FEEDING ECOLOGY OF IBEX (*Capra ibex sibirica*) IN PIN VALLEY NATIONAL PARK, HIMACHAL PRADESH

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7th October 1997

I have great pleasure in forwarding the thesis of Nima Manjrekar, titled *"Feeding ecology of ibex (Capra ibex sibirica) in Pin Valley National Park, Himachal Pradesh"* for acceptance for the degree of **Doctor of Philosophy** in **Wildlife Science**. The thesis embodies original findings and interpretation of facts. This research was carried out by Ms. Manjrekar under my supervision, and has not been submitted in part or full to any other University/Institution for the award of any degree.

(A.J.T. Johnsingh)

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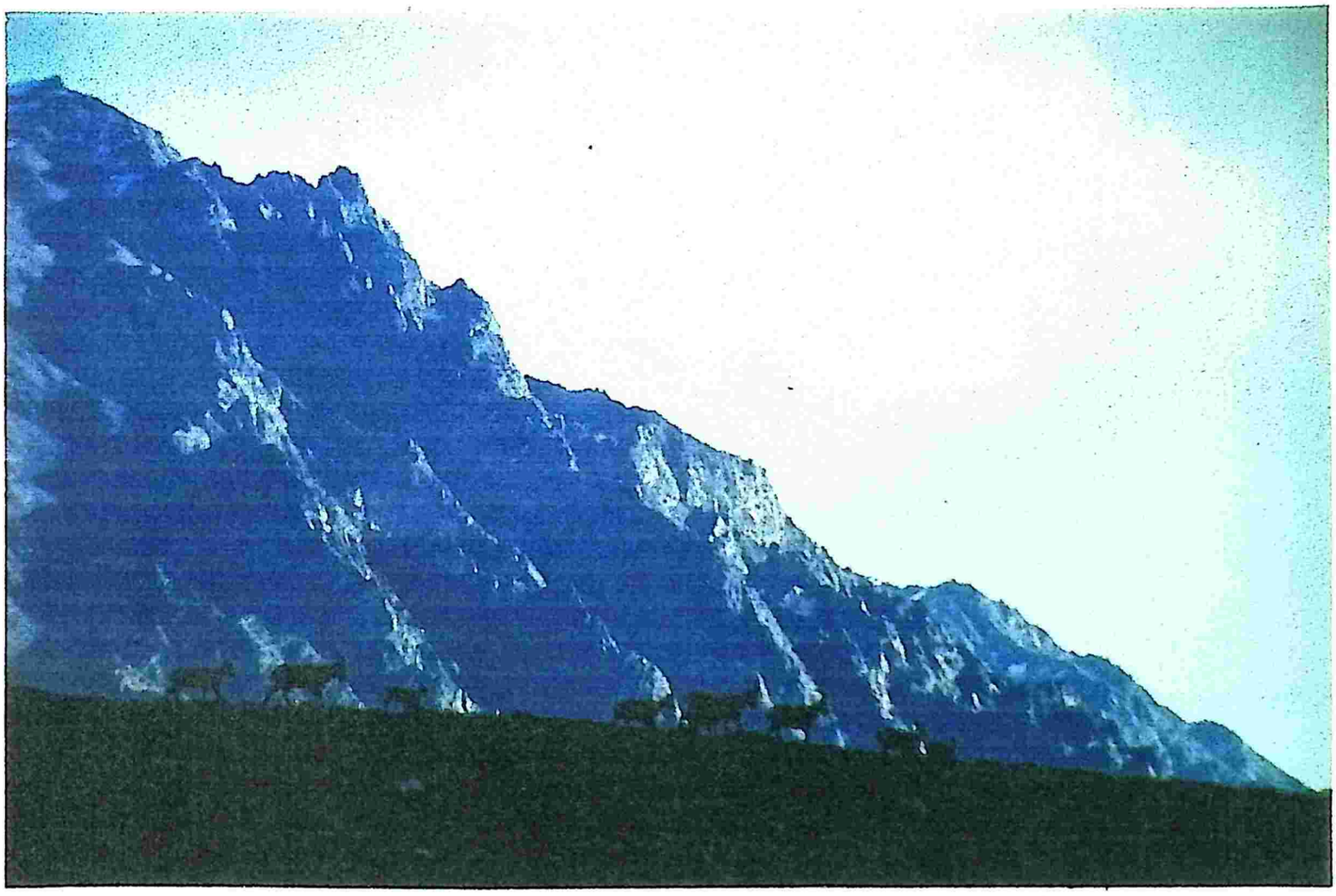

Dedicated to my father and to Mr. B.S. Negi,

who would have been happy to see this piece of work.

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FEEDING ECOLOGY OF IBEX (*Capra ibex sibirica*) IN PIN VALLEY NATIONAL PARK, HIMACHAL PRADESH

Summary

The foraging ecology of the Asiatic ibex was studied in Pin Valley National Park (31°44'55" to 32°11'00"N; 77°45'00" to 78°06'09"E), Lahul and Spiti District, Himachal Pradesh, between October 1991 and October 1994. The National Park encompasses 675 km², and has a buffer of 1150 km². The study area constituted part of the Parahio catchment of the Pin Valley. Thango was the base camp for this study. It was a summer settlement of five families from Sagnam, the largest village of Pin Valley. The local people are Buddhists, of Tibetan origin. Apart from cultivating the land adjacent to the villages, in the buffer zone, they use the Park area for cultivation of barley, wheat, peas, mustard, and potatoes. They also graze sheep, goats, yaks, dzos/dzomos, horses and donkeys in the area. Fuel wood, and fodder for stall-feeding, is collected from the Park before winter.

Being situated in the trans-Himalaya, above the tree line, the vegetation is mostly temperate, and herbaceous, interspersed with some shrub species. The vegetation of the study area was quantified in 0.5 X 0.5 m quadrats, laid randomly along contours, on the different aspects. The vegetation was classified into associations using the computer programme TWINSPAN. Phenological changes of plant species were recorded throughout the growing period, on different aspects, and at various altitudes. The vegetation was classified into nine associations, each with its characteristic requirement of aspect, altitude and slope.

The diet of ibex was determined from feeding signs, and by faecal analysis. Data collected by direct observations were not used for the analysis, because they did not represent all seasons. Estimates of relative plant species availability, and use by ibex were obtained from quadrats laid in areas where ibex had previously been observed feeding. Faecal matter was examined microhistologically, and seasonal diets quantified.

Ibex utilised all vegetation types at one or other time during the year. Based on feeding signs, 37 of 56 plant species in feeding areas were observed to have been eaten by ibex, over all seasons. However, only 29 species were observed in the faecal samples analysed, owing to methodological limitations. A combination of feeding site examination and faecal analysis was found to be more efficient than either of the methods used in isolation.

Seasonal movements of ibex, from lower altitudes in spring to higher altitudes in summer (altitudinal migration), and from one aspect to another, followed snow melt, and the corresponding fresh sprout of food plant species. The downward movement of ibex in autumn can be attributed to more favourable weather conditions in lower areas than in the higher summer ranges, where temperatures fall earlier. There was a shift from a protein-rich diet consisting mainly of young leaves, in spring and summer, to a calorie-rich diet consisting mainly of fruits, in autumn and winter. In spring, per cent crude protein levels of ibex food plants averaged 23.2 ± 0.54 (SE), and showed a steady decrease with advancing season, dropping to 14.5 ± 0.46 in summer, 7.6 ± 0.45 in autumn, and 5.9 ± 0.64 in winter. Calorific values tended to increase with advancing season, corresponding to the formation of fruits and seeds in most species. Calorific

values in spring averaged 4.40±0.05 kcal/g, 4.50±0.05 in summer, 4.53±0.09 in autumn, and 4.89±0.16 in winter. However, diet choice did not seem to be influenced by crude protein content ($P>0.1$), but calorific value of the food plants seemed to influence diet choice to some extent (Pearson's correlation coefficients: spring $r=0.4883$, autumn $r=0.5853$; $P<0.1$). It is speculated that forage digestibility might have an important role to play in food selection by ibex. The presence of tannins in certain food plant species did not deter ibex from feeding on them in winter, when overall food availability and quality was low.

Two potential conservation threats to ibex were identified. Firstly, migratory livestock from the neighbouring areas use the area between June and August every year. There is no control on the numbers of animals entering the area, and the effects of grazing and trampling need to be quantified. They are also potential carriers of disease to ibex. The other problem was the extraction, by uprooting, of shrub species like *Rosa webbiana*, which forms an important autumn and winter food of ibex, as fuelwood by the local people. Fodder species such as *Saussurea jacea*, *Cousinia thomsonii*, and *Festuca kashmiriana* occur in sites used by ibex in winter, and their extraction for stall-feeding of livestock in winter, may reduce the available forage biomass during winter, when availability is already reduced due to snow cover and terrain limitations. These threats are elaborated in relation to the changing socio-economic scenario, and mitigatory measures, such as rotational grazing and fuelwood plantations, are suggested.

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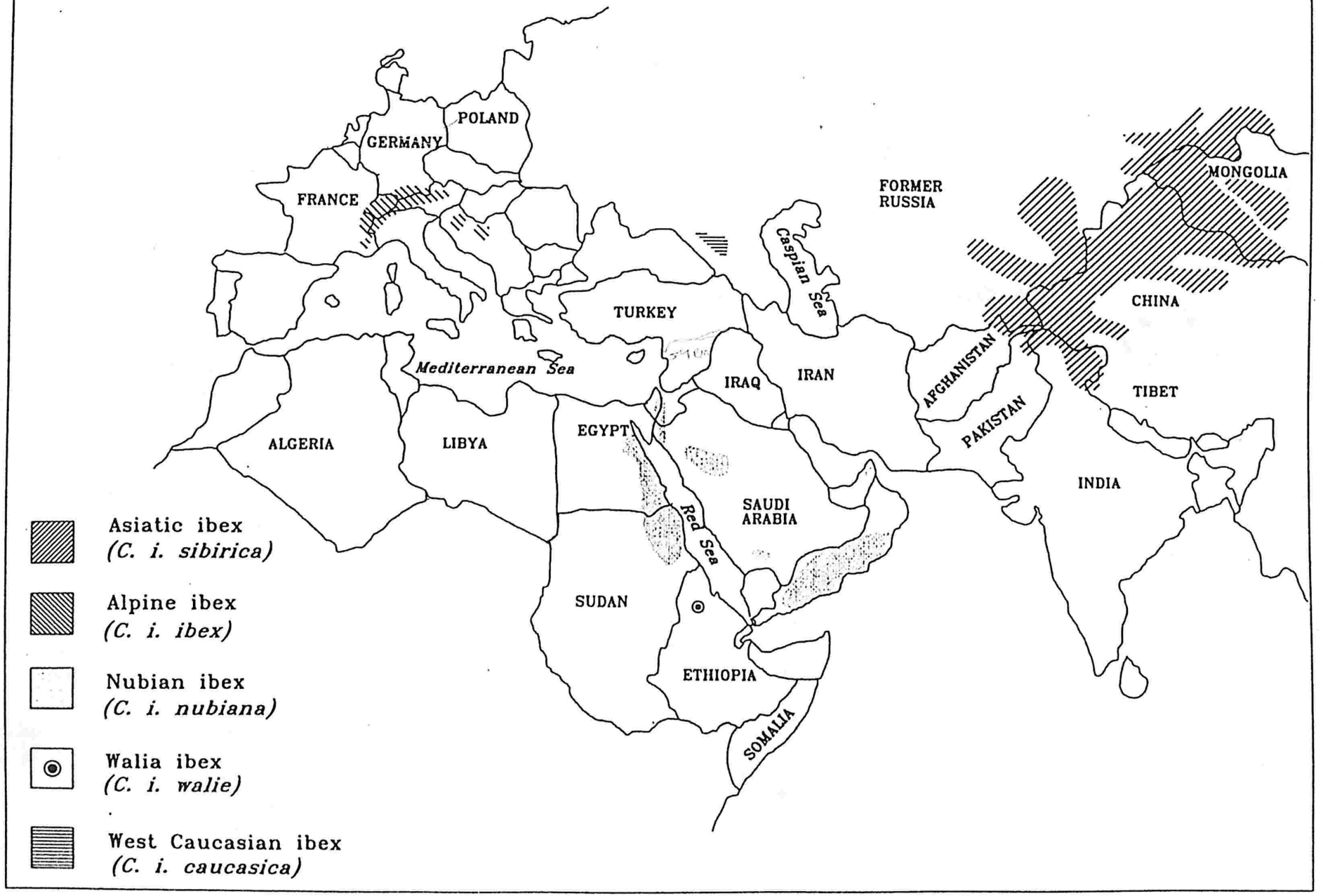
CHAPTER 1. INTRODUCTION

1.1 The background

The Asiatic or Himalayan ibex (*Capra ibex sibirica* Pallas), is distributed in the western trans-Himalaya. It is adapted to extreme seasonality, especially in terms of temperature and food availability in the rugged terrain that it inhabits. The range of the Asiatic ibex stretches from the Hindu Kush mountain range in Afghanistan to the Sayan mountains in Russia, and includes the Pamir, Tien Shan, Kara Tau, Tarbagatay, and Altai mountains (Schaller 1977) (Figure 1.1). Its distribution, however, is not continuous (Heptner *et al.* 1966), unsuitable habitat and hunting being the main causes of such disjunction. In India, it is found in the states of Jammu & Kashmir, and Himachal Pradesh. Prater (1980) and Sharma (1994) report the occurrence of Asiatic ibex further southeast in the mountains of the Kumaon region of Uttar Pradesh. Most of the major mountain ranges in northwestern India and Pakistan have ibex populations (Schaller 1977), and their range extends through most parts of Ladakh, except east of Leh, and in the higher reaches of Himachal Pradesh, west of the Sutlej river. Schaller (1977) opines that the reason that Asiatic ibex does not occur east of Sutlej despite apparently suitable terrain there, is the amount of precipitation, especially in the form of snow. Ibex, like other goats, generally inhabit areas that receive less than 100 cm of precipitation per year, making the Central and Eastern Himalaya unsuitable for them. During this study, we received reports from local people and army personnel that ibex do occur east of the Sutlej, although in low numbers. In April 1992, we found a dead ibex male near the Khab bridge connecting the west and east banks of the Sutlej river at its confluence with the Spiti river.

Figure 1.1: Distribution of subspecies of *Capra ibex*



The habitat of ibex is also home to the snow leopard (*Uncia uncia*), the major predator of ibex. The survival of viable populations of ibex is integral to the survival of snow leopards, especially in areas like Pin Valley National Park, in the Indian state of Himachal Pradesh, where ibex is the only wild ungulate. In most other areas of its distribution in India, it occupies the same habitat as another ungulate, the bharal (*Pseudois nayaur*), which is also an important prey species of the snow leopard.

Relative to the Alpine ibex (*C. i. ibex*) and the Nubian ibex (*C. i. nubiana*), little ecological research has been done on the Asiatic ibex (Heptner *et al.* 1966, Roberts 1977, Schaller 1977, Fox *et al.* 1992). All these studies were very general, either based on surveys, or short-term quantifications, which did not take into account all the seasons. None of these studies involved any quantitative work related to feeding. Ranging of ibex had also not been quantified in previous studies. This study was part of a collaborative project of the Wildlife Institute of India, and the United States Fish and Wildlife Services, initiated in October 1991, to study the ecology and genetics of this subspecies. Field data were collected between April 1992 and October 1994, after an initial reconnaissance between October and December 1991.

Two major components constituted the ecological study, one on the habitat use and ranging of ibex (Bhatnagar 1997), and this study, on the feeding ecology of ibex. For the ranging study, seven animals were radio-collared and ear-tagged, and six others only ear-tagged (Manjrekar and Bhatnagar 1997). During the radio-collaring operation, blood samples were collected, to be analysed for the determination of the taxonomic status of the Asiatic ibex, that is, whether they can be placed under a separate species, or are only a subspecies of *Capra ibex*. The results of this analysis are awaited. Until then, this ibex shall be regarded as a subspecies.

1.2 Significance of feeding ecology studies

One of the most important activities of an animal that has profound influence on other activities, is feeding. The dispersion of food influences especially the ranging of an animal, and also its density, group size and social organisation (Jarman 1974). In the case of ungulates, there is, to a certain extent, a compromise on food, in the process of predator avoidance (Festa-Bianchet 1988). The distance to escape cover influences feeding efficiency in mountain ungulates (Bhatnagar 1997), even if food is not limiting.

The food resource for most mountain ungulates is ephemeral, owing to the climatic extremes found in their habitats. The food resource undergoes seasonal changes in quantity and quality, influencing most activities of the animals. Large herbivores have been variously categorised, either based on body size and digestive system, or on feeding strategy (see Chapter 4). More recently, the importance of diet quality has been emphasised (Gordon and Illius 1996, Robbins *et al.* 1995) in the categorisation of feeding strategy.

Seasonal changes in the quality of food determines ranging patterns of animals (Geist 1971, Schaller 1977, Gonzalez 1985, Hutchins and Geist 1987), and in case of mountain ungulates, this movement is usually altitudinal, following fresh plant growth. This is discussed in greater detail in later chapters. On an annual scale, the changes in food quality are responsible for the delineation of home range. The theory of sexual segregation has been variously explained, as minimisation of competition between males and females, predator avoidance by males after the exhaustion from rut, minimisation of sexually motivated aggression among males during the non-rut period, and optimisation of forage resources (Main and Coblentz 1990, 1996). One of the major factors influencing segregation is food. The males of most ungulates are known

to segregate from females during the non-breeding period, and one of the explanations for this is that the pregnant females require food resource of higher quality. It would not be beneficial for the reproductive fitness of the males, since competition with females for resources during this period might threaten the survival of their own offspring. For females, security is the most important consideration, even if it is at the cost of good quality food resources, whereas, for males, food resource availability is more important than security (Geist 1982, Madhusudan 1995). Breeding in temperate ungulates is timed in such a way that parturition occurs at a time of food is of high quality, to fulfil the high resource requirements of the females for lactation (Nievergelt 1974). Food availability, especially in winter, determines survival rates to a large extent, and therefore population densities in the longer term.

1.3 Objectives of the study

The broad objective of the study on the foraging of ibex was to document and quantify the availability and utilisation by ibex of plant species in Pin Valley National Park. For this, data were collected on the vegetation composition of the area, and its utilisation by ibex in the different seasons. To explain seasonal changes in the diet of ibex, food plants were analysed for their nutritional value.

Analysis was based on the following questions:

- Is the vegetation of the area homogenous?
- How does ibex use the vegetation of the area?
- What is the ibex diet made of?
- Does the diet change seasonally?
- If ibex has seasonal food preferences, what are these based on?
- Are there any threats to ibex in the area?

1.4 Ibex - a review of the literature

Schaller (1977) recognised five subspecies of *Capra ibex*:

(a) Alpine ibex,

(b) Nubian ibex,

(c) Walia or Ethiopian ibex (*C. i. walie*),

(d) Asiatic or Siberian or Himalayan ibex, and

(e) Kuban ibex or West Caucasian tur (*C. i. caucasica*).

1.4.1 Available literature on Asiatic ibex:

Although the Asiatic ibex is the most widely distributed of the ibex subspecies (Schaller 1977), existing information on this subspecies consists only of scattered accounts of its presence (Sterndale 1886), distribution (e.g. Ward 1922, Singh 1958, Dang 1969), and a few hunting accounts (Gore 1905, Burton 1922). Heptner *et al.* (1966) give brief information on altitudinal range, habitat and food plants, morphology of the sexes, population density, breeding, parasitic infestation, predation, and herding behaviour. Schaller (1977) discussed several aspects, such as taxonomy, evolution, geographical and ecological distribution, morphology, herding, feeding habits, breeding and demography, parasites, predators, and response to danger. Rasul (1982) gave an account of its population status in Pakistan, apart from a short description of the species and its habits. Mallon (1991) surveyed 15000 km² in Ladakh, and estimated ibex density at 0.88 and 0.62 ibex/km² in two protected areas. Fox *et al.* (1992) quantified activity patterns and gross habitat use by ibex in the northwest Himalaya, and estimated a population of about 9000 animals in their range in the Indian states of Jammu & Kashmir and Himachal Pradesh. Pandey (1992) made the first population estimate of 700 to 1200 ibex in Pin Valley National Park, Himachal Pradesh, with

densities reaching 2.29/km² in the valleys where the counts were made. This figure is higher than those reported elsewhere: 0.8 to 1.2/km² in central Ladakh (Fox *et al.* 1992), and 0.88 an 0.62/km² (Mallon 1991). Reports by Roberts (1977), and Sharma (1994) are based on anecdotal information and museum studies. Dzieciolowski *et al.* (1980) estimate the Asiatic ibex population at 1000 in the Khuhsyrh Reserve. The population of ibex in the Himalaya is estimated to be between 12000 and 15000 in about 41000 km² of suitable habitat, or a crude density of 0.29 to 0.36/km² (Chundawat and Rawat 1994), but local densities can be higher, especially in well-protected areas such as Pin Valley National Park.

Only preliminary information is available on the feeding ecology of ibex. According to Heptner *et al.* (1966), Asiatic ibex in any one area consume some 80 plant species, mainly grasses, sedges, forbs and sprouts of such shrubs as *Ribes*. Schaller (1977) also recorded a similar variety of ibex food plants. The difficult terrain of ibex habitat is characterised by a harsh climate, accompanied by a marked seasonality in the availability of food for herbivores, and potential competition from livestock. The severe winter often causes 'winter kill' in the animals. All these problems exist in Pin Valley, where the study was conducted.

1.4.2 Morphology of the Asiatic ibex:

The Asiatic ibex is a large goat, with a compressed body supported on strong, short, thick legs (Heptner *et al.* 1966), required for movement in precipitous terrain. As mentioned earlier, the ibex shows sexual dimorphism, with the males being about one-and-a-half times the size of females, and possessing a thick, dark beard, 20-25 cm long, which is either absent or much shorter in females (Plate 1). Adult males weigh between 70 and 90 kg, and stand about 100 cm at the shoulder, while an adult female

weighs between 50 and 55 kg, with a shoulder height of about 70 cm (Heptner *et al.* 1966, Schaller 1977, Prater 1980).

Adult males also possess large, scimitar-shaped horns that are characteristic of the species. The horns are similar to those of the wild goat (*Capra aegagrus*), but the anterior surface is flatter, giving it a triangular shape in cross-section. The anterior surface also has prominent transverse ridges or knobs (Schaller 1977). The horns of all the subspecies are similar, except for minor differences such as the greater curvature of the horns in the Asiatic subspecies when compared to the Alpine subspecies (Heptner *et al.* 1966), and a slight dorsal keel in the Walia ibex (Nievergelt 1990). The adult males of the Asiatic ibex have the largest horns among all the *Capra ibex* subspecies, growing to over 140 cm in old animals. The horns grow throughout the life of the animal, during spring and summer every year, ceasing at the initiation of rut. This annual growth pattern coincides with the availability of nutritious food, and the 'annual rings' thus formed are an indication of the animal's age, and can even indicate years of good vegetation growth in the animal's habitat, or the health of an animal during a particular year. These rings are a result of the stark variation in seasonal growth of the horns, with almost no growth during the winter and a rapid spurt during spring. An average of two ridges or knobs are formed between consecutive annual rings, from the 2^{nd} to the 10^{th} year of the animal's life. As the animal ages, horn growth decreases, and usually only one knob is formed every year, with the rings becoming less and less distinct. Horn data collected by Schaller (1977) confirm that the annual horn increment declines with increasing age. 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 all *Capra* females, with reports of up to 24 and 29 cm from the Himalaya and Tien Shan

respectively (Heptner *et al.* 1966, Schaller 1977). Asiatic ibex are known to live up to 16 years (Grzimek 1990). The oldest male that was recorded during this study was 11 years old, and the oldest female 14 years.

The pelage colour of ibex varies seasonally. During the summer, animals of both sexes are a uniform, light, reddish brown, with a lighter underside, blending well with the mountains. With the arrival of the harsh winter, the ibex acquires a coat of soft, dense underwool (locally known as *pashm*) to keep warm. The females and young males acquire a dark, greyish brown pelage, while the adult males are contrastingly dark brown, with a dull white 'saddle-back' and neck patch. The acquisition of this coat coincides with the beginning of the rut or mating season. The oldest males have the most distinct 'saddle-backs', a sign of their sexual maturity. The winter coat is shed in spring, during which time the animals look extremely ragged and unkempt, and constantly make use of any shrub or rough rock that comes their way to rub against and rid themselves of the underwool, which is not required during the summer. The shed underwool is not collected by the local people on a regular basis, but only opportunistically, and used in the manufacture of clothes that are considerably warmer than those made from sheep wool.

1.4.3 Other subspecies of ibex:

The Alpine ibex, whose population plunged to 50-100 animals, due to excessive hunting in the mid 19th Century, and was confined to Gran Paradiso in Italy, was later reintroduced in the Alps of Italy, Switzerland, France, Austria, Germany, and Yugoslavia. According to an estimate in 1982, Alpine ibex numbered about 22000 animals (Nievergelt 1990). The Nubian ibex occurs on the east and west of the Red Sea, in northern Sudan and in Egypt east of the Nile, on the Sinai peninsula, in Syria,

Israel, Lebanon, South Yemen, and on the western part of the Arabian peninsula adjoining the Red Sea (Schaller 1977, Mendelssohn 1990). In 1986, its estimated population was about 1200 animals, largely confined to Israel (Nievergelt 1990). The Walia ibex has the most restricted distribution among the ibex subspecies, being confined to a small massif in the Simen National Park of Ethiopia. Its population is less than 500 animals (Nievergelt 1981). The Kuban ibex is confined to the western part of the Caucasian mountains (Schaller 1977). The adjoining ranges, the East Caucasian mountains, are inhabited by the East Caucasian or Dagestan tur (*Capra cylindricornis*), which Schaller (1977) considers a separate species, although it has been classified as an ibex subspecies, *C. i. cylindricornis* elsewhere (Hess 1990).

All ibex subspecies are high altitude animals, generally inhabiting areas between the timber line and the permanent snow line, with a reasonable interspersion of cliffs and alpine meadows. The Nubian ibex, however, is adapted to a life in hot, desert-like regions, and inhabits rocky terrain with steep slopes (Mendelssohn 1990). Ibex in the Alps are found at altitudes ranging from 1600 to 3200 m (Nievergelt 1990). The Kuban ibex, in whose habitat the permanent snow line is at a lower altitude, generally remains below 3300 m (Heptner *et al.* 1966). The range of the Asiatic ibex covers altitudes between 500 and 5000 m, the lowest being from the Altai, where they inhabit forested zone (*op. cit.*). Ibex have been recorded even above 5000 m in Chitral in Pakistan (Schaller 1977) and in Pin Valley (*pers. obs.*).

ALPINE IBEX:

This subspecies inhabits Alpine habitat in Austria, Switzerland, France, Italy, and Germany. It had reached near extinction by the beginning of the 19th century, due to excessive hunting (Stüwe and Nievergelt 1991, and references therein) Timely

protection, captive breeding, and reintroductions into their habitat in the Alps, however, helped their recovery, from an initial population of 50-100 animals, to the present day number of over 20000. Nievergelt (1966) studied six colonies of introduced ibex in Switzerland. He compared population sizes, structure and dynamics, and identified factors that determine their habitat requirements. Ibex used the lowest areas of their range in spring, the highest in summer, and the middle areas in winter. This is also evident from the results of a study by Wiersema (1984), who recorded ibex in areas between 1600-2400 m in spring, and 2250-3200 m in summer.

Studies on the feeding habits of Alpine ibex include one by ten Houte de Lange (1978) based on direct observations, and one from the results of analysis of 260 ibex rumens over four years (Frieda and Klansek 1990). Ten Houte de Lange (1978) recorded feeding on 99 of the available 200 plant species. Of these, 60% were monocots, 38% dicot herbs, and 2% shrubs. Twenty five species made up 79% of the diet by frequency. While the total proportion of grasses in the diet was the highest, dicots were greater in terms of the number of species consumed. Frieda and Klansek (1990) found that the diet of ibex consisted of 84.5% grasses, 4.9% herbs, 3.8% shrublets, and 4.1% juniper. The crude fibre content of the diet was relatively high (22-34%), probably owing to the high grass content.

Wiersema and Schröder (1985) and Wiersema and Zonneveld (1990) discuss the use of remote sensing in ibex management. They appreciate the use of Landsat imagery to delineate vegetation zones in ibex habitat. Since snow is a limiting factor for ibex, the relatively snow-free areas can be regarded as potential winter ranges and migratory routes.

NUBIAN IBEX:

This subspecies has also been relatively well-studied. It is widely distributed, inhabiting the mountains of north Africa, Israel, and Saudi Arabia. Krausman and Shaw (1986) rediscovered the Nubian ibex in the Eastern Desert of Egypt, 55 years after it was last reported from the area. Habibi and Grainger (1990) indicate that the present distribution of the Nubian ibex in Saudi Arabia compares with the historical distribution of the subspecies. However, habitat degradation, due to road building and livestock encroachment, continues to be a threat to their survival. They suggest the establishment of national reserves for ibex, in the mountain chain of west Saudi Arabia, which is the main area of ibex distribution.

Based on a survey of the Sinai Desert of Israel, between 1977 and 1979, Baharav and Meiboom (1981) rule out the possibility of competition of ibex with goats of the Bedouin herders, since ibex use more rugged terrain than the domestic animals. Since the enforcement of conservation regulations in the country, an increase in numbers of ibex was observed. The authors estimated a population of ca. 300 animals, 70% of which inhabited the rugged cliffs of south Sinai. They suggested continued protection of these areas from hunting, to maintain the population, and the establishment of some areas with rugged terrain, as ibex reserves.

Gross (1990) studied the nutritional ecology and behaviour of the subspecies in the northern Negev desert of Israel. Hakham and Ritte (1993) studied the effects of foraging by the Nubian ibex on the vegetation, in Israel's En Gedi Nature Reserve. The animals in this area had very small home ranges (0.5 km^2) in the 27 km^2 reserve. Fifty percent of their daily activity involved feeding, of which only 10% was for browsing. Habibi (1991) estimated a population of ca. 160 animals (1 animal/2.5 km^2), with a population structure of 29 ♂♂ : 37.5 ♀♀ : 33.5 juveniles, in the Hawtat bani Tamim

canyons of Saudi Arabia. He recorded a mean group size of 5.17 ibex (range: 1 to 13). Activity was maximum in the early hours of the day. The ibex are generalist feeders. They rut for four weeks from mid October. Tree-felling, and overgrazing by camels in the ibex habitat are problems that require management action (*op. cit.*).

WALIA IBEX:

This subspecies has the most restricted distribution, and has also not been studied extensively. Nievergelt (1974) found similarities in rutting behaviour of this subspecies with that of the Alpine ibex. Dunbar (1978) investigated competition and separation among seven herbivores in the Simen Mountains of Ethiopia, and found that the diet of Walia ibex, chiefly a browser, only overlaps to a certain extent with the klipspringer (*Oreotragus oreotragus*) and the bushbuck (*Tragelaphus scriptus*). However, spatial distribution and ranging patterns minimise potential competition between the species.

Nievergelt (1981) studied the history of the establishment of Walia ibex in the area, its habitat and niche, social system, competition, reproductive cycle, rutting behaviour, home ranges, and food selection, in its restricted range in the Simen Mountains of Ethiopia. Unlike in the case of the Alpine ibex, there are no distinct seasons of food shortage in the range of the Walia ibex. Consequently, food availability is not limiting, there is no distinct rutting season. Since rutting activity takes place throughout the year, although with a peak, the social system demands that males are together with females throughout the year. The differences between the social systems of the two subspecies of ibex are attributed to differences in climate and habitat. The Simen mountains habitat needs to be preserved and protected from human encroachment, if the Walia ibex is to survive.

KUBAN IBEX:

A study on immunocontraception experiments on this subspecies in captivity (Kirkpatrick *et al.* 1992) is the only other publication seen, apart from the work by Heptner *et al.* (1966) on its basic ecology and distribution in the former Soviet Union.

1.5 Origins, morphology, and behaviour of caprids

The subfamily Caprinae includes three tribes: Rupicaprini (goat-antelopes), Caprini (sheep and goats), and Ovibovini (shrub-oxen and musk-oxen) (Geist 1987). Caprids are a very widely distributed group, inhabiting a broad range of altitudes and latitudes, mostly in extreme environments (Geist 1987). Caprids are believed to have originated in the Old World tropics, and at the end of the major glaciations, radiated into the temperate and arctic regions of the New World, with concurrent evolution of more advanced species.

Caprids are believed to have originated in southeast Asia, from where they radiated outwards (Geist 1985, 1987). They arose in the Miocene, from an ancestral goral-like form of rupicaprid. During the late Miocene and early Pliocene, caprids spread over Eurasia and probably parts of Africa, from forested habitat into open mountain areas, consequently becoming larger (Schaller 1977). In the late Pliocene and Pleistocene, the mountain forms radiated further, and evolved particularly in terms of larger horns, a likely adaptation to more open environments (*op. cit.*). The genus *Capra* probably evolved from a tahr-like goat, appearing in the mid-Pleistocene.

Ibex and large sheep are the most recent caprids, which appeared in the middle of the large glaciations, but as genera they may be older. During the last deglaciation period, and with the beginning of vegetation succession, ibex moved towards the

deglaciated mountains and became separated by the beginning of forestation (Nievergelt 1981).

Most caprids are medium-sized, which might have to do with the high seasonality of mountain environments, and the consequent highly seasonal availability of food. Small animals are usually specialist feeders, and if they inhabit areas with sparse vegetation, they will require to spend a large amount of energy in search of food (Jarman 1974, Owen-Smith and Novellie 1982). Medium-sized animals are more generalist feeders, and can cope with seasonality in resource availability much better than small animals, in that they can afford to survive on food of relatively low quality, and can move to areas with better food quality and quantity (Owen-Smith and Novellie 1982). In medium-sized animals, these movements are usually in the form of altitudinal migrations, since their size does not allow long distance migrations as in large animals like the wildebeest (*Connochaetes taurinus*). Large animals, on the other hand, would require larger amounts of food, which a highly seasonal area might not be able to provide. For cliff-dependent ungulates, the upper size limit has been put at 130 kg (Hutchins and Geist 1987), above which the substrate might not be able to withstand the force of the animal's weight while jumping.

The primitive species, the rupicaprids - e.g. serow and goral (*Nemorhaedus* spp.) - inhabit forested areas, while the more 'advanced' genera such as sheep (*Ovis* spp.) and goats (*Capra* spp.), occupy the areas of glacial melt, which are mostly open areas at high altitudes, above the tree-line.

In the more advanced caprids such as ibex, which occupy open habitats, gregariousness evolved as an anti-predator strategy. Sharp and potentially damaging horns were a disadvantage in such a social system, leading to the evolution of curved and blunt horns, acting more as shields (Geist 1978, 1985, 1987), and in the most

advanced genera, *Ovis* and *Capra*, the horns probably act as 'luxury' organs, indicating the ability of the males, which are usually larger than the female, to procure enough resources for both, body maintenance, as well as for horn growth (Geist 1978, 1986, 1987). Horns in males are products of sexual selection, functioning as organs of intrasexual contest and display.

In such sexually dimorphic forms, males do not need to defend resources, but compete for females by setting up dominance hierarchies. This social system requires males and females to be together only during the mating season, and segregate otherwise, in such a way that females maximise security for their young, and males maximise body growth in order to gain dominance. The rut in ibex habitat is very short, owing to the extreme climates, and males are therefore engaged in sexual activity for a consequently brief period of the year. During the remaining part of the year, the animals put on reserves in the form of fat, and still have excess resources left for investment in horn growth (Geist 1974a). Since males require more feed per unit time, they compromise for less secure, but more resource-rich areas (Geist 1982). Territoriality is absent in ungulates of cold areas, since food source is very seasonal, and animals move over large areas to fulfil their forage requirements (Geist 1974b).

1.6 Organisation of the thesis

This thesis is divided into six chapters:

CHAPTER 1. (i) An INTRODUCTION to the study, justifying it, discussing its relevance to conservation, and listing the objectives and questions of the study.

(ii) A review of the literature, listing the subspecies of ibex, describing the morphology of Asiatic ibex, its distribution, previous work carried out on the other subspecies of ibex, and evolution of caprids.

CHAPTER 2. A description of the STUDY AREA, and an overview of the GENERAL METHODS.

CHAPTER 3. An identification of VEGETATION associations, and their species composition in relation to altitude and aspect.

CHAPTER 4. A quantification of the seasonal changes in FOOD COMPOSITION of ibex, and an estimation of food preferences.

CHAPTER 5. An analysis of seasonal changes in FORAGE QUALITY of food plants of ibex.

CHAPTER 6. A GENERAL DISCUSSION, relating seasonal variation in ibex diet to food availability and nutritional content. Management recommendations are also given in this chapter.

CHAPTER 2. STUDY AREA AND GENERAL METHODS

2.1 The trans-Himalaya of Himachal Pradesh

The trans-Himalayan region of the Indian State of Himachal Pradesh runs through the northeastern part of the State, and includes parts of Kinnaur, Kullu and Chamba districts, and almost the entire Lahul & Spiti district. It shares a State boundary with the Ladakh area of Jammu & Kashmir, and an international boundary with Tibet. Tethyan Himalayan formations of the Himachal Pradesh Himalaya are best developed in the Spiti area. The Spiti valley lies between the Great Himalayan and the Zanskar ranges (Negi 1993). The Spiti river, which has its course at the base of the Kunzam range, flows through the 130 kilometre long Spiti valley, and continues into Kinnaur until it joins the Sutlej river at Khab (Mamgain 1975).

The Himalaya receives precipitation only from the south. The trans-Himalaya lies in the rain-shadow area of the main Himalayan mountain wall, and has a Mediterranean influence (Dhar and Mulye 1987). It is a rain-deficient area, since the moisture-laden southwest monsoon winds are blocked by the Greater Himalayan range. The trans-Himalayan region, owing to its location in the temperate latitudes, and the paucity of rain, is termed a 'cold desert'. Altitudes in the area average 3000 metres above mean sea level, and lie above the tree line. The vegetation in most of the region is classified under Dry Alpine Scrub and Dwarf Juniper Scrub (Champion and Seth 1968), consisting of xerophytic herbs such as *Kraschennenikova* sp., *Cousinia* sp., *Rhodiola* sp., *Rosularia* sp., *Chenopodium* sp., *Corydalis* sp., and shrubs such as *Potentilla* sp., *Caragana* sp., and *Artemisia* sp. (Chundawat and Rawat 1994).

The inhabitants of Spiti are *Bhotis*, believed to be descendants of migrants from Tibet and Ladakh. Buddhism is the religion of the people; it took its hold in the area

after Padmasambhava preached his doctrine there, in the ninth century. Traditionally, the people are agropastoralists, leading a subsistence-based lifestyle, cultivating barley, peas and potatoes. Livestock, consisting of yaks, dzos, sheep and goats, are raised for milk and meat, and donkeys as beasts of burden. Hunting is not allowed by the religion, and therefore wild animals are relatively secure.

2.2 The Study Area

The study was done in Pin Valley National Park in the Lahul & Spiti district of Himachal Pradesh (Figure 2.1). This area is part of the trans-Himalaya, but also has attributes of the Greater Himalaya, in terms of terrain and precipitation.

Pin Valley is one of the major areas of the Spiti subdivision of the Lahul and Spiti district. The Pin river constitutes the most important right bank tributary of the Spiti river (Mamgain 1975). It is 50 kilometres long, originating from the Srikand range in the Greater Himalaya, and joining the Spiti river at Sushuna, near Dankhar. The Pin river flows in a general south to north direction, until it reaches Sagnam, where it is joined by one of its major tributaries, the Parahio river. From here, the river flows west to east, until it joins the Spiti river.

Pin Valley National Park (PVNP) encloses the watershed of the Parahio and Pin rivers (Figure 2.2). However, for most parts the Pin river itself flows through the buffer zone. PVNP covers an area of 675 km² (Pandey 1991), with its northern boundary beginning at the Bara Shigri glacier, then following the Hundungma ridge up to the top of the Ratang river, and continuing along the ridge separating Khamengar and Kidul Chu watersheds (*op. cit.*). The eastern boundary begins at the top of Kidul Chu and follows the river until it joins the Parahio. It continues along the Parahio river for a short distance westwards, then follows the ridge separating the Pin and Killung

Figure 2.1: Location of Pin Valley National Park in Himachal Pradesh, India

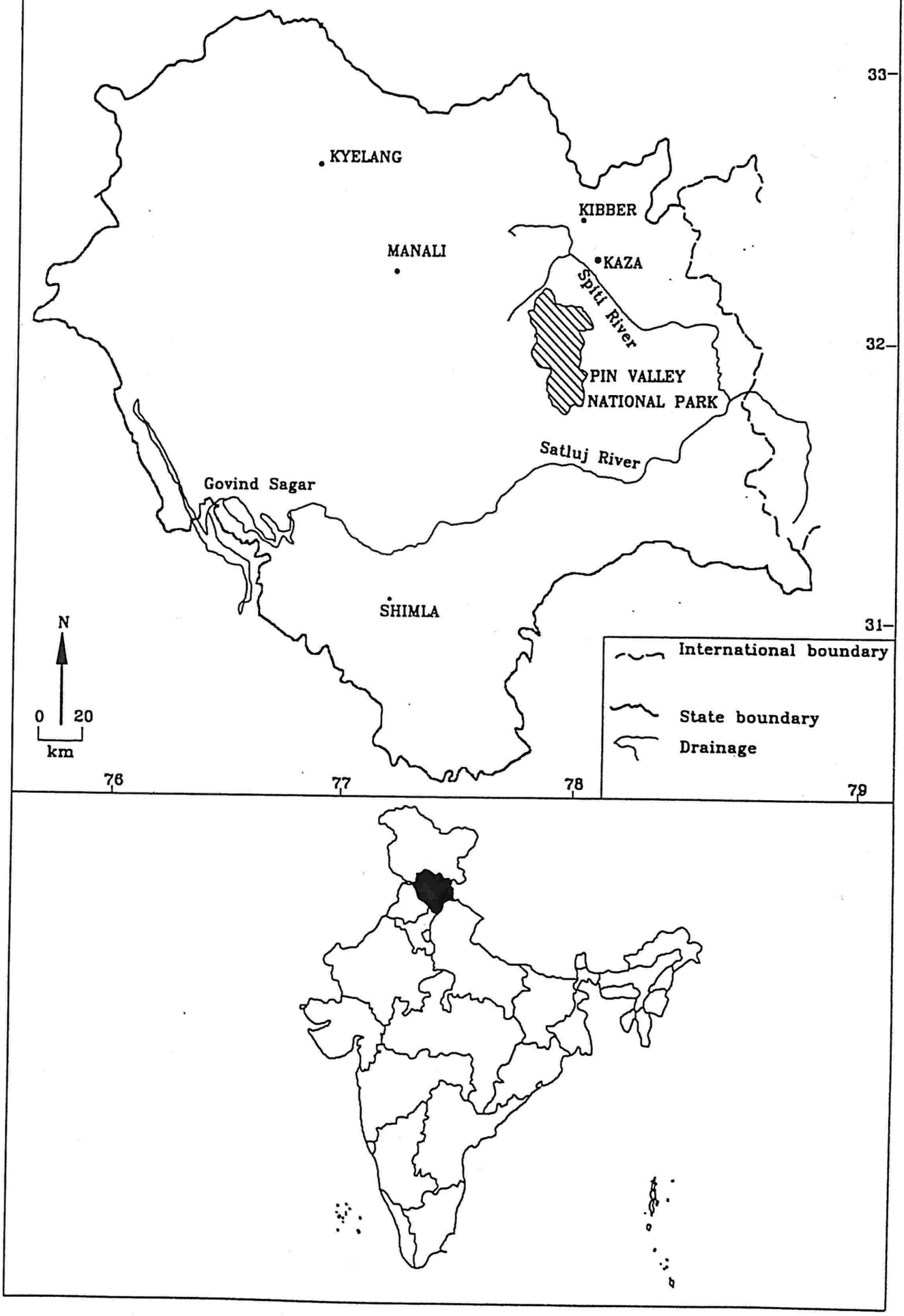
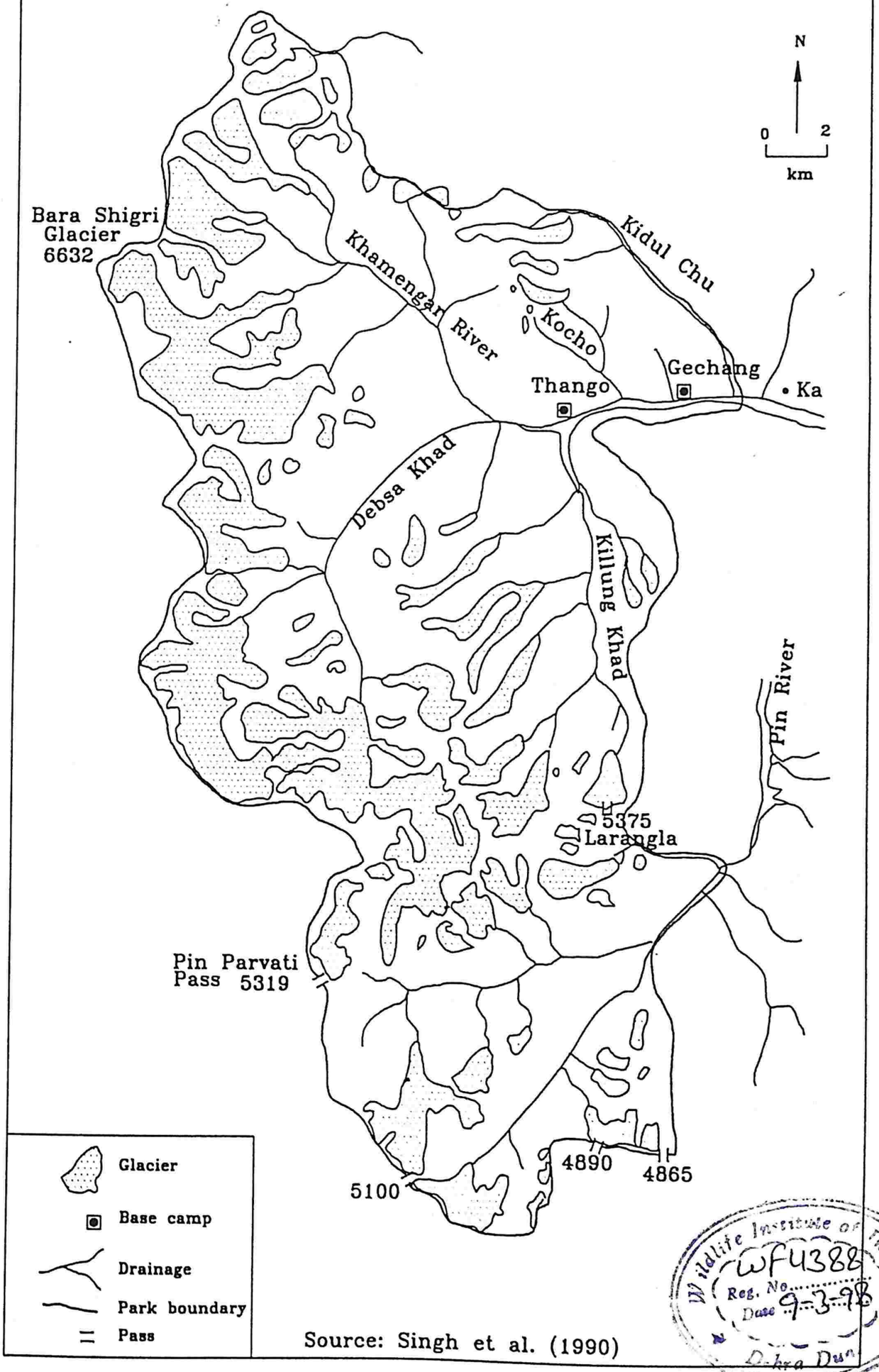


Figure 2.2: Pin Valley National Park showing the location of base camps at Gechang and Thango



Source: Singh et al. (1990)

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watersheds up to Larang La. From Larang La, it follows the watershed flowing into the Pin river, then along the Pin river upstream to Tari Khango. The southern boundary follows the district boundaries of Lahul & Spiti, with Kinnaur and Kullu, up to Shakarang Khango. From here, the western boundary continues along the Kullu district boundary, through the Pin Parvati Pass up to the Bara Shigri glacier. The Parahio watershed was identified as the intensive study area for this project (Plate 2).

The Parahio river valley is, on an average, 250 metres wide and has steep mountains on either side, with an average slope of 35-40°. The area is very prone to avalanches, which are a regular feature during snow-melt every year (March-April).

Altitudes within the park range between 3650 and 6632 m above mean sea level. Temperatures range between -40°C and +33°C over the year. The area receives an average annual rainfall of ca. 17 cm, the rest of the precipitation is in the form of snow, with an annual average of 275 cm. of snow fall.

Except for some *Salix* plantations and isolated *Juniperus* trees (those that survived the over-exploitation for fuel wood), there are no trees in the whole park. Woody shrubs (e.g. *Rosa* sp., *Artemisia* sp., *Salix* sp., *Lonicera* sp., *Ribes* sp.) grow to a maximum height of 2 m. The vegetation in the valley bottom is very distinct (riverine), with mainly *Ephedra gerardiana, Salix* sp. and *Myricaria* sp. Vegetation on the slopes varies with terrain, aspect, degree of slope and substrate. The area can be divided into 5 broad terrain categories: moraines, meadows, cliffs, valley bottoms, and plateaus.

Separate lists of plant, bird, and mammal species identified in the study area are given as Appendices A, B, and C.

The local inhabitants of the area are of Tibetan origin. Buddhism, their religion, does not allow them to hunt, and has been of great importance in the protection of

animals in the wild. Although the population density in the area is relatively low (Mamgain 1975), changes in the social system, especially the breakdown of the polyandrous system, might affect the sustainability of resources in the area.

Within the study area, there are only 3 'dogris' (temporary settlements), one just inside the eastern boundary (Gechang), another at the confluence of Killung and Parahio rivers (Thango), and the other (Kocho) between Gechang and Thango. These dogris are occupied between April and December every year. The buffer zone has 17 villages, the biggest of which is Sagnam (at the junction of the Parahio and Pin rivers). Pin Valley has a total human population of ca. 1500 and a livestock population of ca. 8000 (Krishna Bhatnagar *pers. comm.*). The summer settlements are inhabited between April and December, and the livestock that use the area include yaks, *dzos* (yak-cow hybrids), horses, donkeys, sheep and goats. Except for the horses, these animals are usually not accompanied by people in their grazing areas, and stay in groups varying in number from 10 to 60.

The local people are dependent on the area mainly for agriculture, fuel wood, and for grazing their livestock before the peak winter sets in. Between April and September, they cultivate barley, peas, potatoes and mustard. The area also caters for a major proportion of the fuel wood requirements of the inhabitants of Sagnam. For this purpose the shrubby vegetation is uprooted and used. *Lonicera* sp., *Rosa* sp., *Salix* sp. and *Ephedra gerardiana* are some of the preferred fuel wood species. Green vegetation, especially *Cicer microphyllum* and *Saussurea* sp. is also collected as fodder for stall-feeding of livestock in winter. Livestock dung is collected and used as fuel.

Migratory livestock, from the adjoining districts of Kullu and Kinnaur, use the area during the summer, and are a potential source of trampling and excessive grazing, and therefore soil erosion. Livestock in these areas might also be potential carriers of

disease, and hence a threat to the wild animals. Eight groups use the protected area between late June and mid August every year, with a total of about 4500 sheep and goats, accompanied by people and dogs.

The locals spend the winter in the village, the major activity during the time being stall-feeding of livestock. Women also knit socks and gloves, and weave shawls during the winter. Men make rope out of goat and yak hair. Cultural and religious activities are almost exclusive to winter. Education levels are relatively low, with most children dropping out after secondary school. Very few students continue high school education.

The traditional subsistence-based lifestyle and customs of the local people are now increasingly affected by external pressures and changes. Development of the area began, with the road network improving rapidly in the 1980s, followed by activities such as the construction of irrigation canals, walls to prevent soil erosion, and trekking paths. Tourism is also increasing rapidly, and the danger of it not being properly controlled exists. However, the relative inaccessibility and ruggedness of their habitat, by itself, provides protection to the animals.

2.3 General methods

The year was divided into the four seasons of temperate regions, spring, summer, autumn and winter, for the purpose of analysis of data, and discussion of seasonal changes in vegetation, and subsequent changes in feeding patterns of ibex.

Spring: 16 April to 30 June

Summer: 01 July to 15 September

Autumn: 16 September to 30 November

Winter: 01 December to 15 April

Data were collected on several aspects related to the feeding ecology of ibex. Field methods included a quantification of vegetation parameters, for classification into vegetation associations and subsequent mapping. Data on ibex feeding were collected on a monthly basis, and later combined by season, for analysis. Phenology of plant species was recorded at 15-day intervals, on different aspects and at various altitudes. Plant material, to serve as standard material for microhistological analysis and for nutrient analysis, was also collected at the same sampling points. Faecal pellets of ibex were also collected on a monthly basis, and later combined by season, for analysis of seasonal food habits of ibex.

Laboratory methods included microhistological analysis of faecal material, to quantify the proportions of the plant species constituting the seasonal diet of ibex. Reference slides were prepared from plant material, to identify characteristic epidermal patterns of the various food plant species. Plant material was also used for nutrient analysis, and the species were analysed for crude protein content, calorific value (gross energy), ash content, and presence of tannins. These data were used to explain seasonal ibex food preferences.

CHAPTER 3. VEGETATION STRUCTURE AND COMPOSITION

3.1 Vegetation and herbivores

Vegetation, being the source of food for herbivores, partly determines the herbivore species that inhabit an area, and their densities. Other habitat characteristics, such as terrain and availability of water, also play a role in the herbivore species composition and abundance in an area.

Arctic and alpine vegetation have relatively low above-ground plant biomass levels (Billings 1974, Tieszen 1978), due to the short growing season which is limited by low temperatures. Strong desiccating winds and intense solar radiation are additional environmental stress factors that such vegetation is exposed to (Grime 1979). Very few plant species can cope with the harsh environmental conditions in the highest ranges, resulting in low vegetation density (Polunin and Stainton 1984). The high seasonality of the vegetation, and its relatively low biomass, can only support a correspondingly low ungulate biomass.

All ungulates would be affected in some way or another, by seasonality in food availability. In the vast African plains, rainfall is a major factor for the availability of food for the herbivores (Sinclair 1979). Scarcity of food during the dry season is responsible for migrations by animals like the wildebeest over large distances, in search of greener vegetation (Bell 1991). Altitudinal migrations are more localised, in which animals seasonally move over a range of altitudes, depending on the quality of food available. Such conditions are found in mountainous regions which experience snow fall. Here, vegetative growth is initiated by snow melt in the spring, beginning at lower altitudes, and slowly continuing upwards. Animals follow the fresh plant growth, in the process moving altitudinally upwards during the summer, and coming back to the lower areas

in the autumn, at the end of the growing season. Ibex is one of the few species of ungulates that is adapted to a relatively unproductive environment, and exhibits altitudinal migration.

3.2 High altitude vegetation

Compared to the tropics, which have very little seasonality, high precipitation, and support wooded forests of high biomass, areas at higher latitudes and altitudes have greater seasonality in temperature, and therefore in vegetation growth (Archibold 1995). Precipitation is also lower than in the tropics. Most of the precipitation in these regions is in the form of snow in winter. This precipitation is associated with the 'Westerly' disturbances, which originate in the Mediterranean (Dhar and Mulye 1987). Vegetation in these areas is temperate, and the broad-leaved species are deciduous, while the conifers remain evergreen. Further towards the poles, and at higher altitudes, is the tree-line, above which conditions are unsuitable for tree growth. The vegetation in such areas is mostly herbaceous, with some shrub species. These areas experience a great variation in temperature, and a relatively short period that is suitable for plant growth. Very low winter temperatures, accompanied by snow fall, make conditions difficult for survival. Some areas in these regions also experience minimal precipitation, and can therefore support mainly xerophytic species, giving them the alternate term 'cold deserts'.

Plants growing in such severe cold and dry conditions, have evolved morphological and physiological adaptations for survival (Billings 1974). The plants are usually perennial grasses or herbs, or dwarf shrubs growing close to the ground, with a relatively large root and/or rhizome system (*op. cit.*), for survival during the winter. The plants have the ability to germinate and carry on metabolism at high rates despite

the low atmospheric temperatures. They make best use of warmer temperatures during the summer, completing the production of photosynthetic tissue in the short favourable period (Archibold 1995). Most grasses grow in tussocks, which have dead leaves protecting the plant from desiccation by winds. Unlike annuals, which have to produce seeds by the end of the growing season, perennials have the advantage of vegetative reproduction, and can remain partially dormant through unfavourable periods, living on their underground food reserves.

A striking feature of most high altitude vegetation is its marked seasonality, with a short growing period (Archibold 1995). The plant has to complete all its phenological stages during the time of favourable temperature and precipitation levels. While some plant species have high requirement of sunlight for optimum growth, for other species, moisture might be a more important habitat factor. Moisture levels change with terrain and altitude, and exposure to sunlight changes with aspect, leading to changes in plant species associations at different altitudes and aspects.

In such a scenario, one would expect the vegetation to show definite spatial heterogeneity, in that species associations would vary with altitude and aspect, and other factors like soil type. Temporal changes in the form of seasonal phenology of the various species would also occur. These changes would affect the availability of food for the herbivores, and consequently affect their feeding and ranging behaviour.

3.3 Objectives

The goal of the vegetation study was to examine features that are of relevance to the ecology of ibex, in terms of diet composition and selection. The features of interest were the occurrence and abundance of plant species, and their phenology in

the study area, in relation to habitat features such as altitude, slope, and aspect, and the association of species into communities.

The vegetation description and quantification that formed part of this study was not meant as an exhaustive study of communities, but as a means of understanding the feeding ecology of ibex. The specific objectives of the vegetation study were:

- to determine the occurrence and relative abundance of plant species in the study area, in relation to altitude and aspect
- to examine whether plant species form distinct associations
- if they do, to examine changes in associations with habitat factors such as altitude, aspect and slope
- to determine seasonal changes in phenology, and relate these changes to the habitat factors.

3.4 Methods

Barbour *et al.* (1987) describe various sampling methods that have been used in the description of plant communities. The relevé method of Braun-Blanquet (1928, in Mueller-Dombois and Ellenberg 1974), using cover classes, has frequently been employed for vegetation studies in temperate regions (e.g. Hartmann 1968, 1983, Karunakaran *et al.* 1997). The method of classifying vegetation from relevé data, is given in extensive detail in Mueller-Dombois and Ellenberg (1974). Quadrat sampling, a modification of the relevé method, is especially useful for the quantification of ground vegetation. This method involves counting of individuals within appropriately sized quadrats, and using the abundance values for classification of the area into vegetation types. It has recently gained much relevance in vegetation studies, and is frequently

used (e.g. Auerbach and Shmida 1993, Peinado *et al.* 1995, Sharma and Johnsingh 1996).

If distinct vegetation entities that are required to decide the sampling pattern, are not readily recognisable, random, systematic or stratified random sampling (Mueller-Dombois and Ellenberg 1974) should be conducted. Stratification can be based on features like aspect or altitude, and quadrats sampled for cover, density, frequency, dominance, and importance. Density is estimated by counting the number of individuals of each species (abundance) within a quadrat, and extrapolating the value to a convenient unit area.

3.4.1 Vegetation quantification and analysis:

Stratified random sampling, a combination of systematic and random sampling, was done in this study, the strata being based on aspect and altitude. Sampling was done at regular intervals along the contour, considering a combination of altitude and aspect as a stratum.

The vegetation was mostly herbaceous, with relatively small plants constituting the ground layer, and therefore a small quadrat size (0.5 X 0.5 m) was sufficient to include most species in the samples. Four quadrats were laid at each sampling point. Within each quadrat, the number of individuals of each species was counted. Frequencies from four such quadrats that were laid close to each other, were pooled to comprise frequencies of what shall henceforth be called a 'plot'. A total of 208 such plots were sampled over the entire study area. Altitude, aspect and slope were also recorded at each sampling point. Data on cover were gathered by the point intercept method, by recording either soil, rock, litter, or plant species, in contact with or directly below the stretched thread, at intervals of 20 cm.

Analysis has now been made easy by the availability of computer programmes such as TWINSPAN (Two-Way INdicator SPecies ANalysis) (Hill 1979a), DECORANA (Hill 1979b), and CANOCO (ter Braak 1988). Classification of vegetation by TWINSPAN is based on the concept of dichotomy, in which samples are grouped on the basis of similar species combinations, first into two groups, then four, eight, sixteen, and so on. The analysis requires an input of abundance values of different species in the sample plots. DECORANA and CANOCO are popular computer packages that are widely used for ordination of vegetation. Many recent studies have used these computer programmes for classification and ordination of vegetation data (Schaminée *et al.* 1993, Fernández-Palacios and de Nicolás 1995, Kappelle *et al.* 1995, Porembski *et al.* 1995, Sharma and Johnsingh 1996). However, the final decision on where to halt division is entirely subjective, and requires an adequate field knowledge of the distribution of species in the area (Kershaw and Looney 1985).

The frequency data obtained from the vegetation plots were subjected to TWINSPAN analysis. Based on the major common species in each of the groups, species associations were identified. Since most grasses could not be identified to the species level, especially in their pre-flowering stages, all grasses have been considered together as graminoids.

A thorough reconnaissance and familiarisation prior to sampling is emphasised for the relevé method (Knapp 1984). For this reason, data collection for vegetation classification of the study area was conducted towards the end of the study.

3.4.2 Phenology:

Phenology was recorded at 15-day intervals throughout the growing period (late April to early September), at 13 locations, each location being a combination of one of

three altitudes, and one of seven aspects, but not necessarily exactly the same point for each sampling:

Aspect	Altitude (m)
South	3900, 4100, 4300
North	3900
East	3900, 4100, 4300
West	3900
Northeast	3900, 4100, 4300
Southwest	3900, 4100

Inaccessibility and time constraints did not allow sampling in areas with other combinations of altitude and aspect.

At each location, a 25 m thread was stretched along the contour, and all species that came in contact with the thread were recorded, along with their phenological state (sprout, young leaf, mature leaf, bud, flower, or fruit). The phenological stage that the majority of individuals of a species at each location were in, at the time of sampling, was considered the phenological stage for the species, for that particular combination of altitude and aspect in the entire study area.

3.5 Results

The flora of Pin Valley National Park was represented by 53 plant families, 196 genera and 378 species. A list of species is given in Appendix A. The largest representation of species was from the Family Asteraceae (51 species), followed by Poaceae (26 species), Fabaceae (24 species), and Brassicaceae and Ranunculaceae (30 species each). Of these, 8 species are threatened, 3 are rare, and 11 are endemic to the Western and North-western Himalaya (Aswal and Mehrotra 1994).

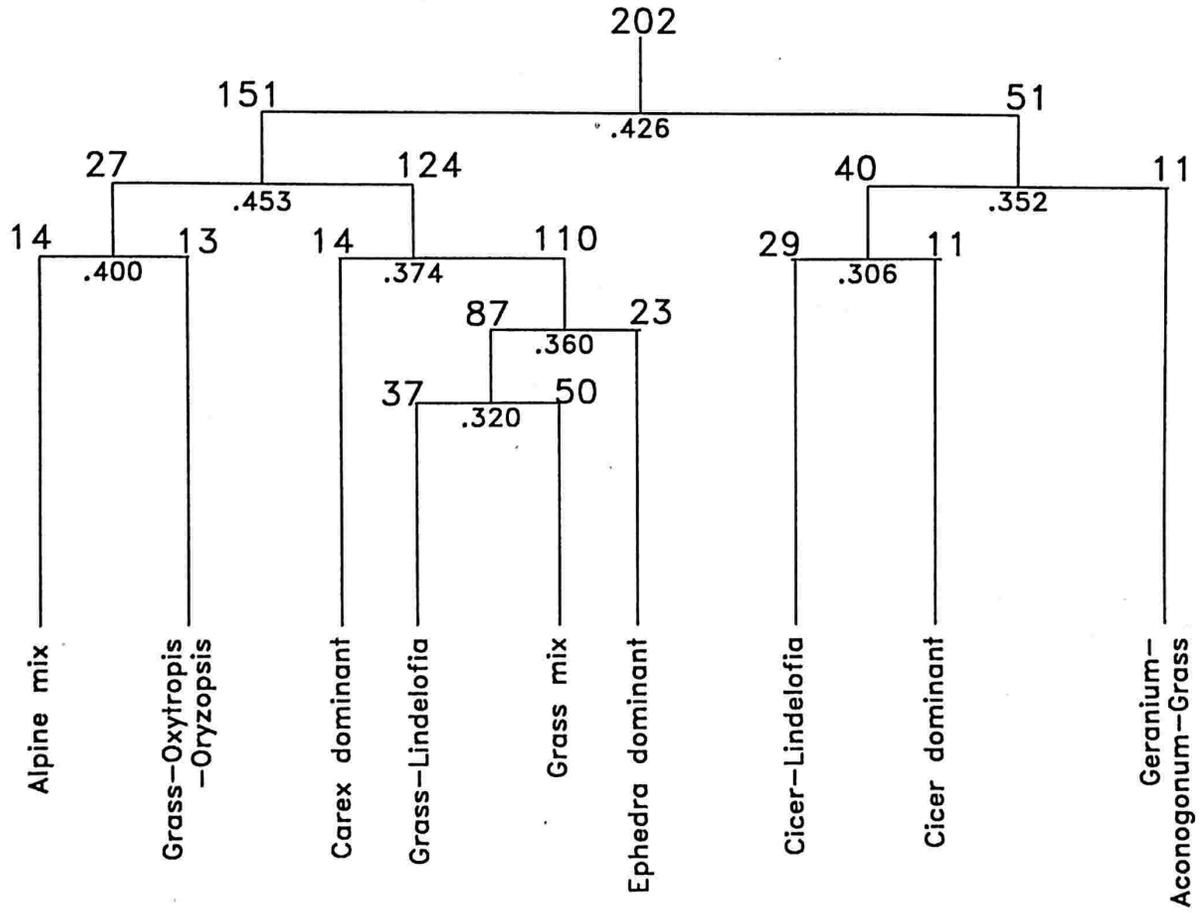
3.5.1 Vegetation associations:

The vegetation occurred in distinct species associations, each being governed by a combination of habitat characteristics, mainly altitude, aspect, and slope. Nine vegetation types were identified from the TWINSPAN output, based on the analysis of data from 202 of the 208 quadrats. They are represented in the form of a dendrogram (Figure 3.1), and each association is described below.

1. Alpine mix: This association represented 7% of the sampled area, and is made up of a number of herbaceous species, including *Geranium pratense*, *Potentilla atrosanguinea*, *Saxifraga* spp., *Silene* spp., *Leontopodium himalayanum*, and *Llyodia serotina*. *Oryzopsis* sp., *Stipa orientalis*, *Bromus* spp., *Poa alpina*, and *Festuca kashmiriana*, were among the grasses in this association. The vegetation cover was relatively dense (averaging 67.8%, and ranging from 52 to 91%), and was restricted to the higher altitudes (above 4000 m), to the N, NE, and E aspects, and to relatively steep slopes (30-35°).

2. *Oxytropis*-Grass-*Oryzopsis*: This association was also restricted to high altitudes, mostly above 4200 m, and accounted for 6.5% of the sampled area. Vegetation cover varied from 49 to 95%, the average being 73.9%. It occurred on slopes of 20-40°, without any obvious preference for aspect. Apart from *Oxytropis*, *Oryzopsis* and other grasses, this association also had *Geranium pratense*, *Nepeta* spp., and *Aconogonum tortuosum*.

Figure 3.1. Dendrogram showing vegetation associations in Pin Valley National Park, based on TWINSPAN classification.



(figures above each division indicate number of plots in each division, figures below each division are Eigen values).

3. *Carex* dominant: This association, making up 7% of the sampled area, was very distinctly dominated by the sedge, *Carex alpina*, and was found on plateaus or areas with very low inclination (<15°). Cover values ranged from 38 to 94%, with an average of 68.1%. It was associated with moist microhabitat, such as natural springs, and relatively flat areas, where water run-off is minimal. Species such as *Eritrichium canum* and *Seseli trilobum* were often found in association with *Carex alpina*.

4. Grass-*Lindelofia*: Several grass species, *Lindelofia anchusoides*, *Ephedra gerardiana*, *Bupleurum falcatum* and *Tragopogon gracile* were the major species constituting this vegetation association, which made up 18.3% of the area sampled. The association was widely distributed, occurring at altitudes ranging from 3650 to 4200 m, and on all aspects except N, NE, and NW, but mostly on the S aspect. It occurred mainly on slopes ranging from 30 to 40°, but was also found on the flatter areas with 0 to 15° slope. Vegetation cover ranged from 24 to 88%, averaging 58.1%.

5. Grass mix: Grasses were the major group constituting this association, with *Nepeta podostachys* and *Eritrichium* spp. also being found commonly. *Tragopogon gracile*, *Artemisia maritima*, *Astragalus candolleanus*, and *A. densiflorus* were less widespread. The association represented 24.7% of the sampled area, and cover value averaged 54.3% (ranging from 17 to 88%). It was found mostly on the E and N aspects, covering a wide altitudinal range, from 3700 to 4400 m, and all the slope categories (0-40°).

6. *Ephedra* dominant: The most frequent associate species of *Ephedra gerardiana* were grasses, especially *Stipa orientalis* and *Oryzopsis* sp., and *Lindelofia anchusoides*. Other associate species included *Tragopogon gracile*, *Eritrichium* spp., and *Dianthus*

angulatus. This association accounted for 11.4% of the sampled area, and cover values ranged between 12 and 81%, averaging 49%. It occurred only at altitudes below 4000 m, and very often on flat areas, especially in the valleys, although it also occurred on the N, E, SE, and S aspects, and sometimes on 20-35° slopes.

7. *Cicer*-Grass-*Lindelofia*: *Cicer microphyllum* and grasses were found in this association, along with *Lindelofia anchusoides*. Very few other species, such as *Nepeta podostachys*, were found in this association. It accounted for 14.3% of the area sampled. Vegetation cover ranged from 32 to 92%, averaging 59%. It was found on altitudes above 3900 m, and on most aspects. However, it was restricted to the steeper slopes, above 30°.

8. *Cicer* dominant: As the name suggests, this association was dominated by *Cicer microphyllum*. Grasses and *Scrophularia decomposita* were its associates. It represented 5.4% of the sampled area, with cover averaging 40.6% (ranging from 10 to 66%). It occurred mostly between 3900 and 4200 m, on most aspects, and seemed to prefer slopes of 30-35°.

9. *Geranium-Aconogonum*-Grass: This association made up 5.4% of the sampled area, with an average vegetation cover of 65.5% (ranging from 39 to 81%). Apart from *Aconogonum tortuosum*, *Geranium pratense* and grasses, this association had a few individuals of species such as *Nepeta podostachys* and *Astragalus densiflorus*. It was restricted to altitudes above 4000 m, on relatively steep slopes (30-35°), and seemed to prefer the E, SE, and NE aspects.

Among the shrub species, only *Rosa webbiana* was represented in the vegetation samples. This may be attributed to the patchy distribution of shrubs such as *Lonicera* spp. Species like *Juniperus communis* and *Cotoneaster duthieanus* occupied microhabitats in the cliffs, which were not included in the samples. *Salix denticulata* was typical of moist microhabitats, occurring in distinct patches along streams, as riverine vegetation.

Soil samples were not analysed during this study, but there were some obvious differences in soil types based on colour. For example, there was a clear zonation between red sandstone base and limestone base within the study area. *Caragana cuneata*, a thorny shrub, was only found on the limestone base. However, since the limestone soil occurred towards the drier parts of the valley, the occurrence of *C. cuneata* might also be related to lower moisture in the area.

3.5.2 Phenology:

The phenology data showed that the growing season, the period from the sprouting of the first species, to the seed set of the last species, lasted for about 135 days, being shorter in the areas of late snow melt. Vegetation growth began in spring, first on the southern aspect, which was most exposed to the sunlight, and where snow melt occurred earliest. Here, species such as *Lindelofia anchusoides*, *Arnebia euchroma*, *Polygonum filicaule*, *Bupleurum falcatum*, and some grasses began to sprout in the last week of April, when temperatures did not go below -5°C, and when there were relatively high moisture levels due to snow melt. This was followed by sprouting on the western aspect, then on the eastern and southwestern aspects. Vegetation growth began only towards the end of May on the northeastern aspect, and soon after on the northern aspect. Altitudinally, growth initiation followed snow melt,

with sprout beginning first at lower altitudes, and moving upwards. Species such as *Leontopodium himalayanum*, *Tanacetum gracile*, *Geranium pratense*, *Artemisia maritima*, and *Saussurea jacea* sprouted only towards the end of spring. Senescence occurred more evenly, with most species ending their growth period by the middle of September.

3.6 Discussion

Due to its location between the Greater Himalaya and the Tibetan Plateau, with the drainage flowing from west to east, Pin Valley exhibits a decrease in atmospheric moisture from west to east. There is a corresponding change in the vegetation, with more xerophytic species occurring downstream, adjoining the Spiti valley (*pers. obs.*).

Tieszen (1978) attributed patterns of plant species distribution to the abundance and availability of soil moisture. Fernández-Palacios and de Nicolás (1995) established that altitude and exposure to wind were the major environmental determinants of variation in the vegetation of Tenerife in the Canary Islands, Kappelle *et al.* (1995) attributed vegetation zonation to variations in altitude (and consequent differences in temperature) and to moisture gradients. Montalvo *et al.* (1993) suggested that availability of water influenced plant species diversity more than temperature, although the two factors were inversely correlated. Uhlig and Uhlig (1991) attributed vegetation changes to diurnal temperature fluctuations rather than to moisture at different altitudes, while aspect did not seem to affect these changes. According to Gerdol (1995), rich vegetation corresponded to a decrease in ion concentration and pH. Druitt *et al.* (1990) observed rapid changes in species composition close to the tree-line, and attributed this to changes in slope and soil nutrients. Tilman (1988) also emphasised the importance of soil type in determining plant species composition.

The influence of slope was apparent in most vegetation associations. While the *Ephedra* dominant and the *Carex* dominant associations preferred flatter terrain (0-15°), the *Oxytropis*-Grass-*Oryzopsis* association occurred on slopes of 20-35°. The alpine meadows, *Cicer*-Grass-*Lindelofia*, *Cicer* dominant, and *Geranium-Aconogonum*-Grass associations were found almost only on slopes of 30-35°, while Grass-*Lindelofia* and Grass mix associations occurred on a wider range of slopes, but mostly between 30 and 40°.

However, some vegetation associations were restricted to certain altitudinal ranges. For example, the *Ephedra* dominant and the *Carex* dominant association were restricted to the lower altitudes, while the alpine meadow, the *Oxytropis*-Grass-*Oryzopsis* and the *Geranium-Aconogonum*-Grass associations were restricted to the higher altitudes (above 4000 m). Preference for aspect was obvious only in three associations. The Grass-*Lindelofia* association was represented most on the S aspect, while the alpine mix and the *Oxytropis*-Grass-*Oryzopsis* seemed to prefer the N, NE, and E aspects.

Holway and Ward (1965) considered snow cover as the primary factor influencing phenology. Shaver and Kummerow (1992) attributed variation in phenophases between species to their morphological differences such as the location of their perennating buds, and intra-species variations to microclimatic differences in their location of growth. According to them, the major factor controlling the onset of growth was the timing of snow melt, and temperature. In the Rudranath area of the central Himalaya, growth initiation was earlier in species of smaller forms, like grasses and sedges, than in the larger forms (Ram *et al.* 1988). Such a pattern was, however, not apparent during this study. Negi *et al.* (1992) observed an equal division of tall forbs into categories of early and late growth initiation. They indicated that small forbs

overcome competition with tall forbs, for light and other resources, by having a shorter growth cycle than tall forbs, apart from the early growth initiation.

CHAPTER 4. IBEX FOOD HABITS

4.1 Introduction

It is important to understand the food habits of an animal, in terms of food availability and preference, for the evaluation and management of its habitat (Nelson and Leege 1982, Norton 1984). One of the most significant factors affecting the patterns of habitat use and behaviour of an animal, is the availability and quality of forage (Putman 1988).

The spatial and temporal distribution of food resources also influences the diet of herbivores. In highly seasonal environments, diet must change seasonally, to accommodate changes in forage quality and availability. In tropical regions, these changes are governed largely by rainfall, with distinct wet and dry seasons, whereas in temperate areas, temperature has a greater influence on the growing season (Putman 1988).

Most herbivores have to compromise on food, in the process of predator avoidance (Festa-Bianchet 1988). The concept of optimal foraging (MacArthur and Pianka 1966) accounts for the various factors that affect the diet of an animal. The optimality of a diet can be measured in terms of the net amount of energy gained in obtaining a food item, in comparison to the energy spent in searching for it, that is, the cost-benefit ratio of obtaining a particular food item. The value of a food item is determined by its nutritional value relative to the costs of acquiring it (MacArthur and Pianka 1966). In more productive environments, or in more productive seasons, although animals consume greater biomass, they usually have a more restricted diet in terms of the number of species constituting their diet, that is, they show high preferences for a few species only, since they have more to choose from.

Jarman (1974) stressed the importance of feeding style in the determination of group size and social structure. Based on their body size and digestive system, ungulate herbivores can be classified into foregut and hindgut fermenters. Foregut fermenters or ruminants are usually smaller than hindgut fermenters, and are usually concentrate or mixed feeders, depending on their size (Eisenberg 1981).

Based on feeding strategy, herbivores can be divided into concentrate feeders (selective), intermediate or mixed feeders (generalist, opportunistic, adaptable), and roughage feeders (non-selective, grass-eaters) (Hofmann and Stewart 1972), although this classification has recently been challenged (Robbins *et al.* 1995, Gordon and Illius 1996), on the basis that the categorisation is not valid solely on anatomical and physiological differences, and should also take into consideration food quality.

The Asiatic ibex, a ruminant, is an intermediate or mixed feeder (Hofmann 1973, quoted in Van Soest 1982). Its habitat is comparable to temperate and arctic regions, where there is extreme seasonality in forage availability and quality. It inhabits areas above the western Himalayan tree-line, where the vegetation is composed mainly of herbs, graminoids, and some shrubs. While there is an abundance of high-quality food resource in spring and summer, there is a decline in food quality in autumn (see Chapter 5), and in winter food is limited not only in quality but also in quantity, since most of the herbaceous vegetation and graminoids are covered in snow. During this time, ibex have to rely either on obtaining food from beneath the snow, or feeding on emergent woody plants. Greater search time and effort in winter, considering the patchy distribution of the preferred food resource, limits feeding efficiency of ibex in winter, although once ibex reached a patch, they were seen to feed intensively in a limited area (Bhatnagar 1997).

There are several methods that can be employed in food habit studies, and none of these methods is without its own weaknesses. Stewart (1967) advocated for the faecal analysis method, and mentioned the possibility of applying correction factors to account for differential digestibility.

The selection of methods depends on the detail required of the study, and the feasibility in terms of proximity to the animal. Direct observation and quantification of bites, oesophageal fistula, quantification of feeding signs, rumen analysis, and faecal analysis are some of the more commonly used methods in feeding studies of ungulates. The rumen analysis method requires the harvest of animals, either specifically for the purpose of rumen collection, or from hunter kills. Rumens obtained from animals that have died of natural causes such as predation, old age, or disease, can also be used.

4.2 Objectives

- to establish plant species constituting seasonal diets of ibex
- to determine preferences of food plant species by ibex
- to identify and explain seasonal changes in the diet of ibex
- to compare and evaluate methods used for food habit studies, with reference to ibex.

4.3 Methods

The year was divided into four seasons, as described in Chapter 2. Spring was the season of vegetative growth initiation, and vegetation cover was relatively sparse, because only a few species had sprouted, and had not attained their maximum biomass by then. In summer there was abundant vegetation, in terms of food for ibex, mostly in the flowering and fruiting stages. Senescence of vegetation set in in autumn,

and most of the vegetation was covered by snow in winter, limiting the availability of forage to ibex. Observations, and collection of plant and faecal material, were made in the winter of 1992-93, and the spring, summer and autumn of 1993 and 1994.

As mentioned in the previous chapter, among the grasses, only *Oryzopsis* sp. and *Stipa orientalis* could be differentiated in the field. Hence, all grasses were considered as a group, the **graminoids**. Faecal fragments could also not be differentiated to species level, and therefore all monocot fragments, including sedges, were considered as graminoids for the analysis.

Since hunting, which would make rumen samples available, is not allowed, and captive ibex are not available for experimentation, only direct observation, quantification of feeding signs and faecal pellet analysis were used as methods. Only two rumens could be collected from snow leopard kills, and were not considered for the analysis since they did not represent seasonal diets.

4.3.1 Direct observation:

This is the most commonly used method, which requires that the animals to be studied are habituated to human presence. While this method allows the quantification of utilisation, usually in terms of a bite count, it does not enable the simultaneous quantification of availability. A problem with this method has been the over-estimation of larger plants, with a corresponding under-estimation of the smaller plants that usually grow within the microenvironment of the larger plant, and are thus easily overlooked or are not visible from the distance of the observer. Also, the assumption that bites of different species are equal does not always hold. When animals feed on larger plants, they usually consume more than when they feed on small plants or selectively on certain parts of a plant.

During this study, it was attempted every month to follow a group of ibex, and record the feeding of one animal at a time by focal animal sampling (Altmann 1974). However, it was possible to get close enough to the animals only in two months, June and November, when the animals were at lower altitudes, in larger groups, and therefore less shy. The animals were watched from a distance of 10 to 25 m, through 8 X 30 binoculars, and a 10-40X spotting scope. Beyond 25 m, it was difficult to observe what the animal was feeding on. Each bite of the ibex, and the species that it was consuming, was recorded. When it went out of viewing distance, observation was begun on another individual that was within 25 m. The time that the focal animal spent in other activities was also recorded. A group scan (Altmann 1974) was also done, to record especially the proportion of time that the animals spent feeding.

4.3.2 Quantification of feeding signs:

This is one of the indirect methods of studying the feeding of ungulates, and is especially useful in the case of shy species that cannot be approached without causing disturbance and change in their behaviour due to the presence of the observer. Apart from quantifying utilisation by the species being studied, this gives an index of availability in the feeding area. The bias to this, however, is that the initial choice by the animals of the feeding site, is not accounted for.

The site at which a group of ibex was previously seen feeding, was visited soon after the animals left the site, so that fresh feeding signs could be differentiated from old ones. Quadrats (0.5 X 0.5 m) were randomly laid in the area, to record the number of individuals of each species present, and the number with feeding signs, within each quadrat. During winter, when the area was covered in snow, the method had to be modified. Ibex tracks in the snow were followed, and the species that had been dug

for (in feeding craters) were recorded. For availability data, the quadrat size had to be changed to 1 X 1 m, for the sake of convenience of digging up snow and recording the species underneath. Data were collected each month, and later divided into the four seasons for analysis.

Preference indices (PI) (Adams and Bailey 1983) were calculated by dividing the proportion of each species consumed, by the proportion of the species available to ibex. This was done separately for each season. A PI of 1.00 indicates consumption in proportion to availability, and therefore no selectivity. Values >1.00 indicate preference, and those <1.00 indicate avoidance, that is, the species are used in smaller proportions than their availability.

4.3.3 Microhistological analysis of faecal pellets:

This is another very widely used method (e.g. Stewart 1967, Todd and Hansen 1973, Green 1987), and its greatest advantage is that it does not involve the sacrifice or manipulation of animals (Holechek *et al.* 1982). Its advantage over the examination of feeding sites is that even species consumed in small proportions would be recorded. Such species, which are usually small plants, tend to be overlooked at feeding sites, either because they are totally consumed and do not leave any sign of their presence on the ground, or because they grow in close proximity of a bigger plant, and are therefore not recorded. The disadvantage of this method is that the proportions of some plants are over-represented, while those of some others are under-represented, due to differential digestibility. This bias has been much discussed in the literature (e.g. Vavra and Holechek 1980, Holechek *et al.* 1982), and the use of correction factors to account for differential digestibility has been suggested (Hansen *et al.* 1973, Dearden *et al.* 1975, Fitzgerald and Waddington 1979). To obtain these correction factors, the

in vitro dry matter digestibility of the food plant species has to be established, and requires the rumen fluid of the animal species under study. The method yields information only on seasonal utilisation, and would not indicate seasonal preferences of the animals, in the absence of data on availability.

The method involves two major steps. First, the preparation of reference material of the food plant species for the identification of epidermal and cellular characteristics of the species, and second, the microhistological examination of faecal material, to estimate the frequency of fragments of various plant species. Plant material was collected in the field, air-dried and then stored in air-tight labelled plastic bags, for later transportation to the laboratory. The plant material was separated by part, i.e. leaf, stem, flower, fruit. This material was ground to a fine powder (to fit a 1 mm mesh) and processed for microhistological examination as follows, based on the method of Sparks and Malechek (1968).

A small quantity of the powdered material was stirred in hot water for 1 minute, to partially remove pigments, which would otherwise obscure characteristic epidermal and cellular patterns of the species. The material was then passed through a fine sieve to remove particles that would be too small for identification. The remaining material was placed on a microscopic slide and to it was added a drop of Hertwig's clearing solution (Scott and Dahl 1980). The slide was then lightly heated until the liquid evaporated, to effect the action of the clearing solution in removing the remaining plant pigments by its bleaching action. After the slide had cooled, a drop of Hoyer's mounting medium (*op. cit.*) was added to it, and the plant material on the slide was evenly spread across the slide, before covering it with a cover slip. The slide was then heated slightly to remove excess mounting medium, and cooled with a moist cloth to remove air bubbles below the cover slip. The slides were oven-dried at 60°C, until the

mounting medium hardened. In the same way, slides were prepared for each of the plant species collected. The slides were viewed under a microscope at 100X magnification, and characteristic epidermal patterns were identified and a diagram was made for each characteristic pattern, for later comparison with fragments found in faecal material. Reference slides of 50 plant species and their parts were made, based on initial field identification of ibex food plant species.

Fresh faecal pellets of ibex were collected in the field every month. The faecal material was also air-dried in field, and stored in labelled plastic bags. In the laboratory, faecal pellet composites were made on a seasonal basis, with the spring composite consisting of 15 pellet groups, summer 16, autumn 15, and winter 23. This material was then prepared for microhistological analysis in the same way as the plant material. Five slides were prepared from each composite, that is, a sample of five slides for each season.

A few assumptions underlie the procedure (Johnson 1982): (i) The plant fragments are randomly distributed on the slide, (ii) The fragments are of equal size, and (iii) dry weight densities of the different plant species are equal. Twenty microscope fields were examined on each slide, and all the identifiable fragments in these fields were recorded. The percent of each species constituting the diet was determined by dividing the number of identifiable fragments of each species by the total number of identifiable fragments, and multiplying by 100, following Sparks and Malechek (1968). Holechek (1982) used other bleaching agents in the treatment of plant material for microhistological analysis.

Seasonal differences in consumption of the major species was examined for statistically, using the chi-square test (Siegel 1956).

4.4 Results

4.4.1 Direct observations:

As mentioned earlier, it was possible to obtain data by this method only in June and November, when ibex could be approached to less than 25 m. Since these data did not represent all seasons, they were not considered for analysis.

4.4.2 Seasonal diet composition, and preferences, based on feeding signs:

An examination of the number of species consumed in each season, revealed that ibex used 5 of 13 species recorded in the quadrats in spring, 20 of 41 in summer, 13 of 40 in autumn, and 20 of 25 in winter (Table 4.1). Ibex movement in winter was restricted by snow, and they were observed to feed in areas that were relatively snow-free because of exposure to wind, such as cliffs and ridges.

The top five food plant species consumed accounted for 70-100% of the diet in each season, and were considered as the 'major' species of the season. In spring, only 34 of the 1267 (2.68%) of the plants available in the sampled area (quadrats) had been fed on. This proportion was higher in the other seasons, with 280 of 1710 (16.37%) fed on in summer, 165 of 749 (22.03%) in autumn, and 354 of 556 (63.67%) in winter.

On an average, preference indices (PIs) among the species consumed, were highest in spring (10.79, range: 5.35 to 20.23), followed by autumn (1.97, range: 0.28 to 4.55) and summer (1.16, range: 0.19 to 6.22), and lowest in winter (0.98, range: 0.35 to 1.57). This indicates greatest selectivity in spring, and least in winter.

Table 4.1. Seasonal availability, use and preference of plant species by ibex in Pin Valley National Park, based on feeding signs.

SEASON	SPECIES	NO. AVL.	NO. FED	% AVL.	% USED	P.I.
SPRING	*Lindelofia anchusoides*	24	13	1.89	38.24	20.23
	Graminoids	56	15	4.42	44.12	9.98
N = 1267	*Ephedra gerardiana*	19	3	1.50	8.82	5.88
	Bupleurum falcatum	6	2	0.47	5.88	12.51
	Ferula jaeschkeana	7	1	0.55	2.94	5.35
	Astragalus prostratus	1	0	0.08	0.00	0.00
	Chaerophyllum villosum	3	0	0.24	0.00	0.00
	Chenopodium album	25	0	1.97	0.00	0.00
	Nepeta podostachys	24	0	1.89	0.00	0.00
	Polygonum filicaule	104	0	8.21	0.00	0.00
	Rosa webbiana	3	0	0.24	0.00	0.00
	Galium serpylloides	170	0	13.42	0.00	0.00
	Bromus sp. (also a graminoid)	825	0	65.11	0.00	0.00

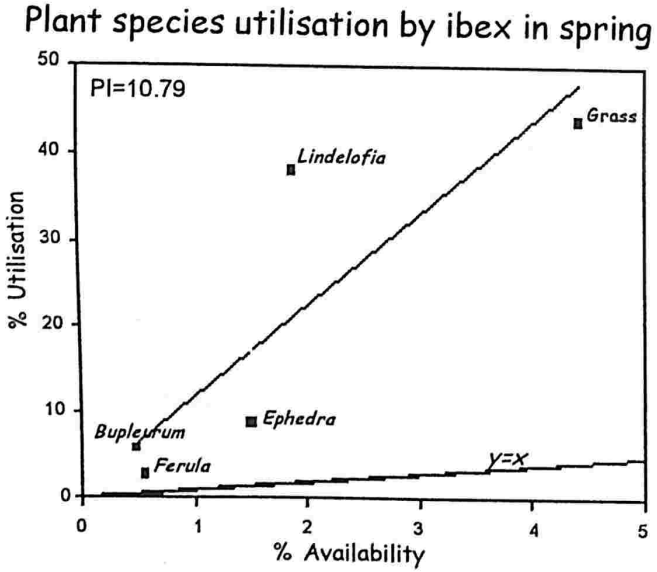
SUMMER	*Cicer microphyllum*	360	173	21.05	61.79	2.94
	Graminoids	241	32	14.09	11.43	0.81
N = 1710	*Lloydia serotina*	55	9	3.22	3.21	1.00
	Epilobium sp.	88	5	5.15	1.79	0.35
	Tragopogon gracile	4	4	0.23	1.43	6.22
	Astragalus densiflorus	17	4	0.99	1.43	1.44
	Arenaria serpyllifolia	3	1	0.18	0.36	2.00
	Polygonum aviculare	64	2	3.74	0.71	0.19
	Potentilla cuneata	9	1	0.53	0.36	0.68
	Eritrichium canum	23	2	1.35	0.71	0.53
	Aconogonum tortuosum	28	1	1.64	0.36	0.22
	Nepeta podostachys	111	17	6.49	6.07	0.94
	Rhodiola heterodonta	23	7	1.35	2.50	1.85
	Geranium pratense	129	6	7.54	2.14	0.28
	Silene sp.	33	6	1.93	2.14	1.11
	Astragalus candolleanus	17	3	0.99	1.07	1.08
	Rosularia alpestris	14	1	0.82	0.36	0.44
	Potentilla atrosanguinea	19	1	1.11	0.36	0.32
	Leontopodium himalayanum	15	0	0.88	0.00	0.00
	Bistorta affinis	7	0	0.41	0.00	0.00
	Bergenia stracheyi	9	0	0.53	0.00	0.00
	Cotoneaster duthieanus	20	0	1.17	0.00	0.00
	Arabidopsis/Draba	23	0	1.35	0.00	0.00
	Ephedra gerardiana	5	0	0.29	0.00	0.00
	Festuca kashmiriana	5	0	0.29	0.00	0.00
	Gagea lutea	1	0	0.06	0.00	0.00
	Lindelofia stylosa	5	0	0.29	0.00	0.00
	Polygonum filicaule	21	0	1.23	0.00	0.00
	Potentilla bifurca	24	0	1.40	0.00	0.00
	Tanacetum gracile	23	0	1.35	0.00	0.00
	Thalictrum foetidum	34	0	2.00	0.00	0.00
	Thymus serpyllum	14	0	0.82	0.00	0.00
	Galium sp.	165	0	9.65	0.00	0.00
	Artemisia maritima	2	0	0.12	0.00	0.00
	Linum perenne	4	0	0.23	0.00	0.00
	Lonicera hypoleuca	1	0	0.06	0.00	0.00
	Potentilla arbuscula	2	0	0.12	0.00	0.00

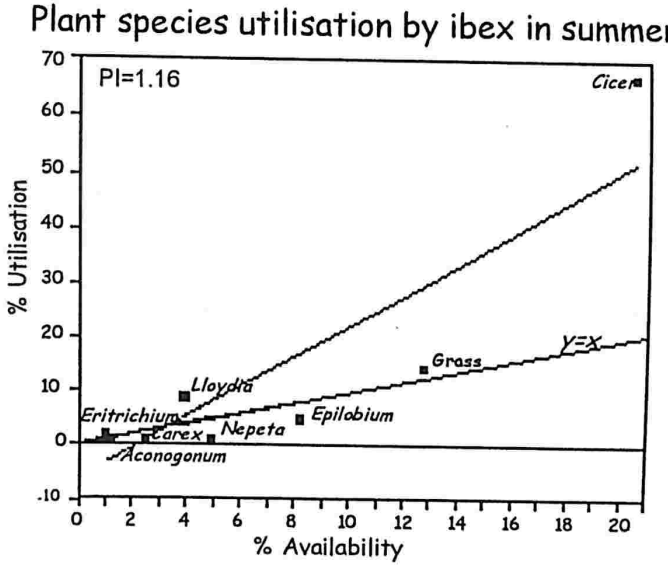
AUTUMN	*Bupleurum falcatum*	6	5	0.80	3.03	3.79
	Tragopogon gracile	2	2	0.27	1.21	4.48
N = 749	*Cicer microphyllum*	207	129	27.64	78.18	2.83
	Artemisia maritima	7	2	0.93	1.21	1.30
	Potentilla atrosanguinea	14	4	1.87	2.42	1.29
	Astragalus densiflorus	12	1	1.60	0.61	0.38
	Geranium pratense	26	2	3.47	1.21	0.35
	Graminoids	214	11	28.57	6.67	0.23
	Tanacetum gracile	4	3	0.53	1.82	3.43
	Rhodiola heterodonta	3	3	0.40	1.82	4.55
	Thalictrum minus	14	1	1.87	0.61	0.33
	Oxytropis cachemiriana	13	1	1.74	0.61	0.35
	Lloydia serotina	2	1	0.27	0.61	2.26
	Aconogonum tortuosum	8	0	1.07	0.00	0.00
	Allium sp.	10	0	1.34	0.00	0.00
	Arenaria serpyllifolia	1	0	0.13	0.00	0.00
	Arnebia euchroma	2	0	0.27	0.00	0.00
	Astragalus candolleanus	3	0	0.40	0.00	0.00
	Bergenia stracheyi	2	0	0.27	0.00	0.00
	Bistorta affinis	5	0	0.67	0.00	0.00
	Chenopodium album	6	0	0.80	0.00	0.00
	Cotoneaster duthieanus	6	0	0.80	0.00	0.00
	Cousinia thomsonii	1	0	0.13	0.00	0.00
	Arabidopsis/Draba	5	0	0.67	0.00	0.00
	Ephedra gerardiana	1	0	0.13	0.00	0.00
	Epilobium sp.	7	0	0.93	0.00	0.00
	Eritrichium canum	5	0	0.67	0.00	0.00
	Leontopodium himalayanum	3	0	0.40	0.00	0.00
	Lindelofia anchusoides	4	0	0.53	0.00	0.00
	Linum perenne	13	0	1.74	0.00	0.00
	Nepeta podostachys	29	0	3.87	0.00	0.00
	Polygonum aviculare	71	0	9.48	0.00	0.00
	Polygonum filicaule	21	0	2.80	0.00	0.00
	Potentilla cuneata	2	0	0.27	0.00	0.00
	Saxifraga sp.	7	0	0.93	0.00	0.00
	Silene sp.	7	0	0.93	0.00	0.00
	Thymus serpyllum	4	0	0.53	0.00	0.00

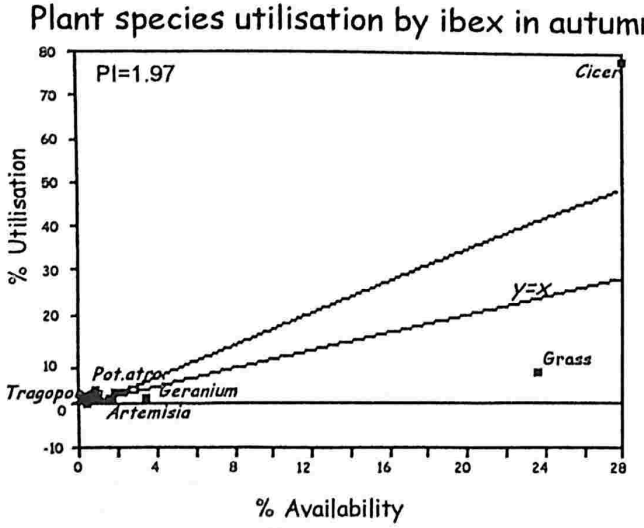
WINTER	*Rosa webbiana*	88	86	15.83	24.29	1.53
	Arnebia euchroma	31	30	5.58	8.47	1.52
N = 556	*Artemisia maritima*	100	85	17.99	24.01	1.33
	Bupleurum falcatum	30	24	5.40	6.78	1.26
	Tragopogon gracile	35	24	6.29	6.78	1.08
	Hyssopus officinalis	16	10	2.88	2.82	1.00
	Ephedra gerardiana	24	12	4.32	3.39	0.78
	Ferula jaeschkeana	20	10	3.60	2.82	0.78
	Cicer microphyllum	37	11	6.65	3.11	0.47
	Aconogonum tortuosum	3	2	0.54	0.56	1.04
	Astragalus candolleanus	10	8	1.80	2.26	1.26
	Astragalus prostratus	15	4	2.70	1.13	0.42
	Graminoids	83	32	14.93	9.04	0.61
	Lindelofia anchusoides	15	6	2.70	1.69	0.63
	Lindelofia stylosa	2	1	0.36	0.28	0.78
	Linum perenne	8	5	1.44	1.41	0.98
	Nepeta podostachys	5	2	0.90	0.56	0.62
	Seseli trilobum	9	2	1.62	0.56	0.35
	Epilobium sp.	1	0	0.18	0.00	0.00
	Lonicera hypoleuca	3	0	0.54	0.00	0.00
	Potentilla arbuscula	19	0	3.42	0.00	0.00
	Polygonum filicaule	2	0	0.36	0.00	0.00

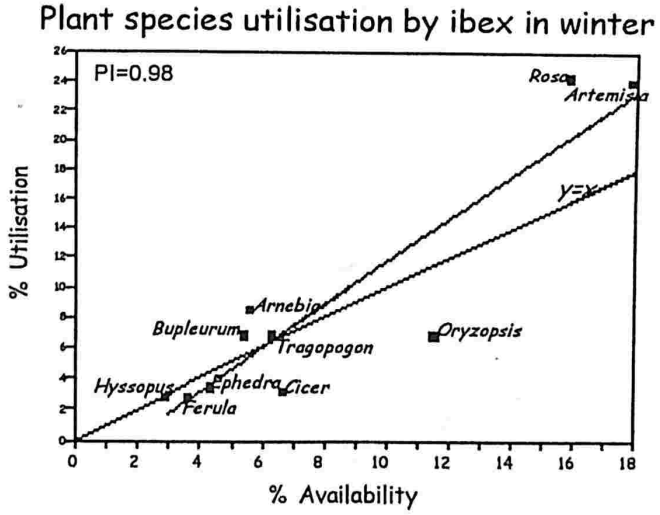
Graminoids (44.12%) and *Lindelofia anchusoides* (38.24%) were important components of the diet in spring. All five species consumed in this season had high preference indices, ranging from 5.35 in *Ferula jaeschkeana* to 20.23 in *Lindelofia anchusoides* (Figure 4.1). In summer, although *Cicer microphyllum* (61.79%) made up the greatest part of the diet, graminoids (11.43%) were also important. Among the major species consumed in summer, *Tragopogon gracile* had the highest PI value (6.22), although it was accounted for by only four feeding signs in the later part of summer. Ibex also showed a preference for *Cicer microphyllum* (PI=2.94) in summer, while other species of the diet did not show much preference. In autumn, when the plants began to senesce, ibex switched from a diet of primarily leaves, to a diet consisting of both leaves and fruits. In this season, *Cicer microphyllum* (78.18%, PI=2.83) continued to be the dominant species in the diet, although fruits of *Bupleurum falcatum* (PI=3.79) and *Tragopogon gracile* (PI=4.48) were preferred more (Table 4.1). In winter, graminoids and herbaceous species such as *Cicer microphyllum* (availability = 6.65%) were difficult to access beneath the snow, and were therefore less available than more woody species, such as *Rosa webbiana* (15.83%) and *Artemisia maritima* (17.99%), that did not get completely buried in the snow. While the fruits of *Rosa webbiana* accounted for 24.29% of the diet in winter, *Artemisia maritima* made up 24.01%. *Arnebia euchroma* (8.47%), and the fruits of *Bupleurum falcatum* and *Tragopogon gracile* (6.78% each) also constituted part of the winter diet of ibex. Preference indices did not deviate much from 1.00 for any species in the winter diet (Figure 4.1).

Figure 4.1. Seasonal utilisation of plant species by ibex in relation to availability, indicating preferences.









4.4.3 Seasonal diet composition, based on faecal pellet analysis:

A greater number of food plant species were identified by this method, when compared to the analysis of feeding signs. While 18 plant species were identified from faecal fragments in spring, 19 were found for summer, 16 for autumn, and 20 for winter (Table 4.2). The top five species in each season accounted for ca. 60-84% of the diet (Table 4.3). Graminoids dominated the diet in spring (40.17%) and summer (28.62%), while in autumn, *Bupleurum falcatum* (27.50%) and *Cotoneaster duthianus* (20.77%) formed a major portion of the diet. In winter, *Seseli trilobum* (25.43%) was the dominant species in the diet, followed by *Ephedra gerardiana* (20.47%) and *Bupleurum falcatum* (19.53%).

The major species varied in the proportion of the diet that they constituted in most seasons. The presence of graminoids showed significant differences ($P<0.001$) between all seasons except between autumn and winter ($\chi^2=2.75$, between 11.87 and 138.90 in other seasons). *B. falcatum* showed significant differences between all seasons, except between winter and autumn ($\chi^2=10.57$), and between spring and summer ($\chi^2=3.0$, between 35.80 and 78.12 in other seasons). *S. trilobum* showed significant differences only between summer and winter ($\chi^2=59.82$), and between winter and autumn ($\chi^2=35.34$). *C. falconeri* showed significant differences between all seasons (χ^2 ranging from 47.38 to 150.00). *E. gerardiana* showed significant differences between all seasons (χ^2 ranging from 15.42 to 137.64), except between summer and autumn, when it was not present. *C. microphyllum* showed significant differences between all seasons except between winter and autumn, when it was absent, and between spring and summer ($\chi^2=9.50$, between 36.94 and 78.95 in other seasons). *A. maritima* showed significant differences only between spring and autumn ($\chi^2=13.32$), and between spring and winter ($\chi^2=15.60$).

Table 4.2. Seasonal food plant species of ibex in Pin Valley National Park, Himachal Pradesh, based on feeding signs, and faecal pellet analysis.

SPECIES	SPRING		SUMMER		AUTUMN		WINTER	
	FS	FP	FS	FP	FS	FP	FS	FP
Graminoids	*	*	*	*	*	*	*	*
Bupleurum falcatum	*	*		*	*	*	*	*
Seseli trilobum		*		*		*	*	*
Lindelofia spp.	*	*		*		*	*	*
Arnebia euchroma		*		*		*		*
Cicer microphyllum		*	*	*	*		*	
Astragalus prostratus		*						
Rosa webbiana		*		*		*		*
Ephedra gerardiana	*	*					*	*
Artemisia maritima		*		*		*	*	*
Ferula jaeschkeana	*	*					*	*
Astragalus spp.		*	*	*	*		*	
Arenaria serpyllifolia		*	*	*	*	*		*
Cotoneaster duthieanus		*		*		*		*
Tanacetum gracile		*		*		*		*
Aconogonum tortuosum		*	*				*	
Polygonum filicaule		*						
Rhodiola heterodonta		*	*		*			
Tragopogon gracile			*	*	*	*	*	*
Geranium pratense			*	*	*	*		*
Potentilla atrosanguinea			*	*	*	*		
Leontopodium himalayanum				*				*
Thymus serpyllum				*		*		*
Thalictrum foetidum				*	*			*
Eritrichium canum			*			*		*
Hyssopus officinalis						*		
Lloydia serotina			*		*			
Epilobium sp.			*					
Nepeta podostachys			*				*	
Silene sp.			*					
Polygonum aviculare			*		*		*	
Potentilla cuneata			*				*	
Rosularia alpestris			*				*	
Oxytropis cachemiriana					*			
Linum perenne							*	

FS = feeding signs; FP = faecal pellets.

Table 4.3. Plant species in the diet of ibex in Pin Valley National Park, Himachal Pradesh, based on faecal pellet analysis.

SEASON	SPECIES	#	%
SPRING	Graminoids	241	40.17
	Bupleurum falcatum	64	10.67
(16th April to 30th June)	*Seseli trilobum*	53	8.83
	Lindelofia spp.	44	7.33
N = 600	*Arnebia euchroma*	41	6.83
	Cicer microphyllum	39	6.50
	Astragalus prostratus	25	4.17
	Rosa webbiana (fruits)	22	3.67
	Ephedra gerardiana	17	2.83
	Artemisia maritima	14	2.33
	Ferula jaeschkeana	13	2.17
	Astragalus spp.	9	1.50
	Arenaria serpyllifolia	7	1.17
	Cotoneaster duthieanus	3	0.50
	Tanacetum gracile	3	0.50
	Aconogonum tortuosum	2	0.33
	Polygonum filicaule	2	0.33
	Rhodiola heterodonta	1	0.17
SUMMER	Graminoids	172	28.62
	Cicer microphyllum	70	11.65
(1st July to 15th September)	*Cotoneaster duthieanus*	57	9.48
	Seseli trilobum	53	8.82
N = 601	*Tragopogon gracile*	49	8.15
	Bupleurum falcatum	47	7.82
	Artemisia maritima	35	5.82
	Astragalus spp.	31	5.16
	Geranium pratense	29	4.83
	Arnebia euchroma	20	3.33
	Potentilla atrosanguinea	12	2.00
	Tanacetum gracile (flowers)	11	1.83
	Arenaria serpyllifolia	5	0.83
	Rosa webbiana (fruits)	4	0.67
	Leontopodium himalayanum	2	0.33
	Thymus serpyllum	2	0.33
	Lindelofia spp.	1	0.17
	Thalictrum foetidum	1	0.17

AUTUMN (16th September to 30th November) N = 549	*Bupleurum falcatum*	151	27.50
	Cotoneaster duthieanus	114	20.77
	Graminoids	79	14.39
	Seseli trilobum	65	11.84
	Artemisia maritima	37	6.74
	Tanacetum gracile (flowers)	30	5.46
	Tragopogon gracile (flowers)	25	4.55
	Arenaria serpyllifolia	17	3.10
	Eritrichium canum	10	1.82
	Arnebia euchroma	6	1.09
	Thymus serpyllum	6	1.09
	Rosa webbiana (fruits)	4	0.73
	Geranium pratense	2	0.36
	Hyssopus officinalis	1	0.18
	Lindelofia spp.	1	0.18
	Potentilla atrosanguinea	1	0.18
WINTER (1st December to 15th April) N = 645	*Seseli trilobum*	167	25.43
	Ephedra gerardiana	132	20.47
	Bupleurum falcatum	126	19.53
	Graminoids	72	11.63
	Arenaria serpyllifolia	45	6.98
	Tanacetum gracile	28	4.34
	Artemisia maritima	23	3.57
	Lindelofia spp.	14	2.17
	Cotoneaster duthieanus	9	1.40
	Arnebia euchroma	5	0.78
	Rosa webbiana (fruits)	5	0.78
	Thymus serpyllum	5	0.78
	Tragopogon gracile	4	0.62
	Thalictrum foetidum	3	0.47
	Eritrichium canum	2	0.31
	Ferula jaeschkeana	2	0.31
	Leontopodium himalayanum	2	0.31
	Geranium pratense	1	0.16

Seven species accounted for 76.7% of the overall diet. These included graminoids (21.96%, range: 11.63 to 40.17%), *Bupleurum falcatum* (16.20%, range: 7.82 to 27.50%), *Seseli trilobum* (13.99%, range: 8.82 to 25.43%), *Cotoneaster duthieanus* (7.52%, range: 0.50 to 20.77%), *Ephedra gerardiana* (6.22%, range: 0 to 20.47%), *Cicer microphyllum* (4.55%, range: 0 to 11.65%), and *Artemisia maritima* (4.55%, range: 2.33 to 6.74%).

In every season, a few species that were recorded from feeding signs, were not found in the faecal pellets. In spring, only five species had feeding signs on them. In the faecal matter, however, 18 species, including the five species recorded in the feeding sites, were found to constitute the diet. In summer, seven species were common to both methods. A total of 30 plant species were identified in the summer diet, based on results of both methods. Of these, 11 species were found only from feeding signs, while 12 were exclusive to faecal analysis. In autumn, there were 22 species in the diet of ibex, of which 7 were common to both methods, 6 were exclusive to feeding signs, and 9 to faecal analysis. In winter, a total of 27 species were recorded by the two methods, of which 12 were common to both methods, 7 exclusive to feeding signs, and 8 to faecal analysis. Of the top five species, three each were common to the two methods in the spring and summer diets, two in autumn, and one in winter.

4.5 Discussion

4.5.1 Ibex diet:

The overall diet, based on results from both methods, consisted mainly of forbs and graminoids. The proportion of graminoids in the diet decreased with advancing season and an increase in the consumption of forbs. Ibex showed shifts in their diet

to specific parts of shrubs, generally fruits, in winter. This can be attributed to easier access to these food items, since herbaceous vegetation is covered in snow during winter, and has a lower nutrient value than the fruits of the emergent species such as *Rosa webbiana*, *Lindelofia* spp., *Bupleurum falcatum*, and *Cotoneaster duthieanus* (see Chapter 5). Adams and Bailey (1983) found that among the food plants in the winter diet of mountain goats, *Festuca* sp. was highly preferred, being utilised on the windswept ridges. The preference of *Artemisia* sp. was very high in the first year of their study, but dropped drastically in the severe winter of the second year of study, presumably because the species occurred mainly in areas of snow accumulation, limiting its availability to the animals. Results from this study conform to those of Korfhage *et al.* (1980), who found from faecal analysis that the summer diet of Rocky Mountain elk (*Cervus elaphus*) consisted of graminoids in high proportions in early summer, and forbs in late summer. Browse was eaten both in early and late summer. While changes in phenology, and subsequently in quality of vegetation probably influenced the diet of ibex in spring, summer, and autumn, availability seemed to be the major limiting factor of the ibex diet in winter. Adamczewski *et al.* (1988) found snow to be a factor limiting the availability of food to caribou (*Rangifer tarandus*) in Canada.

4.5.2 Preferences:

Nudds (1980) discussed the concept of preferences in deer, and indicated that foraging is probably non-random, with animals moving through patches of differentially favourable microhabitats. Except for spring, when all species that were fed on had high preference indices (Table 4.1), ibex did not show very high preferences in the other seasons. The seasonal variation in PI values indicates changes in feeding strategy, from specialist diet in spring, to more generalist in winter. The quality of the food plant

species probably determines this selection (see Chapter 5). The generalist feeding strategy in winter can be attributed to the low availability and quality of food during this season. Tixier *et al.* (1997) also compared utilisation of plant species by roe deer with availability, and found some species in each season to be significantly preferred or avoided. They also found that the proportion of species in the diet being preferred, was highest in spring (81.6%), and decline with advancing season (73% in summer, 62.3% in autumn, and 38.1% in winter). The proportion of species avoided was highest in autumn (18.5%) and summer (16.8%), and relatively low in winter (8.1%) and spring (6.5%).

In spring, when very few species had sprouted, ibex showed a high preference for *Lindelofia anchusoides*, *Bupleurum falcatum*, and graminoids (Table 4.1). The greater potential biomass of the above species, and therefore greater bite size might have influenced their high PI values, compared to those of the smaller species such as *Polygonum filicaule*, *Galium* sp., and *Bromus* sp., which contributed to the availability in terms of numbers of individuals, but not in terms of actual biomass. More species became available in summer, when ibex did not show very high preference for the species available. In autumn, preferences were again higher, probably due to the early senescence of some species, leaving fewer species of adequate/higher nutritional value available to ibex to choose from. In winter, when food was of the lowest quality, and availability was constrained by accessibility beneath the snow, ibex became opportunistic feeders, feeding on all emergent species in the snow, and also digging for some species in the snow.

A similar pattern was seen in mountain goats (*Oreamnos americanus*) in southeast Alaska (Fox and Smith 1988). As the preferred food plants became scarce, and the search time for procuring sufficient food became prohibitively large, Spanish

ibex (*Capra pyrenaica*) expanded their diet by including less preferred items (Alados and Escos 1987), leading to a lower rate of movement in times when the quality of food is low. McCorquodale (1993) found that elk mobility reduced with selectivity, from spring to winter. It has been established that temperate ungulates build up fat reserves in the seasons of abundant and high quality food (Robbins 1983), which will help maintain the physiology of the animals through winter. The low food quality in winter is adequate only for maintenance and not for growth, and therefore large-scale movements would not be cost-effective for the animals. This is discussed in greater detail in the next chapter. Harper *et al.* (1967, in Nelson and Leege 1982) concluded that seasonal forage preferences of Roosevelt elk were also influenced strongly by forage availability and phenology. They found that graminoids made up more than half the diet during all seasons and were especially important during winter months, constituting more than three-fourths of the forage intake. Forbs were used during summer and autumn, but were unimportant in winter and spring. Loggers (1991) demonstrated high selectivity in diets of Dorcas gazelles, in that use and availability showed very low correlation. Seasonal diets of the gazelles also differed significantly.

4.5.3 *Utility of methods:*

From the use of different methods in this study, it is clear that there is no one best method for the evaluation of the feeding habits of ibex. Each method has its limitations, which need to be accounted for while analysing the data. Mofareh *et al.* (1997) compared three techniques commonly used in the determination of the diet of grazing herbivores, bite count, and microhistological analysis of oesophageal extrusa and faeces, and found that although the techniques did not give similar estimates of the diets of steers, the importance ranking of the top 3 species in the diet, based on the

different techniques, were not different. Anthony and Smith (1974) concluded that faecal analysis is the only feasible method of studying the diet of secretive or endangered species. Kessler *et al.* (1981) and Holechek *et al.* (1982) advocated for faecal analysis, despite its limitations. Havstad and Donart (1978) suggested careful interpretation of results, taking into account the assumptions that the technique is subjected to. Johnson and Wofford (1983) found that faecal analysis gave relatively accurate estimates of diet composition. However, Grill *et al.* (1983) did not advise the use of faecal analysis for mixed feeders, due to differential digestibility of different food types (forbs, shrubs, and graminoids). Fox and Smith (1988) found that the biases of microhistological analysis of faecal material did not alter the conclusion regarding the major components of the diet. MacLeod *et al.* (1996), from their study of the diet of bushbuck in South Africa, found that analysis of faecal material was efficient and cost-effective. Mohammad *et al.* (1995) compared the faecal and rumen analysis methods to estimate cattle diets, and found faecal analysis to be the most appropriate technique for studying diets without surgery, and to obtain greater sample sizes.

The major problem with feeding site examination is that small species are more easily overlooked than larger ones. Also, the study of a feeding site yields data of very localised feeding, while results from faecal analysis are usually samples of the diet over larger area, and possibly more varied habitat. In autumn, when plants were dry, it was difficult to differentiate fresh from old feeding signs. However, this method has the distinct advantage that, apart from data on feeding, it yields data on availability of plant species in the feeding site, which is essential in determining relative preference, and avoidance, of species that constitute the diet. Edge *et al.* (1988) determined forage use by elk from feeding site analysis, and recommended additional studies to address feeding site selection within habitats. Wydeven and Dahlgren (1983) supplemented

rumen analysis with feeding site examination. Johnsingh and Sankar (1991) used the feeding site method of Lovaas (1958) to quantify feeding, and deduce preferences.

The utility of faecal analysis in the determination of the diet of large ungulates has been much debated. The most criticised aspect of this method is the differential digestion of various plant species, and of the same species at various phenological stages (e.g. Nelson and Leege 1982, McInnis *et al.* 1983). For example, graminoids are known to be less easily digested, and therefore show up more than some highly digestible dicots. Even the same species is generally more easily digestible in its earlier phenological stages than when it is mature and senescing. There are also some species which have very distinct epidermal patterns that cannot be overlooked during microhistological analysis, while others are less distinct. Fruits are usually quite indistinct, that is, with no characteristic microscopic patterns, and tend to be under-estimated during quantification of plant fragments. Correction factors, which incorporate the effects of digestion on each species, have been used to account for differential digestibility (Hansen *et al.* 1973). The factors are derived by *in vivo* or *in vitro* digestion trials, both of which require tame animals. Dearden *et al.* (1975) and Fitzgerald and Waddington (1979) stressed the application of correction factors to relative densities or proportion of fragments from faecal analysis. Vavra *et al.* (1978) were of the view that actual percentages of a species in the diet were less important than their relative importance values. Advantages of this method include, as mentioned earlier, sampling of a wider range of feeding area, since the animals move from one place to another, and over a larger span of time, since the passage rate in large ruminants ranges between 24 and 120 hours (Stewart 1967). Voth and Black (1973) considered the feeding bout during each activity period as a meal. The day is usually divided into six

feeding bouts, and throughput time of food is about five days, based on which they established that a pellet represents a mixture of at least 30 meals.

During this study, faecal analysis was the most consistent method, in that faecal pellets could be collected throughout the year, while the method for feeding site examination had to be modified in winter, due to snow cover. Direct observations, as already mentioned, could not be made for all seasons.

On comparison of results from the two methods of data collection during this study, discrepancies were evident. These discrepancies, and possible explanations follow.

In spring, of the 18 species found in the diet by faecal analysis, feeding signs were observed only on five species. Graminoids, in both cases, made up the highest proportion of the diet. The species with greatest discrepancy in this season was *Lindelofia anchusoides*, which made up a great proportion of the diet based on feeding signs, but showed up much less in faecal analysis. This difference could be attributed to the fact that the feeding sites that were examined were representative of only a small part of the overall area that ibex fed in, and that the vegetation of the area sampled was dominated by *Lindelofia anchusoides*. Other species that were found only from faecal analysis in spring, made up smaller proportions (mostly <2%) of the diet.

The major difference in results from the two methods in summer and autumn was that of *Cicer microphyllum*, which made up 61.79% and 78.18% respectively, of the diet from feeding sign data. Faecal analysis showed a proportion of only 11.65% in summer, and was not found in the autumn faecal sample. The reason for this is that ibex fed mainly on the flowers of *Cicer microphyllum*, which did not have distinctive epidermal patterns for identification in the faeces. Other species did not show as much variation between the methods, and species such as *Lloydia serotina*, which were fed

on, were not found in the faeces. This might be attributed to the soft and therefore easily digestible tissue of such species. Species such as *Lindelofia* spp., *Seseli trilobum*, and *Thymus serpyllum* were not found in the feeding sites, but occurred in small proportions in the faeces. This could be a result of sampling as well as of indistinct epidermal features of the fragments in the faeces.

In winter, more species were common to the results of the two methods, which could be explained by the lower availability of species to ibex, and consequently less choice for the animals. Species such as *Thymus serpyllum* and *Tanacetum gracile* were found in the faeces, but not at feeding sites. *Nepeta podostachys* and *Hyssopus officinalis*, among others, were found fed on along ibex tracks in the snow, but were not present in the faecal sample. The above indicates the inadequacies of either method by itself, to record the entire spectrum of food plant species of ibex. The two methods, if used to supplement each other, would yield a better understanding of the diet of ibex over the seasons.

Although the diet of ibex is made up mainly of graminoids and forbs, it is seasonally supplemented with flowers and fruits. As in all temperate ungulates, it is strongly influenced by the phenology and availability of vegetation. The feeding strategy of ibex depends on availability and abundance of food plant species. In late summer and autumn, they are generalist feeders, being able to adapt to changes in phenology and availability of vegetation. They are selective only in spring and early summer, the times of abundant food availability, and are non-selective or opportunistic feeders in winter when food is limiting.

CHAPTER 5. FORAGE QUALITY

The importance of the various nutritional components of an animal's diet has long been recognised, and seasonal changes in food composition have been recorded (e.g. Short *et al.* 1966, Johnston *et al.* 1968). Herbivore diets are more complex than those of carnivores, because the variation in composition of plant material is much greater than that of animal material. To obtain a balanced diet, a herbivore has to consume a variety of plants, while a carnivore can get all its nutritional requirements from a single prey species (Westoby 1974).

5.1 Ungulate herbivores and the constituents of their diet

From the point of view of a herbivore, plants have positive nutrients, and negative nutrients (digestive inhibitors and toxins) (Borges 1989), which influence food choice. Positive nutrients include carbohydrates, proteins, fats, and minerals, which are essential in the physiological functioning of the animal's system (Robbins 1983). Negative nutrients are deterrents to herbivory (Westoby 1978), and include structural constituents like fibre, and silica, as well as plant defence mechanisms in the form of secondary compounds like tannins. These negative nutrients often reduce the digestibility of the positive nutrients. For example, tannins bind with proteins, resulting in lower digestibility of the proteins (Robbins 1983).

One component of studies on the nutrition of ungulates deals with aspects of change in their diet, based on the quality of food available to them. Variations in chemical composition of food plants can be attributed to phenological differences, corresponding to seasonal factors like temperature, rainfall and snow fall, and terrain factors like aspect and altitude. Interest in the nutritional aspect of wildlife science

probably originated with studies on livestock, dealing with nutritional deficiencies, and measures to improve milk and meat yield for commercial purposes (Church 1975). However, the earlier studies dealt mainly with positive diet constituents, paying very little attention to factors like toxins and dietary inhibitors. It was later realised that food choice did not always correspond to changes in the proximal nutrient factors, leading to investigations into other dietary factors that might possibly act as deterrents to herbivores (*op. cit.*). Secondary compounds were found to be such deterrents. They have no role to play in the physiology of the plant, and their function was best explained in terms of their role in the plant's anti-herbivore defence mechanism.

The chemical composition of herbivore faeces has also been used as an indicator of diet quality, mostly in terms of nitrogen content (e.g. Erasmus *et al.* 1978, Koerth *et al.* 1984, Green 1985, Leslie and Starkey 1985, 1987, Irwin *et al.* 1993), although it has inherent biases like the over-estimation of nitrogen content, because of ruminal microflora that pass out with faeces, as well as because of tannins forming indigestible bonds with some of the plant proteins before they are digested (Robbins *et al.* 1987a). High levels of tannins lead to low palatability, reduced consumption by the herbivore, and increased faecal nitrogen levels (Bernays *et al.* 1989).

Plant material is at its highest nutritive value during the period of active vegetation growth (e.g. Goodson *et al.* 1991b). In temperate regions, this coincides with spring, when snow melts and temperatures begin to rise to levels favourable for plant growth. With advancing maturity, levels of protein, carbohydrates and digestibility decrease, and there is a corresponding increase in fibre content and lignification, making the plant less palatable to the herbivore. During winter, plants are dormant and at a correspondingly low nutritive state, with an increase in the proportion of structural constituents such as lignin, and therefore lower digestibility. A food plant of highest

quality would be one with high crude protein content, high calorific value, low tannin levels, low fibre, and low ash content.

Proteins contain carbon, hydrogen, oxygen, and a fairly constant percentage of nitrogen (an average of 16%, ranging between 18.9% in nuts and 15.7% in milk protein) (Maynard and Loosli 1969, Robbins 1983). Therefore, to calculate protein content, it is accepted to estimate the nitrogen content, and multiply this value by the factor 6.25 (100/16) (*op. cit.*). The resulting estimate is 'crude' protein, since all plant and animal nitrogen is not necessarily in the form of protein, and the exact proportion of nitrogen to protein may not be known (*op. cit.*). Nitrogen in plants and animals can also be found in the form of nucleic acids and nitrates.

Most plant protein is found within the cytoplasm of the cell, with only small amounts associated with the cell wall. Plant protein increases during early growth or regeneration when active anabolic processes occur (Robbins 1983). Thereafter, it decreases with increasing vegetative maturity, as plants produce more nitrogen-free cell wall components, which are carbohydrates - cellulose, hemicellulose and pectin, for structural support. Early growth in grasses, forbs and browses can often have as much as 20-30% protein on a dry-weight basis, but the protein subsequently falls to as little as 3-4% at maturity (*op. cit.*).

The gross energy of plant or animal material is measured as 'calorific value', and has been found to be relatively uniform, varying usually only between 3.5 and 5 kcal/g of dry matter (Robbins 1983). Evergreen and alpine plant communities are known to have a higher energy content than the normal range (*op.cit.*, Hacker and Ternouth 1987). Energy content of plant seeds ranges from 4.3 to 6.8 kcal/g dry weight, and is directly related to their fat content (Robbins 1983). Plant leaves and stems are

generally less variable than seeds in energy content, and contain energy ranging from 3.9 to 5.1 kcal/g of their dry weight.

Ash is the inorganic matter of plant material, constituted of silica and minerals. Minerals include major essential elements such as Ca, K, Mg, Na, S, and P, trace elements such Fe, Mn, Cu, Co, I, Zn and Si, and non-essential elements like Ti, Al, B and Pb (McDonald *et al.* 1987). Although these minerals are found in low quantities in plants, they are important in the proper functioning of the animal's system. One of the more important minerals for the animal is sodium, which is vital for the functioning of the nervous system. However, a major portion of the ash content is made up of silica, which plays an important role in the mechanical defence of the plant.

Since plant carbohydrates, proteins, and lipids are easily degraded, the development of protective and defensive agents has been an important step in plant evolution (Robbins 1983). Plants can have two types of protective mechanisms, one in the form of physical defences, like spines and thorns, and the other in the form of structural barriers, like lignin, cutin, suberin, and biogenic silica, that impede digestive enzymes or microorganism attack. Plants also produce chemical defences in the form of secondary plant compounds, that interfere with growth, neurological and tissue functioning, reproduction, and digestion (Hanley 1997).

The three most prevalent groups of plant secondary compounds are soluble phenolics (including condensed tannins), alkaloids, and terpenoids (Robbins 1983, Purves *et al.* 1995). The defensive properties of these compounds are primarily due to their ability to bind with proteins and other macromolecules, thereby precipitating cellular proteins, inactivating digestive enzymes, and possibly forming indigestible macromolecules with cell wall carbohydrates.

Tannins occur in 17% of non-woody annuals, 14% of herbaceous perennials, 97% of deciduous woody perennials, and 87% of evergreen woody perennials (Robbins 1983). They prevent bacterial, viral, and fungal attacks, as well as herbivory by both invertebrates and vertebrates. Work on tannins in food plants, and their effects on herbivores includes, Freeland and Janzen (1974), Swain (1977), Rosenthal and Janzen (1979), Owen-Smith (1982), Kumar and Singh (1984), Cooper and Owen-Smith (1985), Schwartz and Hobbs (1985), Robbins *et al.* (1987a), Robbins *et al.* (1987b), Bernays *et al.* (1989), Owen-Smith and Cooper (1989), Raubenheimer (1992), Snyder (1992), and Purves *et al.* (1995). Other secondary compounds like alkaloids, flavonoids, and quinones, have not been given as much attention as tannins (Swain 1977, Owen-Smith and Cooper 1989, Hanley *et al.* 1992).

Plant toxins like alkaloids and glycosides, are qualitative antiherbivore mechanisms, and are effective in small quantities, often less than 2% the dry weight of plant tissue (Cates and Rhoades 1977). They usually affect the nervous system of the herbivore (Purves *et al.* 1995). They are found in flowers and young leaves of annuals and herbaceous perennials, and are less costly for the plant to produce.

5.2 Constraints of an arctic or temperate ungulate

The process of food selection in an animal should take into account the balance between nutrients, and digestion inhibitors and toxins, in such a way that the animal gets as much nutrition from its diet as possible, without being adversely affected by the toxins that the plant material might contain. Crude protein is acknowledged as a reliable indicator of overall nutrient status and palatability (Rodgers 1990). Ruminal activity in ruminants is depressed when the diet contains less than 7% crude protein and negative digestibility occurs below 3% crude protein intake (Robbins 1983). Intake

is also reduced in such conditions, because food is of very low digestibility, and therefore requires greater rumination time (Crawley 1983).

Herbivores in temperate regions are physiologically adapted to cold temperatures and low food availability, by lowering of the metabolic rate as an energy conservation mechanism during winter (Moen 1978). Ruminating time in arctic ruminants, e.g. reindeer, moose (*Alces alces*), and muskox (*Ovibos moschatus*), increase in winter, when quality and quantity of forage are low (Van Soest 1982).

5.3 Objectives

- to estimate quality of individual forage species
- to examine seasonal changes in forage quality

5.4 Methods

5.4.1 Collection of plant material:

Material from major forage species was collected in the field twice every month during the growing season, and once a month during the rest of the year. Samples were collected on N, S, E, W, NE and SW aspects, and at altitudes of 3900 m, 4100 m, and 4300 m (see Section 3.2.2, in Chapter 3). Inaccessibility and time constraints did not allow the collection of samples at 4100 m and 4300 m on the N and W aspects, and at 4300 m on the SW aspect, and on the NW and SE aspects.

Samples were hand-plucked, to simulate a mouthful of an ibex. Each sample was placed in a paper bag and labelled, with species, aspect, altitude and date of collection. On reaching the base-camp, samples were air-dried.

Before laboratory analysis, samples were separated into different plant parts, mainly leaf and stem, and flower and fruit when available. These were dried in the

oven for 24 hours at 60°C, before grinding in an electric grinder for analysis. Seasonal changes in crude protein, calorific value, and ash content of the leaves of forage species was determined. Flower and fruit samples were also analysed whenever relevant. Qualitative analysis for tannin content of forage was also done. Digestibility of forage could not be estimated for want of captive animals required for these trials.

5.4.2 Chemical analyses:

Crude protein: Nitrogen content was estimated by the Kjeldahl method (AOAC 1975). Percent crude protein, on a dry matter basis, was calculated by multiplying total nitrogen by a factor of 6.25.

Calorific value: Gross energy (kcal/g) of plant samples was estimated by igniting them in a Gallenkamp ballistic bomb calorimeter.

Ash content: Percent ash was estimated by combustion of a sample of known weight in a muffle furnace at 600°C for 6 hours. The proportion of the residue left after the combustion of organic matter in the sample, is the ash content for that species.

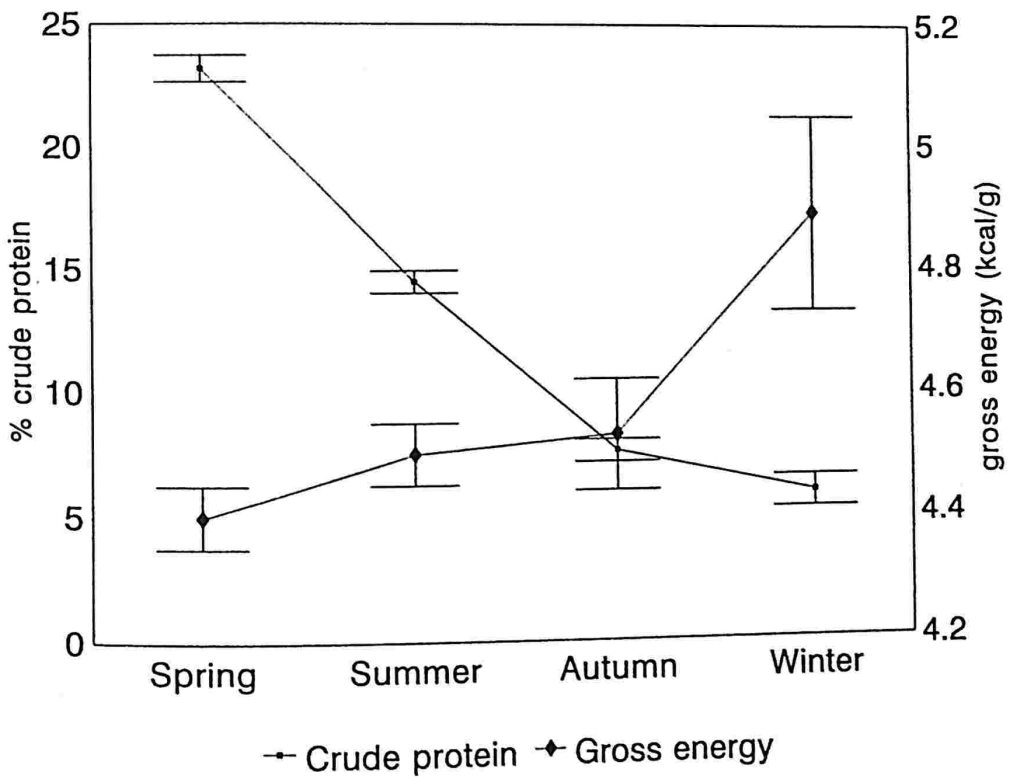
Tannin content: Tannins were estimated qualitatively in the different forage species, by a modification of the acid-vanillin method (Burns 1971).

Plants at different altitudes and on different aspects were not examined for differences in calorific value, and ash content, during their various phenological stages.

5.5 Results

Chemical analyses revealed a seasonal change in forage quality, with food plant species being of the highest nutritional value in spring, and steadily decreasing in quality over summer and autumn, to the lowest in winter (Figure 5.1).

Figure 5.1. Seasonal changes in nutritional content of food plant species of ibex in Pin Valley NP



5.5.1 *Crude protein:*

Crude protein levels were highest in spring (mostly >20%, mean 23.2±0.54 SE), when plants were in their sprouting stage (Table 5.1). Among the important herbaceous food plant species, the leaves of *Cicer microphyllum* had the highest crude protein value in spring (30.78%), others ranged between 12.29% (*Tragopogon gracile*), and 29.83% (*Astragalus prostratus*). Crude protein values in these herbaceous species

decreased with advancing phenology (14.5±0.46 in summer, 7.6±0.45 in autumn, and 5.9±0.64 in winter). Crude protein levels dropped to between 2.51% in grass, and 8.75% in *Cicer microphyllum* during winter, the period of plant senescence. *Ephedra gerardiana*, an evergreen species, did not exhibit much change in crude protein levels (Table 5.1), and *Lonicera hypoleuca*, a shrub, showed relatively high crude protein content in winter (21.42%). In summer, levels of crude protein of most forage species were between 10% and 23%, *Astragalus prostratus* and *Seseli trilobum* having the highest values, 22.88% and 22.65% respectively. Crude protein content continued decreasing through autumn, and further in winter (Figure 5.1).

5.5.2 Calorific value:

Calorific values showed a slight increase with plant maturity (4.40±0.05 kcal/g in spring, 4.50±0.05 in summer, 4.53±0.09 in autumn, and 4.89±0.16 in winter), with a slight tendency to increase with senescence, and the corresponding presence of fruit and seed in winter (Figure 5.1). Many species had values of >5 kcal/g in winter, with *Ferula jaeschkeana* and *Astragalus candolleanus* having the highest values, 5.99 and 5.85 kcal/g respectively (Table 5.2). *Ephedra gerardiana* did not show much change in calorific content over the seasons.

5.5.3 *Ash content:*

There was not much seasonal change in the ash content of the forage (Figure 5.1), with the leaves of most species having highest ash content in spring, ranging from 5.37% in *Thalictrum foetidum*, to 11.5% in *Arnebia euchroma* (Table 5.3). *Arnebia euchroma* showed exceptionally high ash content in summer (17.76%) and autumn (17.89%).

Table 5.1. Seasonal crude protein content of major food plant species of ibex in Pin Valley National Park.
(number of samples analysed are in parantheses)

SPECIES	PERCENT CRUDE PROTEIN			
	Spring	Summer	Autumn	Winter
Aconogonum tortuosum	22.56 (3)	13.31 (4)	5.80 (5)	--
Arnebia euchroma	19.13 (7)	14.37 (6)	8.34 (2)	4.89 (1)
Artemisia maritima	25.15 (7)	17.04 (7)	6.93 (7)	5.13 (3)
Astragalus prostratus	29.83 (4)	22.88 (3)	10.98 (2)	--
Astragalus densiflorus	24.47 (6)	20.62 (4)	11.63 (2)	--
Astragalus candolleanus	26.18 (7)	16.27 (3)	--	3.59 (2)
Bupleurum falcatum	23.23 (7)	13.78 (4)	5.50 (1)	4.04 (4)
Chaerophyllum villosum	26.13 (4)	--	--	--
Cicer microphyllum	30.78 (7)	17.34 (7)	8.09 (4)	8.75 (1)
Cicer flowers	--	15.43 (2)	--	--
Cotoneaster duthieanus	--	--	6.11 (1)	--
Cotoneaster fruits	--	--	8.85 (1)	--
Cousinia thomsonii	19.14 (1)	--	--	4.38 (1)
Ephedra gerardiana	11.26 (6)	13.31 (3)	10.00 (1)	9.39 (3)
Ephedra flowers	14.31 (1)	--	--	--
Ferula jaeschkeana	28.80 (1)	--	--	5.54 (1)
Geranium pratense	--	11.16 (4)	--	--
Graminoids	24.69 (6)	11.08 (12)	4.32 (4)	2.51 (2)
Hyssopus officinale	20.77 (2)	--	--	5.43 (1)
Leontopodium himalayanum	21.38 (2)	7.87 (2)	7.50 (1)	--
Lindelofia anchusoides	24.54 (9)	15.69 (9)	9.74 (5)	8.04 (1)

Lindelofia stylosa	28.68 (4)	20.60 (3)	18.85 (1)	6.30 (1)
Linum perenne	27.22 (2)	--	--	4.67 (1)
Lonicera hypoleuca	--	--	--	21.42 (1)
Nepeta podostachys	22.47 (8)	13.99 (8)	7.90 (3)	--
Nepeta flowers	--	11.48 (4)	7.40 (1)	--
Nepeta sp.	--	17.15 (1)	--	--
Onosma hispidum	--	--	--	3.85 (1)
Oryzopsis sp.	21.83 (7)	13.55 (5)	5.02 (2)	2.62 (1)
Polygonum filicaule	15.90 (1)	9.21 (5)	10.16 (2)	--
Potentilla atrosanguinea	14.52 (2)	10.47 (3)	4.20 (1)	--
Rhodiola heterodonta	16.80 (3)	--	--	--
Ribes glaciale	--	--	--	6.13 (1)
Rosa fruits	7.45 (1)	--	8.65 (1)	6.38 (2)
Seseli trilobum	25.89 (1)	22.65 (3)	4.66 (1)	5.57 (2)
Tanacetum gracile	--	5.69 (1)	--	--
Tanacetum flowers	--	11.85 (1)	--	--
Thalictrum foetidum	28.71 (1)	15.80 (5)	5.03 (1)	--
Tragopogon gracile	12.29 (1)	11.95 (5)	7.87 (2)	--
Tragopogon flowers	--	10.24 (1)	8.29 (2)	--

Table 5.2. **Seasonal calorific value of major food plant species of ibex in Pin Valley National Park.**
(number of samples analysed are in parantheses)

SPECIES	CALORIFIC VALUE (kcal/g)			
	Spring	Summer	Autumn	Winter
Aconogonum tortuosum	4.29 (2)	4.53 (2)	4.18 (3)	--
Arnebia euchroma	4.15 (5)	3.79 (4)	4.13 (2)	3.49 (1)
Artemisia maritima	4.19 (6)	5.27 (3)	4.66 (5)	5.44 (1)
Astragalus prostratus	4.24 (2)	4.50 (2)	5.42 (1)	--
Astragalus densiflorus	4.49 (4)	4.48 (3)	4.62 (1)	--
Astragalus candolleanus	4.52 (4)	4.75 (2)	--	5.85 (1)
Bupleurum falcatum	4.56 (4)	4.84 (4)	4.44 (1)	4.95 (3)
Chaerophyllum villosum	3.86 (4)	--	--	--
Cicer microphyllum	4.41 (5)	4.22 (6)	3.63 (2)	--
Cicer flowers	--	4.05 (1)	--	--
Cotoneaster duthieanus	--	--	5.33 (1)	--
Cotoneaster fruits	--	--	5.29 (1)	--
Cousinia thomsonii	4.20 (1)	--	--	5.17 (1)
Ephedra gerardiana	4.48 (6)	4.56 (4)	4.51 (1)	5.15 (3)
Ferula jaeschkeana	4.11 (1)	--	--	5.99 (1)
Geranium pratense	--	4.43 (3)	--	--
Graminoids	4.75 (4)	4.55 (8)	4.65 (4)	3.96 (2)
Hyssopus officinale	3.95 (1)	--	--	5.33 (1)
Leontopodium himalayanum	3.78 (1)	4.03 (2)	--	--
Lindelofia anchusoides	4.60 (8)	4.19 (8)	3.69 (2)	--
Lindelofia stylosa	4.59 (4)	4.19 (3)	--	3.43 (1)

Linum perenne	4.97 (1)	--	--	5.23 (1)
Nepeta podostachys	4.47 (3)	5.00 (7)	5.04 (2)	--
Nepeta flowers	--	4.50 (1)	4.85 (1)	--
Nepeta sp.	--	4.61 (1)	--	--
Onosma hispidum	--	--	--	3.36 (1)
Oryzopsis sp.	4.79 (4)	4.34 (4)	4.86 (2)	5.47 (1)
Polygonum filicaule	4.61 (1)	4.19 (2)	4.80 (1)	--
Potentilla atrosanguinea	4.14 (2)	4.76 (2)	4.34 (1)	--
Rhodiola heterodonta	4.10 (3)	--	--	--
Ribes glaciale	--	--	--	4.64 (1)
Rosa fruits	--	--	3.85 (1)	5.03 (2)
Seseli trilobum	4.05 (1)	4.59 (2)	4.32 (1)	4.98 (2)
Thalictrum foetidum	4.60 (1)	4.87 (4)	--	--
Tragopogon gracile	4.14 (1)	4.58 (4)	--	--
Tragopogon flowers	--	4.13 (1)	4.78 (2)	--

Table 5.3. Seasonal ash content of major food plant species of ibex in Pin Valley National Park.
(number of samples analysed are in parantheses)

SPECIES	PERCENT ASH			
	Spring	Summer	Autumn	Winter
Aconogonum tortuosum	7.58 (3)	6.66 (2)	6.56(5)	--
Arnebia euchroma	11.50 (6)	17.76 (4)	17.89 (2)	--
Artemisia maritima	9.56 (7)	8.74 (6)	7.69 (7)	3.50 (1)
Astragalus prostratus	6.55 (3)	9.08 (2)	9.70 (2)	--
Astragalus densiflorus	7.33 (5)	7.72 (3)	8.72 (2)	--
Astragalus candolleanus	6.21 (4)	8.77 (3)	--	6.76 (1)
Bupleurum falcatum	6.80 (5)	7.16 (4)	7.44 (1)	2.65 (3)
Chaerophyllum villosum	10.37 (4)	--	--	--
Cicer microphyllum	9.63 (4)	10.19 (7)	12.11 (4)	--
Cicer flowers	--	5.42 (2)	--	--
Cotoneaster duthieanus	--	--	3.51 (1)	--
Cotoneaster fruits	--	--	3.87 (1)	--
Cousinia thomsonii	9.33 (1)	--	--	6.29 (1)
Ephedra gerardiana	5.86 (8)	6.05 (4)	5.93 (1)	5.42 (3)
Ephedra flowers	8.53 (1)	--	--	--
Ferula jaeschkeana	9.56 (1)	--	--	1.40 (1)
Geranium pratense	--	5.48 (4)	--	--
Graminoids	8.14 (4)	5.49 (12)	3.87 (5)	2.10 (2)
Hyssopus officinale	8.20 (1)	--	--	--
Leontopodium himalayanum	11.20 (2)	6.95 (2)	8.50 (1)	--
Lindelofia anchusoides	8.73 (8)	13.04 (8)	15.43 (3)	--

Lindelofia stylosa	8.13 (4)	13.11 (3)	13.83 (1)	19.01 (1)
Linum perenne	7.55 (2)	--	--	1.15 (1)
Nepeta podostachys	10.46 (5)	10.20 (7)	8.23 (3)	--
Nepeta flowers	--	8.07 (4)	6.87 (1)	--
Nepeta sp.	--	9.09 (1)	--	--
Oryzopsis sp.	7.04 (4)	8.38 (5)	8.81 (3)	--
Polygonum filicaule	8.62 (1)	3.75 (3)	8.15 (2)	--
Potentilla atrosanguinea	10.50 (2)	4.53 (3)	4.79 (1)	--
Rhodiola heterodonta	8.96 (3)	--	--	--
Rosa fruits	3.73 (1)	--	4.96 (1)	3.58 (2)
Seseli trilobum	8.69 (1)	7.94 (2)	8.06 (1)	5.03 (2)
Tanacetum gracile	--	9.87 (1)	--	--
Tanacetum flowers	--	5.67 (1)	--	--
Thalictrum foetidum	5.37 (1)	7.46 (3)	--	--
Tragopogon gracile	7.89 (1)	7.47 (5)	5.66 (1)	--
Tragopogon flowers	--	4.32 (1)	6.17 (2)	--

Lindelofia spp. also showed an increase in ash content from spring to autumn, while *Ephedra gerardiana* did not show much change in ash content over the seasons.

5.5.4 Tannins:

Ephedra gerardiana, *Polygonum filicaule*, *Aconogonum tortuosum*, and *Cotoneaster duthieanus* had tannins at all phenological stages, whereas some species showed the presence of tannins only during the later phenological stages (e.g. *Potentilla atrosanguinea*, and *Geranium pratense*). The flowers of *Cicer microphyllum* and *Nepeta podostachys* also showed the presence of tannins.

5.6 Discussion

The analysis of forage species over the seasons showed a decrease in crude protein (CP) content from spring to winter. Calorific content showed a slight increase with season, while ash content remained relatively constant over the seasons. These results conform with studies of the chemical composition of temperate plant species elsewhere (e.g. Short *et al.* 1966, Wallmo *et al.* 1977).

5.6.1 Crude protein content:

Young grass leaves had high crude protein levels in spring (24.69%), which then decreased quite rapidly with plant growth, to a lowest of 2.51% during winter. Legumes, known for their ability to fix atmospheric nitrogen, have correspondingly high overall crude protein levels, as seen in *Cicer microphyllum* during this study. *C. microphyllum* showed a decrease in crude protein content, from 30.78% in spring, to 8.75% in winter. Minson (1976, in Jones and Wilson 1987) found legumes to contain 15-18% crude protein, while grasses contained 6-9%. Montane temperate herbaceous plants are also known to be of higher quality in terms of their higher crude protein

levels (Jones and Wilson 1987), and lower fibre content (Geist 1974b) than their tropical counterparts.

Goodson *et al.* (1991b) studied feeding of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) in winter, and found that protein in the diet decreased from 17.1% to 5.9% in open areas, and from 14% to 5% in shrubby areas. Urness *et al.* (1975) recorded a change in dietary protein of white-tailed deer, from 25% in spring to 10% in autumn. Goodson *et al.* (1991a) recorded seasonal movement, from open areas in early winter, to shrubby areas later in winter. These movements were attributed to greater accessibility of browse in peak winter, as well as to differences in protein and fibre contents. Similar movements were shown by ibex during this study. In early winter, when the snow was still soft, the animals could dig through the snow to feed on herbaceous vegetation underneath. Later in the winter, the snow became compact, making it difficult for the animals to access plants beneath the snow. They used species emerging through the snow, when the snow was too compact to dig.

Short *et al.* (1966) found that the nutrient content of browse plants of the mule deer (*Odocoileus hemionus*) in Colorado also decreased with advancing season. While protein content of the food plants ranged from 8 to 17% in spring, it declined to 6-10% in autumn, and further to 6-7% in winter. Johnston *et al.* (1968) studied the chemical composition of alpine tundra plants, and found generally high crude protein and phosphorus levels in the plants. CP content in grasses decreased from 24.4% in spring to 4.9% in winter, from 27.3% to 7.4% in forbs, and from 20.6% to 5.8% in shrubs. Skre *et al.* (1975) recorded a seasonal decline in CP levels of alpine and subalpine plants in Norway. While CP in monocots declined from 28% to 6%, that of forbs decreased from 22% to 8%. Kilcher (1981) found that CP content in the leaves of tropical legumes declined from 26% to 15%, with advancing phenology.

5.6.2 Calorific value:

Another frequently studied aspect of diet composition is its energy content or calorific value. Energy content is generally higher in temperate plants (Jones and Wilson 1987) than in tropical plants. Short *et al.* (1966) found highest calorific values in mule deer browse species in winter (up to 5.5 kcal/g), probably due to the presence of energy-rich fruits during later phenological stages. The results of this study conform with the above studies. The increase in calorific value of some of the major food plants of ibex (Table 5.2) might be attributed to an increase in lipid content corresponding to seed formation. The high energy content of *Artemisia*, even in summer, is probably due to the presence of essential oils in the species (see also Wallmo *et al.* 1977).

5.6.3 Ash content:

Ash is usually high in leafy tissue, and low in fruits and woody tissue (Short *et al.* 1966). Short *et al.* (1966) recorded ash content values varying from 2.1% (in mahogany in winter) to 8% (in rabbitbrush in summer). The lower ash content of plant material in winter can be attributed to differences in the proportions of leaf to non-leaf material during the different seasons. In spring and summer, the samples collected for analysis had a greater proportion of leaf material, whereas the autumn and winter material had greater proportions of stem, fruit and seed.

5.6.4 Tannin content:

Fast-growing plants have the advantage of being less apparent to a herbivore, in that the herbivore has relatively less time to discover a short-lived herbaceous plant, than it would have, to discover a perennial shrub. Therefore, long-lived plants require to invest more resources in anti-herbivore defence than annuals or perennials.

Cates and Rhoades (1977) found that while about 80% of woody perennials contained tannins, only 15% of annual and perennial dicot species showed the presence of tannins. They justify this in terms of the cost that the plant has to bear to produce these secondary compounds. Ephemeral plants have to invest most of their nutrition in completing their life cycle in the short favourable period available for growth, and therefore cannot afford to invest much of their resources in the production of 'expensive' secondary defence mechanisms.

5.6.5 Aspect, altitude, and crude protein levels:

Plant growth begins earliest on the south- and west-facing slopes, aspects on which snow melt occurs first, due to greatest exposure to the sun. Plant growth follows the line of snow melt, beginning first at the lowest altitudes and continuing upwards. This phenomenon is well-known for all temperate zones in the northern hemisphere (Nelson and Leege 1982).

Results of the crude protein analysis of plant species collected during this study at different altitudes and on different aspects, did not show consistency. During spring, when plant growth begins, plants at the lower altitudes have slightly higher crude protein values than those at higher altitudes. For example, while the crude protein content of *Cicer microphyllum* on the southern aspect in spring was 34.3% at an altitude of 3900 m, it was 31.2% at 4100 m. The reason for these differences in the early growth stages, could be because plants at the lower altitudes and on the sun-exposed aspects would have produced more photosynthetic tissue by then, than those at higher altitudes and on aspects with lower exposure to the sun. Plants would also not have started producing much of their mechanical support tissue, in the form of fibre in the stem. However, in spring, species such as *Lindelofia anchusoides* showed higher crude protein levels at higher altitudes (27.1% at 4100 m) than at lower altitudes

(23.6% at 3900 m). This may have been because *L. anchusoides* was one of the earliest sprouting species, appearing about 15 days earlier than *C. microphyllum* on the same aspect, and at the same altitude.

At later phenological stages, when the plant tissue began to mature, CP values declined in plants at lower altitudes and on more sun-exposed aspects. During this time, plants at higher altitudes and on those aspects exposed less to the sun, had relatively higher CP values, since they were then still at an earlier phenological stage, that is, they had younger plant tissue. For example, in summer, *Epilobium brevifolium* had 12.2% crude protein at 4300 m, compared to 11.4% at 4100 m. During the same season, *Nepeta podostachys* contained 13.6% crude protein at 3900 m on the northern aspect, which was less exposed to the sun, and where plant growth began later, while the same species contained 12.2% at the same altitude on the western aspect.

CHAPTER 6. GENERAL DISCUSSION

The purpose of this final chapter is to bring together and discuss results of Chapters 3, 4 and 5. Therefore, it will deal with food habits of ibex in relation to vegetation of the area, and in relation to seasonal changes in quality of food plants. Other activities that might, directly or indirectly, affect ibex in the area, will also briefly be discussed, concluding with appropriate management recommendations.

6.1 Utilisation of vegetation associations

Ibex used all the nine vegetation associations identified in the study area, at one or other time during the year. Seasonal use of the different vegetation associations is not a result of the availability of food plant species alone, but is also likely to be influenced by the phenological stage, and therefore the quality of food during the different seasons.

In spring, when *Lindelofia anchusoides* made up a major proportion of the diet, ibex used the Grass-*Lindelofia* association more than any of the others. Thus ibex spent a considerable amount of time on the southern aspect, where this association is most commonly found. The early snow melt on this aspect in spring, along with freshly sprouted vegetation, mainly graminoids, *Lindelofia anchusoides*, and *Bupleurum falcatum*, strongly influenced their use of the area. On the other aspects, snow melt, and corresponding vegetation growth, occurred later. Ibex followed snow melt, and the phenology of food plant species, utilising the youngest plants and their parts at any given time. The movement of ibex was in the form of altitudinal migrations, with ibex moving from the lowest altitudes in spring, to the highest in peak summer. This corresponded to the use of vegetation associations in the lower altitudes in spring, to the use of the alpine mix, the *Oxytropis*-Grass-*Oryzopsis*, and the *Geranium*-

Aconogonum-Grass vegetation associations in summer, and then a downward movement again in autumn, into the *Cicer* dominant and *Cicer*-Grass-*Lindelofia* association. The northern and eastern aspects were used more than the other aspects in summer (Bhatnagar 1997), because the vegetation was in earlier phenological stages due to later sprouting. In winter, ibex seemed to use aspects and vegetation types without preference, selecting wind-blown, relatively snow-free areas such as crests and cliffs, where vegetation was more easily accessible.

6.2 Nutritional considerations

It is possible for ibex to put on fat reserves only during the growing season, in spring and summer, when vegetation is abundant and of high quality. In autumn, the quality of vegetation falls rapidly, and in winter, it is only enough for maintenance, with animals losing their fat reserves towards the end of winter, when plant availability is at its lowest. The 'boom-and-bust' environment, typical of temperate regions, in which a super-abundance of forage is followed by a shortage, has led to the adaptations of animals living in such areas. Goodson *et al.* (1991a) showed that the availability of green forage limited the nutrition of Rocky Mountain bighorn sheep in northcentral Colorado, in winter and early spring.

As a means to conserve energy, ibex have seasonally differing activity patterns (Bhatnagar 1997). Feeding was bimodal in the warmer seasons, with two major peaks, one early in the morning, and the other late in the afternoon. This changed to a unimodal pattern in peak winter, with feeding taking place late in the forenoon and early in the afternoon, making use of the sunlight hours.

Food choice by ruminants largely results from physical and chemical factors of the plants (Arnold and Hill 1972). Selective foraging by animals living in seasonal environments accounts for the relative balance of nutrient intake over the seasons.

Forage value can be expressed as the nutritional value per unit time (Hanley 1997). The nutritional value of a forage is the combined effect of the positive value of digestible energy and the negative value of allelochemicals. Handling time of the food, predator avoidance, and social interactions also play an important role in food selection (*op. cit.*). The role of learning should also be considered in optimal foraging (Owen-Smith and Novellie 1982). Hobbs *et al.* (1983) found a change in the botanical composition of the diets of mule deer, elk, and mountain sheep, with a change in forage quality. As the quality of grasses declined, less grasses and more forbs were consumed. They also established that variability in botanical characteristics among individuals was much greater than variability in nutritional characteristics, suggesting that the animals "obtain the same nutritional end by different dietary means".

Protein has been considered the single most important factor that governs food choice by a herbivore (Hanley and Brady 1977, White 1978). However, a comparison of the seasonal changes in crude protein content of some of the major food plants of ibex, with their consumption by ibex, showed only a slight correlation (Figure 6.1). This relation was not significant in any season ($P>0.1$). Crude protein content of the seasonal diets of ibex changed at a similar rate as that of the available forage. This does not concur with the results of Hart *et al.* (1983), who found that dietary protein of cattle did not decline as sharply as the crude protein levels of the forage, indicating selection of plants with higher than average crude protein content in the later part of the growing season. Tixier *et al.* (1997) found that food selection by roe deer (*Capreolus capreolus*) was determined by carbohydrate and fibre content, and not by crude protein content of the available plants.

The choice of food plant species in the diet of ibex did not seem to be influenced either by crude protein (Figure 6.1) or ash content (Figure 6.2) in any season ($P>0.1$), but calorific value influenced diet choice to some extent in spring and autumn

(Pearson's correlation coefficients: spring r=0.4883, autumn r=0.5853; P<0.1) (Figure 6.3). Crude protein, by itself, is therefore likely not to be a limiting factor in the diet of ibex. Radwan and Crouch (1974) did not find any consistent chemical basis for observed plant species preferences by black-tailed deer. Short (1975) found a relation between forage quality and seasonal diet of white-tailed deer.

A study on winter diets of elk (Hobbs *et al.* 1981) showed a shift from more grasses in early winter, to more browse later in the season. This was attributed to differences in crude protein content in grasses and browse. Animals retained a relatively constant crude protein intake by changing the proportions of grass and browse in the diet. Ibex in the study area consumed graminoids more in their sprouting stage, during spring (40.17% of diet) than during other seasons (11.63 to 28.62%), corresponding to decreasing levels of crude protein, increasing ash content, and the relative non-availability of grasses in winter.

It has been established that chemical factors, such as tannins and alkaloids, are feeding deterrents (Robbins *et al.* 1987a, Robbins *et al.* 1987b). However, only the effects of tannins have been studied quantitatively (Hanley 1997). In this study, *Geranium pratense* formed a part of the diet in summer, autumn and winter, despite its tannin content. During winter, the 'lean' period, when the choice of food species was limited and ibex did not show distinct food preferences, species with secondary compounds were also eaten. For example, *Ephedra gerardiana*, which contains tannins in all seasons, was not found in the diet in summer and autumn, but formed a significant part of the winter diet, and continued to be eaten in early spring, when availability of fresh sprouts of other species was limited. Alpine ibex in the Swiss Alps were found to feed on certain plant species despite the presence of tannins and alkaloids in them (ten Houte de Lange 1978). Klötzli (1965) concluded from his study on the roe deer, that tannin-rich plants such as *Geranium robertianum* and *Circaea*

lutetiana were significantly selected for. Roe deer also fed on plants with high concentration of tannins and other phenolics, suggesting that they had the ability to deactivate these compounds (Tixier *et al.* 1997).

Wielgolaski (1975) attributed selective grazing by sheep to the content of mono- and oligosaccharides, while lignin content had a strong negative effect on selection. Seip and Bunnell (1985) did not observe selection by Stone's sheep (*Ovis dalli stonei*) for high protein and low fibre forage, but rather avoidance of plant species containing secondary compounds.

It is speculated that forage digestibility, in terms of digestible energy, might have an important role to play in food selection by ibex. Owen-Smith and Novellie (1982) established that digestible energy was more limiting than crude protein in the diet of the kudu. Sæther and Andersen (1990) stressed the importance of forage digestibility, which is inversely related to fibre and lignin content, in the energetic gain and therefore food choice by moose.

Figure 6.1. Seasonal diet of ibex in Pin Valley National Park in relation to crude protein content of forage.

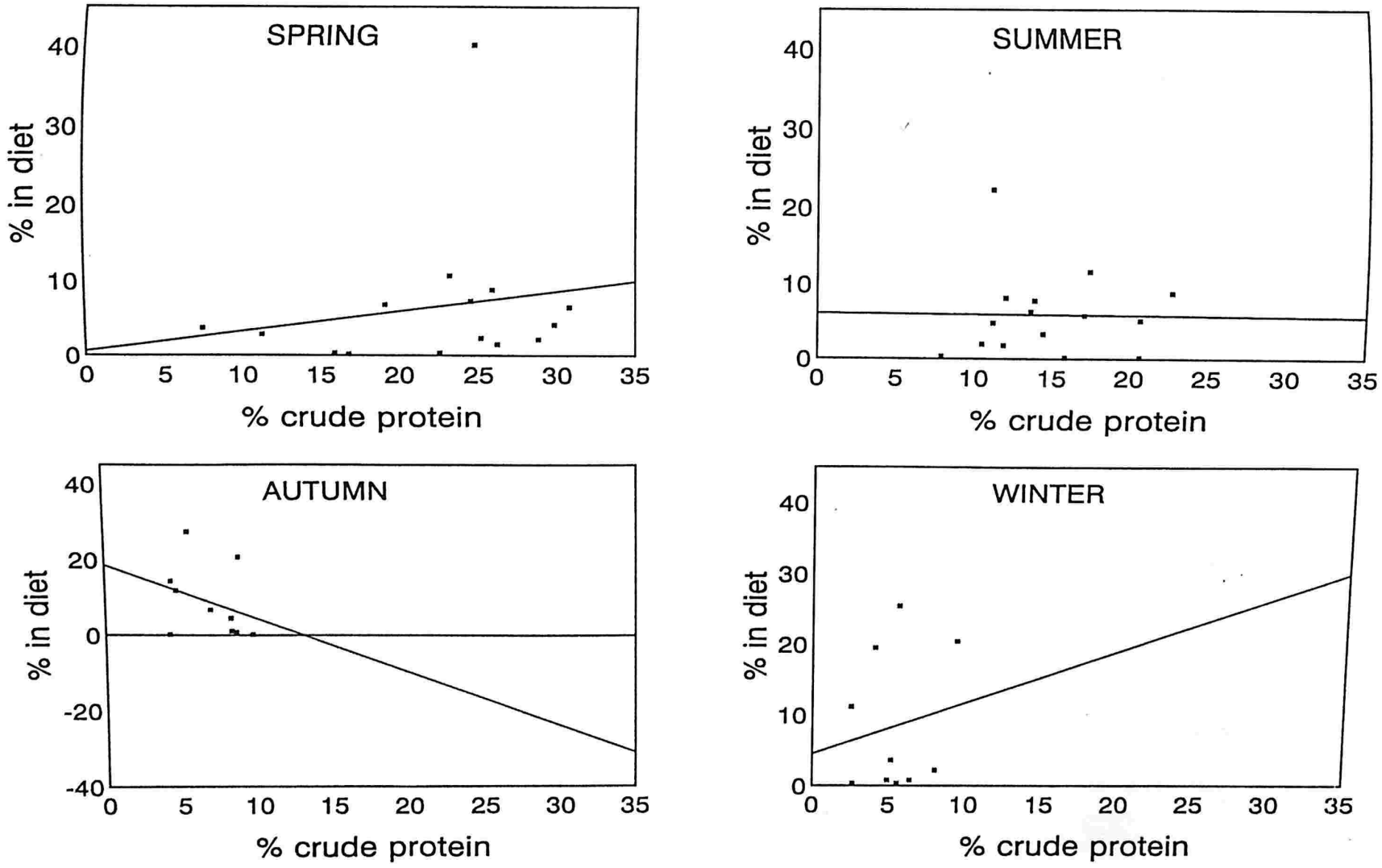


Figure 6.2. Seasonal diet of ibex in Pin Valley National Park in relation to ash content of forage.

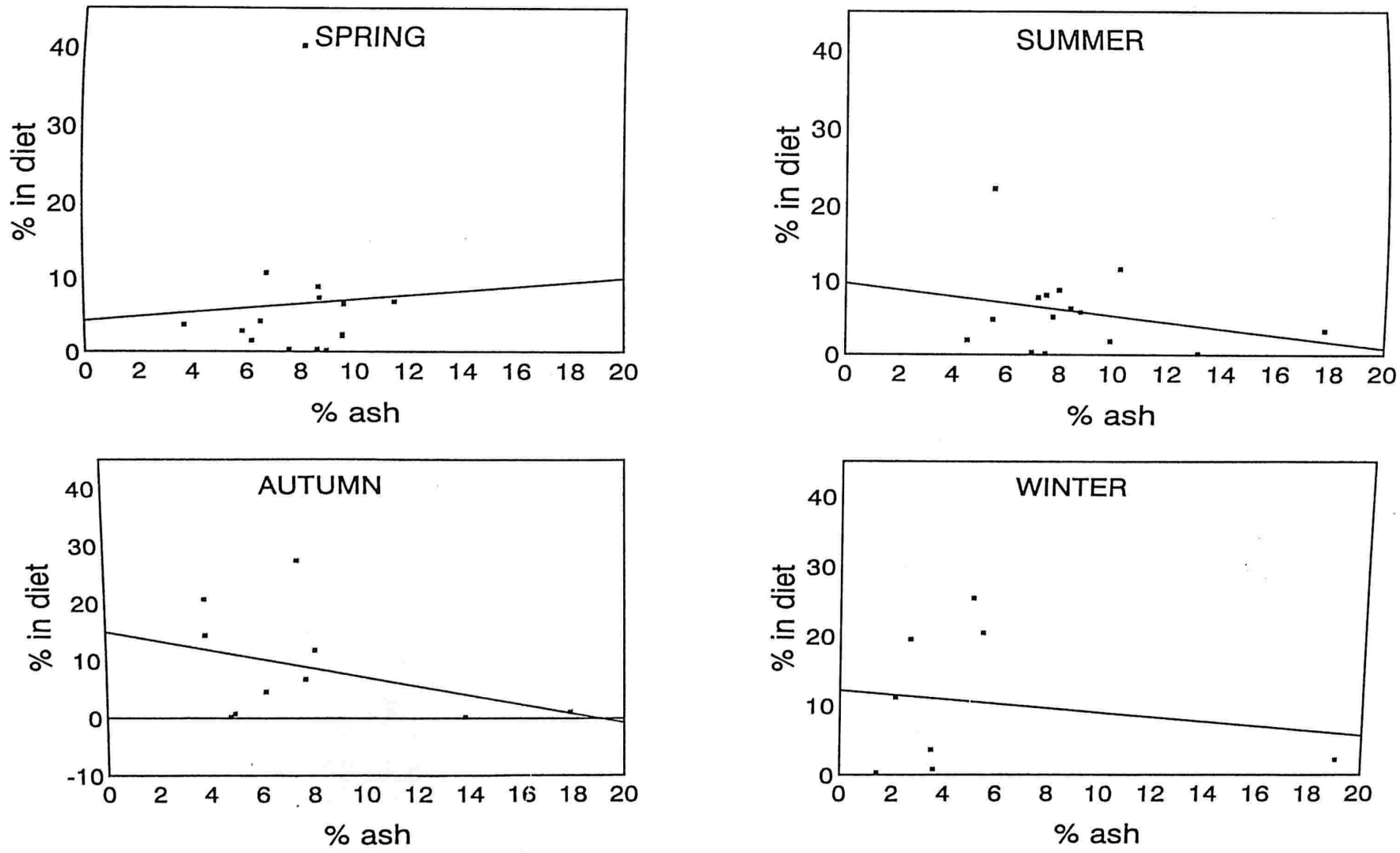
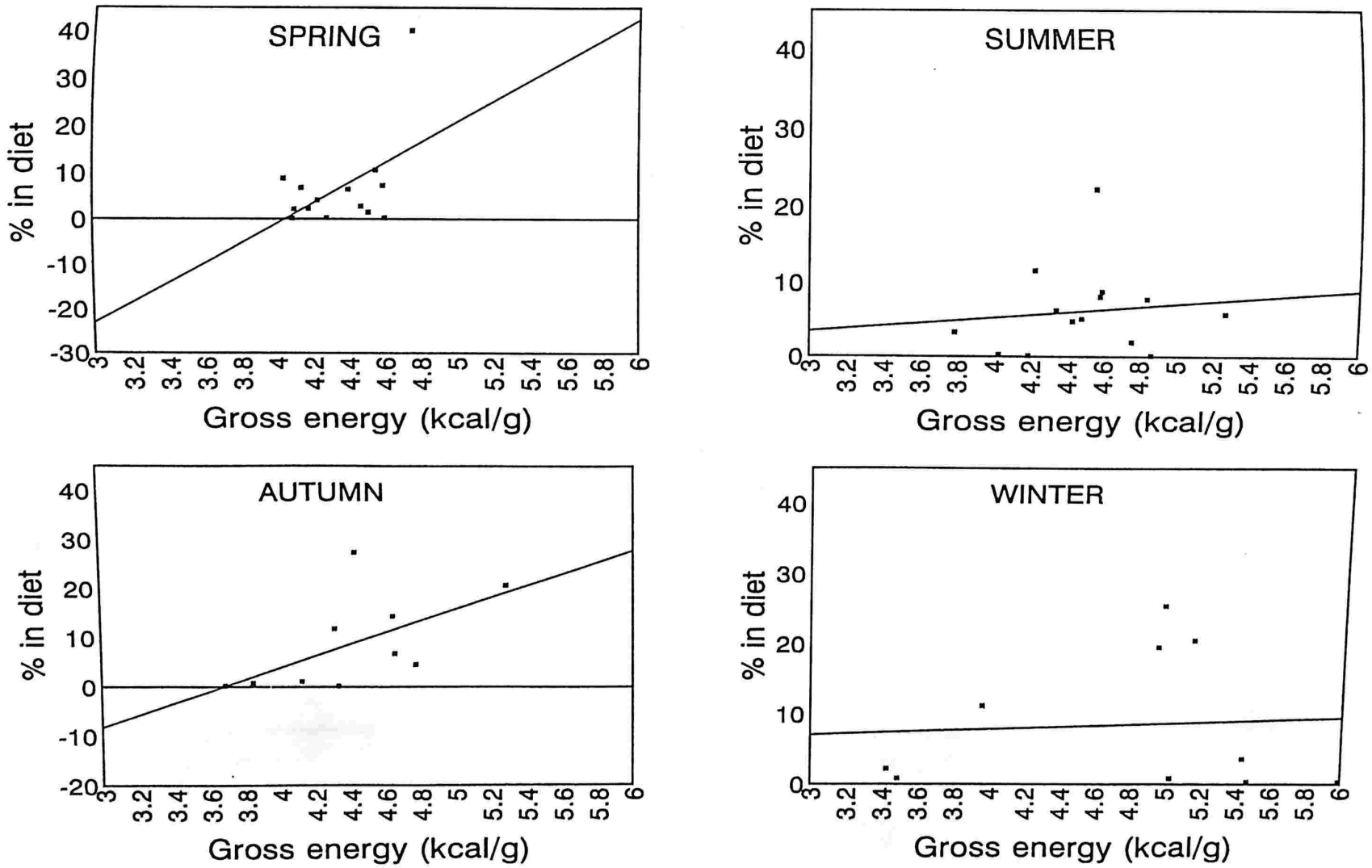


Figure 6.3. Seasonal diet of ibex in Pin Valley National Park in relation to gross energy content of forage.



6.3 Management considerations

Pin Valley National Park, being protected by its relative inaccessibility, requires little management to maintain/preserve the habitat. The two artificial water-holes in the Park, were used by the local livestock rather than by ibex, for which purpose they were created. It is not necessary to continue with such supplementation activities, since water is not a scarce resource to the wild animals in the Park. It is important to establish alternate sources of fuel wood for use by the local people. However, the Forest Department plantations of species such as *Rosa webbiana* and *Salix* sp. have been unsuccessful, and require greater levels of post-plantation care and monitoring.

Tourism began in the area only in 1993, when innerline restrictions were abolished. No restriction on tourist numbers has been enforced, and it could lead to uncontrolled use of the area during the short summer season, and consequent negative effects, such as littering. Tourists should be educated about the shortage of resources in the area, and encouraged to bring their own fuel sources, such as camp-stoves, when they are in the area. All litter should either be buried or burnt, or carried out of the area for proper disposal elsewhere.

The use of the Park by migratory graziers (Plate 3) from the neighbouring districts of Kullu and Kinnaur in summer, and the corresponding movement of ibex to higher altitudes, brings up the question of whether ibex are displaced by the graziers, whether their movement is purely related to changes in phenology of vegetation, or whether a combination of factors directs their movement. The graziers have been using the area for over 300 years, and ibex might have adapted themselves to moving to other areas during this time. Eight groups of migratory graziers use the National Park area for about 2½ months every year, between June and August. The effects of intense grazing and trampling by such large numbers of livestock in a small area should not be ignored (Manjrekar and Bhatnagar 1997). This should be quantified by

implementing a system of rotational grazing, on an experimental basis. That is, the closure of one area at a time for a specified period, say one or two years, to establish responses of the vegetation, and of ibex, to the removal of grazing and trampling pressure.

Each migratory grazier is issued a permit for a specified number of livestock that he is allowed to graze in the area. This number varies between 300 and 800 livestock per grazier. However, there is no vigilant check on the numbers of livestock that come into the area, and most graziers bring 10-20% larger groups of livestock than they are permitted. It should also be made mandatory that the livestock are vaccinated against infectious diseases such as foot-and-mouth disease, which is a potential threat to ibex. Cases of foot-and-mouth disease were seen among the migratory livestock every year. Another threat to ibex is from the dogs that accompany the graziers. There have been instances of ibex being chased by the dogs.

All local livestock, except horses, are unaccompanied, and do not seem to affect use of the area by ibex (see also Bhatnagar 1997). Ibex have been seen passing through groups of yaks, and dzos/dzomos, and in close proximity to groups of sheep and goats of the local people. The lower numbers of local livestock in a group (usually between 10 and 60 animals, as against 500 to 1000 migratory livestock), and the absence of people and dogs accompanying the groups, is the most likely reason for their negligible disturbance to ibex.

The effects of the extraction of woody species by the local people for fuel wood (Plate 4) should be quantified by long-term monitoring of the dynamics of those species. Their availability, extraction, and regeneration are some of the aspects that need to be quantified. From this study, it was obvious that one of the woody species, *Rosa webbiana*, was an important source of food for ibex during winter, the period of lowest resource availability. The extraction of this species causes a depletion in the

important winter food resource for ibex, and might ultimately lead to a lower survival of ibex through winter, and should therefore be discouraged, by providing alternate fuel sources. The other woody species do not seem to play such an important role in the diet of ibex. Fortunately, the provision of cooking gas (LPG) has become very popular among the local people, and reduces the fuel wood requirement in summer. For the winter, fuel wood is required to keep the house warm. Unlike a few years ago, many of the local people can now afford to buy the fuel wood that is supplied by the Social Forestry Division of the Forest Department, from earnings by working on short-term jobs that they get with the various Government Departments, implementing development activities. They therefore depend less heavily on wood collected from the Park. The provision of electricity in the villages surrounding the Park, has also eased the pressure on the fuel wood species to a certain extent, with people beginning to use electric stoves for cooking.

Herbaceous species, such as *Cicer microphyllum*, *Cousinia thomsonii*, *Festuca kashmiriana* and *Saussurea jacea*, are collected by cutting, as fodder for stall-feeding of livestock in winter. However, they are usually collected only after September, when senescence begins to set in, and they are of relatively low nutritional value. By this time, ibex have usually begun to feed mainly on fruit and seed material. These fodder species were not identified in the winter diet of ibex, although they were found in the winter feeding areas of ibex.

To summarise the management recommendations:

1. Water management is not required.
2. Fuel wood plantations should be maintained.
3. Rotational grazing should be implemented on an experimental basis, to quantify impacts of migratory livestock.
4. Control on numbers of migratory livestock using the Park should be enforced.
5. Regular vaccination of migratory and local livestock should be made mandatory.
6. Extraction on *Rosa webbiana* as source of fuel wood from the Park should be prohibited.

6.4 Conclusions

The diet of ibex is made up mainly of grasses and forbs. Seasonally, the diet is supplemented with flowers and fruits. As in all temperate ungulates, it is strongly influenced by the phenology and availability of vegetation. Results from this study indicate that ibex change their feeding strategy, depending on availability and abundance of food plant species. In late summer and autumn, they are generalist feeders, being able to adapt to changes in phenology and availability of vegetation. They are selective only in spring and early summer, the times of abundant food availability, and are opportunistic feeders in winter when food is limiting both in quantity as well as in quality.

Among the methods used for this study, the examination of feeding sites gave feeding data, as well as a good estimate of availability within the pre-selected site. From this, preference indices for the various food species could be obtained. These indices cannot be obtained from microhistological analysis of faeces. However, the advantage of the faecal analysis method is that it is representative of larger time and area segments in which ibex had previously fed. If digestibility trials could be

conducted on the food species of ibex, the faecal analysis method would be the most cost-effective method. Extensive sampling of feeding sites at shorter intervals would yield a more precise depiction of availability and use, but would require considerable man-power.

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Appendix A. **Checklist of plants collected and recorded in the Parahio catchment, Pin Valley National Park, Himachal Pradesh (including cultigens) (based on collections by author, and field observations and identification by Dr. G.S. Rawat).** (Nomenclature is based on Aswal and Mehrotra 1994).

Amaranthaceae

Kochia sp.

Amaryllidaceae

Allium carolinianum DC.
A. stracheyi Baker

Apiaceae

Acronema tenera Edgew.
Bupleurum falcatum var. *gracillimum* Wolff.
B. himalayense Klotz.
B. longicaule Wall.
B. thomsonii Clarke
Carum carvi Linn.
Chaerophyllum reflexum Lindl.
C. villosum Wall.
Ferula jaeschkeana Vatke*
Heracleum candicans Wall.
Ligusticum elatum Clarke
Pleurospermum candollii Benth.
Selinum tenuifolium Wall.
Seseli trilobum Clarke*$

Asteraceae

Achillea millefolium Linn.
Anaphalis nepalensis Hk. f. var. *cuneifolia* Hk. f.
A. royleana DC.
A. virgata Thoms.
Arctium lappa Linn.
Artemisia biennis Willd.
A. dracunculus Linn.
A. gmelinii Web.
A. macrocephala Jacq.
A. maritima Linn.
A. salsoloides Willd.
A. sieversiana Willd.
Aster diplostephioides Clarke
A. flaccidus Bunge
A. falconeri Hutch.
Brachyactis sp.
Carduus nutans Linn.
Chrysanthemum pyrethroides Fedtsch.
Cousinia thomsonii Clarke
Cremanthodium sp.
Crepis multicaulis Ledeb.
Echinops cornigerus DC.
Erigeron multiradiatus Benth.
E. alpinus Linn.
Inula obtusifolia Kerner
Jurinea ceratocarpa Benth.
Lactuca lessertiana Clarke
L. macrorhiza Hk. f.
Leontopodium himalayanum DC.
Ligularia amplexicaulis DC.
Picris hieracioides Linn.
Psychrogeton andryaloides Novopokr
Saussurea bracteata Decne
S. candolleana Wall.
S. glanduligera Sch.-Bip.
S. gnaphalodes Sch.-Bip.$
S. jacea Clarke
S. taraxacifolia Wall.
Senecio pedunculatus Edgew.
Soroseris glomerata Stebbins
Tanacetum gracile Hk. f. & Th.
T. longifolium Wall.
T. tibeticum Hk. f. & Th.
Taraxacum officinale Wigg.
T. wattii Hk. f.
Tragopogon gracilis D.Don
T. pratense Linn.
Waldheimia glabra Regel
W. tomentosa Regel
Youngia glauca Edgew.
Y. tenuifolia Babcock & Stebbins

Boraginaceae

Arnebia benthamii Wall.
A. euchroma Johnston#
A. guttata Bunge
Asperugo procumbens Linn.
Asperula cynanchica Hk. f.

Cynoglossum nervosum Benth.
Eritrichium canum Benth.
E. fruticulosum Klotz.
Hackelia uncinata Fischer
Lindelofia anchusoides Lehm.
L. stylosa Brand
Myosotis arvensis Hoffm.
Onosma hispidum Wall.

Brassicaceae

Alyssum sp.
Arabidopsis himalaica Schulz
Arabis amplexicaulis Edgew.
A. nova Vill.
Barbarea vulgaris R. Br.
Braya thomsonii Hk. f.
Capsella bursa-pastoris Medik.
Chorispora sabulosa Camb.
Christolea crassifolia Camb.
C. himalayensis Jarfi
Draba altaica Bunge
D. cachemirica Gand.
D. glomerata Royle
D. lanceolata Royle
D. lasiophylla Royle
D. oreades Schrenk
D. stenocarpa Hk. f. & Th.
Lepidium capitatum Hk. f. & Th.
L. latifolium Linn.
Sisymbrium brassiciforme C. A. Mey.
Tauscheria lasiocarpa Fisch.
Thlaspi andersonii Schulz
T. arvense Linn.

Campanulaceae

Campanula cashmeriana Royle
C. argyrotricha Wall.
Codonopsis rotundifolia Benth.

Cannabaceae

Cannabis sativa Linn.

Caprifoliaceae

Lonicera heterophylla Decne.
L. myrtillus Hk. f. & Th.
L. spinosa Walp. Rep.
L. obovata Royle
L. hypoleuca Decne

Caryophyllaceae

Arenaria festucoides Benth.
A. glanduligera Edgew.
A. serpyllifolia Linn.
Cerastium cerastoides Britton
C. vulgatum Linn.
Dianthus angulatus Royle
Gypsophila cerastoides D.Don
Sagina procumbens Linn.
Silene apetala Linn.
S. himalayensis Edgew.
S. indica Benth.
S. macrorhiza Royle
S. moorcroftiana
S. saginoides Linn.
S. vulgaris Garcke
Stellaria alsine Hoffm.
S. cherleriae Fisch.
S. palustris Ehrh.
S. cherleriae Fisch.

Chenopodiaceae

Axyris amaranthoides Linn.
Chenopodium album Linn.
C. botrys Linn.
C. foliolosum Aschers
Eurotia ceratoides C.A. Mey
Microgynoecium tibeticum Hk. f.

Convolvulaceae

Convolvulus arvensis Linn.
Cuscuta europaea Linn.

Crassulaceae

Rhodiola heterodonta A. Boriss.
R. quadrifida Fisch. & May.
R. crenulata Ohba
Rosularia alpestris A. Boriss.
Sempervivum acuminatum Decne.
S. mucronatum Edgew.

Cupressaceae

Juniperus communis Linn.#
J. macropoda Boiss.
J. indica Bertol.

Cyperaceae

Carex alpina Sw.
C. atrata Clarke
C. atrofusca Sch.
Eleocharis palustris R. Br.
Kobresia capillifolia Clarke
K. duthiei Clarke
Scirpus sp.

Elaegnaceae

Hippophae rhamnoides Linn.
ssp. *turkestanica* Rousi

Ephedraceae

Ephedra gerardiana Wall.#

Euphorbiaceae

Euphorbia kanaorica Boiss.
E. tibetica Boiss.

Fabaceae

Astragalus candolleanus Royle
A. densiflorus Kar. & Kir.
A. frigidus A. Gray
A. grahamianus Royle
A. ladakensis Balak.
A. rhizanthus Royle
A. strobiliferus Royle
A. thomsonianus Benth.
A. himalayanus Benth.
Caragana gerardiana Royle
C. versicolor DC.
Cicer microphyllum Benth.
Hedysarum astragaloides Benth
H. microcalyx Baker
Medicago falcata Linn.
M. lupulina Linn.
Oxytropis cachemiriana Camb.
O. lapponica (Wall) Gay.
O. microphylla DC.
O. mollis Royle
Thermopsis inflata Camb.
Trifolium repens Linn.
Trigonella emodi Benth.
T. pubescens Edgew.

Fumariaceae

Corydalis cashmeriana Royle
C. crassifolia Royle
C. crassissima Camb.
C. govaniana Wall.
C. meifolia Wall.

Gentianaceae

Gentiana nubigena Edgew.
G. venusta Griseb. Gen.
Gentianella moorcroftiana A. Shaw
G. tenella Borner
Gentianopsis paludosa Ma.
Lomatogonium carinthiacum Br.
L. spathulata Fer.
Swertia ciliata Burtt.
S. cordata Clarke

Geraniaceae

Biebersteinia odora Steph.
Geranium himalayense Klotz.
G. pratense Linn.
G. wallichianum D. Don

Grossulariaceae

Ribes glaciale Wall.
R. orientale Desf.

Haemodoraceae

Aletris pauciflora Hand.-Mazz.

Juncaceae

Juncus himalensis Koltz.
Luzula spicata DC.

Juncaginaceae

Triglochin maritimum Linn.
T. palustris Linn.

Lamiaceae

Clinopodium umbrosum Koch
Dracocephalum heterophyllum Benth.
Elsholtzia densa Benth.
E. eriostachya Benth.
E. strobilifera Benth.
Hyssopus officinalis Linn.
Lamium rhomboideum Benth.
Mentha longifolia Huds.
Nepeta discolor Royle
N. eriostachya Benth.
N. floccosa Benth.
N. longibracteata Benth.
Nepeta podostachys Benth.
Origanum vulgare Linn.
Scutellaria prostrata Jacq.
Stachys sp.
Thymus linearis Linn.
T. serpyllum Linn.

Liliaceae

Eremurus himalaicus Baker#
Gagea lutea Ker-Gawl.
G. persica Boiss.
Lloydia serotina Rchb.

Linaceae

Linum perenne Linn.

Malvaceae

Malva verticillata Linn.

Onagraceae

Epilobium amurense Hausskn.
E. angustifolium Linn.
E. brevifolium D. Don
E. latifolium Linn.
E. leiophyllum Hausskn.
E. royleanum Hausskn.

Orchidaceae

Ponerorchis chusua Soo
Dactylorhiza hatagirea Soo#

Orobanchaceae

Orobanche alba Steph.
O. hansii Kerner

Papaveraceae

Meconopsis aculeata Royle

Plantaginaceae

Plantago tibetica Hk. f. & Th.

Poaceae

Agrostis vinealis Schreb.
A. gigantea Roth.
A. munroana Aitch.
A. pilosula Trin.
A. stolonifera Linn.
Bromus gracillimus Bunge
Calamogrostis emodensis Griseb.
C. pseudophragmites Koel.
Calamagrostis holciformis Jaub. & Spach.
Deschampsia caespitosa Beauv.
Elymus dahuricus Turcz.
E. longe-aristatus Tzvelev
Eremopoa soongarica Bor.
Festuca kashmiriana Stapf
Hordeum vulgare Linn.
Leymus secalinus Tzvelev

Melica persica Kunth
Oryzopsis sp.
Pennisetum flaccidum Griseb.
Poa alpina Linn.
P. pratensis Linn. ssp. *angustifolia*
P. annua Linn.
Stipa orientalis Trin.
S. brandisii Mez
Trisetum clarkei Stewart
T. spicatum Richt.

Polygonaceae

Fagopyrum tataricum Gaertn. Fruct.
Oxyria digyna Hill
Polygonum affine D. Don
P. alpinum All. Fl. Pedem.
P. aviculare Linn.
P. cognatum Meissn.
P. delicatulum Meissn.
P. filicaule Wall.
P. glaciale Hk. f.
P. islandicum Hk. f.
P. plebejum R. Br. Prodr.
P. tortuosum D.Don
P. viviparum Linn.
Rheum emodi Wall.
R. moorcroftianum Royle
R. webbianum Royle#
Rumex acetosa Linn.
R. nepalensis Spreng.
R. patientia Linn.

Potamogetonaceae

Potamogeton sp.

Primulaceae

Primula denticulata Smith.
P. minutissima Jacq.

Ranunculaceae

Aconitum rotundifolium Kar. & Kir.
A. violaceum Jacq.
Adonis aestivalis Linn.
Anemone obtusiloba D.Don
A. rupicola Camb.
Aquilegia fragrans Benth.
A. pubiflora Wall.
Clematis orientalis Linn.
Delphinium brunonianum Royle
D. cashmerianum Royle
D. vestitum Wall.
Halerpestis sarmentosa Komarov
H. tricuspis Hand.-Mazz.
Oxygraphis endlicheri Bennett & Chandra
Paraquilegia anemonoides Ulbr.
P. microphylla Drumm
Ranunculus adoxifolius Hand.-Mazz.
R. brotherusii Edgew.
R. hirtellus D. Don
R. laetus Wall.
Thalictrum alpinum Linn.
T. foetidum Linn.
T. secundum Edgew.

Rhamnaceae

Rhamnus prostrata Jacq.

Rosaceae

Cotoneaster duthieanus Klotz.
C. falconeri Klotz.
Potentilla anserina Linn
P. arbuscula D. Don
P. atrosanguinea Lodd. var. *argyrophylla*
P. bifurca Linn.
P. cuneata Wall.
P. curviseta HK. f.
P. desertorum Bunge
P. eriocarpa Wall.
P. gelida C. A. Mey.
P. microphylla D. Don
P. multifida Linn.
P. nivea Linn.
P. salesoviana Steph.
Rosa macrophylla Lindl.
R. webbiana Wall.
Sibbaldia parviflora Willd.
S. perpusilla Chatterjee
Sorbus aucuparia Linn.

Rubiaceae

Galium aparine Linn.
G. boreale Linn.
G. serpylloides Royle*
G. verum Linn.
Rubia tibetica Hk. f.

Salicaceae

Populus balsamifera Linn.
Salix daphnoides Vill.
S. denticulata Anderss.
S. flagellaris Anderss.
S. lindleyana Wall.
S. oxycarpa Anderss.
S. pycnostachya Anderss.

Santalaceae

Thesium multicaule Ledeb.

Saxifragaceae

Bergenia stracheyi Engl.
Saxifraga sibirica Linn.
S. flagellaris Willd. ssp. *stenophylla* Royle

Scrophulariaceae

Euphrasia himalaica Wettst.
Lancea tibetica Hk. f. & Th.*$
Pedicularis albida Pennell*
P. bicornuta Klotz.
P. hoffmeisteri Klotz.
P. longiflora Rudolph.
P. rhinanthoides Sch.
Scrophularia calycina Benth.
S. decomposita Royle
S. edgeworthii
S. koelzii Pennell*
Verbascum thapsus Linn.
Veronica anagallis Linn. var. *aquatica*
V. biloba Linn.*
V. lanosa Royle

Selaginaceae

Lagotis sp.

Solanaceae

Hyoscyamus niger Linn.#
Physochlaena praealta Miers.#
Solanum tuberosum Linn.

Tamaricaceae

Myricaria germanica Desv.
Tamaricaria elegans Quiser & Ali

Urticaceae

Urtica sp.

Valerianaceae

Valeriana dioica Clarke

Violaceae

Viola kunawarensis Royle
V. pilosa Bl. Cat. Gew. Buitenz

* - endemic
$ - rare
\# - threatened

Appendix B. Checklist of birds recorded in the Parahio catchment, Pin Valley National Park, Himachal Pradesh.

(? indicates doubtful identification)

Ardeidae

Grey heron (*Ardea cineria*)
Pond heron (*Ardeola grayii*)

Anatidae

Ruddy shelduck (*Tadorna ferruginea*)
Common teal (*Anas crecca*) ?

Accipitridae

Himalayan griffon (*Gyps himalayensis*)
Bearded vulture or Lämmergeier (*Gypaetus barbatus*)
Golden eagle (*Aquila chrysaetos*)

Falconidae

Kestrel (*Falco tinnunculus*)

Phasianidae

Chukar partridge (*Alectoris chukar*)
Himalayan snowcock (*Tetraogallus himalayensis*)

Rallidae

Moorhen (*Gallinula chloropus*)

Charadriidae

Lapwing (*Vanellus vanellus*)
Green sandpiper (*Tringa ochropus*)

Columbidae

Blue rock pigeon (*Columba livia*)
Hill pigeon (*Columba rupestris*)
Snow pigeon (*Columba leuconota*)
Rufous turtle dove (*Streptopelia orientalis*)
Spotted dove (*Streptopelia chinensis*)

Psittacidae

Roseringed parakeet (*Psittacula krameri*)

Strigidae

Himalayan wood owl (*Strix aluco*) ?

Apodidae

Himalayan swiftlet (*Collocalia brevirostris*)
Whitethroated spinetail swift (*Collocalia caudacuta*)
Alpine swift (*Apus melba*)
The swift (*Apus apus*)
House swift (*Apus affinis*)

Coraciidae

European roller (*Coracias garrulus*) ?

Upupidae

Hoopoe (*Upupa epops*)

Alaudidae

Lesser short-toed lark (*Calandrella rufescens*) ?
Horned lark (*Eremophila alpestris albigula*)

Hirundinidae

Swallow (*Hirundo rustica*)

Laniidae

Greybacked or Tibetan shrike
(*Lanius tephronotus*)

Oriolidae

Golden oriole (*Oriolus oriolus*)

Dicruridae

Grey or ashy drongo
(*Dicrurus leucophaeus*)

Corvidae

Yellowbilled or alpine chough
(*Pyrrhocorax graculus*)
Redbilled chough
(*Pyrrhocorax pyrrhocorax*)
House crow (*Corvus splendens*)
Jungle crow (*Corvus macrorhynchos*)
Raven (*Corvus corax*)

Sylviinae

Brown leaf warbler or chiffchaff
(*Phylloscopus collybita*)
Olivaceous leaf warbler
(*Phylloscopus griseolus*)

Turdinae

Black redstart
(*Phoenicurus ochruros phoenicuroides*)
Guldenstädt's redstart
(*Phoenicurus erythrogaster*)
Desert wheatear (*Oenanthe deserti*)
Whitecapped redstart or river chat
(*Chaimarrornis leucocephalus*) ?
Blue rock thrush (*Monticola solitarius*)

Cinclidae

Whitebreasted dipper (*Cinclus cinclus*)

Prunellidae

Robin accentor (*Prunella rubeculoides*)
Brown accentor (*Prunella fulvescens*) ?

Motacillidae

Vinaceousbreasted pipit
(*Anthus roseatus*) ?
Upland pipit (*Anthus sylvanus*)
Yellowheaded wagtail (*Motacilla citreola*)
Grey wagtail (*Motacilla cineria*) ?
Pied or white wagtail (*Motacilla alba*)
Large pied wagtail
(*Motacilla maderaspatensis*)

Ploceidae

House sparrow (*Passer domesticus*)
Mandelli's snow finch
(*Montifringilla taczanowskii*)

Fringillidae

Goldfinch (*Carduelis carduelis*)
Goldfronted finch (*Serinus pusillus*)
Hodgson's mountain finch
(*Leucosticte nemoricola*)
Common rosefinch or scarlet grosbeak
(*Carpodacus erythrinus*)
Great rosefinch (*Carpodacus rubicilla*)
Redbreasted rosefinch
(*Carpodacus puniceus*)

Emberizidae

Rock bunting (*Emberiza cia*)

Appendix C. **Checklist of mammals recorded in the Parahio catchment, Pin Valley National Park, Himachal Pradesh.**
(? indicates unconfirmed evidence)

Felidae

Snow leopard (*Uncia uncia*)

Canidae

Red fox (*Vulpes vulpes montana*)
Wolf (*Canis lupus chanco*) ?

Mustelidae

Himalayan weasel (*Mustela sibirica*)
Pale weasel (*Mustela altaica temon*) ?
Beech or stone marten (*Martes foina*)

Chiroptera

Serotine (*Eptesicus serotinus*) ?

Rodentia

Indian field mouse (*Mus booduga*) ?
House mouse (*Mus musculus*)
Royle's vole (*Alticola roylei*)

Ochotonidae

Pika or mouse-hare (*Ochotona roylei*)

Bovidae

Himalayan ibex (*Capra ibex sibirica*)

Plate 1. Asiatic ibex (*Capra ibex sibirica*).
Adult female and kid in foreground, adult males in background.

Plate 2. A view of the Parahio catchment, which formed the intensive study area.

Plate 3. Migratory livestock graze in the area in large numbers for two-and-a-half months every year.

Plate 4. The extraction of fuel wood from the Park, by the local people, might affect ibex in winter.