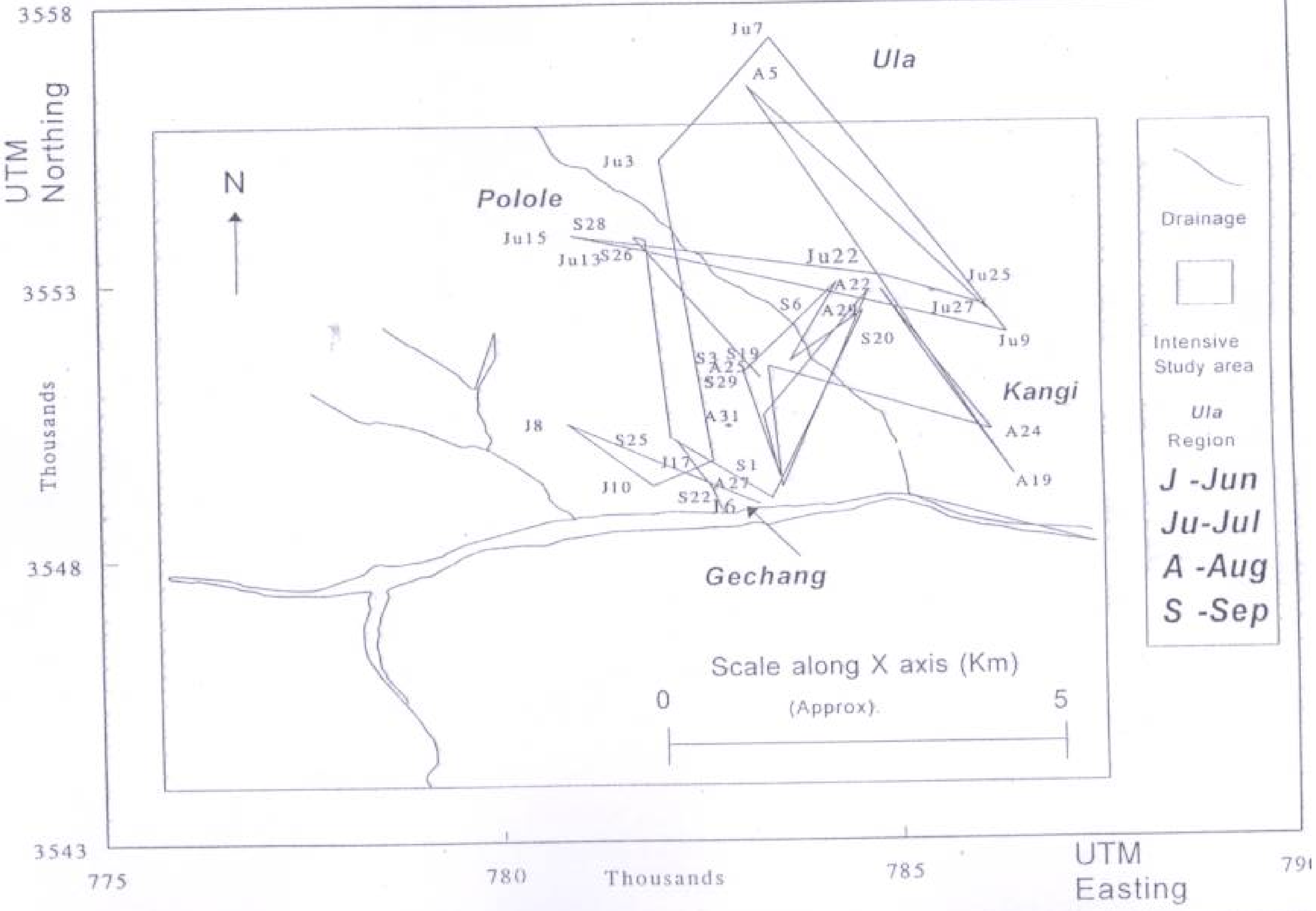


Fig. 4.7: Migration of Female no.15 in July, 1994 to the Ula-Polole-Kangi area. Figure shows consequetive locations joined by lines and their respective month and date are given.



4.3.5 **Movement Patterns - Index of 'Concentration'**

Animals may move within their seasonal home range in a 'concentrated' or a 'dispersed' manner. The measure of concentration, 'r', was consistently high in winter, especially peak winter for all animals (Table 4.7). This indicates that ibex used their winter range more intensively compared to other seasons. The usage pattern in summer and autumn was more dispersed as indicated by the lower values of 'r' occurring in these seasons for all animals.

In order to test whether the distribution of the angles between consecutive locations, a_i, departs from a uniform circular distribution, the Rayleigh's z statistic was calculated. The null hypothesis was that the direction of movement was random while the alternative hypothesis was that it was oriented.

Animals mostly moved in a random fashion in all seasons ($p>0.05$; Table 4.7). Females 1, 3 and 7 had oriented movements during peak winter ($z = 4.06$, 4.06 and 5.55, $p \leq 0.05$) when they moved between patches in a restricted home range. Female 1 also had such movements in late winter ($z = 3.70$, $p = 0.05$) and female 7 in summer ($z = 3.52$, $p = 0.05$). Female 15 showed oriented movement during summer, when she migrated to an adjoining area ($z = 2.98$, $p = 0.05$). Males moved within their seasonal ranges randomly except male 11 in late winter who showed oriented movement ($z = 3.66$, $p = 0.05$). Data on male 12 could not be collected for two seasons, summer and autumn, hence, it is not possible to comment on its movement patterns during this time period.

Table 4.7:'Index of concentration' (r) test of randomness in movement patterns, for the seven collared animals. The index 'r' can vary between 0 and 1. See Section 4.2.3 for details of the indices.

SEASON	ANIMAL						
	_1	_3	_7	_15	_11	_12	_13
SUMMER, '94	0.18	0.15	0.29*	0.40*	0.23	-	0.28
AUTUMN, '94	0.11	0.09	0.15	0.30	0.19	-	0.10
EARLY WINTER, '94	0.08	0.11	0.20	0.35	0.16	0.26	0.19
PEAK WINTER, '95	0.54*	0.54*	0.63*	0.42	0.40	0.26	0.54
LATE WINTER, '95	0.43*	0.33	0.22	-	0.44*	0.26	0.17
SPRING, '95	0.20	0.23	0.24	0.50	0.23	0.15	0.12

*Rayleigh's z ($z=nr^2$) statistic testing for 'randomness' of movement is rejected ($p \leq 0.05$) and these were 'oriented' movements.

4.4 **DISCUSSION**

4.4.1 **Home Range and Core Zone Sizes**

The annual home range sizes for ibex in Pin Valley are much larger than those reported for the Alpine ibex. For males of the latter species, Bassano and Apollonio (*unpubl. data*) reported a mean size of 3.52 km^2 (range 1.81 to 7.93 km^2, SD 2.258, minimum convex polygon with 95% of locations). The Alpine ibex habitat is quite different in terms of much higher forage availability and less arid conditions. Desert bighorn sheep range sizes were comparable to the Asiatic ibex from this study. Annual female range sizes between 13 and 21 km^2 and male range size between 11.7 to 37.3 km^2 were reported by Leslie (1977) and Leslie and Douglas (1979). Mountain goat (*Oreamnos americanus*) range sizes also matched this study with animals ranging in *ca.* 10 to 20 km^2 annually (Fox *et al.* 1989).

Ecological Correlates of Mobility and Range Sizes

Foraging theory suggests that the value of a food item is determined by its nutritive value relative to the costs of acquiring it (MacArthur and Pianka 1966). Since high quality forage is patchily distributed, acquiring it is associated with higher search effort and reduced intake rates (Jarman 1974). When nutritive quality varies greatly among species, maximum benefit in terms of nutrients and/or energy may be achieved by increasing the search effort for higher quality food, even at the cost of reduced biomass intake (Goodson *et al.* 1991a, McCorquodale 1993).

Forage availability in terms of quantity and quality follows a distinct seasonal pattern in the cold desert region of Pin Valley (Table 4.2). Forage was relatively abundant during summer and ibex could acquire the required amount of forage by moving less within a smaller seasonal range. In this study the trend was opposite and ibex moved most in a large area during this season. Why was this so?

Ibex, like most other temperate/alpine ungulates, have a short summer season to recoup from the rigors of the severe winter. Males have to build body and horn size to enhance survival and combat abilities (Geist 1971, Schaller 1977), while most females have to take care of parturition and lactation costs (Geist 1971, Schaller 1977). In terms of net biomass availability summer is the season of abundance but in terms of preferred diet the season may still consist of scarce and patchily distributed items. Hence ibex have to move faster, covering a larger area during the season. In summer, ibex did feed on few species favouring plant parts such as growing shoots, flowers and fruits, suggesting greater selectivity (Manjrekar 1997, *pers. observ.*). Under existing conditions, feeding selectively on plant parts by increasing the search effort may be the best strategy for maximum returns for ibex. This was also suggested for caprini and deer species by Goodson *et al.* 1991a, McCorquodale 1993.

In winter, ibex used their range in a concentrated manner (Section 4.3.5), travelling less, when deep snow in peak winter restricted their movements. Owing to constraints imposed by terrain and snow conditions the areas 'usable' by ibex during winter were restricted to small patches, often 1-2 ha in extent (such as avalanche paths, wind-blown crests and broken steep areas) which were used for prolonged periods of 7-10 days (see Section 5.3.3 for more details). Animals travelled to other similar sites, often 0.5 to 2 km away in a single file. The primary goal of ibex in this season was probably to obtain sufficient bulk forage to keep the rumen full and survive the winter. The optimal strategy thus would be to find sites with greater security and forage biomass that have favourable snow conditions and use these patches intensively by spending minimum energy in search of foraging areas and moving between patches. This strategy was observed in this study and also in case of Spanish ibex (*Capra pyrenaica*) (Alados and Escos 1987), bighorn sheep (Goodson *et al.* 1991 a,b) and various deer species (Moen 1976, Holzenbein and Schewede 1989, McCorquodale 1993). Ungulates may restrict movements and conserve energy by lowering activity rates and time searching for food in winter. In other words the give-up-density (*sensu* Kotler *et al.* 1994) of a patch would be lower than for any time period without snow. Snow restricted mobility and access to forage thus increasing the search effort to locate and forage within a patch. This in turn reduced the average rate of movement and range size. My observations on ibex feeding signs revealed close cropping of plants during winter. Also, the nutritive quality in terms of % crude protein and anti-herbivory compounds in terms of % tannin content was less variable across species and animals foraged with relative un-selectivity (Manjrekar 1997).

By spring the body condition of most animals was poor (*pers. observ.*). During this season, the thaw in the lower, south facing slopes initiated sprouting, especially of *Lindelofia anchusoides* and some grasses. The net biomass available was low and very patchy. Animals close-cropped available sprout and moved faster between patches to allow for regrowth and exploit the scarce, high quality resource within a constrained area (as determined by thaw). Thus the rate of daily travel was relatively high (Fig. 4.2) but range size remained small (Table 4.5, 4.6).

This study reveals that ibex moved faster covering larger ranges while feeding selectively during the snow-free periods, especially summer. During this period, resources of variable quality were abundant and widely distributed. But during winter, forage was more or less of uniform quality and access to it was difficult through snow, thus animal movement and range sizes were restricted. In spring ibex exploited the sparse sprout by moving more within a restricted snow-free area. Forage quantity or availability, quality and snow characteristics were thus important determinants of ibex movements and range sizes.

4.4.2**Range Shifts and Migrations**

All radio-collared ibex showed distinct patterns of mobility during the pre-rut and the rutting period when some amount of range shift was observed. Adult males moved faster during the pre/early rut in December, 1994 (Fig 4.2b) compared to other seasons and other animals and shifted range to a different part of the study area (Fig. 4.5, 4.4 e,f) where they continued to stay during the rut. Caprine males, especially *Ovis* and *Capra* have to establish a dominance hierarchy for mating rights over an oestrus female (Geist 1971, Schaller 1977). This activity is highest during the pre-rut period when adult males move between groups to contest and establish their dominance (Schaller 1977, Bhatnagar, Y.V., *unpubl. data*). The adult males (no. 11 and 12) moved faster, possibly in order to locate a group, establish their dominance and find oestrus females. Males of *Capra* spp., (unlike *Ovis* spp.) do not move between groups during the rut (Schaller 1977) and this was demonstrated among these two males settling down in separate groups in the Kangi/Minser area during the rut in January, 1995.

The sub-adult male 13, migrated at the initiation of peak rut in January, 1995. The departure clearly coincided with an increase in courting and mating activity and its return with the cessation of this activity. The excursion may be due to social intolerance by its possible kin group or by other adult males in the group. The sub-adult male was courting before he left the Gechang area and no sign of aggression directed against it by adults of either sex were observed. Excursions by sub-adults have been recorded for ungulates (Geist 1971, Cochran and Smith 1983, Cedarlund and Hakan 1992, Lovari and Festa-Bianchet 1997). The excursions in these studies were related to dispersal and establishment of new home ranges and not such short term (month long) excursions. Bighorn sheep males are often known to go on long 'exploratory' excursions, possibly in order to familiarise with the area (Krausmann, P, *pers. comm*.). In case of this sub-adult male, it is unlikely that the month long migration was for foraging requirements. However, social intolerance coupled with exploratory behaviour is the most likely reason for the excursion. Rare or no aggression directed against the sub-adult males means that there were some other subtle means of showing intolerance for them. Rarity of aggression towards dispersing sub-adult male mountain goats has also been reported (Lovari and Festa-Bianchet 1997).

Female 1, 3 and 7 also shifted range to largely occupy the Kirthao area, during the peak rut in January which is *ca.* 3 km west of the mean location in the second fortnight of December (Fig. 4.4 a,b,c). They were in the same group along with adult males (n = 16). It is difficult to judge whether their shift was the result of some habitat related parameter or any social reason. Earlier in the year, the three females shifted to occupy unique areas away from those occupied through the rest of the year. These were rugged areas occupied during parturition in late June-July (Fig. 4.4 a,b,c). Female 1 and 3 were pregnant during capture and bore young during this period. Such retreat into rugged areas for parturition by caprini females is well documented (Geist 1971, Schaller 1977, Nievergelt 1981). Female 7 was observed with a trailing kid on some occasions during the study period but the relationship could not be ascertained. The reason for her retreat close to an area where female 3 went could be related to familial bonds.

Enhanced accessibility to better quality forage and/or reduced risk of predation at the other site result in migrations (Fryxell and Sinclair 1988). However, it is not clear whether the areas where male 12 and female 15 migrated had superior forage in terms of availability and quality. Female 15 did not use areas significantly higher than the other ibex who remained in the intensive study area (mean elevation by _15 was 4443 ± 73 m, n=13, and by others, 4399 ± 30, n=93; Mann Whitney U test, p>0.05). It is thus difficult to attribute any definite reason for the occurrence of such migration in the two individuals.

Summer migrations have been observed in some ibex populations in Ladakh, India (Chundawat, *pers. comm.*). In Pin Valley, about 30 of the *ca.* 150 resident people who visit the national park during summer were asked about ibex presence in the area during summer. All of them believed that ibex migrated out during summer. However, my study showed that only two out of 8 marked (ear tagged and collared) adults showed summer migrations. This may suggest that summer migration was not the norm within Pin Valley, and that this population may not have much selective benefit of migrating out. The sampling was however inadequate to come to any definite conclusion on this aspect of ibex ecology. The local belief of ibex migrating out may be partly due to the relative difficulty in seeing ibex during this season due to their greater camouflage (paler pelage colour) than other seasons and their occurring on higher slopes rarely visited by people.

Although the sample size was poor, this study does show the occurrence of summer migrations in the Pin Valley population. The question of what proportion, where and why they migrate is, however, still unanswered. With a larger sample of marked individuals these questions can be addressed. Both animals who migrated, did so to areas outside the protected area. Summer is the season when people are out collecting fuel and fodder and the likelihood of disturbances caused by them is higher. With mounting human pressures in the fragile trans-Himalayan ecosystems, the above questions may have significant conservation implications.

Table 4.6:Harmonic mean home range (95 %) and core zone (CZ) (55 %) area estimates for the seven radio-collared animals. Also given are the sample size and number of core zones. Animals 1, 3 7 & 15 are females and the others are males.

SEASON		**F1** **N**	**AREA (km²)**			**F3** **N**	**AREA (km²)**			**F7** **N**	**AREA (km²)**			**F15** **N**	**AREA (km²)**			**MEAN AREA (km²)**	
			95%	**55%**	**#CZ**		**95%**	**55%**	**#CZ**		**95%**	**55%**	**#CZ**		**95%**	**55%**	**#CZ**	**95%**	**55%**
Summer		40	8.12	1.57	7	40	8.42	1.49	7	42	10.38	1.09	7	19	9.57	1.49	5	8.97 (0.71)	1.38 (0.15)
Autumn		34	6.07	0.74	2	37	8.07	0.78	3	35	5.96	0.77	3	13	2.00	0.20	5	6.70 (0.69)	0.76 (0.01)
Winter		57	6.42	1.07	4	59	6.54	1.14	7	61	4.93	1.30	3	15	3.83	0.69	2	5.96 (0.52)	1.17 (0.07)
WINTER^	**Early**	21	3.41	0.49	4	21	1.94	0.64	3	23	4.19	0.31	2					3.18 (0.66)	0.48 (0.1)
	Peak	19	1.43	0.42	3	19	0.68	0.32	3	19	1.32	0.25	3					1.14 (0.23)	0.33 (0.05)
	Late	17	1.70	0.30	2	19	3.97	0.38	5	19	3.67	0.33	4					3.11 (0.71)	0.34 (0.02)
Spring		18	6.50	0.56	2	20	2.73	0.49	5	21	1.74	0.44	7	10	0.49	0.06	4	3.66 (1.45)	0.50 (0.04)
ANNUAL		164	14.25	3.12	2	169	13.79	2.95	3	175	17.59	3.04	3	61	33.38	3.38	7	15.21 (1.2)	3.04 (0.05)

		M11				**M12**				**M13**									
Summer		32	10.44	2.63	4			-		31	9.71	1.69	9					10.08 (0.37)	2.16 (0.47)
Autumn		24	9.02	0.68	3			-		32	7.12	0.47	6					8.07	0.58

SEASON		F1 N	AREA (km²)			F3 N	AREA (km²)			F7 N	AREA (km²)			F15 N	AREA (km²)			MEAN AREA (km²)	
			95%	55%	#CZ		95%	55%	#CZ		95%	55%	#CZ		95%	55%	#CZ	95%	55%
																		(4.36)	(0.11)
Winter		51	20.98	2.92	5	46	11.26	1.45	5	47	26.15	2.46	1					19.46 (4.36)	2.28 (0.44)
WINTER	Early	15	4.30	0.75	4	12	2.96	0.32	2	12	15.29	0.76	1					7.52 (3.91)	0.61 (0.15)
	Peak	19	2.43	0.63	2	16	3.35	0.36	3	16	16.23	1.18	1					7.34 (4.46)	0.72 (0.24)
	Late	17	4.21	0.22	1	18	0.77	0.21	1	19	3.13	0.29	2					2.70 (1.02)	0.24 (0.03)
Spring		18	1.60	0.17	7	19	2.93	0.87	1	20	2.98	0.72	7					2.50 (0.45)	0.59 (0.21)
ANNUAL		136	35.02	6.85	2	82	29.8*	3.62	4	147	46.41	3.67	1					40.72 (5.7)	5.26 (1.59)

* Does not include the summer and autumn home ranges when it migrated out to an unknown site

^ Winter has been devided into early (1 Dec.-15 Jan.), peak (16 Jan.-28 Feb.) and late (1 Mar.-15 Apr.)

CHAPTER 5: HABITAT UTILIZATION BY IBEX

5.1 INTRODUCTION

Habitat provides food and cover essential for a species to survive. Hence, habitat utilization studies are central to the study of animal ecology. Optimal habitat for a species is the area providing maximum opportunities for survival and reproductive success (Partridge 1978).

Animals show a hierarchy of selections based on their adaptations; each level of selection being conditional on the previous one. First, they select a geographical area (*first order selection)*, within which they select a home range (*second order*), then various habitat components (*third order*) and finally forage species (*fourth order*) (Johnson 1980). In this chapter the third order selection by ibex in Pin Valley will be discussed.

Seasonally variable microhabitat and forage conditions (Section 4.2.3) are expected to influence habitat utilization trends of ibex. Winter in Pin Valley is extremely harsh (Fig. 2.3) and it can be termed the 'pinch period' for ibex. Quality of winter habitat can influence the survival of the species. Deep snow in this season deters ibex mobility and leads to concentrated use of habitat (Section 4.3.5). Therefore, the role of snow as a factor governing habitat utilization was studied.

Numerous studies on *Capra* and *Ovis* have shown that escape terrain is an important determinant of habitat selection (Geist 1971, Schaller 1977, Risenhoover and Bailey 1985, Kotler *et al.* 1994, Oli 1996). The use of escape terrain or areas closer to it was studied to understand the importance of this variable for ibex.

A region adjoining the study area, Kibber Wildlife Sanctuary, where ibex are absent in most of the range, was compared with Pin Valley to identify the possible factors that could have prevented ibex from colonising Kibber. This is likely to strengthen our knowledge of the crucial habitat requirements for the species.

Ibex is one of the primary wild prey for the endangered snow leopard in some regions of the Himalaya. Knowledge of ibex ecology would be exceedingly useful for planning suitable conservation measures for snow leopard.

The objectives of this study are as follows:

1. To determine seasonal habitat selection trends of ibex.
2. To study the importance of escape terrain in determining use of areas by ibex.
3. To study the role of snow in determining habitat use by ibex.
4. To compare the habitat of Pin Valley with an adjacent protected area where ibex are absent from most of the range.

5.2 METHODS

5.2.1 Availability of Habitat

Habitat selection by ibex was determined from observed usage in relation to the availability of various habitat variables. To determine the availability, Marcum and Loftsgaarden's (1980) method for quantifying habitat variables at random points in the study area was used.

The entire study area was gridded (point grid method) on a 1:50,000 Survey of India (SOI) topo-sheet at every 1 cm (500 m) which gave 400 points. Out of these, 50 % grid points were randomly selected using random numbers generated with the aid of a pocket calculator for respective rows and columns and marked on the map. Each point was carefully located on the ground and the habitat variables (Table 5.1) were quantified in a *ca.* 30 m radius plot. All parameters except altitude were visually estimated. This was done owing to the limitation imposed by the manner in which utilization data could be collected (Section 5.2.2). Most sightings of ibex were at distances ranging from 200 to 5000 m, often in almost inaccessible terrain. Measuring habitat variables for each and every sighting would have severely impeded the data collection process, i.e. few sightings would have been obtained and some points may be missed out due to difficult access. Hence the reliability of 'measured' habitat variable data was traded off for collecting a larger data set based on visual estimation. Some useful biotic variables such as vegetation biomass were also not collected for the same reason. In order to keep the 'availability' data consistent with the 'utilization' data the same estimation methods were followed.

Table 5.1:Habitat variables and their categories used in quantifying habitat use by ibex in Pin Valley National Park.

HABITAT VARIABLE	CATEGORIES/DESCRIPTION
Terrain type	1. **Interspersed Rocky Slopes (IRS) I**: steep (usually >40°), broken areas, usually below large rocky slabs & cliffs. 2. **Rocky slabs**: parallel rock slabs with occasional plant patches. 3. **Cliffs**: rocky slopes > 50° 4.**Rocky slopes**: slopes with an exposed rock cover of >20%, usually stony fields 5.**Smooth slopes**: smooth slopes with rock cover < 20%, usually good vegetation cover. 6. **Scree**: loose rocky slopes fanning out below rocky slabs and cliffs. 7. **Old moraine**: steep unstable high bank, often bordering the valley bottom. 8. **Valley bottom**: usually rocky, flat land at the base of the valley; has occasional shrubby patches. 9. **Glaciers**.
Aspect	North (338° to 23°), North-East (24° to 68°), East (69° to 113°), South-East (114° to 158°), South (159° to 203°), South-West (204° to 248°), West (249° to 293°), North-West (294° to 337°).
Slope	Angle estimated in degrees at every 5° interval
Closest dist. to cliffs (escape terrain)	Estimated in units of 5 m
# directions in which escape terrain is present	8 directions recognised w.r.t. the observers position and ibex as - above,above right, right, below right, below, below left, left and above left, & categorised as 0, 1-2, 3-4, 5-6 & 7-8 directions.
Altitude	Elevation in meters
Cover values for exposed rock, soil, plant & **snow.**	Recorded in % in units of 5 (within a 30m radius plots)

The importance of directions in which escape terrain (ET) exists was perceived as an important factor in the winter of 1993-94, subsequently this parameter was also recorded for each observation. In a rugged tract such as Pin Valley, ET can be available in all directions, but for a primarily saltatorial animal such as ibex, ET, for example at 500 m cannot be said as 'available' to it. Ibex were mostly (*ca.* 80 %) present within 100 m from ET (see Table 5.6 and 5.7 below), hence, this distance was taken as a cut off to record the directions in which ET was available (Fig. 5.1).

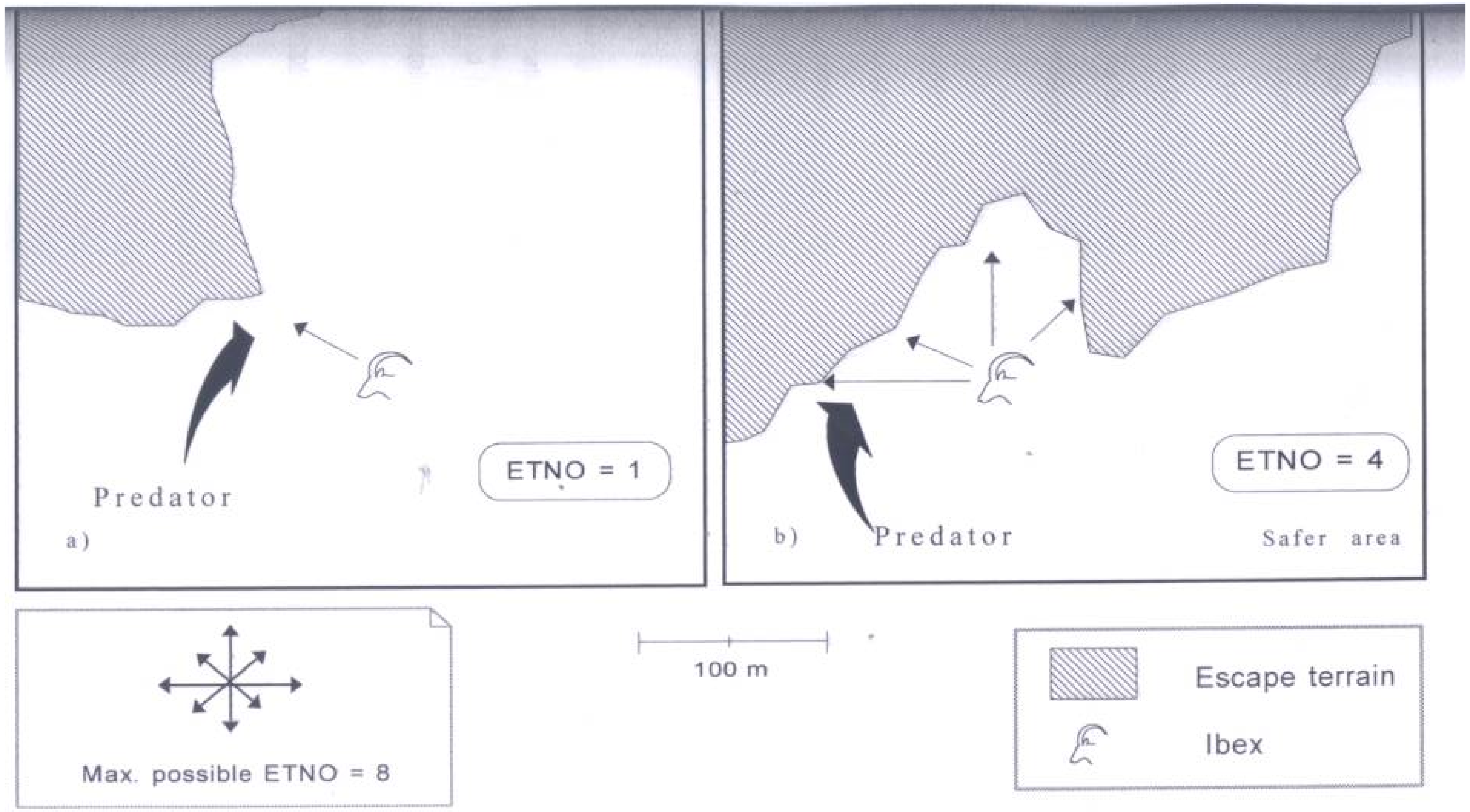


Fig. 5.1: Schematic representation of directions in which escape terrain exists within 100 m (ETNO). In fig. a) ibex has only a single escape route while in fig. b), it has 4 routes. Site b), hence is safer. See Section 5.4.2 for details.

5.2.2 Utilization: Trail Monitoring

Data on the use of habitat variables by ibex were collected along six trails *viz.* Debsa (*ca.* 4 km), Khaminger (*ca.* 5 km), Killung (*ca.* 4 km), Kocho (*ca.* 4 km), Kidul Chu (*ca.* 5 km) and Parahio (*ca.* 6 km) (Fig. 2.2). These trails were walked between May 1992 and May 1994 (*ca.* 1200 km) and were supplemented by a search of upper parts (>4200m) in the warm period between mid-July to mid-September. Winter trails were limited to two, 3 km trails and regular observations from vantage points (n=3). Problems encountered using this method are mentioned in Section 3.2

Whenever a group of ibex was encountered the individuals in the group were counted, sexed and aged based on the classification presented in Chapter 3.0 (Section 3.4) and habitat variables (Table 5.1) were noted at the centre of activity (where the greatest aggregation of ibex was present).

5.2.3 Habitat Use of Radio-Collared Animals

Radio tracking was undertaken between June 1994 and June 1995. Each location was plotted on a 1:50,000 Survey of India topographical map. Similarly group and habitat variables recorded from trails were also recorded (see Chapter 4.0 for details of schedule and methods used).

Pooling data across collared animals

Collared animals often occurred in the same group and were thus associated with one another in varying degrees (Section 4.3.1). Cluster analysis formed two broad groups; first, the three females (1,3 and 7) which were closely associated with one another and the second, including (males 11, 12, 13 and female 15) which were loosely associated (Fig. 4.1). All radio-collared females were adults and three out of four were pregnant when captured i.e. in a similar biological condition so their 'utilization' data were pooled. Male data were also pooled and differences in the use of habitat variables by males and females were tested using chi square test of independence (White and Garrot 1990).

5.2.4 Analysis

Description of the study area

The availability data were analyzed to find out associations (χ^2 test) and correlations (Pearson's correlation) between various variables in the study area, besides obtaining the proportional availability of different categories.

Utilization of habitat

Seasonal differences in the use of categories of habitat variables were tested using a chi square test of independence (Sokal and Rohlf 1995). In order to have a multivariate perspective, Principal Components Analysis (PCA) ordination (Norusis 1990) was used to test for differences in seasonal utilization and to determine the seasonal 'factors' influencing ibex habitat utilization.

Proportional availability of habitat categories was compared with seasonal proportion utilized to obtain information on habitat selection based on a non-mapping technique (Marcum and Loftsgaarden 1980). For habitat variables with up to six categories, 90 %, and for those with more than 6 categories, 80 % simultaneous confidence intervals were generated. Caution should be maintained not to take 'preference' and 'avoidance' in absolute terms (see Appendix 7 for a brief review and justification of analysis methods available and that were used).

Comparison of used and unused areas

During the winter of 1992-93 an area was identified as a relatively unused site by ibex based on very few (2) sightings and one track from late December to January end. This site, the Kidul Chu valley, was compared to a highly used site, the Parahio valley (Gechang area) using Mann-Whitney U test on individual habitat variables collected on random points at each site.

Kibber wildlife sanctuary is an area *ca.* 50 km north of the Pin Valley National Park (Fig. 2.2) with a small population of ibex in its western part (Bhatnagar, *unpubl. data*; Rana 1994). Habitat variables from 177 random plots from this sanctuary were collected. Analysis similar to that done for the Kidul Chu area was performed for studying differences between Pin Valley and Kibber in the relative occurrence of habitat variables. Logistic regression (Norusis 1990) on the 'availability' data of the two areas was used to determine variables that differentiated the two data sets. A preliminary model for predicting ibex presence in trans-Himalayan areas was also developed using logistic regression.

5.3 RESULTS

5.3.1 Description of the Study Area

Relative occurrence of habitats

Over half the intensive study area (ISA) had rugged terrain with rocky 'slabs/cliffs' and 'interspersed rocky slopes' covering 31% (all n in this section are 200) and 22.5 %, respectively (Table 5.2). 'Rocky slopes' and 'smooth slopes' were less common constituting 12 % and 17 % of the ISA, respectively. Other terrain types such as 'scree', 'old moraine' and 'valley bottom' were rare and put together, constituted 11 % of the ISA. 'Glaciers' and permanent ice fields covered 6.5 % of the ISA.

Most parts of the ISA (55%) had steep slopes (31° to 60°) with a mean inclination of 39° (median 40°) (Table 5.2). A large part of the ISA (65 %) was within 50 m from escape terrain (ET) but areas farther than 1 km also existed. Mean distance to ET was 76 m. Only 19 % of the ISA had no ET within 100 m from the centre of the plot in all eight directions while the mean number of directions was 3.5 (median 2). The ISA had a mean rock cover of 57.8 % (median 65 %) and over 1/3rd of the area had rock cover exceeding 80 %. Plant cover was sparse in the ISA (mean 28 %, median 10) with *ca.* 38 % area with no or only traces of vegetation. The ISA occurred between 3,600 m and 5,400 m with a mean elevation of 4,420 m (median 4,385 m).

Correlation and association among variables

Steeper slopes were usually closer to ET ($r = -0.535$, $p \leq 0.001$, all n in this paragraph are 200) and had ET available in more directions ($r = 0.419$, $p \leq 0.001$) (Table 5.3). As expected, areas closer to ET had ET available in more directions ($r = -0.687$, $p \leq 0.001$). Steeper areas ($r = 0.141$), sites close to ET ($r = -0.209$) and with ET available in more directions ($r = 0.196$) tended to be more rocky ($p \leq 0.05$). Areas with high rockiness usually had lower plant cover ($r = -0.545$, $p \leq 0.001$). Plant cover usually declined at higher altitudes ($r = -0.424$, $p \leq 0.001$).

Table 5.3: Correlations between different variables in the intensive study area of Pin Valley National Park based on sampling in August, 1994 from 200 random points. Distance to escape terrain (DTET) was $\log_n$ transformed while percent rock and plant cover were arcsine transformed. (Pearson's Correlation Coefficient)

	SLOPE	DTET	ETNO	RC (%)	PC (%)	ALT. (m)
SLOPE	.					
DTET	-0.535$^{\wedge}$	.				
ETNO	0.419$^{\wedge}$	-0.687$^{\wedge}$	.			
RC (%)	0.141*	-0.209*	0.196*	.		
PC (%)	0.145*	-0.114	0.056	-0.545$^{\wedge}$	.	
ALT (m)	-0.071	0.183*	-0.14	0.045	-0.424$^{\wedge}$	.

$^{\wedge}$DTET is Escape terrain; ETNO is directions in which ET present; RC Rock cover; PC Plant cover; ALT Altitude

One tailed significance: $^{\wedge}$ $p \leq 0.001$, * $p \leq 0.05$

Percent occurrence of distance to ET and plant cover categories in different terrain types were studied based on the 200 random plots (Table 5.4). Most interspersed rocky slopes (IRS) were within 50 m from ET (*ca.* 82 %, n = 45) while *ca.* 92 % (n = 62) of slabs/cliffs constituted ET itself (i.e. distance to ET = 0). Rocky slopes primarily occurred within 50 m from ET but not on ET (58 %, n= 24) . Smooth slopes mainly occurred farther, between 51 and 100 m from ET (41 %, n=34).

Most terrain types except smooth slopes had low (00-30%) plant cover (Table 5.4). Smooth slopes were usually well vegetated (85.3 %, n = 34) with plant cover exceeding 60 %.

Table 5.4:Percentage occurrence of different distance to escape terrain (a) and plant cover (b) categories in terrain types. Figures in parenthesis are number of observations per terrain type.

a. Terrain Type	00m	01-50m	51-100m	101-150m	> 150m
Interspersed Rocky slope (45)	15.6	66.7	15.6	00.0	2.2
Slabs/Cliffs (62)	91.9	8.1	00.0	00.0	00.0
Rocky Slopes (24)	00.0	58.3	12.5	16.7	12.5
Smooth slopes (34)	00.0	32.4	41.2	08.8	17.6
Scree/Old Moraine/ Valley Bottom (22)	04.5	27.7	36.4	04.5	27.3
Glaciers (13)	00.0	00.0	00.0	00.0	100
b.	00-30%	31-60%	61-100%		
Interspersed Rocky slope (45)	51.1	37.8	11.1		
Slabs/Cliffs (62)	98.4	1.6	00.0		
Rocky Slopes (24)	58.3	12.5	29.2		
Smooth slopes (34)	14.7	00.0	85.3		
Scree/Old Moraine/ Valley Bottom (22)	80.9	19.1	04.8		
Glaciers (13)	100.0	00.0	00.0		

5.3.2 **Seasonal Habitat Utilization**

Collared males and females used various habitat variables in a similar manner during all seasons (χ^2 test, p>0.05), except for altitude and aspect in early winter. Because of this similarity in habitat utilization trends the entire data set for these animals was pooled.

Factor analysis using PCA on distance to ET (natural log), slope, altitude, rock cover, snow cover and plant cover (arcsine transformed) extracted two factors that explained 67.3 % of the variation in the data of the first phase (trail monitoring) of the study (November 1992 to May 1994). Factor 1 (PC1) explained 36.8 % of variation in the data while PC2 explained 30.5 % of the variation. While PC1 was the 'snow, food (plant cover) and altitude factor', PC2 was the 'security factor' as it had strong relation with distance to ET, rockiness and slope. Ordination based on principal components analysis showed seasonal differences in use of habitat variables (Fig. 5.2). Winter stood out in terms of ibex using areas with high snow cover, higher altitudes and lower plant cover (exposed through the snow) compared to spring and autumn as per the PC1. In this

Fig. 5.2: Principal Components Analysis ordination of the ibex habitat usage data in winter (1), spring (2), summer (3) & autumn (4) during the trail phase (Nov.,1992 to May, 1994). Analysis includes snow cover (see Fig 5.3 for analysis without snow cover)

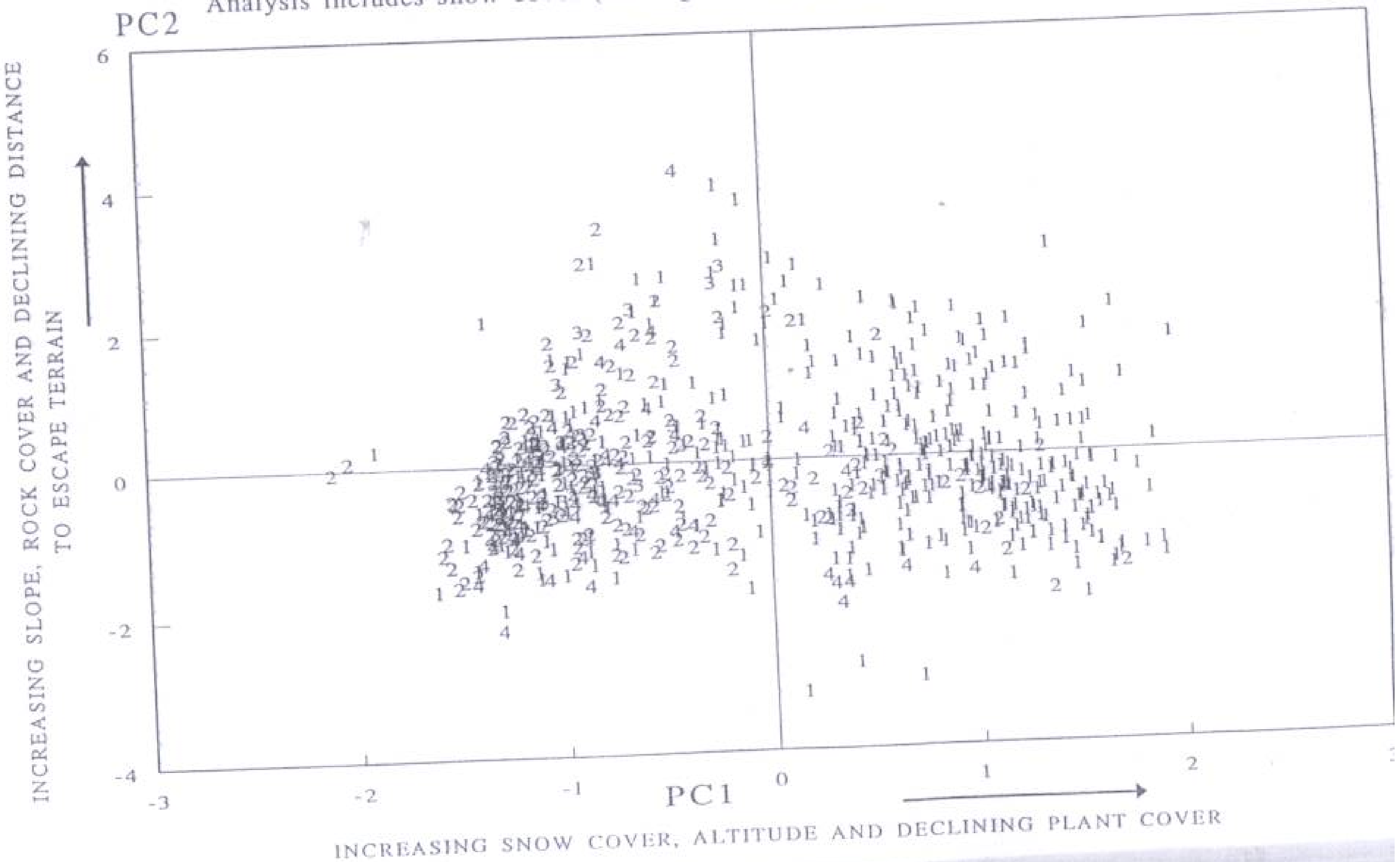


Fig. 5.3: Principal Components Analysis ordination of the ibex habitat usage data in winter(1), spring (2), summer (3) & autumn (4) during the trail phase (Nov.,1992 to May, 1994). Snow cover excluded from the analysis. (see Fig 5.2 for analysis with snow cover)

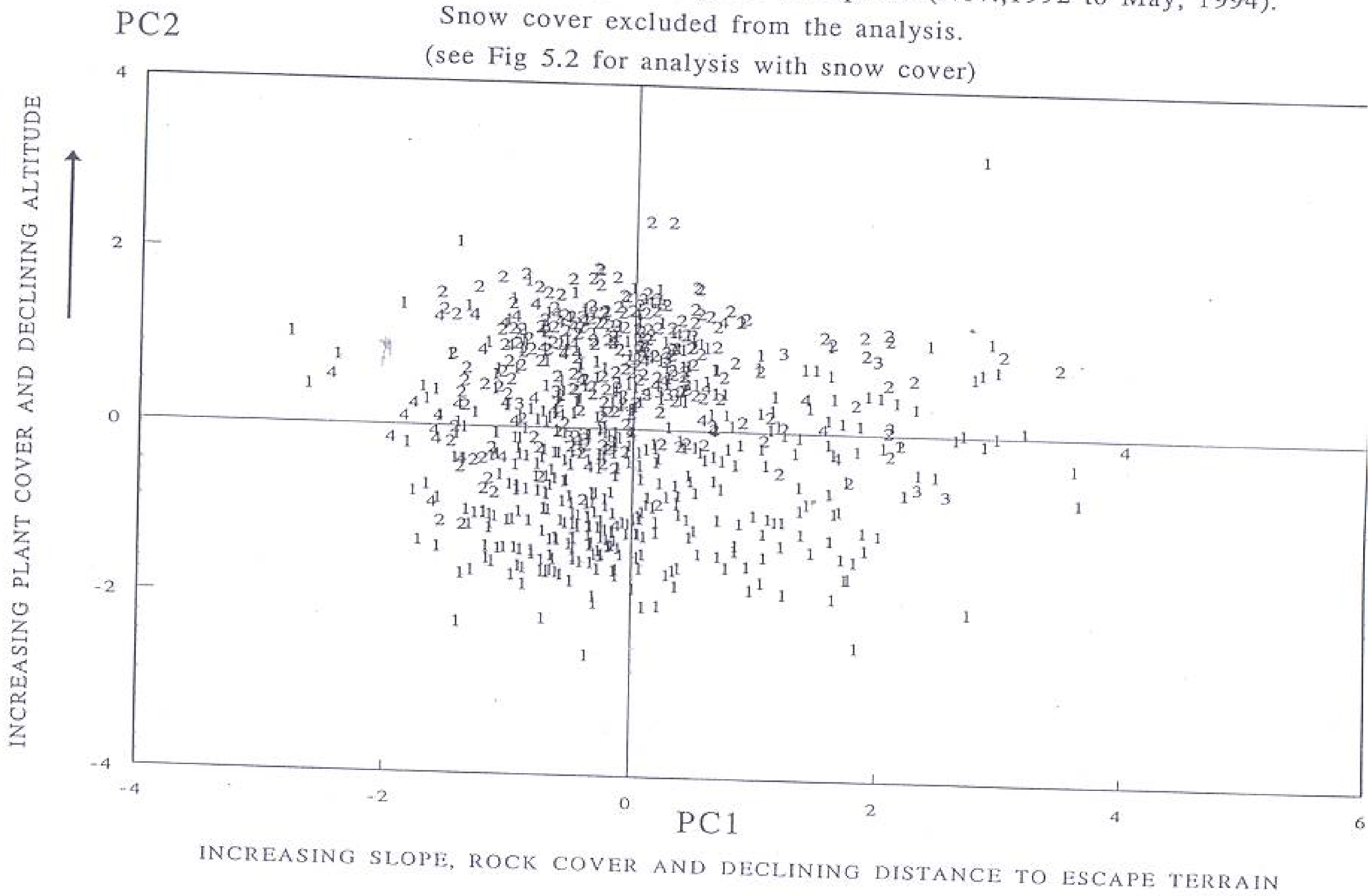


Fig. 5.4: Principal Components Analysis ordination of the ibex habitat usage data in winter (1), spring (2), summer (3) & autumn (4) during the telemetry phase (June,1994 to May, 1995). Snow cover excluded from the analysis.

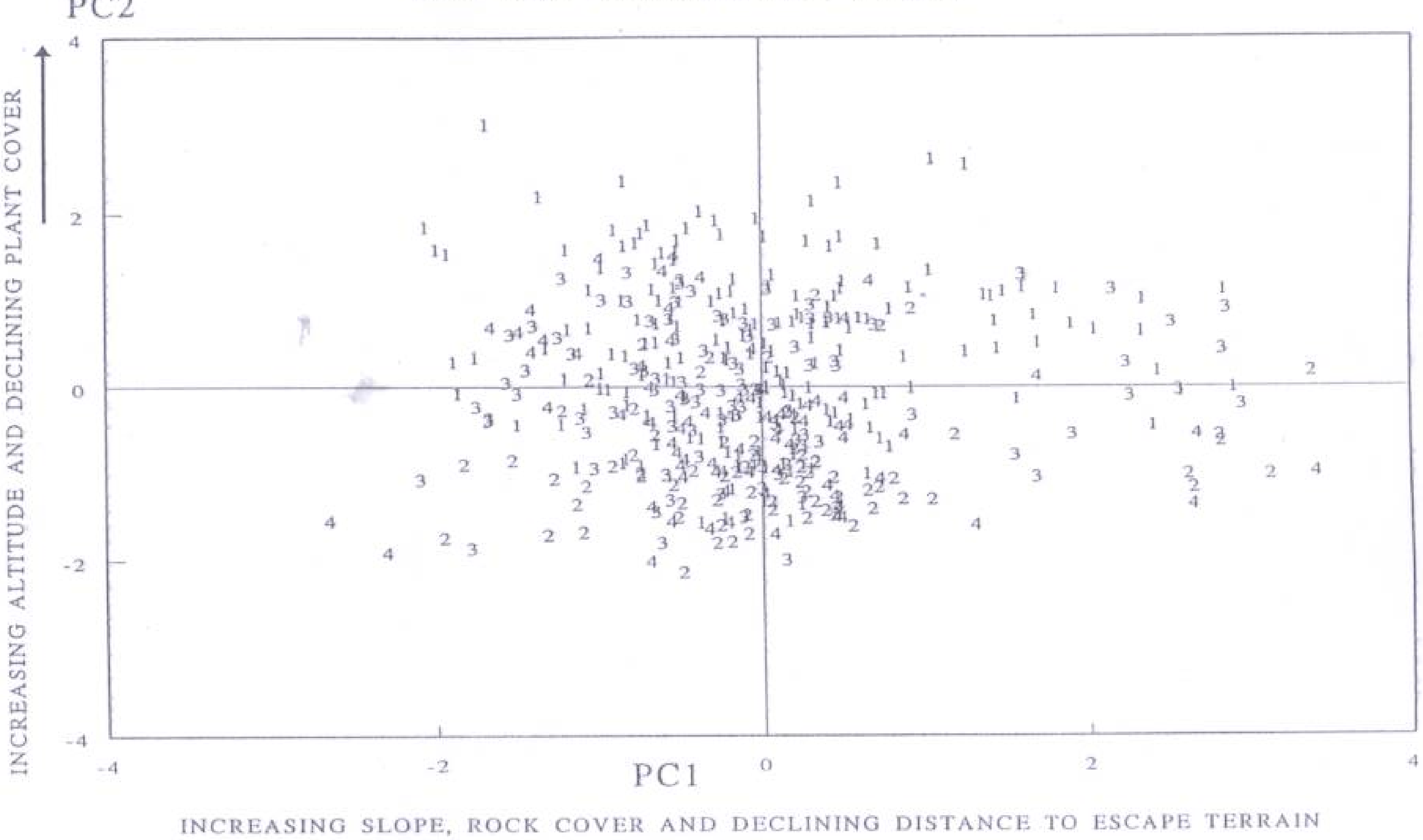
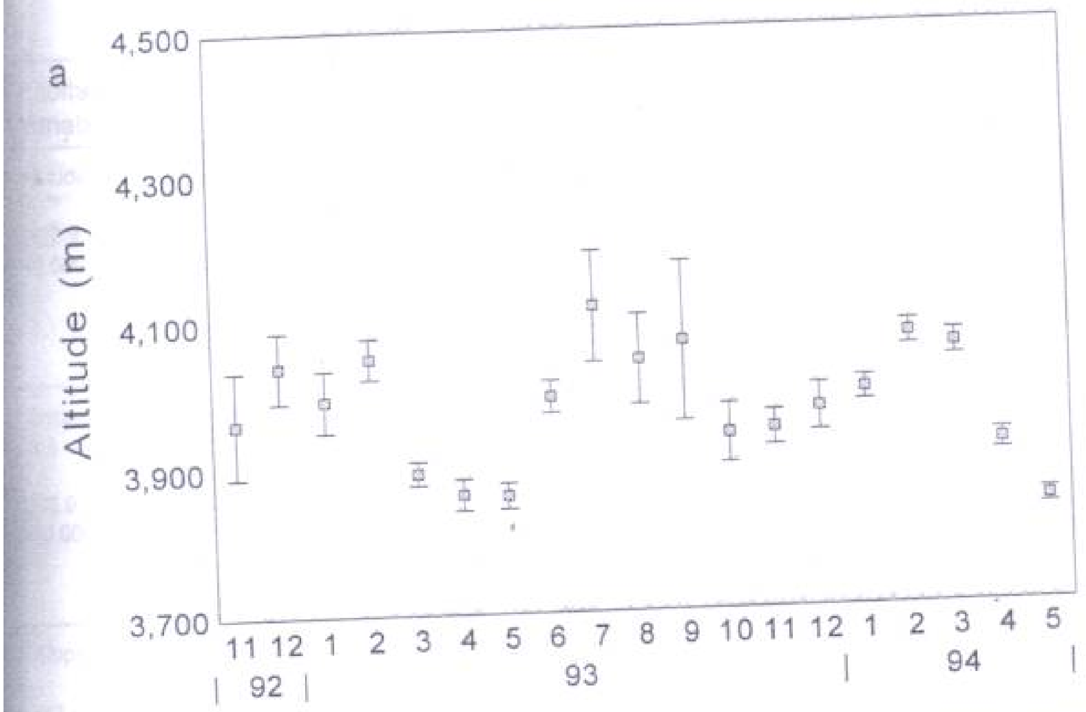
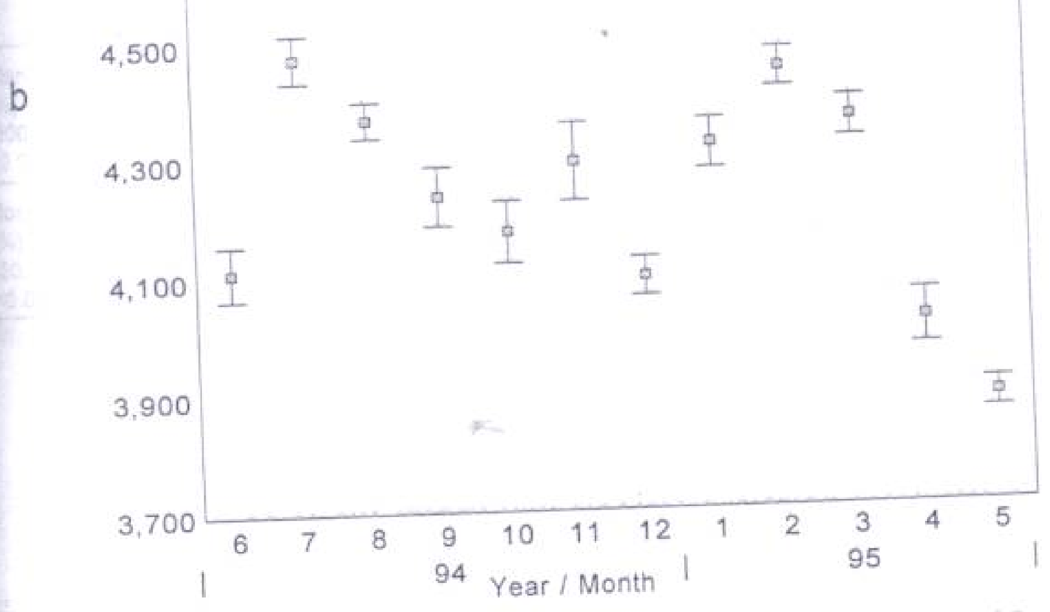


Fig. 5.5: Mean altitude (S.E) used by ibex in the trail phase (a) and the telemetry phase (b), (November, 1992 to May, 1995)

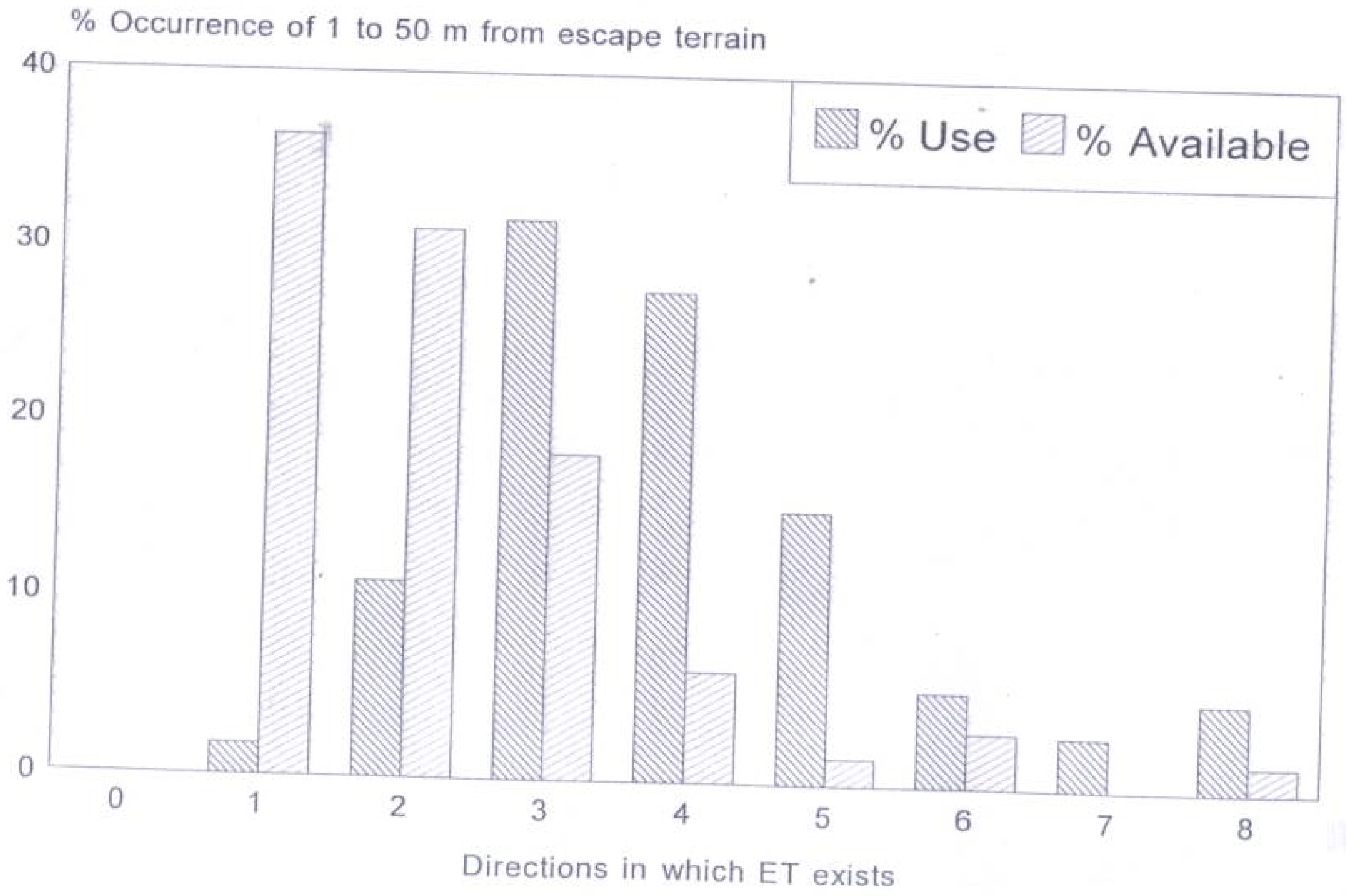


Monthly n (in sequence) = 11, 16, 32, 53, 47, 39, 62, 35, 9, 7, 3, 9, 38, 28, 72, 57, 99, 131, 65



Monthly n (in sequence) = 42, 54, 45, 32, 28, 33, 55, 30, 43, 29, 27, 35

Fig. 5.6: Percent use vs. availability of directions in which ET exists in the most used distance to escape terrain class (1 to 50 m) Use data is for the period between June, 1994 and May, 1995.



season, ibex used areas offering better security (greater rockiness, slope and areas closer to ET) compared to the other two seasons. Data on summer 1993 was limited to only 17 sightings hence are not discussed here. As separation of winter along the variable snow cover is quite obvious, this was excluded in the next analysis to see if winter was still different. PC1 (41.3 % of variation) was the 'security factor', related positively to slope and rock cover and negatively to distance to ET, while PC2 (23.4 % of the variation) was the 'food and altitude factor'. Ordination on the two PCs still showed winter extending out of the main cluster into areas of greater ruggedness (higher slope, rock cover and closer to ET) at higher elevations and in areas with lower exposed plant cover (Fig. 5.3).

Factor analysis on the pooled data of the seven collared animals during the 'telemetry' phase (June 1994 to May 1995) of the study extracted two factors that accounted for 65.1 % of the variation (PC1 43.3 % and PC2 21.8 %). PC1 was the 'security factor' being primarily related to rock cover, slope and distance to escape terrain. PC2 was the food and altitude factor, being related to altitude and plant cover (Fig. 5.4). Winter was different mainly in terms of use of areas at higher altitudes and with lower exposed plant cover. The segregation of seasons along the 'ruggedness' or the 'security' axis (PC1) was however not marked.

The 'trail phase' of the study revealed that ibex used terrain types (TTY), aspect (ASP), slope (SL), distance to escape terrain (DTET), altitude (ALT), plant cover (PC), snow cover (SN) and rock cover (RC) differently (χ^2 test, $p<0.001$) during winter, spring and autumn (Appendix 8 a). During the 'telemetry' phase the use of these variables, except slope, differed ($p<0.001$) in the winter, spring, summer and autumn (Appendix 8 b). The use of slope was marginally different in the four seasons ($p=0.07$). The trends of seasonal differences in selection trends of each variable in the two phases are discussed in Section 5.3.3 below.

5.3.3 **Habitats Preferences**

Habitat selection analysis was done separately for the two phases due to differences in the type of data gathered (Section 5.2). It is again emphasised here that the terms 'preference' and 'avoidance' in this section are used in a relative sense. Habitats showing 'avoidance' may be actually crucial under some circumstances. Preference means that this category was used more than expected in proportion to its availability, and avoidance means that it was used less than expected in proportion to availability.

Trail phase

During the 'trail phase' of the study, terrain type, aspect, slope, distance to ET, altitude, rock cover and plant cover categories were used disproportionate to their availability in all seasons (χ^2 test, $p<0.05$), except early winter when aspect and slope were used in proportion to their availability ($p>0.05$) (Table 5.6).

Rocky slopes were preferred by ibex in all seasons (Table 5.6) while interspersed rocky slopes (IRS) were also preferred during peak and late winter. IRS was used relatively more than other categories in spring, autumn and early winter but was not 'preferred'. Southerly slopes (SE, S, SW), especially the south facing slopes, were used more during all seasons (Table 5.6). It may be noted that the range of aspects used were fewer during late winter and spring compared to summer and autumn when the use was more evenly distributed across seasons.

Moderate to steep slopes (31° to 60°) were used relatively more than what was available during all seasons while steeper slopes (>60°) were consistently 'avoided' (Table 5.6). The use of gentle slopes (<31°) was higher during autumn and early winter compared to other seasons. Ibex used steeper slopes during peak (mean 42.7°) and late winter (mean 42.6°) compared to other seasons (mean <40°) (Table 5.5a).

Ibex preferred to stay within 50 m from escape terrain but avoided **being on it** in all seasons (Table 5.6). They preferred to use areas farther from escape terrain (51 to 100 m) during autumn but the use of areas 1 to 50 m from ET was still quite high (43%). Ibex consistently avoided areas farther than 150 m from escape terrain. They were only once observed at 250 m from ET during autumn although areas greater than 200 m from ET constituted *ca.* 14 % of the study area. During peak and late winter ibex used areas closest to ET (mean < 28 m) while during autumn they occurred farthest (mean 65 m) (Table 5.5a).

Ibex mainly used areas up to 4,200 m elevation in all seasons. The preference for the lowest altitudinal zone was quite clear during spring but during the other seasons altitudes between 3,801 and 4,000 m were preferred. During peak and late winter ibex used even higher slopes (4,001 to 4,200 m) to a greater degree. Areas above 4,400 m were consistently avoided by ibex. Highest altitudes were used during peak winter (mean 4,018 m) while lowest during spring (mean 3,867 m) (Table 5.5a, Fig. 5.5a).

The 'availability' of rock, plant and snow cover only matched summer and to some extent autumn since this data was collected during August. As summer data was insufficient, preferences were calculated only for autumn (Table 5.6). Ibex mostly occurred in areas with rock cover less than 80 % and preferred areas with 21 to 40 % rock cover. Moderate to high plant cover was used relatively more by ibex with a preference for areas with 41 to 60 % plant cover during autumn.

Table 5.5a: Seasonal mean, SE, median, minimum and maximum value for the use of various habitat variables during the 'trail phase' of the study (November, 1992 to May, 1994). Sample sizes for each season are: spring 248, autumn 60, early winter 44, peak winter 360 and late winter 84. Kruskaal-Wallis 1-way ANOVA chi sq., df and p value for seasonal differences also given in parenthesis.

Habitat Variable	Season	Mean	SE	Median	Min.	Max.
Altitude (m) (122.9, 4, <0.0001)	Spring	3866.8	7.9	3850	3700	4600
	Autumn	3955.0	20.8	3900	3700	4500
	Early Winter	3996.6	27.1	3975	3700	4450
	Peak winter	4018.3	9.2	4050	3670	4700
	Late winter	3981.2	17.3	3950	3700	4200
Distance to ET (m) (92.9, 4, <0.0001)	Spring	42.5	2.5	30	0	200
	Autumn	64.8	7.5	50	0	250
	Early winter	55.8	8.0	45	0	200
	Peak winter	27.6	1.6	20	0	200
	Late winter	14.0	2.2	10	0	100
Slope (°) (57.4, 4, <0.0001)	Spring	39.9	0.4	40	30	70
	Autumn	38.1	1.1	40	20	85
	Early winter	37.2	1.8	40	0	80
	Peak winter	42.7	0.4	40	20	80
	Late winter	42.6	1.1	40	0	65
Plant cover (%)* (300.7,4, <0.0001)	Spring	36.0	1.6	35	0	95
	Autumn	43.1	3.4	45	1	95
Rock cover (%) (50.7, 4, <0.0001)	Spring	40.5	1.6	38	1	95
	Autumn	35.9	3.1	35	1	95

[*] Percent cover value of 1 indicates traces of plant or rock cover

Table 5.5b:Seasonal mean, SE, median, minimum and maximum value for the use of various habitat variables during the 'telemetry' phase of the study (June, 1994 to May, 1995). Sample sizes for each season are: spring 77, autumn 106, summer 78 , early winter 35, peak winter 96 and late winter 61. Kruskaal-Wallis 1-way ANOVA chi sq., df and p value for seasonal differences also given in parenthesis.

Habitat Var.	Season	Mean	SE	Median	Min.	Max.
Altitude (m) (124.3, 5, <0.0001)	Spring	3978.7	25.7	3920	3700	4640
	Summer	4404.0	27.9	4440	3700	4880
	Autumn	4225.0	36.7	4195	3680	4620
	Early Winter	4095.7	32.5	4080	3800	4680
	Peak winter	4390.3	26.8	4320	3920	5080
	Late winter	4307.4	33.5	4360	3720	4900
Distance to ET (m) (29.1, 5, <0.0001)	Spring	29.5	2.3	25	0	80
	Summer	35.6	3.9	20	0	200
	Autumn	21.1	2.3	20	0	150
	Early winter	32.6	4.5	20	10	120
	Peak winter	21.0	1.7	20	0	80
	Late winter	19.9	3.0	10	0	90
Direct-ions in which ET exists (53.2,5, <0.0001)	Spring	3.7	0.2	3	1	8
	Summer	3.7	0.2	3	0	8
	Autumn	3.7	0.2	4	0	8
	Early winter	3.9	0.3	4	0	7
	Peak winter	4.9	0.2	4.5	1	8
	Late winter	5.0	0.3	5	1	8
	Summer	37.2	0.7	35	20	60
	Autumn	34.7	0.9	35	0	70
	Early winter	35.5	1.1	35	15	45
	Peak winter	36.4	1.0	35	10	50
	Late winter	37.3	1.3	40	10	60

Habitat Variable	Season	Mean	S.E.	Median	Min.	Max.
Plant cover (%)[*] (240.9, 5, <0.0001)	Spring	39.8	2.7	40	1	85
	Summer	48.4	2.2	50	1	100
	Autumn	51.2	2.3	50	10	100
Rock cover (%) (30.9, 5, <0.0001)	Spring	40.1	2.4	40	5	100
	Summer	41.6	2.2	40	1	95
	Autumn	38.6	2.1	40	1	85

[*] Percent cover value of 1 indicates traces of plant or rock cover

Telemetry phase

During the 'telemetry' phase of the study, terrain type, aspect, slope, distance to ET, altitude, rock cover and plant cover categories were used disproportionate to their availability in all seasons (χ^2 test, $p<0.05$). During early winter aspect and altitude classes had to be clubbed due to low sample size (Table 5.7).

'Rocky slopes' were used relatively more than expected during all seasons, except during peak and late winter when IRS were preferred (Table 5.7). IRS were preferred during summer too and its use during other seasons was also relatively high. The open, smooth slopes were used in proportion to availability during most of the year except peak and late winter.

East and southerly aspects (SE, S and SW) were used relatively more during all seasons while only south and south-western slopes were preferred during spring and winter months (Table 5.7). Ibex had a tendency to occur more equitably among aspects during summer and autumn.

Slopes with an angle of 31° to 60° were preferred during all seasons except autumn while steeper slopes were almost completely unused (Table 5.7). Less steep slopes were avoided during summer.

Ibex preferred to stay within 50 m but not on escape terrain during all seasons except autumn, when they ventured farther. The use of areas more than 100m from ET was not observed during peak and late winter and during spring. Escape terrain (i.e., distance to ET = 0m) was used relatively more during late winter than other seasons. Ibex were never seen farther than 200 m from ET during this phase of the study and were closest to ET during peak and late winter (Table 5.5b).

Ibex preferred to stay in areas with ET available in 3 to 6 directions in all seasons (Table 5.7). Areas where ET was not available within 100 m and areas with ET in 7, 8 directions (i.e. on ET) were consistently avoided except in late winter when the use of the latter areas was comparatively higher. Mean number of directions in which ET existed varied between 3.7 and 5.0 in different seasons, the higher directions being used in peak and late winter (Table 5.5b).

Ibex preferred lower altitudinal zones (3801 to 4000m) during spring and shifted to higher altitudes (4401 to 4600m) during summer (Table 5.7). Atltitudes comparable to summer (4201 to 4400m and 4401 to 4600m) were preferred during peak and late winter while lower areas were preferred during early winter or the rutting season. The lowest altitudinal zone (3600 to 3,800m) was used relatively more than other seasons in spring and autumn. Elevations more than 4,800m were consistently avoided. Although the mean elevation used by ibex was highest (4,404 m) during summer, the highest records of ibex were during peak and late winter (5,080 m and 4,900 m respectively) (Table 5.5b, Fig. 5.5b). During these winter months the mean elevation also exceeded 4,300 m.

Ibex used areas of a wide range of rockiness during summer and autumn but preferred areas with 21 to 40 % rock cover during these seasons (Table 5.7). Areas with very high rockiness were avoided in both seasons. A wide range of plant cover categories (21 to 40 % to 61 to 80 %) were preferred during summer but only 41 to 60 % plant cover areas were used relatively more in autumn.

5.3.4 Comparison of Used and Unused Areas

Within the study area (Kidul Chu and Gechang areas)

The Kidul Chu region was relatively unused by ibex during the winter of 1992-93 in spite of having higher exposed plant cover and lower snow cover compared to the more 'used' area (Gechang) (Table 5.8) ($p<0.001$). It however had lower mean slope, was less rocky and was mostly farther from ET ($p<0.001$).

Table 5.8: Comparison of areas used (Gechang area, n=208) and not used (Kidul Chu, n=56) by ibex in Pin Valley National Park during the winter of 1992-93. Significance values by Mann-Whitney U test.

Habitat	Area	Mean ± S.E.	Median	Z	p
Slope (°)	Unused	40.4±2.3	35	-4.19	<0.0001
	Used	46.3±1.0	45		
DTET (m)	Unused	139.3±19.6	100	-4.45	<0.0001
	Used	55.3±5.9	5		
PC (%)	Unused	10.8±1.7	7.5	-6.48	<0.0001
	Used	2.2±0.3	0.0		
RC (%)	Unused	23.8±4.3	10	-2.68	0.0074
	Used	30.6±1.9	20		
SN (%)	Unused	52.2±3.3	60	-3.48	0.0005
	Used	64.3±2.0	70		

Note:DTET Distance to escape terrain, PC Plant cover, RC Rock cover, SN Snow cover.

Pin Valley and Kibber

The Kibber area (ibex rare or absent in most of the range) had higher plant cover than Pin Valley (ibex present) but was less rocky ($p<0.0001$) (Table 5.9). It however had lower slope, was usually farther from ET and had ET available in fewer directions as compared to Pin Valley ($p<0.0001$).

Table 5.9: Comparison of areas used (Pin Valley, n=200) and not used (Kibber-Langza, n=177) by ibex in Spiti, Himachal Pradesh. Significance values by Mann-Whitney U test.

Habitat	Area	Mean ± S.E.	Median	Z	p
Slope (°)	Unused	26.9±1.5	25	-7.70	<0.0001
	Used	39.6±1.3	40		
DTET (m)	Unused	391.3±27.4	250	-10.89	<0.0001
	Used	76.1±9.1	30		
ETNO	Unused	1.2±0.18	0	-9.20	<0.0001
	Used	3.5±0.23	2		
PC (%)	Unused	49.8±2.4	50	-6.52	<0.0001
	Used	28.2±2.4	10		
RC (%)	Unused	21.1±2.3	5	-9.68	<0.0001
	Used	57.8±2.6	65		

Note:DTET Distance to escape terrain, ETNO Directions in which ET exists, PC Plant cover, RC Rock cover, SN Snow cover.

The logistic regression model developed for the Kibber and Pin Valley (PV) study sites correctly classified 152 (76.66 %) of the PV plots and 141 (79 %) of the Kibber plots (overall 77.72 %) suggesting a good fit (see Appendix 9 for the detailed steps in the analysis and the goodness of fit statistic). Escape terrain had the greatest predictive value for the cases (regression coefficient, $B_i = -0.6110$) followed by rockiness ($B_i = 0.0283$) and lastly slope ($B_i = -0.0415$). Negative values of B_i for that variable show that one unit increase in the value of the variable will reduce the log odds ratio by a factor of the value of B_i. For positive values the opposite will be true. Interestingly plant cover was not included in the model. The regression equation for the probability of ibex occurring was thus:

$$\mathbf{P(ibex) = \frac{1}{1 + e^{-z}}}$$

Where, $z = 3.0286 - 0.6110$ (*Natural log of Dist. to ET in m*) + 0.0283 (*Square root of Rock cover in %*) - 0.0415 (*Slope in degrees*)

5.4 DISCUSSION

Animals range within their habitats to obtain food, reproduce and take care of their young and to minimise chances of getting preyed upon. Therefore, in order to enhance their inclusive fitness, ibex should select habitats with an optimal availability of food and structural resources that maximise their survival. The following is a discussion in this perspective.

The habitat variables recorded in this study can be grouped into those related to 'security' (distance to ET, directions in which ET exists, slope and rockiness) and 'food' (plant cover and altitude) which is revealed by factor analysis on the utilization data.

5.4.1 Seasonal Use of Habitats

Since there was a general agreement in the results of habitat selection in the two phases (Table 5.6, 5.7), these are being discussed together.

While the physical features such as slope, altitude, distance to ET, terrain type and rockiness remained constant through out the year, forage availability and quality were seasonally variable (Section 4.2.3). Also, different degrees of snow cover, depth and compactness during almost half the year (December to May) affected the accessibility to forage and ET. The seasonal difference in the proportion use of habitat (Appendix 8 a & b) is likely to be the result of the seasonally variable availability of resources. In the following paragraphs I will discuss the seasonal trends in the use of habitat variables and the importance of ET and snow cover in governing habitat use by ibex.

Ibex consistently used steep slopes (31° to 60°), areas 1 to 50 m from ET and with ET available in 3 to 6 directions (Table 5.6 & 5.7) during the entire year. The relative use of other categories of these variables however, differed seasonally. The use of steep slopes and areas near ET are adaptations of various caprini and rupicaprini against predation (Geist 1971, Schaller 1977, Risenhoover and Bailey 1985, Kotler *et al* 1994, Chundawat 1992, Oli 1996). The use of such areas by ibex further demonstrates that escape terrain is an important habitat variable for this species.

Ibex were facultative in the use of slopes facing various aspects from summer through early winter (Table 5.6, 5.7) but choose primarily southerly aspects (SE, S and SW) from peak winter to spring, the period of high snow cover. In the northern hemisphere the winter sun has a high inclination towards the south and thus the south facing slopes get higher insolation and are warmer (Perla and Martinelli 1975). Ambient temperatures in Pin Valley during winter dropped to a minimum of -40°C. Simultaneous records of temperature on the north and south facing slopes showed a mean difference of 5°C (n=10) in January, 1994. Due to this reason south facing slopes provide warmer areas for basking and were used more by ibex. Warmer, south facing slopes were used more by mountain sheep and mountain goat during winter (Tilton and Willard 1981, Fox *et al.* 1989). Southern slopes also are the first areas where sprouting initiates in late winter/spring. As the snow melt progressed from spring to summer, more areas became conducive for ibex and they moved into other aspects. This trend continued till early winter when the first major snow fall occurred and temperatures dropped (Fig. 2.3). This feature is also reflected by the concentrated use of habitat by ibex in winter and dispersed use in summer (Section 4.3.5).

In the ISA, ibex had an altitudinal gradient of *ca.* 2,500 m (3,700 to 5,200 m) available to them. Within this, there were considerable seasonal movements. Ibex occupied the lowest part of their range during the spring sprout but migrated to higher altitudes during summer (Table 5.5a,b, Fig. 5.5 a,b), most likely in response to better quality forage available with retreating snow (Manjrekar 1997) and to avoid increasing temperatures at lower altitudes (Fig. 2.3). In the summer of 1994 (telemetry phase), ibex were often seen (n=20) on or very close to avalanche debris during warmer periods of the day. In the previous summers sightings were limited to cloudy and hence slightly cooler days when ibex descended to lower slopes. Disturbance to ibex by flies was also observed to be higher at lower altitudes than at higher elevations (Bhatnagar, *unpubl. data*). Thus, higher temperatures (at times touching 32°C) at lower altitudes, and insect harassment may have a significant role in ibex migrating higher during summer. Insect harassment was vital in animals avoiding habitats (Wright 1980, Mugangu *et al.* 1995). However, better forage at higher altitudes may be the primary reason for the altitudinal migration. Ibex descended briefly during autumn but with the first major snow retreated to higher elevations during peak winter (Table 5.5a,b, Fig. 5.5a,b). The use of higher and thus colder elevations during winter was unexpected. This movement was probably because of the snow fall patterns, its accumulation in the area and the terrain. Snow covered the entire region from the valley bottom to the highest elevations between late December and early March, thus unlike other areas in Alps (Wiersema and Schroder 1985) or the Himalaya, snow free areas were not available for ibex at lower altitudes. Higher elevations were observed to have more snow free sites (wind blown sites and avalanche chutes) as compared to lower slopes that were mostly less steep and often accumulated snow deposited from higher elevations (Bhatnagar, *unpubl. data*). Thus ibex may have preferred to stay at higher elevations in spite of the lower temperatures.

During winter interspersed rocky slopes were the most used terrain type and the use was also higher compared to other seasons (Table 5.6, 5.7). IRS were invariably close to ET, were highly rocky but had relatively sparse vegetation (Table 5.4). Ibex may have preferred such habitats because steep, rocky areas are likely to shed snow early, exposing forage. Also steep slopes are likely to have lower snow accumulation (Fox *et al.* 1989). Thus, ibex preferred IRS and **higher slopes in winter**, in spite of lower plant cover in such sites due to the relative ease of finding forage due to less or no snow. Between November and May ibex primarily, on over 100 occasions, bedded on IRS slopes and this habitat gains importance due to this fact too. During most of winter, the whole of Pin Valley, from valley bottom to the high peaks is covered under deep snow. In fact, at lower elevations the accumulation may be more due to lesser inclination and lower wind speed. Due to relatively higher temperatures at lower elevations, some amount of crusting and compaction occurs by mid February and this further impedes access to forage. It was also observed that the lower elevations had lesser availability of escape terrain. Thus, the physical features of Pin Valley habitat may result in ibex using higher elevations in the colder months.

Winter is recognised to be the 'pinch period' for most ungulates inhabiting high altitude and latitudes regions when snow, low temperatures and poor quality forage cause decline in their body condition (Geist 1971, Schaller 1977, McCorquodale 1993, Fowler *et al.* 1967, Fox *et al.* 1989). Snow is widespread and has an overbearing influence on the mobility and accessibility to forage and escape terrain to ungulates (Tilton and Willard 1981, McCorquodale 1993). Animals have to invest considerable energy to first locate, then uncover and finally exploit forage buried under snow or seek patches with relatively less snow (Schaefer and Messier 1995). Studies on mule deer and elk have shown that they have to spend approximately double the energy on travel through 30 cm snow compared to bare ground and energy costs increased exponentially at greater sinking depths (Parker *et al.* 1984). Such data for ibex are not available but are likely to be similar. Ibex were seen travelling through snow reaching their upper chest and should be consuming considerable energy in the process. Both these constraints imposed by snow, i.e. extra costs of travel/movement and in procuring food, restricted habitat 'usable' by ibex to such areas that offered a combination of relatively less snow (IRS, avalanche chutes and wind blown crests), and areas close to ET, in spite of usually less forage available at such sites. Ibex foraged with least selectivity during winter (Manjrekar 1997). Site selection was thus likely to be primarily governed by the physical characteristics of the habitat that resulted in the least snow coverage.

5.4.2 **Predation**

Over half the ibex sightings in any season (except autumn in the trail and summer in the telemetry phase) were in areas 1 to 50 m from ET. This illustrates the importance of such areas for ibex and is hence discussed in greater detail below.

The large predators occurring in Pin Valley are the snow leopard, domestic dogs (*Canis familiaris*) and red fox. However, the red fox was never seen to attack ibex of any age class. Also, ibex did not show any alarm when a pair of red foxes passed within 10 m of a group of *ca.* 9 ibex with a year old young. Foxes may however pose a threat to neonates. Domestic dogs were seen attacking ibex groups on three occasions. On all occasions ibex quickly retreated into escape terrain. Ibex-snow leopard encounters were seen twice and ibex killed by snow leopard were collected on 10 occasions. The presence of wolf in the area could not be confirmed by me and my colleague, Ms. Nima Manjrekar. However, on one occasion in November 1993, we did see 'large dog' spoor and later visited a horse kill that seemed to be a result of wolf attack (based on the widely scattered and cleaned bone surfaces). In the summer of 1995 approximately five livestock kills were reported by locals within a span of two days that were suspected to be the result of wolf predation. Golden eagle were common in the study area and it was seen in the vicinity of ibex on many occasions but only on one occasion in July (kidding season) ibex showed some alarm. Golden eagles may be a threat only to neonates as was also observed in case of bharal in Ladakh (Chundawat *pers. comm.*).

Ibex may react differently if the danger was perceived suddenly and close to them or was perceived from a distance. On perceiving danger at a distance, ibex bunched up and in a rigid posture gave repeated whistling alarm calls looking in the direction of the danger. This was the reaction when a snow leopard was not in their direct view and when there was an unknown danger such as only hearing stones rolled off by an approaching human/animal. After sighting the snow leopard ibex retreated into steeper areas and usually left the locality for a few days. In case the perceived danger (or even human or a domestic animal) suddenly appearing very close (10 to 15 m) to them, ibex, probably not recognising the identity of the intruder, instantly retreated into cliffs (n=4). The same reaction occurred when dogs chased (n=3).

A kill by snow leopard during winter was observed to occur within 50 m from ET when the predator attacked from the direction of the ET. This brings out the need for reconsidering the utility of 'distance to escape terrain' *vis-a-vis* the snow leopard, a predator relying on stalking in contrast to a cursorial predator such as wolf or domestic dog. Based on preliminary results from their study on bharal, Longva and Fox (1997), have concluded that bharal, in areas with wolf and snow leopard, occur closer to ET when compared to areas where only snow leopard occurs. With wolf being either absent or rare and very few domestic dogs occurring within the study area, that too during the snow free months, the use of areas so near ET by ibex in Pin Valley seems to require further study (Such areas invariably have boulders and shrubs that can provide more stalking cover for snow leopard compared to open sites).

In this regard I would like to bring out the nature of use of the areas with ET available in various directions. The percent occurrence of the most used distance to ET class, i.e. 1 to 50 m, was plotted against directions in which ET was available in the random (availability) and the 'used' plots (Fig. 5.6). While a combination of this distance to ET class and 1 or 2 directions was most common in the random plots, ibex mostly occurred in areas with 3 to 4 directions. This indicates a proportionally greater use of 3 to 4 directions by ibex. Ibex are more adept at swiftly climbing cliffs than running, may be even moderate distances, due to their stocky legs and strong knees (Schaller 1977, Geist 1987). Ibex have evolved with the threat of cursorial predators. Because of their adaptations and the danger of cursorial predators not being absent, ibex tend to stay near ET in Pin Valley. Also, to avoid predation by a solitary stalking predator like snow leopard they choose to stay mainly in such areas where the predator is able to block at most one of the escape routes. The relatively lower use of areas with even greater security offered by more directions (>4) may be a result of such areas being on or very close to ET, where forage is scarce i.e. the amount is so low as to be uneconomical in terms of forage harvest rate.

5.4.3 Comparison of Habitat in 'Used' and 'Unused' Areas

Within the Spiti region, Kibber Wildlife Sanctuary lies at the northern periphery of the ibex range, with populations of ibex occurring immediately to the west of the region and some individuals coming within the western part of the area mainly in winter (Bhatnagar, *unpubl. data*, Forest Department Census records). This is a vast region of largely rolling plateau not colonised by ibex.

Ibex distribution may be limited in sites with lower availability of ET, with ET available in fewer directions and lower slope angles, as illustrated by the random points in Kibber (relatively unused) and Pin Valley (used site) (Table 5.9). Ibex preferred areas with moderate to high plant cover in Pin Valley (Table 5.6, 5.7) but they may not be attracted to areas with high plant cover if it occurs in less secure areas (less slope, fewer directions of ET and farther from ET). Comparison of the Kidul Chu (relatively unused) and the Gechang (used) areas in the winter of 1992-93 further illustrates this point. Ibex rejected an area with higher *exposed* plant cover and lesser snow that could have required lesser foraging effort, most likely because it was less secure (Table 5.8).

The logistic regression model may be used to predict whether an event will occur, as well as in identifying the variables useful in making the prediction (Norusis 1990). The purpose of doing this analysis in this study was primarily to identify the important variables governing ibex occurrence. Escape terrain, rockiness and slope were important variables. Ibex would select areas closer to ET, and to a weaker degree, slope, while selecting for more rocky areas. The exclusion of plant cover from the model further highlights that this variable will not be the deciding factor in ibex not choosing an area (but see below).

Predatory risk is a foraging cost for many animals (Kotler 1984, Brown *et al.* 1988, Kotler *et al.* 1994). Thus areas with lower predatory risk (closer to ET) will require lower time spent on vigilance (Risenhoover and Bailey 1985) and will have a lower forage 'give-up-density' (Kotler *et al.* 1994). In other words, feeding in such sites will be more efficient in spite of lower forage abundance. Due to this reason ibex may be selecting more secure areas in spite of relatively lower forage availability.

Plant cover is just one of the factors in the entire spectrum of forage characteristics of an area that may be important to herbivores. Plant cover has been used as a rough estimate of forage availability in this study. While plant species constituting a site and its relative biomass may be more important in determining *patch use*, ibex may not reject areas due to their plant species choice, until a minimum quantity of forage, and average nutritional requirements are met. Landscape elements constituting both security and forage requirements might govern ibex populations colonising and establishing in an area. The primary cues for selecting a region, however, may be based on factors such as the relative rockiness and availability of ET.

Limitations of the model

The logistic regression model developed in this study points out the importance of the availability of escape areas, rockiness and slope. The predictive value of the model is however, limited because of not including other potentially relevant parameters such as presence of possible competitors, snowfall patterns and a more accurate measure of forage availability such as plant biomass. Competitors such as bharal, in this case, may be a significant influence especially due to the limited availability of winter habitat (broken areas). Bharal and ibex have similar habitat utilization trends. However, bharal can probably forage farther from ET compared to ibex and this may give them an upper hand where more open and rolling areas occur (Schaller 1977, Schaller *et al.* 1987). Also, the evolutionary history and the direction of radiation of the two species may be important. Ibex has probably radiated from the Mediterranean region while bharal probably evolved close to the Tibetan plateau (Schaller 1977). It may have colonised the area before ibex arrived and had an advantage. Ibex and bharal overlap in narrow strips in two parts of their range *viz.* the Taxkorgan reserve in China (Schaller *et al.* 1987) and near Leh in Ladakh (Osborne *et al.* 1983, Mallon 1991). The Kibber region is the third area where there is overlap. More areas of overlap are likely along the Pir Panjal range in Himachal Pradesh.

5.4.4 Some Possible Biases in the Study

Habitat utilization trends in the two phases of the study were similar in terms of 'preferences', except in the case of aspect and altitude (Table 5.6 and 5.7). During the 'trail' phase the monitoring was more wide ranging and covered a substantial part of the northern slopes (N, NE and NW). This is reflected in a relatively higher use of these areas, especially during winter. The collared animals never crossed the Parahio river to the area which accounted for availability of bulk of the northern aspects.

While animals in the 'trail' phase were never seen above 4,600 m, during the 'telemetry' phase they were located in areas above 4,800 m during all seasons. These differences are more likely due to limitations of 'sightability' of ibex from trails that go largely along the lower valley (Section 3.2).

Table 5.2:Relative occurence (%) of categories of habitat variables in the intensive study area of Pin Valley National Park based on sampling in August, 1994 from 200 randomly laid plots (availability). Mean (SE) and median for interval scale variables given at the end of the table.

Terrain Type		Aspect		Slope		Dt. to escape terrain (ET)		Directions in which ET exists		Rock cover		Plant cover		Altitude	
Category	%	Category	%	Category	%	Category	%	Category	%	Category	%	Category	%	Category	%
Interspersed rocky slope	22.5	N	14.5	00-05	2.5	00	32.5	0	19.0	00-20	24.0	00	38.0	3600-4000	22.5
Rocky Slab/Cliffs	31.0	NE	9.5	06-30	32.0	01-50	33.0	1,2	38.0	21-40	11.0	05-20	21.0	4001-4400	30.0
Rocky Slope	12.0	E	18.0	31-60	55.0	51-100	16.0	3,4	8.5	41-60	13.5	21-40	12.0	4401-4800	24.0
Soily slopes/Meadows	17.0	SE	12.0	61-90	10.5	101-150	4.0	5,6	1.5	61-80	13.0	41-60	8.0	4801-5200	17.5
Scree/old moraine/valley bottom	11.5	S	18.5			> 150	14.5	7,8	33.0	81-100	38.5	61-80	9.5	> 5200	6.0
Glacier	6.5	SW	13.0									81-100	11.5		
		W	6.5												
		NW	7.0												
Mean ± SE	-		-	**39.6 ± 1.3**		**76.1 ± 9.1**		**3.5 ± 0.23**		**57.8 ± 2.6**		**28.2 ± 2.4**		**4419.5 ± 33.1**	
Median				**40**		**30**		**2**		**65**		**10**		**4385**	

Table 5.6:Seasonal habitat selection during the 'trail monitoring' phase of the study (November, 1992 to May, 1994). Preference (+), avoidance (-) and use in proportion to availability (=) are used in a relative sense (see text for). Analysis based on Marcum and Loftsgaarden (1980). Alpha for simultaneous confidence intervals set at 0.09 (91 %) for variables with upto 5 classes and at 0.2 (80 %) with over 5 classes. Summer, 1993 data not presented due to insufficient sightings (17).

Habitat category	Proportion available (n=200)	Spring, 1993		Autumn, 1993		Early winter (1992-93 +1993-94)*		Peak winter (1992-93 +1993-94)		Late winter (1992-93 +1993-94)	
		Proportion utilized (n=248)	Relative selection	Proportion utilized (n=60)	Relative selection	Proportion utilized (n=44)	Relative selection	Proportion utilized (n=360)	Relative selection	Proportion utilized (n=84)	Relative selection
TERRAIN TYPE											
IRS	0.225	0.28	=	0.25	=	0.39	=	0.54	+	0.42	+
SLAB/CLIFF	0.310	0.13	-	0.10	-	0.07	-	0.14	=	0.32	=
ROCKY SLOPE	0.120	0.47	+	0.47	+	0.43	+	0.26	+	0.24	+
SOILY SLOPE	0.170	0.08	-	0.17	=	0.05	-	0.04	-	0.00	-
OTHERS^	0.110	0.05	-	0.02	-	0.07	=	0.02	-	0.02	-
GLACIER	0.065	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
CHI SQ,df, p		91.2,5,<0.0001		44.1,5,<0.0001		38.8,5,0.0001		126.7,5,<0.0001		38.0,5,<0.0001	
ASPECT											
N	0.145	0.02	-	0.07	=	0.12	=	0.11	=	0.04	-
NE	0.095	0.00	-	0.02	-	0.05	=	0.03	-	0.00	-
E	0.180	0.05	-	0.18	=	0.26	=	0.18	=	0.00	-
SE	0.120	0.13	=	0.15	=	0.14	=	0.11	=	0.02	-
S	0.185	0.63	+	0.45	+	0.28	=	0.33	+	0.37	+
SW	0.130	0.12	=	0.08	=	0.16	=	0.11	=	0.41	+

Habitat category	Proportion available (n=200)	Spring, 1993		Autumn, 1993		Early winter (1992-93 +1993-94)*		Peak winter (1992-93 +1993-94)		Late winter (1992-93 +1993-94)	
		Proportion utilized (n=248)	Relative selection	Proportion utilized (n=60)	Relative selection	Proportion utilized (n=44)	Relative selection	Proportion utilized (n=360)	Relative selection	Proportion utilized (n=84)	Relative selection
W	0.065	0.04	=	0.03	=	0.00	-	0.06	=	0.16	=
NW	0.070	0.00	-	0.02	=	0.00	-	0.05	=	0.00	-
CHI SQ.,df,p		130.7,7,<0.0001		23.2,7,0.002		9.9,7,0.19		21.2,7,0.004		75.4,7,<0.0001	
SLOPE (°)											
00-30	0.18	0.06	-	0.22	=	0.27	=	0.05	-	0.10	-
31-60	0.55	0.93	+	0.77	+	0.70	=	0.93	+	0.88	+
61-90	0.105	0.01	-	0.02	-	0.02	-	0.02	-	0.02	-
CHI SQ.,df,p		86.9,2,<0.0001		10.3,2,0.005		4.8,2,0.09		114.7,2,<0.0001		28.4,2,<0.0001	
DISTANCE TO ESCAPE TERRAIN (m)											
00	0.323	0.08	-	0.08	-	0.09	-	0.22	-	0.26	=
1-50	0.330	0.63	+	0.43	=	0.55	+	0.64	+	0.69	+
51-100	0.160	0.22	=	0.33	+	0.27	=	0.14	=	0.05	-
101-150	0.040	0.05	=	0.08	=	0.02	=	0.01	=	0.00	-
>151	0.145	0.02	-	0.07	=	0.07	=	0.00	-	0.00	-
CHI SQ.,df,p		80.8,4,<0.0001		22.3,4,0.0002		15.9,4,0.003		84.4,4,<0.0001		39.8,4,<0.0001	*Contd..*

HABITAT CATEGORY	PROPORTION AVAILABLE (n=200)	SPRING, 1993		AUTUMN, 1993		EARLY WINTER (1992-93+1993-94)*		PEAK WINTER (1992-93+1993-94)		LATE WINTER (1992-93+1993-94)	
		PROPORTION UTILIZED (n=248)	RELATIVE SELECTION	PROPORTION UTILIZED (n=60)	RELATIVE SELECTION	PROPORTION UTILIZED (n=44)	RELATIVE SELECTION	PROPORTION UTILIZED (n=360)	RELATIVE SELECTION	PROPORTION UTILIZED (n=84)	RELATIVE SELECTION
ALTITUDE (M)											
3600-3800	0.115	0.430	+	0.22	=	0.09	=	0.19	+	0.20	=
3801-4000	0.110	0.050	-	0.52	+	0.52	+	0.30	+	0.43	+
4001-4200	0.170	0.080	-	0.23	=	0.30	=	0.43	+	0.37	+
4201-4400	0.130	0.00	-	0.02	-	0.07	=	0.08	=	0.00	-
4401-4600	0.130	0.00	-	0.02	-	0.02	-	0.00	-	0.00	-
4601-4800	0.110	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
>4800	0.235	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
CHI SQ,df,p		237.5,6,<0.0001		74.0,6,<0.0001		56.5,6,<0.0001		219.6,6,<0.0001		93.7,6,<0.0001	
ROCK COVER (%)											
00-20	0.240			0.33	=						
21-40	0.110			0.30	+						
41-60	0.135			0.23	=						
61-80	0.130			0.10	=						
81-100	0.385			0.03	-						
PLANT COVER (%)				34.3,4,<0.0001							

00-20	0.590		0.23	-			
21-40	0.120		0.25	=			
41-60	0.080		0.28	+			
61-80	0.095		0.13	=			
81-100	0.115		0.10	=			
SNOW COVER (%)			32.5,4,<0.0001				
00-20	0.93		0.83				
21-60	0.01		0.03				
61-100	0.06		0.13				
			5.34,2,0.07 (Exp. value in >20% cells were <5)				

^'OTHERS' stand for SCREE,VALLEY BOTTOM,OLD MORAINE

[*] The two winters of 1992-93 and 1993-94 have been merged due to low sample sizes for early and late winter

n.b.:Some habitat categories used in this table are different from Table 5.5 due to sample size requirments of chi square tests (Sokal and Rohlf, 1990)

Table 5.7: Seasonal habitat selection during the 'telemetry' phase of the study (June, 1994 to May, 1995). Preference (+), avoidance (-) and use in proportion to availability (=) are used in a relative sense (see text for explanation). Analysis based on Marcum and Loftsgaarden (1980). Alpha for simultaneous confidence intervals set at 0.09 (91 %) for variables with upto 5 classes and at 0.2 (80 %) with over 5 classes. Aspect and altitude categories had to be clubbed owing to small sample size

HABITAT CATEGORY	PROPORTION AVAILABLE (n=200)	SPRING, 1994		SUMMER, 1994		AUTUMN, 1994		EARLY WINTER (1994)*		PEAK WINTER (1994-95)		LATE WINTER (1995)	
		PROPORTION UTILIZED (n=77)	RELATIVE SELECTION	PROPORTION UTILIZED (n=105)	RELATIVE SELECTION	PROPORTION UTILIZED (n=78)	RELATIVE SELECTION	PROPORTION UTILIZED (n=34)	RELATIVE SELECTION	PROPORTION UTILIZED (n=96)	RELATIVE SELECTION	PROPORTION UTILIZED (n=61)	RELATIVE SELECTION
TERRAIN TYPE													
IRS	0.225	0.28	=	0.40	+	0.30	=	0.38	=	0.68	+	0.46	+
SLAB/CLIFF	0.310	0.08	-	0.13	-	0.10	-	0.00	-	0.06	-	0.30	=
ROCKY SLOPE	0.120	0.46	+	0.25	+	0.35	+	0.35	+	0.22	=	0.25	=
SOILY SLOPE	0.170	0.16	=	0.22	=	0.24	=	0.24	=	0.04	-	0.00	-
OTHERS^	0.110	0.04	=	0.00	-	0.01	-	0.03	-	0.00	-	0.00	-
GLACIER	0.065	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
CHI SQ,df,p		50.1,5,<0.0001		42.1,5,<0.0001		39.4,5,<0.0001		28.5,5,0.0001		82.3,5,<0.0001		35.2,5,<0.0001	
ASPECT													
N	0.145	0.00	-	0.00	-	0.00	-	Pl. see at		0.00	-	0.00	-
NE	0.095	0.00	-	0.07	=	0.04	=	end of		0.00	-	0.00	-
E	0.180	0.05	-	0.34	+	0.15	=	table		0.06	-	0.15	=
SE	0.120	0.21	=	0.14	=	0.24	+			0.15	=	0.12	=
S	0.185	0.57	+	0.20	=	0.31	=			0.37	+	0.33	=
SW	0.130	0.15	=	0.11	=	0.14	=			0.40	+	0.28	+

W	0.065	0.01	-	0.12	=	0.09	=			0.03	=	0.13	=
NW	0.070	0.01	-	0.01	-	0.01	+			0.00	-	0.00	-
CHISQ.,df,p		61.1,7,<0.0001		31.9,7,<0.0001		27.2,7,0.0003				67.3,7,<0.0001		32.2,7,<0.0001	
SLOPE (°)													
00-30	0.345	0.25	=	0.23	-	0.44	=	0.27	=	0.28	=	0.30	=
31-60	0.550	0.75	+	0.78	+	0.55	=	0.74	+	0.72	+	0.70	+
61-90	0.105	0.00	-	0.00	-	0.01	-	0.00	-	0.00	-	0.00	-
CHISQ.,df,p		13.6,2,<0.0011		19.3,2,<0.0001		7.28,2,0.026		5.86,2,0.05		13.9,2,<0.0009		8.66,2,<0.013	
DISTANCE TO ESCAPE TERRAIN (m)													
00	0.323	0.08	-	0.12	-	0.06	-	0.00	-	0.10	-	0.20	=
1-50	0.330	0.82	+	0.64	+	0.90	+	0.79	+	0.87	+	0.69	+
51-100	0.160	0.10	=	0.21	=	0.03	-	0.18	=	0.03	-	0.12	=
101-150	0.040	0.00	-	0.01	=	0.01	=	0.03	=	0.00	-	0.00	-
>151	0.145	0.00	-	0.02	-	0.00	-	0.00	-	0.00	-	0.00	-
CHISQ.,df,p		57.2,4,<0.0001		38.0,4,<0.0001		73.0,4,<0.0001		31.9,4,<0.0001		76.2,4,<0.0001		29.8,4,<0.0001	*Contd..*

HABITAT CATEGORY	PROPORTION AVAILABLE (n=200)	SPRING, 1993		SUMMER, 1994		AUTUMN, 1993		EARLY WINTER (1992-93+1993-94)*		PEAK WINTER (1992-93+1993-94)		LATE WINTER (1992-93+1993-94)	
		PROPORTION UTILIZED (n=77	RELATIVE SELECTION	PROPORTION UTILIZED (n=105)	RELATIVE SELECTION	PROPORTION UTILIZED (n=78)	RELATIVE SELECTION	PROPORTION UTILIZED (n=34)	RELATIVE SELECTION	PROPORTION UTILIZED (n=96)	RELATIVE SELECTION	PROPORTION UTILIZED (n=61)	RELATIVE SELECTION
DIRECTIONS IN WHICH ESCAPE TERRAIN EXISTS													
0	0.190	0.00	-	0.03	-	0.01	-	0.03	-	0.00	-	0.00	-
1,2	0.380	0.26	=	0.26	=	0.17	-	0.09	-	0.05	-	0.12	-
3,4	0.085	0.49	+	0.48	+	0.65	+	0.59	+	0.45	+	0.38	+
5,6	0.015	0.10	+	0.07	=	0.10	+	0.24	+	0.30	+	0.20	+
7,8	0.330	0.14	-	0.16	-	0.06	-	0.06	-	0.20	-	0.31	=
CHI SQ,df,p		81.7,4,<0.0001		75.7,4,<0.0001		121.2,4,<0.0001		95.7,4,<0.0001		139.3,4,<0.0001		74.9,4,<0.0001	
ALTITUDE (M)													
3600-3800	0.115	0.17	=	0.03	-	0.12	=	Pl. see at		0.00	-	0.02	-
3801-4000	0.110	0.48	+	0.07	=	0.13	=	end		0.03	-	0.20	=
4001-4200	0.170	0.22	=	0.15	=	0.30	=	of table		0.21	=	0.07	-
4201-4400	0.130	0.07	=	0.23	=	0.23	=			0.39	+	0.30	+
4401-4600	0.130	0.04	-	0.25	+	0.04	-			0.12	=	0.34	+
4601-4800	0.110	0.03	-	0.17	=	0.13	=			0.18	=	0.07	=
>4800	0.235	0.00	-	0.10	-	0.05	-			0.08	-	0.02	-
CHI SQ,df,p		66.9,6,<0.0001		23.2,6,0.0007		23.1,6,0.0008				46.6,6,<0.0001		437.6,6,<0.0001	
ROCK COVER (%)													

00-20	0.240			0.19	=	0.21	=			
21-40	0.110			0.44	+	0.49	+			
41-60	0.135			0.19	=	0.19	=			
61-80	0.130			0.13	=	0.09	=			
81-100	0.385			0.06	-	0.01	-			
PLANT COVER (%)				58.2,4,<0.0001		67.3,4,<0.0001				
00-20	0.590			0.12	-	0.09	-			
21-40	0.120			0.26	+	0.28	=			
41-60	0.080			0.36	+	0.35	+			
61-80	0.095			0.23	+	0.22	=			
81-100	0.115			0.02	-	0.05	=			
				85.4,4,<0.0001		75.2,4,<0.0001				
EARLY WINTER-ASPECT						EARLY WINTER-ALTITUDE				
N,NE,NW	0.145	0.11	=			3600-4000m		0.115	0.35	+
E	0.095	0.06	=			4001-4400m		0.110	0.62	+
SE,S,SW	0.180	0.77	+			>4400m		0.170	0.03	-
W	0.120	0.06	=					24.5,2,<0.0001		
CHI SQ, df,P		13.7,3,0.003								

^'OTHERS' stand for SCREE,VALLEY BOTTOM,OLD MORAINE
n.b.:Some habitat categories used in this table are different from Table 5.5 due to sample size requirments of chi square tests (Sokal and Rohlf, 1990)

CHAPTER 6: ECOLOGICAL SEPARATION BETWEEN IBEX AND LIVESTOCK

6.1**INTRODUCTION**

There are a total of 17 villages with a human population of *ca.* 1,258 people in Pin Valley. All these villages are located in the 'buffer zone', to the east and south of the national park (Fig 2.2). Of these, only eight depend to varying degrees on the Parahio catchment that constitutes the northern part of the national park and the area covered by this study (Bhatnagar 1996). Sagnam, the largest village in Pin Valley, with about 62 families, has local rights over most of the Parahio catchment. The other seven villages use the Kidul chu valley whose right bank lies within the national park. People depend on the national park for fuel wood, fodder, pastures and some agricultural land. Pin valley has a total livestock population of *ca.* 2,361 animals while the eight dependent villages have a total of *ca.* 1,266 animals with a mean livestock holding of 9.77 animals/family (Pandey 1991, Bhatnagar 1996). People own yak (*Bos grunniens*), yak-cow hybrids (males are called dzo while females, dzomo), horses, donkeys, sheep and goats (*Capra hircus*). Based on a survey of 75 families (livestock holding 733) in the eight dependent villages (Bhatnagar 1996) reported that goats (27 %) and sheep (24 %) dominate the holding, followed by donkeys (15 %), horses (12 %), dzomos (9 %), yaks (8 %), cows (3 %) and dzos (1 %).

Livestock is grazed in the Pin Valley National Park for approximately six to eight months between May and December every year. By December end, animals are herded back to the villages to avoid the severe winter and are stall-fed till May or June.

Seventeen migratory herders from Simla and Kinnaur districts, with *ca.* 8,000 sheep and goats, have been permitted to graze their stock in Pin Valley by the forest department (Pandey 1991). Every June, they enter the region from the Bhaba pass lying south of the national park and leave the park by mid August, spending *ca.* 55 days in the region. Seven to eight groups with *ca.* 2,900 sheep and goat graze their stock in the upper Parahio catchment, in the Khaminger, Debsa and Killung nalas.

With such seemingly high pressures on the study area, especially during the only period with productive vegetation, I wanted to study the impacts of livestock on ibex at the level of micro-habitat use. Detailed work on the migratory livestock could not be done as the radio-collared ibex used different areas. However, possible impacts of migratory livestock grazing have been discussed. The study was carried out with the objectives:

1. To quantify the relative abundance and distribution of livestock in the study area.
2. To study the extent of overlap between ibex and livestock in their habitat requirements.

3. 6.2 METHODS

6.2.1 Livestock Abundance and Distribution

Residents who brought in livestock from the dependent villages were interviewed to learn about the numbers of various species being brought into the study area, and the localities where they were grazed. This information was crosschecked by actual counts in those areas to get an estimate of abundance and distribution.

6.2.2 Habitat Utilization by Livestock

Data on the habitat utilization (as per Table 5.1) by livestock was collected along the trails while monitoring the radio-collared ibex. Approximately 10 km in the Kidul Chu valley and eight km in the Parahio-Kocho valley were regularly surveyed in the process.

Habitat variables that determine use by ibex and livestock may differ. For example, the value of distance to escape terrain (ET) for ibex is not the same for horses or other livestock species, except goat and possibly sheep. The variables were, however, recorded for livestock only to differentiate between usage by ibex and livestock and not for studying habitat use by livestock *per se*.

Also, livestock species differ in habitat use patterns, for example, while donkeys mostly forage near habitations on the valley bottom, yaks forage on the higher slopes. It must be noted that the purpose of this analysis is primarily to look for differences in patterns of usage between ibex and livestock. Hence, all livestock species are considered together.

6.2.3 Analysis

Seasonal differences in the use of various habitat categories by livestock was checked based on a Chi square test of independence (Sokal and Rohlf 1995). For nominal variables, differences between ibex and livestock was checked based on a Chi square test of independence while differences between continuous variables was checked based on Mann-Whitney U test (Sokal and Rohlf 1995).

Habitat preferences of livestock was investigated based on Marcum and Loftsgaarden (1980) 'non-mapping technique' (See Section 5.2.1 for more details).

6.3 RESULTS

6.3.1 Livestock Abundance and Distribution

Livestock species can be grouped into three categories:

1. those that were dependent on human settlements (sheep, goats, donkeys, cow/dzomo), i.e. who were daily directed to pastures and herded back into pens. Their distribution was thus quite predictable near settlements (Fig. 6.1).
2. those that were free ranging (yaks) (Fig 6.2)
3. or partially free ranging (adult horses), who may be herded back into pens, but were essentially kept in pastures far from settlements (Fig 6.2).

The dependent villages had a livestock holding of *ca.* 1,266 animals but only *ca.* 350 of these (28 %) were grazed within the study area (approx. 350 km^2) (Table 6.1). Many animals from the first category were grazed close to the villages while those from the second category, were grazed further downstream along the Pin river. Sheep and goats constituted roughly half the population grazed in the study area (Table 6.1). Approximately 220 of the 350 animals grazed outside the eastern fringe of the national park, occasionally coming into the right bank of the Kidul Chu river, i.e. within the national park.

As already mentioned in Section 6.1 above, the migratory graziers brought in *ca.* 2,900 sheep and goats with some 20 donkeys and two to three dogs per group.

Table 6.1: Species wise population estimates of livestock in the eight villages dependent on the Parahio catchment, Pin Valley National Park and that actually graze in or in the vicinity of the study area. The

overall population estimates are from Pandey (1991) and the estimates for Parahio are based on counts and interviews with locals.

Species	Dependent Villages	Study area (Parahio)
Sheep & Goat	529	145
Horse	134	60
Yak, Dzo	211	60
Cows, Dzomo	149	40
Donkeys	243	45
Total livestock	1266	350

6.3.2Habitat and Spatial Separation

Livestock showed seasonal differences in the use of terrain type ($\chi^2=37.4$, df=6, $p<0.0001$), aspect ($\chi^2=80.4$, df=12, $p<0.0001$), distance to escape terrain ($\chi^2=37.6$, df=8, $p<0.0001$), directions in which ET exists ($\chi^2=26.7$, df=4, $p<0.0001$) and altitude ($\chi^2=24.8$, df=6, $p=0.0004$). There were however, no seasonal differences in the use of slope categories ($\chi^2=2.2$, df=2, $p=0.33$). Since ibex also showed seasonal differences in habitat use, the three seasons, spring, summer and autumn are considered separately.

There was a high degree of spatial overlap between ibex and resident livestock in spring (Fig. 6.3). In summer, however, ibex moved to higher elevations (Fig. 6.5), while most livestock remained along the valley bottom, thus, resulting in spatial separation (Fig 6.4).

Ibex choice of terrain type, aspect, slope, distance to escape terrain, directions in which escape terrain exists, and altitude differed from that of livestock ($p<0.05$) in all seasons, except spring, for the use of aspect ($p>0.05$) (Table 6.2, 6.3). Altitudinal separation was minimum during spring (difference of 199.5 m between means) (Fig. 6.5, 6.3) and maximum during summer (difference of 512.3 m between means) (Fig. 6.5, 6.4). Compared to ibex, livestock used less steep slopes ($p<0.05$) in all seasons, occurred farther from escape terrain ($p<0.05$) and in areas with escape terrain in fewer directions ($p<0.05$) (Table 6.2). Their use of rocky slopes, smooth slopes and 'other' terrain types was high during all three seasons, while ibex mostly occurred on interspersed rocky slopes and rocky slopes (Table 6.3). Ibex also used 'slab/cliffs' occasionally while livestock never used these habitats. During spring both ibex and livestock mostly used the southern slopes but in summer and autumn dispersed into other aspects (Table 6.3).

Ibex and resident livestock showed similarities in the selection trends for terrain type, aspect, and to some extent altitude during spring (Table 6.4). Both groups of animals preferred rocky slopes during all seasons but the use of interspersed rocky slopes by ibex and smooth slopes and 'other' terrain types by livestock was high during summer and autumn. Ibex and livestock have significant differences in the use of other habitat variables. While ibex preferred slopes with an inclination between 31° and 60° livestock consistently preferred slopes $\leq 30^\circ$ (Table 6.4). Livestock preferred areas farther than 100 m from escape terrain during summer and autumn while ibex were consistent in preferring areas one to 50 m from escape terrain (Table 6.4). Similarly, ibex preferred areas with escape terrain in 3 or 4 directions while livestock preferred areas with escape terrain not within 100 m in any direction (Table 6.4). Livestock preferred to stay below 4,000 m in all seasons, while ibex preferred 4,401 to 4,600 m during summer (Table 6.4; Fig 6.3). During spring and autumn there was some overlap in the use of altitudes by ibex and livestock between 3,600 m and 4,000 m, but ibex used a much wider range of altitudes upto, 4,400 m in spring and 4,800 m during autumn.

Table 6.2:Differences in the usage of terrain type and aspect by ibex and livestock (LS) in the intensive study area, Pin Valley N.P. Seasonal sample size for ibex (spring, summer, autumn): 61, 78, 61 and LS :55, 165, 76. χ^2 statistic for differences also given.

Habitat Variable	Category	Spring		Summer		Autumn	
		Ibex	LS	Ibex	LS	Ibex	LS
Terrain type	IRS	24.6	5.5	40.0	5.5	29.5	0.0
	Slab/Cl.	6.6	0.0	13.3	0.0	10.3	0.0
	Rocky Sl.	44.3	69.1	24.8	41.5	34.6	23.7
	Smooth Sl.	19.7	14.5	21.9	40.2	24.4	51.3
	Others^	4.9	10.9	0.0	12.8	1.3	25.0
	Glacier	0.0	0.0	0.0	0.0	0.0	0.0
χ^2, df, p		10.4, 2, 0.005[1]		87.2, 4, <0.001		55.9, 4,<0.001	
Aspect	N	0.0	4.0	0.0	7.5	0.0	5.2
	NE	0.0	0.0	6.7	2.7	3.9	1.7
	E	6.7	6.0	34.3	17.8	15.6	3.4
	SE	21.7	10.0	14.3	4.8	24.7	12.1
	S	60.0	76.0	20.0	19.9	31.2	50.0
	SW	8.3	2.0	11.4	9.6	14.3	5.2
	W	1.7	0.0	12.4	34.2	9.1	20.7
	NW	1.7	2.0	1.0	3.4	1.3	1.7
χ^2, df, p		0.112, 1, 0.74[2]		36.5, 7, <0.001		16.8, 5, 0.005	

^Others: Scree, Valley bottom & Old moraine

[1] Slab/cliff, others & glacier had to be dropped due to sample size constraints of χ^2 test

[2] Northern (N, NE, E, W, NW) & southern (SE, S, SW) aspects had to be clubbed due to sample size constraints of χ^2 test

Table 6.4: Seasonal habitat selection by livestock (LS) compared to that of ibex during the three seasons of overlap (May, 1994 to December, 1994 and in May, 1995) in the intensive study area. Preferences are calculated based on Marcum and Loftsgaarden's (1980) Bonferroni confidence intervals. Preference (+), avoidance (-) and usage in proportion to availability (=) must be treated in a relative sense. χ^2 values are for differences in the use and availability of LS only. (all p<0.0001). See Table 5.7 for details of ibex preferences.

Habitat Variable & category	% Avl.	Spring			Summer			Autumn		
		% Use LS	Pref. LS	Pref. Ibex	% Use LS	Pref. LS	Pref. Ibex	% Use LS	Pref. LS	Pref. Ibex
Terrain type										
IRS	22.5	5.5	-	=	5.5	-	+	0.0	-	=
Sl/Cl.	31.0	0.0	-	-	0.0	-	-	0.0	-	-
RS	12.0	69.1	+	+	41.5	+	+	23.7	+	+
SS	17.0	14.5	=	=	40.2	+	=	51.3	+	=
Others*	11.0	10.9	=	=	12.8	=	-	2.5	+	-
Glacier	6.5	0.0	-	-	0.0	-	-	0.0	-	-
		85.3, 5			127.9, 5			82.3, 5		
Aspect										
Flat	1.0	9.1	=	=	11.5	+	=	23.7	+	=
N,NE,NW	31.0	5.5	-	-	12.1	-	-	6.6	-	-
E	18.0	5.5	-	-	15.8	=	+	2.6	-	=
SE	12.0	9.1	=	=	4.2	-	=	9.2	=	+
S	18.5	69.1	+	+	17.6	=	=	38.2	+	=
SW	13.0	1.8	-	=	8.5	=	=	3.9	-	=
W	6.5	0.0	-	-	30.3	+	=	15.8	=	=
		72.3, 6			69.8, 6			80.9, 6		
SL (°)										
00-30	34.5	76.4	+	=	78.2	+	-	85.5	+	=
31-60	55.0	23.6	-	+	21.8	-	+	14.5	-	=
61-90	10.5	0.0	-	-	0.0	-	-	0.0	-	-
		31.9, 2			74.0, 2			58.2, 2		
DTET (m)										
0	32.5	0.0	-	-	1.2	-	-	0.0	-	-
01-50	33.0	14.5	-	+	6.7	-	+	17.1	-	+
51-100	16.0	52.7	+	=	2.3	=	=	17.1	=	-
101-150	4.0	14.5	=	-	13.3	+	=	15.8	+	=
>150	14.5	18.2	=	-	55.8	+	-	50.0	+	-
		55.3, 4			136.3, 4			***Contd..***		
ETNO										

0	19.0	32.7	=	-	69.1	+	-	67.1	+	-
1,2	38.0	61.8	+	=	27.9	=	=	26.3	=	=
3,4	8.5	5.5	=	+	0.6	-	+	6.6	=	+
5 to 8	34.5	0.0	-	=	2.4	-	=	0.0	-	=
		28.9, 3			115.2, 3			68.2, 3		
Altitude (m)										
3600-3800	11.5	65.5	+	=	40.6	+	-	69.7	+	=
3801-4000	11.0	30.9	+	+	41.8	+	=	21.1	=	=
4001-4200	17.0	1.8	-	=	9.7	=	=	3.9	-	=
4201-4400	13.0	1.8	-	=	6.1	-	=	5.3	-	=
4401-4600	13.0	0.0	-	-	1.8	-	+	0.0	-	-
4601-4800	11.0	0.0	-	-	0.0	-	=	0.0	-	=
>4801	23.5	0.0	-	-	0.0	-	-	0.0	-	-
		103.0, 6			144.6, 6			118.0, 6		

[*]Terrain type 'others' includes scree, valley bottom and old moraine.

Fig. 6.1: Approximate distribution and abundance of livestock dependent on human settlements i.e. sheep, goats (S/G), donkeys (D), cows and dzomos(C/Dz) within the study area between May and December.

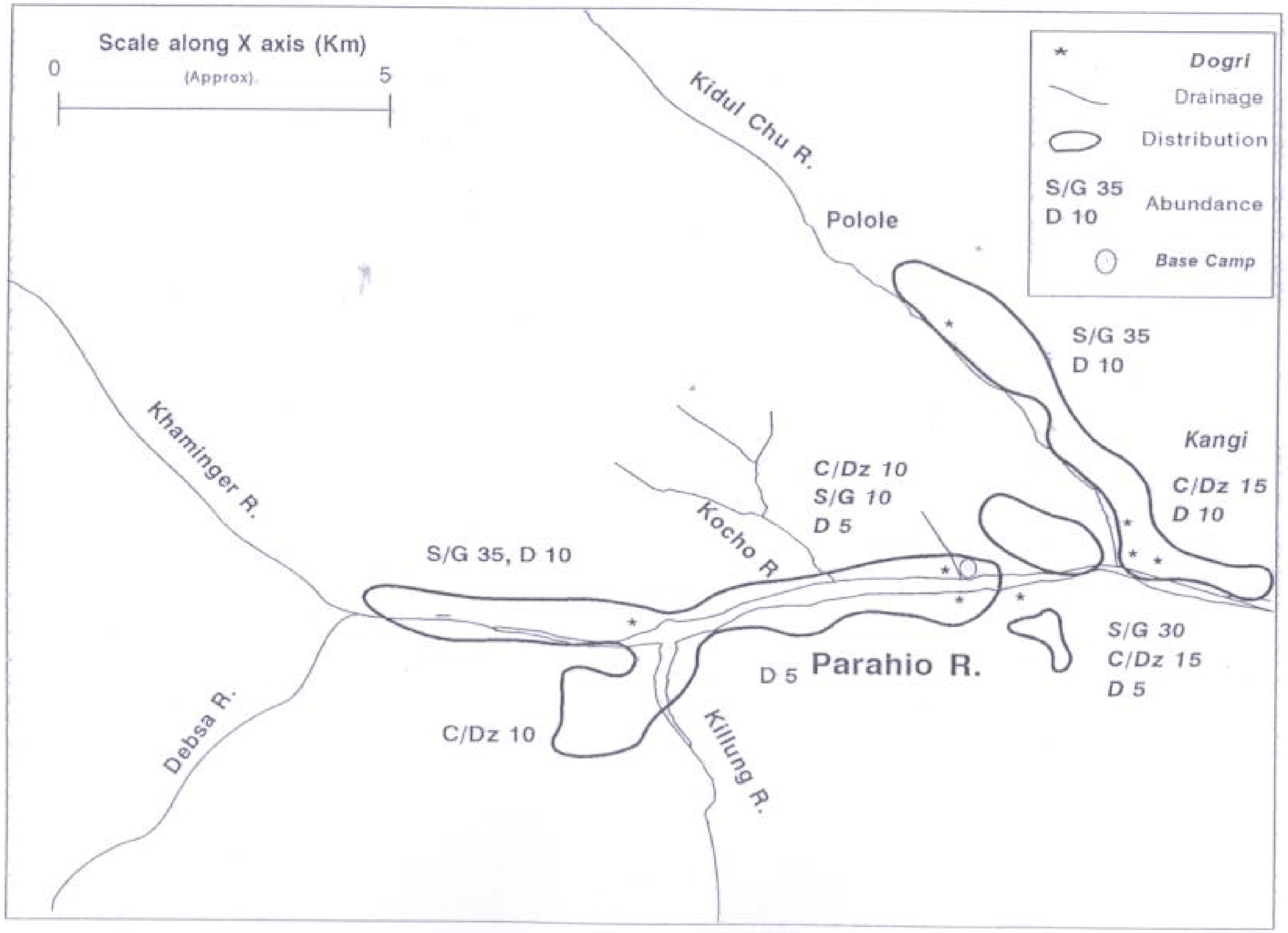


Fig. 6.2: Approximate distribution and abundance of livestock largely independent of human settlements i.e. yak/dzso (Y) and horse (H) within the study area between May and December.

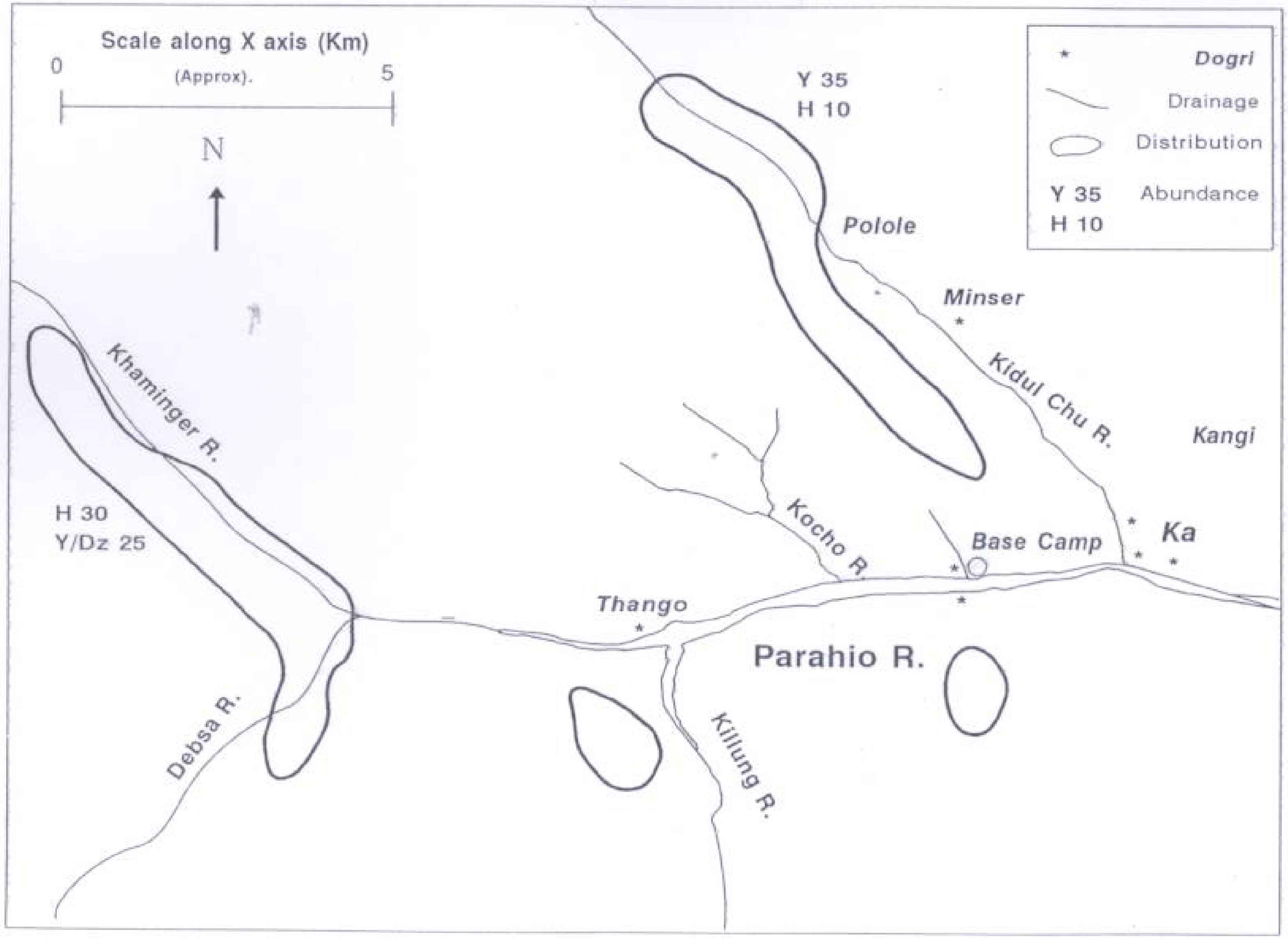


Fig. 6.3: Distribution of ibex (n=61) and livestock (n=55) in the intensive study area, Pin Valley N.P during spring (June 1994 and May 1995)

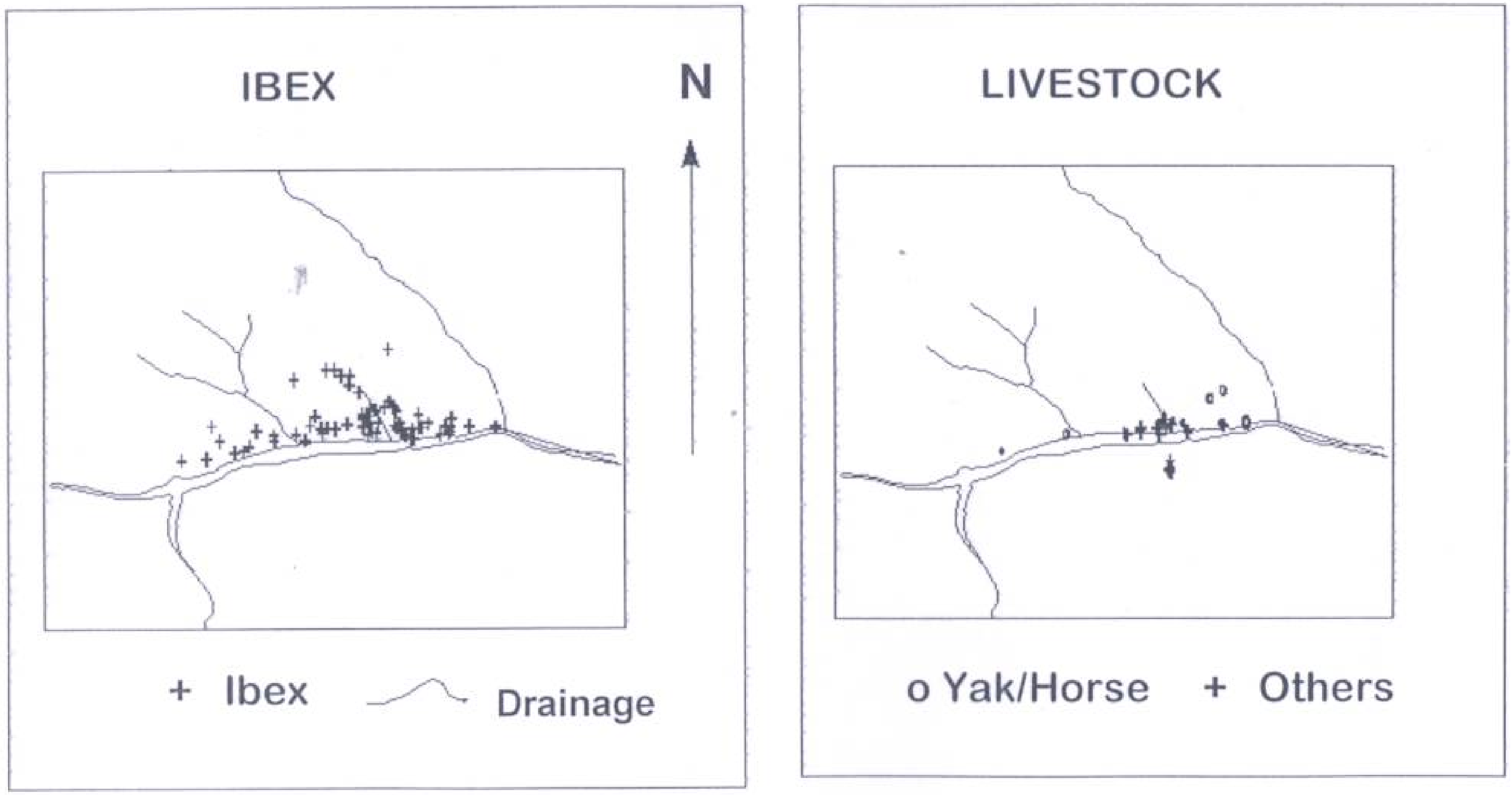


Fig. 6.4: Distribution of ibex (n=78) and livestock (n=165) in the intensive study are
Pin Valley N.P in summer (July - Sept. 1994)

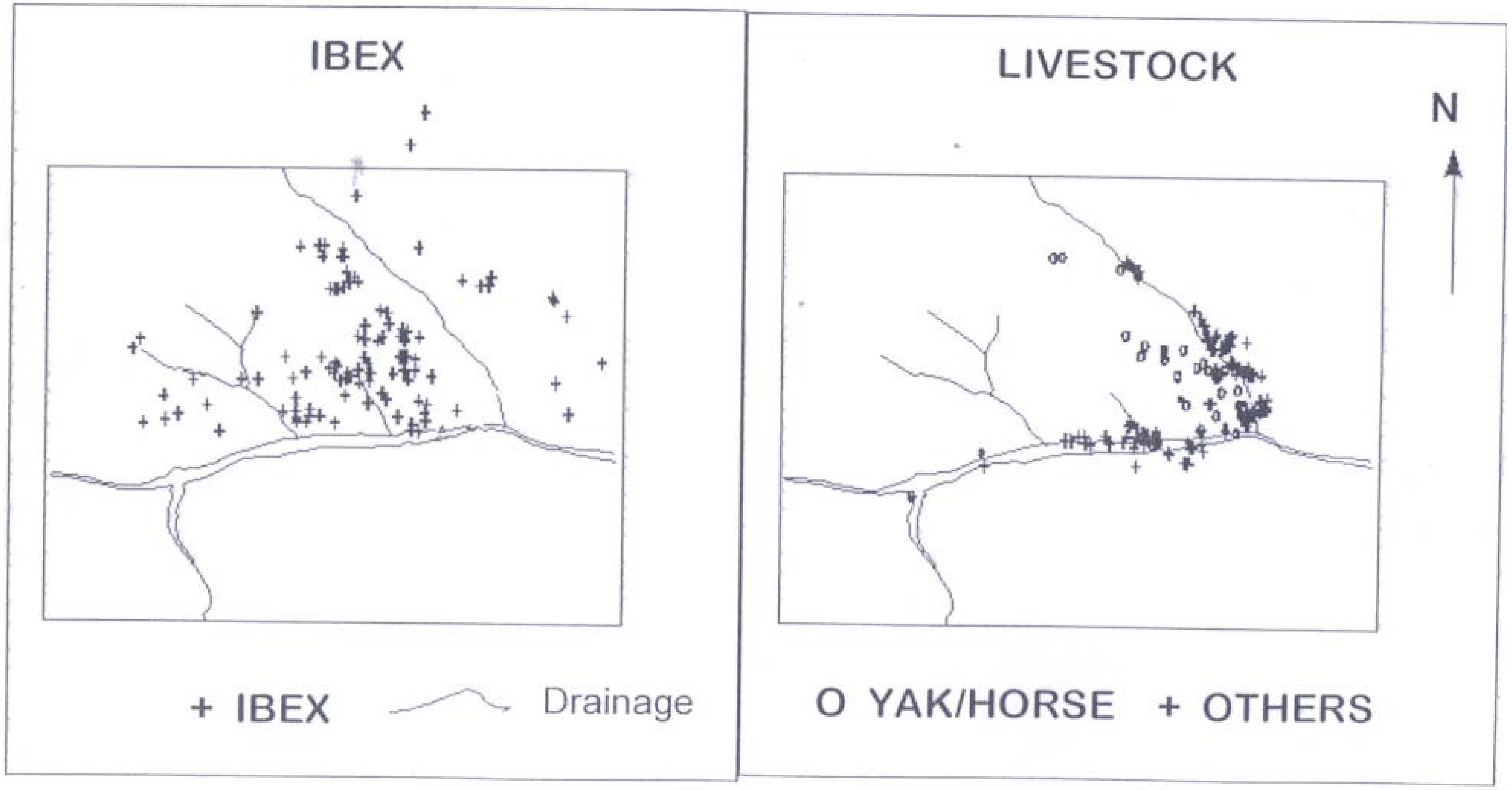
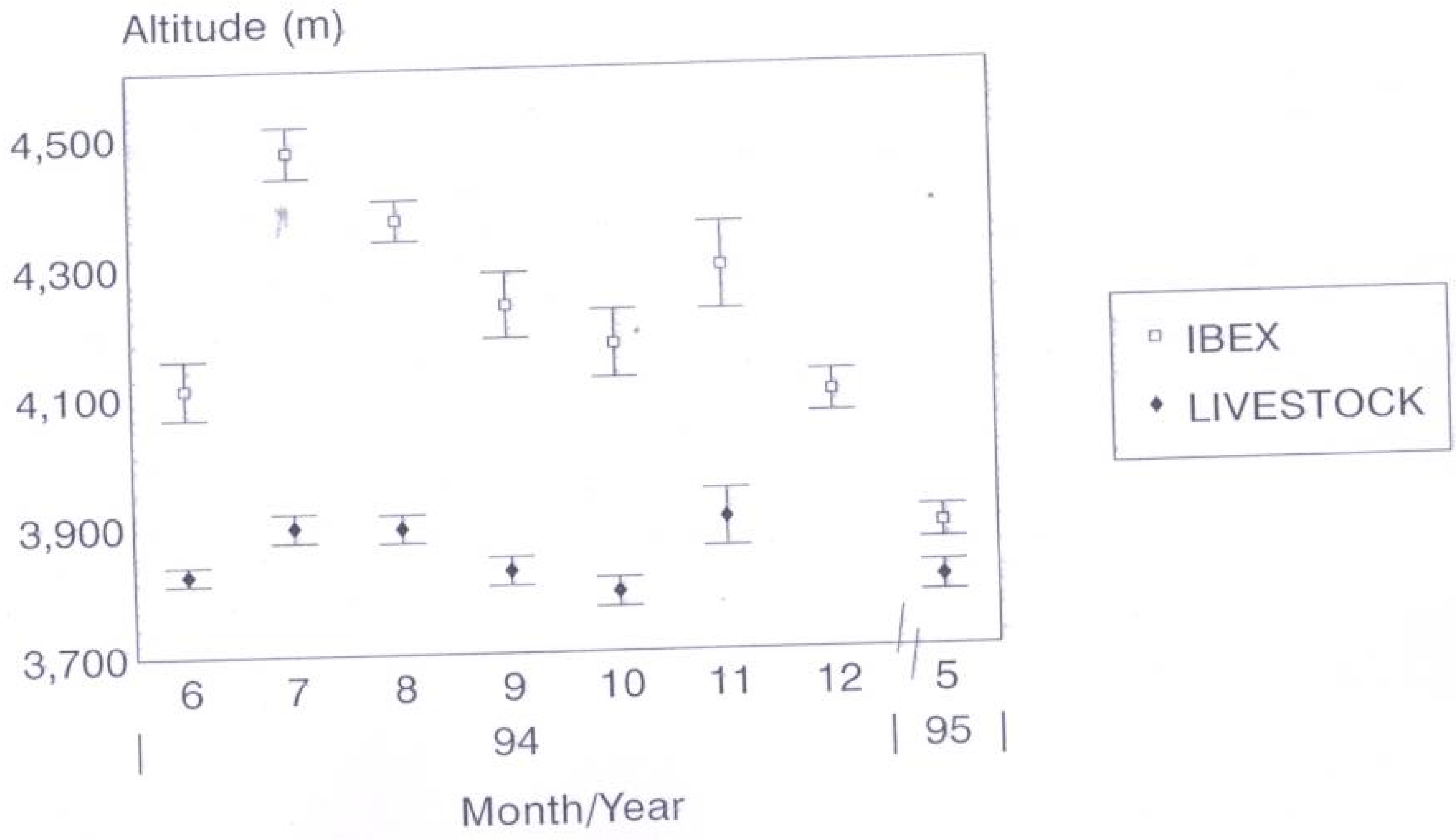


Fig. 6.5: Mean monthly altitudinal use (S.E) by ibex and livestock during the period of overlap (May to December) in the intensive study area. Valley bottom is usually at ca. 3,700 m



Monthly n for ibex: 33, 55, 30, 43, 29, 27, 35, 27
Monthly n for livestock: 11, 71, 66, 49, 52, 3, 0, 27

6.4 DISCUSSION

Through the snow free periods the study area had a livestock density of *ca.* 1.00/km² (from Table 6.1). Including the migratory livestock this would rise to 9.28 animals/km² and if unusable areas such as permanent ice fields are excluded, these values will further increase. Pandey (1992) estimated an ibex density of 2.29 per km² for the Pin Valley national park. In other words there are *ca.* 0.44 resident livestock to every ibex and *ca.* 4 domestic animals (including migratory ones) to every ibex in the area between June and mid-August. Given these values of abundance, the pressures on the area imposed by livestock could be considerable. The distribution maps for resident livestock (Fig. 6.3, 6.4) however, show that the concentrated use of areas by livestock was limited to the lowest slopes near the valley bottom during all three seasons. This is also indicated by the usage data (Table 6.2, 6.3, 6.4). Since data is available mainly for resident livestock, we will discuss the mechanisms of habitat separation and the potential threats to ibex by these.

6.4.1 Habitat Separation Between Ibex and Resident Livestock

There was some overlap in the use of altitudes, terrain types and aspect by ibex and livestock during spring and autumn (Fig. 6.3, Table 6.4). However, the separation between the two was clear in the use of slope, distance to escape terrain and directions in which escape terrain exists during all seasons (Table 6.2, 6.3, 6.4). The separation between ibex and livestock was highest during summer when they differed in the use of altitude and terrain type apart from all other variables. Ibex and livestock are thus likely to compete for resources during spring and autumn, while during summer the possibility of either 'exploitation' or 'scramble' competition is excluded due to spatial separation. Ibex were often seen foraging in the vicinity, and also in the same group as livestock during spring and autumn. This shows that the chance of interference competition was minimal even during the period of overlap.

Before proceeding further on competition between ibex and livestock we will take a look at the human intervention in the use of habitats by the resident livestock. Approximately 66 % of the 350 resident livestock (category 1, Section 6.3.1) were daily directed into pastures, selected on a rotation basis by the owners, and were left to forage for *ca.* 10 to 12 hours. Some of these were herded back into pens during mid-day for a few hours. The choice of pastures was made by the owners, for whom an important consideration was proximity to their settlements. Usually all animals from this category were located within 2 km from the settlements, and that too along the lower valley. A major proportion of livestock was left to graze in the crop fields after harvesting in August with the purpose of manuring the fields. There was thus a decline in the altitudnal use by livestock in September-October.

Competition is defined as the use of resource by an individual or a species in a way that reduces its availability for other individuals or species (Ricklifs 1974). Competition may thus occur where the resource is scarce, non-renewable or renewed at a rate lower than demand. Competition usually leads to niche partitioning in such a manner that in most natural communities species may co-exist (Milinski and Parker 1991). Sympatric animals utilizing similar resources may separate at the spatial level, at the level of use of micro-habitats and finally at the level of selection of plant species or plant parts (Dunbar 1978, Seegmiller and Ohmart 1981, Dodd and Smith 1988, Harris and Miller 1995).

Ibex in Pin Valley separate from resident livestock in the use of steeper areas, areas closer to escape terrain, with escape terrain available in more directions and during summer, altitude. What needs to be considered is whether ibex separate into such areas owing to competition from livestock or independent of this.

During spring, the period of high spatial overlap, both groups used the lowest altitudes where the snow had thawed and fresh sprout was available. During this period ibex had little choice to go into the upper slopes which were snow bound and where plants had not sprouted. During May and June ibex were often attracted by green pastures developed by the residents[1] at Gechang hardly 50 m from their house. Ibex primarily fed on *Lindelofia anchusoides* and some grasses which sprouted early, apart from some reportedly unpalatable species such as *Polygonum filicaule* and *Nepeta* sp. (Manjrekar, *in prep.*). 'Exploitation competition' between ibex and livestock during this period is thus quite likely, but is probably minimised by separation in terms of use of slope and more rugged areas. Harris and Miller (1995) showed that although

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[1] Residents at Gechang spread a mixture of ash and soil on the snow covered fields and pastures adjoining it during early May to hasten thawing. These patches thus become green islands in late May and June.

sheep and six wild ungulates in the Quinghai province, China had spatial overlap, they had different diet selection trends in summer.

As temperatures increased, ibex moved higher on the slopes where better quality forage and cooler temperatures were available (see Section 5.4.1), while bulk of the resident livestock continued to forage in the lower slopes. As stated earlier, the question is whether this migration to higher altitudes was triggered by livestock or was it because of other environmental factors. During this period the two groups were usually separated by *ca.* 500 m altitudinally, with little overlap. Ibex did not use the empty areas between the two distributions. There was considerable magnitude of difference in the use of slope, distance to escape terrain and directions in which it was available (Table 6.2). Thus, it is likely that resident livestock utilize the largely 'vacant area' that ibex rarely used owing to their adaptations and are unlikely to pose a direct threat to ibex.

How would the summer foraging by livestock limit the availability of forage during the period when they were not present in the area, i.e. winter? The habitat usage by ibex in winter shows clear avoidance for areas with excessive snow and a preference for rugged areas with easier accessibility to forage and escape terrain (Section 5.4.1). Also, they never or rarely descend to areas as low as 3,800 m, the median altitude of livestock usage (Table 6.2) (see Section 5.4.1 for more details on this aspect). Thus even during this period, resident livestock do not pose a threat to ibex.

6.4.2 **Potential Threats to Ibex by Resident Livestock**

The previous passages suggest that there is likely to be no adverse impact of resident livestock on ibex. This statement has to be taken with caution as the primary reason for this is the more or less stable resident livestock population in Pin Valley and the manner in which people restrict usage by their livestock to near their settlements. Residents said that although they may like to own more livestock, a restriction on this was imposed due to the amount of fodder they can collect for the winter stall feeding (Bhatnagar 1996). With extra fodder being made available, there is a likelyhood that the livestock holding may grow and cause adverse impact on ibex usage. A final verdict on the possible affect of livestock on ibex usage can be given when livestock is removed from the area and a similar study is carried out.

Resident livestock may pose a threat to ibex through transmission of contagious diseases. People in the area occasionally reported cases of foot-and-mouth disease and pneumonia among their livestock. However, during the course of the study when over 8,000 ibex were sighted only on one occasion a limping ibex, probably infected by foot-and-mouth disease was observed.

Pastures with *Festuca* sp. occur in gullies on the north facing slopes. This grass is preferred for stall feeding livestock in winter and feeding yaks used for ploughing during May-June. Traditional local law have allocated pastures to households whose members collect numerous back-loads of this grass in September. Ibex often foraged in these pastures during winter of 1992-93. This may be a significant threat to ibex using northern slopes.

6.4.3 **Other Threats to Ibex in Pin Valley National Park**

Migratory Livestock

Intensive grazing by migratory livestock over the years has caused degradation of the pastures used by them (Bhatnagar 1996, Manjrekar, *unpubl. data*). All eight herdsmen who were interviewed during the summer of 1993 opined that their pastures were being overgrown by unpalatable species or less preferred species such as *Cicer microphylla*. Many residents from Sagnam village also complained about increasing numbers of sheep and goats being brought into the area. According to the Forest Department records *ca.* 2,900 sheep and goats are permitted to enter the Parahio catchment, but our counts yield at least 500 extra animals.

A minimum of 10 animals infected by foot-and-mouth disease were present in the summer of 1993 in two groups at Debsa and Khaminger. The national park administration took strict action on the owners and have made vaccination of all animals mandatory. Transmission of disease by migratory livestock may be a significant threat to ibex.

Another significant threat posed by the migratory herdsmen is the accompanying Tibetan *bhutia* dogs. Each group has two to three dogs who have been reported to be quite ferocious. Occasionally some are left behind in the valley and cause havoc among the resident livestock. These animals killed some 8 sheep and goats in the summer of 1994 near Sagnam village. Ibex got alarmed when dogs barked, even from considerable distances. I observed such dogs chasing ibex on three and attacking ibex on one occasion.

Fuelwood Extraction

In the extreme cold region of Pin Valley, warmth during winters is provided only by burning wood. Cooking till recently (1994-95) was exclusively done on fuelwood and dung in all seasons. People require enormous quantities of fuelwood for winter sustenance. The Government heavily subsidizes fuelwood for the locals (charging *ca.* 30 % of actual cost) but still, an estimated minimum of 1,021 kg/family is extracted from the national park and its surrounding areas (Bhatnagar 1996). Over 65 % of the 75 families sampled agreed that the national park and adjoining areas were getting degraded, attributing fuelwood extraction as the primary reason for degradation (Bhatnagar 1996). Uprooting of shrubs such as *Rosa* spp., *Ephedra* sp., *Lonicera* spp. and *Caragana* sp. for fire wood, is likely to reduce their regeneration. Many of the older residents at Sagnam village reported stands of *Betula utilis* and *Juniperus macropoda* at two sites within the national park, barely 50 years back. Today the few remaining ones are restricted to inaccessible cliffs or sites protected by religion (Bhatnagar 1996).

Wild caprines were the ancestors of domestic sheep and goats and are still an important genetic resource (Shakleton 1997). Caprinae populations are particularly vulnerable to extinctions because of three main factors: genetic isolation, specialised habitat requirments and a low reproductive rate (Shakleton 1997, Hutchins and Geist 1987). Asiatic ibex has a wide distribution, but different populations are often widely separated (Schaller 1977). The genetic variability of the sub-species may be high, but within populations, it may be low. Also, a significant portion of its distribution is along international borders were unrest may pose further threat to the sub-species. It is important to have a larger coverage of ibex range under the protected area network in India for effective and long-term survival of the species.

Table 6.3:Differences in the use of altitude, slope, distance to escape terrain and directions in which it exists by ibex and livestock (LS) in the intensive study area, Pin Valley N.P. Seasonal sample size for ibex (spring, summer, autumn): 61, 78, 61 and LS :55, 165, 76. Mann-Whitney U test, Z statistic and p value for differences also given.

Habitat Variable	Animal	Spring				Summer				Autumn			
		Mean (SE)	Median	Min.	Max.	Mean (SE)	Median	Min.	Max.	Mean (SE)	Median	Min.	Max.
Altitude	Ibex	4007.2 (30.8)	3940	3700	4640	4400.6 (28.8)	4440	3700	4880	4225.0 (36.7)	4195	3680	4920
	LS	3807.7 (13.0)	3780	3640	4240	3888.3 (14.3)	3840	3640	4570	3795.8 (16.8)	3760	3600	4300
		-5.4, <0.001				-11.9, <0.001				-8.41, <0.001			
Slope	Ibex	35.2 (1.1)	35	0	50	37.4 (0.7)	35	20	60	34.6 (0.96)	35	0	70
	LS	24.8 (1.5)	30	0	40	20.7 (1.0)	25	0	50	14.9 (1.5)	10	0	40
		-5.75, <0.001				-10.3, <0.001				-7.89, <0.001			
Dist. to Escape Terrain	Ibex	31.3 (2.7)	30	0	80	35.6 (3.6)	20	0	200	21.2 (2.2)	20	0	150
	LS	103.3 (7.7)	90	10	250	210.2 (10.6)	200	0	800	169.6 (11.5)	165	20	500
		-7.68, <0.001				-11.8, <0.001				-10.2, <0.001			
Dirs. of Escape Terrain	Ibex	3.8 (0.3)	3	1	8	3.7 (0.2)	3	0	8	3.7 (0.2)	4	0	8
	LS	0.94 (0.1)	1	0	3	0.52 (0.1)	0	0	8	0.51 (0.1)	0	0	3
		-8.24, <0.001				-11.6, <0.001				-10.2, <0.001			

REFERENCES

Anon, 1992. The Indian Wildlife (Protection) Act, 1972. Government of India. Dehradun, Natraj Publishers.

Aebischer, N.J., Robortson, P.A. and Kenward, R.E. 1993. Compositional analysis of habitat use from animal radio-tracking data. *Ecology* 74(5):1313-1325

Aldos, C.L. and Escos, J. 1987. Relationships between movement rate, agonistic displacements and forage availability in Spanish ibexes (*Capra pyrenaica*). *Biol. Behav.* 12:245-255

Alldredge, J.R. and Ratti, J.T. 1986. Comparision of some statistical techniques for analysis of resource selection. *J. Wildl. Manage.* 50(1):157-165.

Alldredge, J.R. and Ratti, J.T. 1992. Further comparision of some statistical techniques for analysis of resource selection. *J. Wildl. Manage.* 56(1):1-9.

Altmann, J. 1974. Observational study of behaviour: sampling methods. *Behaviour*. 49:227-267.

Anderson, D.J. 1982. The home range: a new nonparametric estimation technique. *Ecology*. 63:103-112.

Baker, R.R. 1978. The Evolutionary Ecology of Animal Migration. Hodder & Stoughton, London.

Bhatnagar, K. 1996. A Study on Peoples Dependence and Attitudes in the Pin Valley National Park. Report submitted to World Wide Fund for Nature-India. 45pp

Bhatnagar, Y.V. 1993. Pin Valley National Park and its wildlife. *The Himalayan Journal*. Vol. 50, pp202-204.

Bhatnagar, Y.V., Manjrekar, N., Stuewe, M., Rawat, G.S., Johnsingh, A.J.T. 1997. Grouping patterns of Asiatic ibex, *Capra ibex sibirica* in Pin Valley National Park, India. Paper presented in the 2nd World Conference on Mountain Ungulates, Saint Vincent, Italy, 5-7 May, 1997. Abstracts.

Bhatnagar, Y.V. 1994. Origin and distribution of Himalayan ungulates and factors affecting their present distribution. pgs 246-254. In. Pangtey, Y.P.S and Rawal, R.S. High Altitudes of the Himalaya. Nainital, Gunodaya Prakashan.

Bowen W.D. 1982. Home range and spatial organisation of coyotes in Jasper National Park, Alberta. *J. Wildl. Manage.* 46, 201-216.

Brown, J.S., Kotler, B.P., Smith, R.J. and Wirtz, W.O. 1988. The effects of owl predation on foraging behaviour of heteromyid rodents. *Oecologia.* 76:408-415.

Burt, W.H. 1943. Territoriality and home range concepts as applied to mammals. *Journal of Mammalogy*. 24:346-352.

Byers, C.R., Steinhorst, R.K. and Krausman, P.R. 1984. Clarification of a technique for analysis of utilization-availability data. *J. Wildl. Manage.* 48(3):1050-1053.

Cedarlund, G.N. and Hakan, K.G.S. 1992. Dispersal of sub-adult moose (*Alces alces*) in a nonmigratory population. *Can. J. Zool.* 70(7):1309-1314

Champion, H.G. and Seth, S.K. 1968. The Forest Types of India. The Government of India Press, Delhi.

Chundawat, R.S. 1992. Ecological studies of snow leopard and associated prey species in Hemis High Altitude National Park, Ladakh (J & K). PhD thesis submitted to the Rajasthan University, Jaipur.

Chundawat, R.S. and Rawat, G.S. 1994. Indian cold deserts: A status report on biodiversity. Dehradun, Wildlife Institute of India. 36pp.

Cochran, M.H. and Smith, E.L. 1983. Intermountain movements by a desert bighorn ram in western Arizona. Desert Bighorn Council Trans. 27:1-2.

Dixon K.R. and Chapman, J.A. 1980. Harmonic mean measure of animal activity areas. *Ecology.* 61:1040-1044.

Dodd, N.J. and Smith, R.H. 1988. Habitat and spatial relationships of sympatric desert bighorn sheep and cattle. Final Report submitted to Arizona Game and Fish Department. Project W-78-R. 25p.

Dunbar, R.I.M. 1978. Competition and niche separation in a high altitude herbivore community in Ethiopia. *E. Afr. Wildl. J.* 16:183-199.

Ford, R.G. and Krumme, D.W. 1979. The analysis of space use patterns. *J. Theor. Biol.* 76:125-155.

Fowler, J.F., Newsom, J.D. and Short, H.L. 1967. Seasonal variation in food consumption and Weight gain in male and female white-tailed deer. Proceedings, Annual Conference of Southeast Association Game and Fish Commissio. 21:24-32.

Fox, J.L., Smith, C.A. and Schoen, J.W. 1989. Relation between mountain goats and their habitat in southeastern Alasks. Gen. Tech. Rep. PNW-GTr-246. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 25p.

Fox, J.L., Nurbu, C. and Chundawat, R.S. 1991. The mountain ungulates of Ladakh, India. *Biol Conserv.* 58:167-190.

Fox, J.L., Sinha, S.P. and Chundawat, R.S. 1992. Activity patterns and habitat use of ibex in Himalaya Mountains of India. *J. Mammal.* 73:527-534.

Fryxell, J.M. and Sinclair, A.R.E. 1988. Causes and consequences of migration by large herbivores. *TREE.* 3(9):237-241.

Garshelis, D.L. and Pelton, M.R. 1981. Movements of black bears in the Great Smokey Mountains National Park. *J. Wildl. Manage.* 45(4):912-925

Gautestad, A.O. and Mysternd, I. 1995. The home range ghost. *OIKOS*. 74:195-204.

Geist, V. 1987. On the evolution of caprinae. pp 3-40. In Soma, H. (Ed.) The Biology and Management of Capricornis and Related Mountain Ungulates. London, Croom Helm.

Geist, V. 1971. Mountain Sheep: a Study in Behaviour and Evolution. University of Chicago Press, Chicago. 383pp.

Goodson, N.J., Stevens, D.R. and Bailey J.A. 1991a. Winter-spring foraging ecology and nutrition of bighorn sheep on montane ranges. *J. Wildl. Manage.* 55(3):422-433

Goodson, N.J., Stevens, D.R. and Bailey J.A. 1991b. Effects of snow on foraging ecology and nutrition of bighorn sheep. *J. Wildl Manage.* 55(2):214-222

Gupta, R.K. 1994. Arcto-alpine and boreal elements in the high altitude flora of north-west Himalaya. pgs. 11-32. In. Pangtey, Y.P.S and Rawal, R.S. High Altitudes of the Himalaya. Nainital, Gunodaya Prakashan.

Harris, S., Cresswell, W.J., Forde, P.G., Trewella, W.J, Woolard, T. and Wray, S. 1990. Home-range analysis using radio-tracking data-a review of problems and techniques particularly as applied to study of mammals. *Mammel. Rev.* 20(2/3):97-123.

Harris, R.B. and Miller, D.J. 1995. Overlap of summer habitats and diets of Tibetan Plateau ungulates. *Mammalia.* 59(2):197-212.

*__Harrison, J.L. 1958.__ Range of movements of Malayan rats. *J. Mammal.* 39:190-206.

*__Hayne, D.W. 1949.__ Calculation of size of home range. *J. Mammal.* 30:1-18

Heptner, V.G., Nasimovic, A.A. and Bannikov, A.G. 1966. Die Säugetiere der Sovietunion. Vol. 1. Paahufer und Unpaahufer. Gustav Fischer Verlag, Jena.

Holzenbein, S. and Schewede, G. 1989. Activity and movements of female white-tailed deer during the rut. *J. Wildl. Manage.* 53(1):219-223.

Hutchins, M. and Geist, V. 1987. Behavioral considerations in the management of mountain-dwelling ungulates. *Mountain Research and Development*. 7(2):135-144.

Jarman, P.J. 1974. The social organisation of antilope in relation to their ecology. *Behaviour*. 48: 215-267.

Jennrich, R.I. and Turner, F.B. 1969. Measurement of non-circular home range. *J. Theor. Biol.* 22:227-237

Johnsingh, A.J.T. and Mishra, C. 1997. Conservation status and research of mountain ungulates in India. Paper presented in the 2nd World Conference on Mountain Ungulates, Saint Vincent, Italy, 5-7 May, 1997. Abstracts.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology.* 61(1):65-71.

Kie, J.G., Baldwin, J.A. and Evans, C.J. 1994. Calhome: Home Range Analysis Programme - Electronic Users Manual. Unpubl. Electronic User's Manual.

Knight, T.W. and Morris, D.W. 1996. How amny habitats do landscapes contain? *Ecology* 77(6):1756-1764.

Koeppl, J.W, Korch, G.W., Slade, N.A. and Airoldi, J.P. 1985. Robust statistics for spatial analysis: the center of activity. In Wiley, E.O (Ed.) Occasional papers of the Museum of Natural History. The University of Kansas, Lawrence, Kansas. p 24.

Kotler, B.P. 1984. Risk of predation and the structure of desert rodent communities. *Ecology.* 65:689-701.

Kotler, B.P., Gross, J.E. and Mitchell, W.A. 1994. Appling patch use to assess aspects of foraging behaviour in Nubian ibex. *J. Wildl. Manage.* 58(2):299-307.

Leslie, D.M. 1977. Home range, group size, and group integrity of the desert bighorn sheep in the River Mountains, Nevada. Desert Bighorn Council Trans. 21:25-28.

Leslie, D.M and Doughlas, C.L. 1979. Desert bighorn sheep of the River Mountains, Nevada. *Wildl. Monogr.* 66:1-56

Longwa, K.S and Fox, J.L. 1997. Anti-predator habitat selection of blue sheep in two areas of differing predator composition. In Abstracts of the 2nd World Conference on Mountain Ungulates, St. Vincent, Italy, 5-7 May, 1997.

Lovari, S. and Festa-Bianchet, M. 1997. Are young mountain goat males ousted from nursery groups by adult females. (Abstract) 2nd World Conference on Mountain Ungulates, St. Vincent, Italy, 5-7 May, 1997. p91-92.4

MacArthur, R.H. and Pianka, E.R. 1966. On optimal use of a patchy environment. *Amer. Natur.*, 100:603-609

Magurran, A.E. 1988. Ecological Diversity and its Measurement. Croom-Helm, London. 179pp.

Mallon, D. 1983. The status of Ladak Urial, *Ovis orientalis vignii* in Ladak, India. *Biol. Conserv.* 27(4):373-381

Mallon, D. 1991. Status and conservation of large mammals in Ladakh. *Biol. Conserv.* 56:101-119.

Mani, M.S. 1974. Ecology and Biogeography in India. The Hague, W. Junk Publishers.

Manjrekar, N. 1997. Feeding ecology of ibex (*Capra ibex sibirica*) in Pin Valley National Park, Himachal Pradesh. PhD thesis submitted to the Saurashtra University, Rajkot.

Manjrekar, N. and Bhatnagar, Y.V. 1997. Asiatic ibex, a goat of the desolate cold desert. pp. 18-27 In. Manfredi, P. (Ed.) In Danger: Habitats, Species and People. Ranthambhore Foundation, New Delhi, 159pp.

Marcum, C.L. and Loftsgaarden, D.O. 1980. A non-mapping technique for studying habitat preferences. *J. Wildl. Manage.* 44(4):963-968.

McCorquodale, S.M. 1993. Winter foraging behaviour of elk in the shrub-steppe of Washington. *J. Wildl. Manage.* 57(4):881-890

McNay, R.S. Morgan, J.A. and Bunnell, F.L. 1994. Characterising independence of observationss in movements of columbian black-tailed deer. *J. Wildl. Manage.* 58(3):422-429.

Milinski, M. and Parker, G.A. 1991. Competition for resources. In.: Krebs, J.R. and davis, N.B. (Eds.) Behavioural Ecology: An evolutionary approach. Oxford, Blackwell Scientific Publications. 482pp.

Moen, A.N. 1976. Energy conservation by white-tailed deer in winter. *Ecology.* 57:192-198.

***Mohr, C.O. 1947.** Table of eqivalant populations of North American small mammals. *Amirican Midland Naturalist.* 37:223-249.

Mugangu, T.E., Hunter, M.L. and Gilbert, J.R. 1995. Food, water and predation: a study of habitat selection by buffalo in Virunga National Park, Zaire. *Mammalia* 59(3):346-362.

Nath, A. 1982. Some observations on wildlife in the upper Suru, northern Zanskar and Markha valley of Ladakh. *Intl. Ped. Book of Snow Leopards*. 3:11-24.

Neivergelt, B. 1981. Ibexes in an African Environment. Springger-Verlag. 189p

Neu, C.W., Byers, C.R. and Peek, J.M. 1974. A technique for analysis of utilization-availability data. *J. Wildl. Manage.* 38(3):541-545.

Norusis, M.J. 1990. SPSS/PC+ Advanced Statistics 4.0 for the IBM PC/XT/AT and PS2. Chicago, SPSS Inc.

Oli, M.K. 1996. Seasonal patterns in habitat use of blue sheep *Pseudois nayaur* (Artiodactyla, Bovidae) in Nepal. *Mammalia.* 60(2):187-193.

Osborne, B., Mallon, D. and Fraser, S. 1983. Ladakh, threatened stronghold of Himalayan wildlife. *Oryx.* 17:182-189.

Pandey, S. 1991. Management Plan for Pin Valley National Park (1990-91 to 2000-01). Himachal Pradesh Forest Department. Himachal Pradesh

Pandey, S. 1992. Estimation of density of ibex *Capra ibex* Linn. in Pin Valley National Park, Himachal Pradesh. *J. Bombay Nat. His. Soc.* 89(3):361-363.

Parker, K.L., Robbins, C.T., and Hanley, T.A. 1984. Energy expenditures for locomotion by mule deer and elk. *J.*

Wildl. Manage. 48:475-488.

Partridge, L. 1978. Habitat selection. pg. 351-376. In. Krebs, J.R. and Davis, N.B. (Eds.) Bahavioral Ecology: an Evolutionary Approach. Oxford, Blackwell Sci. Publ.

Perla, R.I. and Martinelli, M. 1975. Avalanche Handbook. U.S. Dep. Agric., Agric. Handb. 498, 238 p.

Petocz, R.G. 1978. Report on the Afgan Pamir: ecological reconnaissance. UNDP/FAO/Dept. of Forests & Range, Kabul. 30pp.

Prater, S. H. 1980. The Book of Indian Animals. BNHS, Bombay. 324p

Puri, G.S., Gupta, R.K., Meher-Homji, V.M. and Puri, S. 1989. Forest Ecology: Plant form, diversity, communities and succession. Vol. 2. Oxford & IBH Publ. Co. New Delhi.

Rana, B.S. 1994. Management Plan for the Kibber Wildlife Sanctuary. Himachal Pradesh Forest Department. Himachal Pradesh

Ranjitsinh, M.A.K. 1981. Himalayan Fauna. In.: Lall, J.S. (Ed.) The Himalaya: Aspects of Change. New Delhi, Oxford University Press.

Reynolds, T.D. and Laundre, J.W. 1990. Time intervals for estimating pronghorn and coyote home range and daily movements. *J. Wildl. Manage.* 54(2):316-322.

Ricklefs, R.E. 1974. Ecology. Nelson, London

Risenhoover, K.L. and Bailey, J.A. 1985. Foraging ecology of mountain sheep: implications for habitat management. *J. Wildl. Manage.* 49(3):797-804.

Robbins, C.T. 1983. Wildlife Feeding and Nutrition. New York, Academic Press. 343 pp.

Roberts, T. J. 1977. Mammals of Pakistan. London, Ernest Benn. 361pp.

Rodgers, W.A. and Panwar, H.S. 1988. Planning a protected area network in India. Vol. 1. The report. Dehradun, Wildlife Institute of India. 341pp.

Sanderson, G.C. 1966. The study of mammal movements-a review. *J. Wildl. Manage.* 30:215-235.

Schaefer, J.A. and Messier, F. 1995. Winter foraging by muskoxen: a hierarchial approach to patch residence time and crratering behaviour. *Oecologia* 104:39-44.

Schaller, G.B. 1977. Mountain Monarchs: Wild Sheep and Goats of the Himalaya. Chicago, Chicago University Press. 425pp.

Schaller, G.B., Talipu, L.H., Hua, L., Junrang, R., Mingjiang, Q and Habin, W. 1987. Status of large mammals in the Taxkorgan reserve, Xinjiang, China. *Biol. Conserv.* 42:53-71.

Schwartz, C.C. and Franzmann, A.W. 1981. Big game investigations: black bear predation on moose. Alaska Department of Fish and Game. 46pp.

Schweinfurth, U. 1957. Die horizontale und vertikale verbreitung der vegetaion in Himalaya. Bonner Geographic, Abh. 20:1-372.

Seegmiller, R.F. and Ohmart, R.D. 1981. Ecological relationships of feral burros and desert bighorn sheep. *Wildlife Monographs*. No. 78. 57pp.

Shakleton, D.M. 1997. Why caprinae? pgs. 5-7. In. Shakleton, D.M. Wild Sheep and Goats and their Relatives:

Status survey and conservation action plan for caprinae. IUCN, Gland. 390pp.

Shannon, N.H., Hudson, R.J., Brink, V.C. and Kitts, W.D. 1975. Determinants of spatial distribution of mountain bighorn sheep. *J. Wildl. Manage.* 39(2):387-401.

Sharma, B.D. 1994. High altitude wildlife in India. Delhi, Oxford & IBH Publ. Co. 291p

Singh, S., Kothari, A. and Pande, P. 1990. Directory of National Parks and Sanctuaries in Himachal Pradesh. New Delhi, Indian Inst. of Public Administration. 164pp.

Sokal, R.R. and Rohlf, F.J. 1995. Biometry: The Principles and Practice of Statistics in Biological Research. New York, W.H. Freeman & Co. 887pp.

Southwood, T.R.E. 1966. Ecological Methods:with Particular Reference to the Study of Insect Populations. London, Chapman & Hall.

Swihart, R.K., Slade, N.A. and Bergstrom, B.J. 1988. Relating body size to rate of home range use in mammals. *Ecology.* 62(2):393-399.

Tilton, M.E. and Willard, E.E. 1981. Winter habitat selection by mountain sheep. *J. Wildl. Manage.* 46(2):359-366.Fox, J.L., Sinha S.P and Chundawat R.S. (1992) Activity patterns and habitat use of ibex in the Himalaya mountains of India. *J. Mammal.* 73(3):527-534.

Van Winkle, W. 1975. Comparision of several probablistic home-range models. *J. Wildl. Manage.* 39:118-123.

Van Winkle, W., Martin, D.C. and Sebetich, M.J. 1973. A home-range model for animals inhabitong an ecotone. *Ecology.* 54:205-209.

Veeder, A.L. 1983. Movement patterns of a group of free-ranging mountain gorillas (*Gorilla gorilla beringei*) and their relation to food availability. *Am. L. Primatol.* 7:73-88.

Wadia, D. 1966. Geology of India. London, Macmillan.

*****White, J.E. 1964.** An index of the range of activity. *American Midland Naturalist.* 71:369-373.

White, G.C. and Garrot, R.A. 1990. Analysis of Wildlife Radio-tracking Data. Academic Press, San Diego. 383pp.

Wiersema, G. 1988. Climate and vegetation characteristics of ibex habitats in the European Alps. *Mount. Res. Dev.* 9(2):119-128.

Wiersema, G. and Schroder, W. 1985. How to find suitable ibex (*Capra ibex* L.) habitat using landsat imagery. In. Lovari, S. The Biology and Management of Mountain Ungulates. London, Croom Helm, 279pp.

Worton, B.J. 1989. Kernal methods for estimating the utilization distribution in home range studies. *Ecology*. 70: 164-168.

Wright, J.M. 1980. Spring and summer vegetation preferences of semi-domestic reindeer on northwestSeward Peninsula. In. Reimers, E., Gaare, E. and Skjenneberg, S. (eds.). Proc. 2nd Int. Reindeer/Caribou Symp., Roros, Norway, 1979.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J. 718pp.

* Original not seen

APPENDICES

Appendix 1: **Abundance estimates of *Capra ibex sibirica* from various study sites within it's range. Many of the reports may not be comparable due to varying methods used to estimate abundance.**

Region	Area (km²)	Year/ Month	Source	# ibex seen/ Estimated	Density (/km²)
Afganistan					
Small Pamir	-	-	Petocz, 1978	687 max.#	-
Big Pamir	-	-	Petocz, 1978	490 max #	-
Pakistan					
Golen Gol, Chitral	24	1974, Feb.	Schaller, 1977	16	-
Dorah Pass area, NW Chitral	50	1972, July	Schaller, 1977	10	-
NE Chitral	200	-	Schaller, 1977	4	-
Besti, Chitral	40	1972, Aug.	Schaller, 1977	72	1.8
Besti, Chitral	55	1972, Feb.	Schaller, 1977	40	0.7
Besti, Chitral	140	-	Gulbas Khan, Game Watcher (Schaller, 1977)	200	1.4
Murkusi Pass, Hunza	25	-	Schaller, 1977	59	0.4
Upper Baraldo Valley	-	Winter	Schaller, 1977	49	-
India					
Jammu & Kashmir					
Kargil	-	-	Ranjitsinh, 1981	2 groups	-
Kanji Nala (3810 m)	-	-	Wildlife Dept., J&K (Sharma, 1994)	ca. 250	-
Kanji Sanctuary, Ladakh	-	-	Wildlife Dept., J&K (Mallon, 1991)	222	0.88
Suru Valley, Ladakh	-	-	Nath, 1982	87 (5 groups)	-
Upper Suru & Rangeleun, Ladakh	-	-	Nath, 1982	400	-
Slot Valley, (3,965-6,100m), Ladakh	-	-	Nath, 1982	150	-
Near Zang la (4,950m)	-	-	Nath, 1982	250	-
Rizong Sanctuary, Ladakh	-	1984	Wildlife Dept., J&K (Mallon, 1991)	174	0.62
Lungnag Valley, Ladakh	-	-	Mallon, 1991	Present	-
Trans-Himalayan Ladakh	-	-	Fox *et al.*, 1991	6000	-

Region	Area (km²)	Year/ Month	Source	# ibex seen/ Estimated	Density (/km²)
S of Zanskar range (Ladakh) to Himachal Pradesh	17,000	-	Fox *et al.*, 1992	3000	-
Suru Valley, Ladakh	-	1985, Nov./Dec.	Fox *et al.*, 1992	250-350	4-6 (intensive study area) 0.5-0.6 (year round habitat)
Tsarap-Kurghiak Valley, Ladakh	-	-	Fox *et al.*, 1991	-	0.5-0.6
Central Ladakh	-	-	Fox *et al.*, 1991	-	0.8-1.2
Himachal Pradesh Solung & Namta Valley	-	-	Ranjitsinh, 1981	Present	-
Pin Valley National Park (PVNP)	76	1987, Nov.	Pandey, 1992	174	2.29
PVNP	76	1990, Nov.	Pandey, 1991 (PVNP, Mgmt. Plan.)	118	1.6
PVNP	ca. 62 (following Pandey 1992)	1993, Nov.	Unpubl. data (Bhatnagar, in prep.)	149	2.42
Commonwealth of Independent States					
Tersker Alatau	200	1949	Heptner *et al.*, 1966	550	2.8
Eastern Pamir	100	-	Heptner *et al.*, 1966	600	6

Appendix 2:**Monthly number of locations for the radio-collared animals.**

MONTH	COLLARED ANIMALS						
	F1	F3	F7	F15	M11	M12	M13
JUN. 94	14	12	15	4	11	15	17
JUL. 94	16	18	19	8	16	2	15
AUG. 94	18	15	16	8	8	-	10
SEP. 94	13	15	16	10	16	-	12
OCT. 94	14	16	14	5	11	-	14
NOV. 94	13	13	12	1	5	-	12
DEC. 94	13	13	15	4	9	6	10
JAN. 95	14	14	14	11	12	11	4
FEB. 95	13	13	13	-	13	11	14
MAR. 95	11	12	12	-	10	11	12
APR. 95	12	15	16	3	14	15	15
MAY 95	12	12	12	7	11	11	12
MEAN	13.6	14.0	14.5	10.0	11.3	10.3	12.3
SD	1.9	1.9	2.1	6.1 (n=10)	3.2	4.4 (n=8)	3.3

Appendix 3:**Seasonal mean sampling interval (± SE) between sightings of the seven collared animals. Sample sizes in parenthesis.**

SEASONS	SAMPLING INTERVAL (hours) FOR COLLARED ANIMALS						
	_1 (163)	_3 (169)	_7 (173)	_15 (60)	_11 (135)	_12 (81)	_13 (145)
WINTER	56.8±7.5 (57)	54.9±7.1 (59)	53.1±6.8 (61)	142.0±36.6 (15)	63.5±8.9 (51)	61.9±9.1 (46)	68.9±10.1 (47)
SPRING*	57.1±10.1 (33)	56.0±9.8 (33)	50.9±8.6 (37)	131.4±36.4 (14)	59.1±11.1 (29)	53.0±9.2 (34)	47.2±7.9 (37)
SUMMER	45.5±7.2 (40)	46.2±7.3 (40)	43.9±6.8 (42)	135.2±31.0 (19)	57.8±10.2 (32)	2006.0± 1418.5 (2)	59.8±10.7 (31)
AUTUMN	53.7±9.2 (34)	50.0±8.2 (37)	52.1±8.8 (35)	114.4±31.7 (13)	76.8±15.7 (24)	-	57.6±10.2 (32)
MEAN INTERVAL±SE	53.5±4.2	52.0±4.0	50.2±3.8	131.6±17.0	63.6±5.5	106.3±12	59.1±4.9
MEAN LOCATIONS PER SEASON±SE	(41±0.86)	(42±0.9)	(44±0.9)	(15±0.39)	(34±1.0)	(40±1.0)	(37±0.58)

* June, 1994 and 16 April, 1994 to 31 May, 1995

Appendix 4:**Association matrix between radio-collared animals - a) summer b) autumn c) winter and d) spring, based on Sorensen's index. Higher values reflect greater spatio-temporal overlap.**

a. Summer	F1	F3	F7	F15	M11	M12	M13
F1		0.538	0.602	0.189	0.083	0.000	0.405
F3			0.620	0.157	0.057	0.000	0.220
F7				0.179	0.080	0.000	0.420
F15					0.044	0.000	0.085
M11						0.000	0.508
M12							0.000
b. Autumn							
F1		0.603	0.800	0.130	0.305	0.000	0.866
F3			0.600	0.080	0.320	0.000	0.400
F7				0.174	0.305	0.000	0.510
F15					0.025	0.000	0.047
M11						0.000	0.464
M12							0.000
c. Winter							
F1		0.598	0.695	0.000	0.130	0.019	0.272
F3			0.770	0.000	0.110	0.19	0.370
F7				0.000	0.109	0.038	0.380
F15					0.448	0.127	0.000
M11						0.080	0.163
M12							0.086
d. Spring							
F1		0.812	0.703	0.208	0.333	0.417	0.595
F3			0.77	0.130	0.400	0.310	0.600
F7				0.115	0.490	0.420	0.720
F15					0.045	0.240	0.154
M11						0.698	0.696
M12							0.590

Appendix 5:**Justification for use of home range analysis techniques**

The earliest home range estimation was using the minimum convex polygon (MCP) in which the outermost locations were joined to make a convex polygon (Mohr 1947). Subsequently, more sophisticated techniques, both parametric, that assume bivariate normality (Jennrich & Turner 1969, Van Winkle 1975) and non parametric (Ford and Krumme 1979, Dixon and Chapman 1980, Anderson 1982, Worton 1989) have been proposed. These have been reviewed in Anderson (1982), Harris *et al*. (1990) and White and Garrot (1990), among others.

Most of these techniques are based on the utilization distribution (UD) or the distribution of an animal's position on a plane.

HR estimates are calculated by drawing equal height contours around the UD and is defined as the smallest area which accounts for 95% (or some other %) of the animals space utilization (Jennrich and Turner 1969, Anderson 1982: Dixon and Chapman 1980, Worton 1989). The parametric (see references above) fourier transform (Ford and Krumme 1979) and the adaptive kernel method (AK) (Worton 1989) produce a probability density function but the harmonic mean method (HM) (Dixon & Chapman 1980) does not. The parametric ellipse based methods require strong assumptions regarding bivariate normality and are not appropriate for skewed and multi-modal distributions.

Further, they also assume the arithmetic mean at the centre of the ellipse to be the centre of activity. These methods do not give an idea of the shape of the UD and include areas not visited by the animal (Harris *et al.* 1990). As most of the data were skewed and multi-modal in this study, parametric methods were not used.

The important expectations from the home range analysis were

1. Seasonal shifts in ranges
2. Size estimates
3. Core zone shape and size
4. Seasonal shifts of core zone

In order to achieve these, MCP, HM and AK were tested.

MCP (Mohr 1947) is known for its simple calculation, interpretation and robustness and comparability with other studies (White & Garrot 1990, Harris *et al*. 1990). In order to exclude outliers, a 95% home range estimate can also be calculated (White and Garrot 1990). This method was used in spite of some disadvantages such as never reaching an asymptote (Jennrich and Turner 1969) always having convex edges, thus losing information on the shape of the home range as per the actual locations and also including areas not visited by the animal (White and Garrot 1990, Harris *et al.* 1990).

The HM method gives a better idea of the shape and configuration of the home range, excluding most areas not visited by the animal and is also useful in determining 'core zone or core areas' and centres of activity (Dixon and Chapman 1980, Harris *et al*. 1990). The former is useful in studies of seasonal range shifts and habitat use studies.

Hayne (1949) introduced the concept of 'centre of activity' which was primarily the bivariate arithmetic mean (AM) of all locations and was subsequently used extensively in home range studies (Harrison 1958, White 1964, Sanderson 1966, Van Winkle *et al.* 1973 Van Winkle 1975). The main limitations of this measure was that in case of a skewed, milti-modal or semi circular UD, the AM may actually lie outside the home range in a totally unused site. Also it allows for only a single centre even for a multi-modal distribution (Dixon and Chapman 1980, White and Garrot 1990). Dixon and Chapman (1980) proposed a simple method to calculate the areas of high animal activity based on the HM method. The 95% contour is often taken as a home range estimate and 50% contour as a 'core zone' estimate. This latter is defined as the area of high animal use and contributes 50% (or any other % of observations) (Dixon and Chapman 1980, Harris *et al*. 1990, White and Garrot 1990). To help in determining the option of isopleth value for core zone Harris *et al*. (1990) suggest plotting the HM, home range size against various isopleth values and decide on the point of inflexion of the curve as the core zone isopleth value. The isopleth value for most animals in this study varied between 40 and 65%. Therefore a value of 55% has been fixed as defining the core zone.

HM (Dixon & Chapman 1980) and AK (Worton 1989) give a good idea of the configuration of the home range, largely avoid including areas not visited by the animal and show multi-modal distributions. The algorithm needs a user defined specification of grid size that is superimposed on the UD to calculate home range polygons. The grid origin and the cell size can influence the actual shape and size of the home range polygon although the influence is not as marked in the AK (Worton 1989, Harris *et al*. 1990, White & Garrot 1990). Worton (1989) states that HM estimates of home range is a statistically incorrect form of the kernel methods. However the AK requires another user defined variable called the band width or smoothening parameter (Worton 1990, Kie *et al.* 1994) which yields a Least Square Cross Validation score (LSCV). One gets a good fit when the score is 'minimised'. This was tested and found to be a cumbersome iterative process. The band width specifications that minimised LSCV were different for different animals and seasons . Also, in most cases AK (95%) estimates included a large vacant area around the actual UD and were thus approximately double a comparable MCP or HM estimator

The HM method estimates (using a ca. 250X250 m grid or 30 X 30 cell grid) mostly covered the UD with lesser gap all around and was used along with MCP in this study.

One common problem with both HM and AK was that in multi-modal distributions 95% polygons often did not connect the areas in between. In such cases the travel path between the clusters is not expected to influence the area calculations significantly.

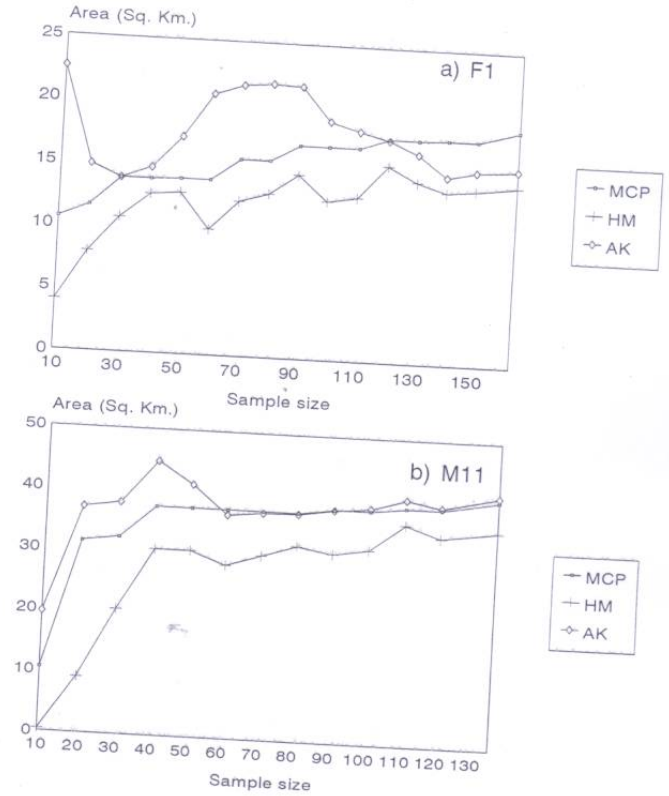
Appendix 6:**Asymptotic sample sizes**

Asymptotic sample size is defined as the number of locations after which additional locations result in a minimum increase in home range size (Harris *et al*. 1990).

Calculation of asymptotes is considered important for initiating home range estimation (White and Garrot 1990, Harris *et al*. 1990) and this estimate should be made before a majority of the field work is done. The concept is however fraught with some difficulties. Each animal may reach asymptotes at different sample sizes, for different seasons based on its biological condition. Some animals may never reach an asymptote (Gautestad and Mysternd 1995). Differences may occur when the time interval for calculating asymptote is inappropriate such as during a period of range shift or due to an animal being in a transient stage such as a dispensing sub-adult (Bowen 1982, Harris *et al*. 1990). Also, values calculated at the beginning of the study may not be applicable for other time periods when the above conditions may occur. Values calculated for the entire year may not be applicable to different seasons. To compound this may be logistic constraints and the need for maintaining independence between observations for most home range analysis techniques (Dixon and Chapman 1980, Swihart *et al*. 1988, Worton 1989, Harris *et al*. 1990). In this study, logistic and weather constraints did not allow a more intensive sampling regime and primarily determined the sample sizes.

The seasonal ranges of most animals using Minimum convex polygon (MCP), Harmonic mean (HM) and Adaptive kernel (AK) (see references) were not asymptotic. However in the entire data set of each animal, the asymptote occurred between 40 and 60 locations for different animals when data were entered randomly (Fig. A). As the observations for all animals exceeded these values the data is considered to be sufficient. However, caution is needed while interpreting seasonal size information which were based on fewer locations. Rate of travel and estimates based on core area (core zone), however, may be largely unaffected since a more or less regular sampling interval was maintained (Reynolds and Laundre 1990, McNay *et al.* 1994).

Fig. A: Asymptotic sample size estimation based on randomised selection from 12 month data of a) Female 1 and b) Male 11. Three methods of home range analysis viz. minimum convex polygon (MCP), Harmonic Mean (HM) and Adaptive Kernal (AK) have been compared



Appendix 7.**A brief review of the available methods of habitat selection analysis -Justification for the use of Marcum and Loftsgaarden's (1980) method.**

Techniques of determining habitat use by animals have been reviewed by White and Garrot (1990) and they have been evaluated under a range of conditions using computer simulations by Alldredge and Ratti (1986, 1992). Aebischer *et al.* (1993) further presented various shortcomings in all the previous methods and suggested a 'comopsitional analysis' based on log-ratios of proportion use.

Habitat 'preference' has mainly been considered as *use* of a habitat in relation to its *availability* (Neu *et al.* 1974, Marcum and Loftsgaarden 1980, Johnson 1980, Byers *et al.* 1984, Alldredge and Ratti 1986, 1992). Johnson (1980) provided various definitions in this regard. *Availability* of a habitat component is the quantity of the component accessible to the animals. *Usage* of a component is the quantity of the component utilized by the consumer. *Selection* is the process by which the animal actually chooses the component. Usage is said to be *selective* if it is disproportionate to the availability of the component. *Preference* of an animal for a component is the likelihood of that component being chosen if offered on an equal basis with others.

An animals movements within its range defines a trajectory through space and time and its habitat use is reflected by the proportion of the trajectory contained in each habitat type (Aebischer *et al.* 1993). Such trajectories for a substantial number of individuals would give a picture of the overall habitat selection by the species in an area. Studies on habitat selection utilize data from transect monitoring or monitoring from observation posts of animals or their signs, (Neu *et al* 1974, Nievergelt 1981) or telemetry studies on some radio collared animals (Harris *et al.* 1990). While the first method is likely to yield information that may be a generalization for the population, the latter may make sense only for the individuals studied due to the problem of individual variations in habitat selection based on age-sex of the studied animals (Aebischer *et al.* 1993).

Aebischer *et al.* (1993) discuss four problems facing all analysis techniques using radio-telemetry data. Two of these also apply to transect based data. These are an arbitrary definition of the study area and non-independence of proportions available. Under most field conditions decisions regarding what is available to the animals are subjective as availability is mostly defined in an arbitrarily defined study area (see also Johnson 1980). Since most methods to determine preferences are highly sensitive to the proportion availability of habitats, changes in the boundary of the study area are likely to reflect in the preferences. Because of the problem of non-independence of proportions, the proportion availability of all categories of habitat sum to one. This means that preference of one category will invariably lead to the avoidance of another. In case, on some biological basis a habitat has to be excluded or included in the analysis, it will effect the selection of other categories too (Johnson 1980).

The other two difficulties mainly relate to telemetry based studies. Animals may differ in their habitat use trends according to their age-sex class, hence pooling data across animals is not justified unless checked for lack of differences. The last problem relates to pooling data across animals of the same age-sex class also as it may not account for individual variations in selection trends of animals. The possible serial correlations between consecutive observations of an animal may not cause a major problem. The compositional analysis suggested by Aebischer *et al.* (1993) overcomes these problems by treating each animal as the sample instead of each observation. Regarding the definition of the study area, it treats selection at two stages. The animal first selects a home range within a geographical region (Johnson's (1980) 'second order selection') and then within a home range it selects habitats (Johnson's 'third order selection'). The use of habitats is first compared as proportion present within the home range of each animal versus proportion available in the study area. Then the proportion used as per the locations is compared to the proportion available within the home range or the 'core zone'. Implicit in this analysis is hence **mapped** habitat variables or availability accessed at the level of the study area and each home range by any other method. A habitat map for my study area is not yet available and sampling by any other method within the home range was not carried out. Hence, compositional analysis could not be used in the study.

Other analysis methods except Johnson's (1980) and Marcum and Loftsgaarden's (1980), require the availability data to be collected accurately (White and Garrot 1990, Alldredge and Ratti 1986, 1992). This was not so in case of the study. Johnson's (1980) method was not used due to the loss of information because of using ranks instead of actual proportions (White and Garrot 1990).

Marcum and Loftsgaarden's (1980) method suggests estimation of availability based on random points, testing for lack of independence between 'use' and 'availability' proportions and in case independence is found, forming Bonferroni simultaneous confidence intervals for the **difference** in the proportion available and proportion used to determine preferences. This method was used in this study primarily because the availability data was not accurate.

Appendix 9: Logistic regression (Method: Forward Stepwise (WALD)) output from SPSS (Norusis, 1990) for the Pin Valley (n=200)(ibex present) and Kibber area (n=177)(ibex rare or absent).

```
      Total number of cases:      377 (Unweighted)
      Number of selected cases:   377
      Number of unselected cases: 0

      Number of selected cases:                 377
      Number rejected because of missing data:  0
      Number of cases included in the analysis: 377

Dependent Variable Encoding:

Original       Internal
Value          Value
     .00       0  KIBBER      Ibex rare or absent
    1.00       1  PIN VALLEY        Ibex present

Dependent Variable..   IBEX

Beginning Block Number  0.  Initial Log Likelihood Function

-2 Log Likelihood   521.22892

* Constant is included in the model.

Estimation terminated at iteration number 2 because
parameter estimates changed by less than .001

Classification Table for IBEX
                    Predicted
                  .00    1.00     Percent Correct
                    0      1
Observed        -----------------
   .00      0       0     177        .00%
                -----------------
   1.00     1       0     200     100.00%
                -----------------
                       Overall  53.05%

---------------------- Variables in the Equation -----------------------

Variable           B      S.E.     Wald    df      Sig       R   Exp(B)

Constant       .1222     .1032   1.4014     1    .2365
Beginning Block Number  1.  Method: Forward Stepwise (WALD)
--------------- Variables not in the Equation -----------------
Residual Chi Square    118.653 with      4 df     Sig =  .0000

Variable          Score    df      Sig       R

ETLN            94.3166     1    .0000   .4208  Dist. to ET (natural log)
PCT                  41.9564       1      .0000    .2769   Plant  cover  (sq.root
transformed)
RCT                   92.0407       1      .0000    .4156   Rock  cover  (sq.root
transformed)
SL              38.8993     1    .0000   .2661  Slope

Variable(s) Entered on Step Number
1..       ETLN

Estimation terminated at iteration number 4 because
Log Likelihood decreased by less than .01 percent.

 -2 Log Likelihood      413.588
 Goodness of Fit        429.936
```

```
                     Chi-Square    df Significance

 Model Chi-Square       107.641     1        .0000
 Improvement            107.641     1        .0000

Classification Table for IBEX
                    Predicted
                   .00    1.00     Percent Correct
                     0       1
Observed        -----------------
   .00      0      141      36      79.66%
                -----------------
   1.00     1       59     141      70.50%
                -----------------
                           Overall  74.80%

---------------------- Variables in the Equation -----------------------

Variable           B      S.E.     Wald    df      Sig       R   Exp(B)

ETLN          -.5750     .0688  69.9354     1    .0000  -.3610    .5627
Constant      2.5036     .3276  58.3880     1    .0000


             Observed Groups and Predicted Probabilities

      80 -                                                       1    -
         .                                                       1    .
         .                                                       1    .
F        .                                                       1    .
R     60 -                                                       1    -
E        .                                                       1    .
Q        .                                                       1    .
U        .                                                       1    .
E     40 -                                                       1    -
N        .                                                       1    .
C        .                                                       1    .
Y        .                                     1                 1    .
      20 -               1      1    1         1                 1    -
         .           0   01 1   1 1  11      1 1  1              0    .
         .          0000 00 0 1 0 0 0011  11 1 1  1              0    .
         .          0000000 0 0 0 0 00000 00 011 11 1  1         0    .
Predicted_____________________________________________________________________
  Prob:   0            .25            .5             .75             1
  Group:  000000000000000000000000000000111111111111111111111111111111
          Predicted Probability is of Membership for 1.00
          Symbols: 0 - .00
                   1 - 1.00
          Each Symbol Represents 5 Cases.

--------------- Variables not in the Equation -----------------
Residual Chi Square     30.216 with      3 df     Sig =  .0000

Variable          Score    df      Sig       R

PCT              2.6658     1    .1025   .0357
RCT             16.9193     1    .0000   .1692
SL               5.4650     1    .0194   .0815

Variable(s) Entered on Step Number
2..       RCT

Estimation terminated at iteration number 4 because
Log Likelihood decreased by less than .01 percent.

 -2 Log Likelihood      396.816
 Goodness of Fit        451.713
```

```
                     Chi-Square    df Significance
 Model Chi-Square       124.413     2        .0000
 Improvement             16.772     1        .0000
Classification Table for IBEX

                    Predicted
                   .00    1.00     Percent Correct
                     0       1
Observed        _________________
   .00      0      144      33      81.36%
                _________________
   1.00     1       48     152      76.00%
                _________________
                           Overall  78.51%

---------------------- Variables in the Equation -----------------------

Variable           B      S.E.     Wald    df      Sig       R   Exp(B)

ETLN          -.3883     .0828  21.9804     1    .0000  -.1958    .6782
RCT            .0216     .0054  16.1432     1    .0001   .1647   1.0218
Constant      1.0154     .4922   4.2561     1    .0391


             Observed Groups and Predicted Probabilities

      32 -                                                            -
         .                                                            .
         .                                                        1   .
F        .                                                        11  .
R     24 -                                                        11  -
E        .                                                        11  .
Q        .                                                        11  .
U        .                  1                                     11  .
E     16 -          0       1                                     11  -
N        .          0  1  101                                    111  .
C        .          01 0  000 1                                  111  .
Y        .          00 0  00001  11                  1          1101  .
       8 -         000100100001  01   1   1  1 1 1 1 1          1101  -
         .        0000000100000 1011 11  11111111111111  1      1101  .
         .        000000000000000001110 101111111111111 11      1101  .
         .        0000000000000000000001000000010000100111  1 110000  .
Predicted ____________________________________________________________
  Prob:   0            .25            .5             .75             1
  Group:  000000000000000000000000000000111111111111111111111111111111
          Predicted Probability is of Membership for 1.00
          Symbols: 0 - .00
                   1 - 1.00
          Each Symbol Represents 2 Cases.

--------------- Variables not in the Equation -----------------
Residual Chi Square     14.079 with        2 df    Sig =  .0009

Variable          Score    df      Sig       R

PCT              1.2867     1    .2567   .0000
SL              13.2867     1    .0003   .1472

Variable(s) Entered on Step Number
3..        SL

Estimation terminated at iteration number 4 because
Log Likelihood decreased by less than .01 percent.

 -2 Log Likelihood      383.429
 Goodness of Fit        397.909
```

```
                     Chi-Square    df Significance

 Model Chi-Square       137.800     3        .0000
 Improvement             13.387     1        .0003
```

```
Classification Table for IBEX
                    Predicted
                   .00    1.00     Percent Correct
                     0       1
Observed        _________________
   .00      0      141      36      79.66%
                _________________
   1.00     1       48     152      76.00%
                _________________
                           Overall  77.72%
```

```
---------------------- Variables in the Equation -----------------------

Variable           B      S.E.     Wald    df      Sig       R   Exp(B)

ETLN          -.6110     .1091  31.3572     1    .0000  -.2373    .5428
RCT            .0283     .0059  22.6159     1    .0000   .1989   1.0287
SL            -.0415     .0116  12.7510     1    .0004  -.1436    .9594
Constant      3.0286     .7720  15.3918     1    .0001
```

```
             Observed Groups and Predicted Probabilities

      32 -                                                            -
         .                                                            .
         .                                                            .
F        .                                                         1  .
R     24 -                                                         1  -
E        .                                                         1  .
Q        .                                                         1  .
U        .                                                         1  .
E     16 -                    1                                   11  -
N        .              1     1                                   11  .
C        .           0  0   1 0                           1       11  .
Y        .           0 101  0 0                           1     1 11  .
       8 -       0 1 0 10111000    1 1   1     1     1    1     1 111 -
         .      000000 000010001  10001  1 1 1 111111111110   1 11111 .
         .     000000000000000010 00000 00 1111111111011110  11 01111 .
         .   00000000000000000000000000000101000000100111001000101000 .
Predicted ____________________________________________________________
  Prob:   0            .25           .5             .75             1
  Group:  000000000000000000000000000000111111111111111111111111111111
          Predicted Probability is of Membership for 1.00
          Symbols: 0 - .00
                   1 - 1.00
          Each Symbol Represents 2 Cases.
```

```
--------------- Variables not in the Equation -----------------
Residual Chi Square       .794 with      1 df     Sig =  .3728


Variable          Score    df      Sig       R

PCT               .7945     1    .3728   .0000
```

```
No more variables can be deleted or added.
```

Appendix 8 a:Frequency distribution of sightings in various categories of habitat in winter (488 sightings), spring (248) and autumn (60) covering the period from November, 1992 to May, 1994. Percent seasonal sightings, chi square value, degrees of freedom (df) and significance value (p) for seasonal difference also given.

TTY	WINTER	SPRING	AUTUMN	ASP	WINTER	SPRING	AUTUMN	ETET (m)	WINTER	SPRING	AUTUMN	ALT (m)	WINTER	SPRING	AUTUMN
IRS	245 50.2%	69 27.8%	15 25.0%	N	49 10.1%	5 2.0%	4 6.7%	0	104 21.3%	21 8.5%	5 8.3%	3600-3800	88 18.0%	106 42.7%	13 21.7%
S/C	80 16.4%	32 12.9%	6 10.0%	NE	14 2.9%	0 0.0%	1 1.7%	1-50	311 63.7%	157 63.3%	26 43.3%	3801-4000	166 34.0%	120 48.4%	31 51.7%
RS	133 27.3%	116 46.8%	28 46.7%	E	77 15.9%	13 5.2%	11 18.3%	51-100	65 13.3%	54 21.8%	20 33.3%	4001-4200	199 40.8%	20 8.1%	14 23.3%
SS	18 3.7%	19 7.7%	10 16.7%	SE	49 10.1%	33 13.3%	9 15.0%	101-150	4 0.8%	12 4.8%	5 8.3%	4201-5400	35 7.2%	2 0.8%	2 5.1%
OTHERS	12 2.5%	12 4.8%	1 1.7%	S	162 33.4%	157 63.3%	27 45.0%	>151	4 0.8%	4 1.6%	4 6.7%				
				SW	81 16.7%	30 12.1%	5 8.3%								
				W	34 7.0%	9 3.6%	2 3.3%								
				NW	19 3.9%	1 0.4%	1 1.7%								
Chi sq., df & p	67.7, 8, <0.0001				89.9, 14, <0.0001				69.1, 8, <0.0001				124.7, 6, <0.0001		
ROCK COVER (%)	WINTER	SPRING	AUTUMN	PLANT COVER (%)	WINTER	SPRING	AUTUMN	SNOW COVER (%)	WINTER	SPRING	AUTUMN	SLOPE (°)	WINTER	SPRING	AUTUMN

TTY	WINTER	SPRING	AUTUMN	ASP	WINTER	SPRING	AUTUMN	ETET (m)	WINTER	SPRING	AUTUMN	ALT (m)	WINTER	SPRING	AUTUMN
00-20	249 51.0%	70 28.2%	20 33.3%	00-20	399 81.8%	88 35.5%	14 23.3%	00-20	119 24.4%	208 83.9%	50 83.3%	00-25	12 2.5%	00 0%	4 6.7%
21-40	117 24.0%	77 31.0%	18 30.0%	21-40	45 9.2%	62 25.0%	15 25.0%	21-40	44 9.0%	13 5.2%	1 1.7%	26-45	381 78.1%	227 91.5%	53 88.8%
41-60	65 13.3%	47 19.0%	14 23.3%	41-60	18 3.7%	52 21.0%	17 28.3%	41-60	80 16.4%	10 4.0%	1 1.7%	46-90	95 19.5%	21 8.5%	3 5.0%
61-80	39 8.0%	39 15.7%	6 10.0%	61-80	20 4.1%	37 14.9%	8 13.3%	61-80	129 26.4%	9 3.6%	6 10.0%				
81-100	18 3.7%	15 6.0%	2 2.6%	81-100	6 1.2%	9 3.6%	6 10.0%	81-100	116 23.8%	8 3.2%	2 3.3%				
Chi sq., df, p	41.9, 8, <0.0001			208.3, 8, <0.0001				273.9, 8, <0.0001				33.4, 4, <0.0001			

Appendix 8 b:Frequency distribution of sightings in various categories of habitat in winter, spring, summer and autumn covering the period from June, 1994 to may, 1995. Percent seasonal sightings, chi square value, degrees of freedom (df) and significance value (p) also given.

Tty	Winter (191)	Spring (77)	Summer (105)	Autumn (78)	Asp	Winter (192)	Spring (76)	Summer (105)	Autumn (77)	Dtet (m)	Winter (192)	Spring (77)	Summer (106)	Autumn (78)	Alt (m)	Winter (192)	Spring (77)	Summer (106)	Autumn (78)
IRS	106 55.5%	21 27.3%	42 40.0%	23 29.5%	N	0 0%	0 0%	0 0%	0 0%	0	22 11.5%	6 7.8%	12 11.3%	5 6.4%	3600-3800	2 1.0%	13 16.9%	3 2.8%	9 11.5%
S/C	24 12.6%	6 7.8%	14 13.3%	8 10.3%	NE	4 2.1%	0 0.0%	7 6.7%	3 3.9%	1-50	152 79.2%	63 91.8%	63 59.4%	70 89.7%	3801-4000	27 14.1%	37 48.1%	8 7.5%	10 12.8%
RS	48 25.1%	35 45.5%	26 24.8%	27 34.6%	E	17 8.9%	4 5.3%	36 34.3%	12 15.6%	51-100	15 7.8%	8 10.4%	20 18.9%	2 2.6%	4001-4200	37 19.3%	17 22.1%	15 21.5%	23 29.5%
SS	12 6.3%	12 15.6%	23 21.9%	19 24.4%	SE	26 13.5%	16 21.1%	15 14.3%	19 24.7%	101-150	3 1.6%	0 0%	11 10.4%	1 1.3%	4201-5400	126 65.6%	10 13.0%	80 75.5%	36 46.2 %
OTHERS	1 0.5%	3 3.9%	0 0%	1 1.3%	S	71 37.0%	43 56.6%	21 20.0%	24 31.2%	>151	4 0.8%	4 1.6%		4 6.7%					
					SW	61 31.8%	11 14.5%	12 11.4%	11 14.3%										
					W	13 6.8%	1 1.3%	13 12.4%	7 9.1%										
					NW	0 0%	1 1.3%	1 1.0%	1 1.3%										
Chi sq., df & p	50.8, 12, <0.0001					92.9, 18, <0.0001					43.2, 9, <0.0001					119.5, 9, <0.0001			

Tty	Winter (191)	Spring (77)	Summer (105)	Autumn (78)	Asp	Winter (192)	Spring (76)	Summer (105)	Autumn (77)	Dtet (m)	Winter (192)	Spring (77)	Summer (106)	Autumn (78)	Alt (m)	Winter (192)	Spring (77)	Summer (106)	Autumn (78)
Rock cover (%)	Winter (191)	Spring (77)	Summer (96)	Autumn (77)	Plant cover (%)	Winter (191)	Spring (77)	Summer (96)	Autumn (77)	Snow cover (%)	Winter (191)	Spring (75)	Summer (84)	Autumn (71)	Slope (°)	Winter (191)	Spring (77)	Summer (102)	Autumn (78)
00-20	56 29.3%	17 22.1%	18 18.8%	16 20.8%	00-20	143 74.9%	21 27.3%	12 12.5%	7 9.1%	00-20	31 16.2%	68 90.7%	81 96.4%	71 100%	00-25	27 14.1%	8 10.4%	4 3.9%	9 11.5%
21-40	93 48.7%	33 42.9%	42 43.8%	38 49.4%	21-40	33 17.3%	23 29.9%	25 26.0%	23 29.9%	21-40	21 11.0%	5 6.7%	2 2.4%	0 0%	26-45	143 74.9%	64 83.1%	89 87.3%	66 84.6%
41-60	35 18.3%	18 23.4%	18 18.8%	15 19.5%	41-60	12 6.3%	18 23.4%	35 36.5%	26 33.8%	41-60	73 38.2%	0 0%	0 0%	0 0%	46-90	21 11.0%	5 6.5%	5 6.5%	3 3.8%
61-80	6 3.1%	5 6.5%	12 12.5%	7 9.1%	61-80	3 1.6%	14 18.2%	22 22.9%	17 22.1%	61-80	54 28.3%	2 2.7%	0 0%	0 0%					
81-100	1 0.5%	4 5.2%	6 6.3%	1 1.3	81-100	0 0%	1 1.3%	2 2.1%	4 5.2%	81-100	12 6.3%	0 0%	1 1.2%	0 0%					
Chi sq., df & p	24.2, 12, 0.02					180.6, 12, <0.0001					282.3, 12, <0.0001					11.8, 6, 0.06523			

A view of the National Park from Choyam in the Khamingar valley, Pin Valley National Park.

An adult ibex male (bottom) and female at a salt lick near Gechang. Note the marked sexual dimorphism.

Part of the study area during summer in August 1994. The only short season (July to mid-September) with plant growth.

Part of the study area in winter (January 1994). From January through March, the entire region from the valley bottom to the peaks is blanketed by a thick layer of snow. The base camp is located at the centre of the frame.

An avalanche close to the base camp (February 1993).

Terrain types in the study area: valley bottom (1); the steep bank on the sides, the old moraine (2); loose rubble slopes, scree (3); broken areas, interspersed rocky slopes (4); cliffs/rocky slabs (5); smooth slopes (6).

The radio-collared sub-adult male ibex no. 13.

The Kibber Wildlife Sanctuary. Note the rolling slopes in the region.