Exploring ecological separation between Himalayan blue sheep and Himalayan ibex during winter in Indian Trans-Himalaya

by

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Dissertation Thesis

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Under the supervision of

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भारतीय वन्यजीव संस्थान
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AcSIR

DECLARATION

I hereby declare that the work conducted under the thesis entitled **"Exploring ecological separation between Himalayan blue sheep and Himalayan ibex during winter in Indian Trans-Himalaya",** is a record of original and independent research work done by me and subsequently submitted for the award of the degree of **Master's in Wildlife Science** at the **Academy of Scientific and Innovative Research**. This research work has been carried out under the guidance and supervision of **Dr. S. Sathyakumar, Registrar and Scientist - G**, and co-supervision of **Dr. Salvador Lyngdoh, Scientist – E** of Wildlife Institute of India, Dehradun, **and Dr. Yash Veer Bhatnagar, Country Representative, IUCN**, New Delhi. The work has not formed the basis for the award of any other degree, diploma, or any other qualification. I also declare that the thesis embodies my work, analysis, observation, understanding and the particulars given in it are true to the best of my knowledge.

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CERTIFICATE

This is to certify that the thesis by **Prakruthi G M** entitled "**Exploring ecological separation between Himalayan blue sheep and Himalayan ibex during winter in Indian Trans-Himalaya**" is an original and independent research work submitted to the **Academy of Scientific and Innovative Research**, for the award of the degree of **Master's in Wildlife Science**.

Prakruthi G M has put one semester of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

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EXECUTIVE SUMMARY

According to resource selection theory, two related species with similar ecological requirements compete for the same resources. They can only coexist if they are ecologically separated, either by habitat or food preference. This study explored the resource use and ecological separation of ibex (*Capra sibirica himalayanus*) and blue sheep (*Pseudois nayaur*) during the winter in the Spiti Valley, focusing on their segregation in space, habitat use patterns, diet, and activity pattern. The study was conducted in Kibber and Chicham areas (57 km^2) of Kibber Wildlife Sanctuary, Himachal Pradesh, India. This study slightly deviates from the findings of a previous study by Namgail (2006), which reveals a high overlap in the habitat use between ibex and blue sheep in the Zanskar mountains.

Systematic sampling using transects and trails, vantage points, opportunistic sampling, and camera traps was employed. Habitat and vegetation variables were recorded at random points and animal sightings to understand the patterns of habitat use and food selection. Spatial and temporal overlaps were analysed and micro-histological analysis of faecal samples compared the proportions of monocots and dicots in their diets. The study investigated how ungulates utilize habitats and their dietary habits with the availability of resources in their environment.

Results showed substantial overlap in activity patterns, with the Jaccard similarity index indicating less spatial overlap between the species. The generalized linear model and Non-metric dimensional analysis indicated segregation based on their habitat preferences. However, there were no significant differences in their diets, the two species differed in the use of habitat at finer scales. Ibex preferred interspersed rocky slopes and slabs because of high rocky areas (escape terrain) and sparse vegetation, trading food for security. Blue sheep preferred less rocky areas with high vegetation cover like smooth slopes. Ibex preferred areas with more escape routes available than blue sheep.

Thus, I conclude that Blue sheep, being more abundant than ibex, occupy distinct regions within the study area, and have a competitive advantage. While ibex are present in smaller numbers and confined to a specific region. Understanding their ecological requirements, especially in harsh winters, is crucial for targeted conservation efforts to ensure the sustainability of these species in a rapidly changing environment. Future research should focus on climate change impacts on habitat use and resource availability.

1. INTRODUCTION

The availability of adequate quantities of usable resources is necessary for the survival of individual animals and populations (Manly et al., 1993). In environments, where resources are unevenly distributed and change over time, animals adopt specialized or generalized feeding strategies (Schoener, 1971). The main focus in animal ecology lies in understanding how the animal interacts with its environment, particularly in terms of the food it consumes and the varieties of habitats it occupies (Johnson, 1980).

Although several studies (Namgail et al., 2010; Mishra et al., 2007; Bagchi et al., 2004; Suryawanshi et al., 2009; Koetke at al., 2020) have addressed aspects of resource selection by ungulates in Trans-Himalayan region, very few studies have been carried out in winter months (Namgail, 2006; Fox et al., 1992; Raghavan, 2003; Mishra, 2001), when the resources are scarce. The present study aims to explore aspects of winter resource use by ibex (*Capra sibrica himalayanus*) and blue sheep (*Pseudois nayaur*) and their segregation in utilization in Spiti Valley.

1.1 Resource selection and theories

Two related species having similar ecological requirements compete for the same resources and coexist only when they are separated ecologically, either by habitat or food preference, or both. When two species of different sizes occupy the same habitat, it can be inferred that they are selecting different foods. If they are of the same size and have similar morphology, the habitat is partitioned, or competition between the species can be expected (Schaller, 1977).

Resource selection occurs in a hierarchical pattern, starting from the overall geographical range of a species and then to individual home ranges. Then, there is further selection of general features (habitats), and finally, there is the choice of specific elements (food) within the feeding site (general features). The selection criteria can vary at each level (Johnson, 1980; Wiens, 1981).

Competition arises when resources are limited, finite, or replenished at an insufficient pace to meet the demand. When resources are limited, ungulates with the same habitat will likely compete for them (Pianka & Huey, 1978). Sympatric species of similar-sized ungulates that have similar foraging strategies may compete for resources, but only if there is a high degree of overlap in their use of spatial and trophic resources, and such resources are limited (Putman, 1996; Prins & Olff, 1998; Hulbert & Andersen, 2001). This competition can lead to the exclusion of one species by the other or to a reduction in the abundance of both species (Sale, 1974; Abrams, 1998). Alternatively, if the resources are abundant, they coexist by smoothly sharing without competing for resources. Both ecological forces (current competition and predation) and evolutionary history (ghost of competition past) can be attributed to resource partitioning among the ungulate communities (Connell, 1980). The major selective force is considered to be competition, causing differential use of resources by coexisting species (MacArthur, 1972; Cody, 1975; Pianka, 1976; Roughgarden, 1983). Competition serves as a crucial bridge between limited resources and niche differentiation. It is not just a consequence of resource scarcity but also a driving force behind niche partitioning (Milinski & Parker, 1991). The intricate interplay between resources, competition, and niche shapes the coexistence of species (Xian,2008).

In line with the Habitat Selection theory (Hutchinson, 1957; Orians & Wittenberger (1991), species that coexist in the same geographical area with overlapping ecological niches exhibit distinct behavioral traits that result in their spatial or temporal separation within that shared range (Namgail, 2001; Darmon et al., 2011). The classical concept of 'Niche' underscores the significance of inter-specific competition and resource partitioning in facilitating the coexistence of species (Hutchinson, 1959; Schoener, 1974; Giller, 1984; Goldberg & Barton, 1992; Whitfield, 2002). Differential resource selection is one critical relationship that enables the species to coexist (Rosenzweig, 1981). It can be related to habitat preferences, food choices, or anti-predator tactics (Namgail et al., 2007). Native herbivores have evolved to coexist with each other in natural ecosystems over millions of years (Voefen & Prfns, 1999).

1.2 Resource Selection in Trans-Himalayas

Many studies have examined the interaction between livestock and wild ungulates (). Few studies have looked into the interaction between wild ungulates and very few have been conducted in the winter season.

Studies in Nepal and the Indian Trans Himalayas say that blue sheep and ibex have a closer relationship with free-ranging yaks than small livestock regarding habitat use (Shrestha & Wegge, 2008; Bagchi et al., 2004). The expansion of goat and sheep grazing into higher elevations during the summer has increased competition for resources with blue sheep (*Pseudois nayaur*) (Shrestha & Wegge, 2008). A study in Mongolia by Odonjavkhlan et al. (2021) suggests that topography is crucial in facilitating the coexistence of Tibetan Argali and blue sheep at a broad regional scale. Their actual overlap within their home ranges is constrained, primarily by differences in terrain ruggedness, thus suggesting that fine-scale habitat variations influence their ability to share space. Research conducted by Bhatnagar et al. (1997) and Bagchi et al. (2004) reports on the habitat partitioning between ibex (*Capra sibirica*) and livestock. Ibex occupy more rugged and inaccessible areas of the mountains, while domestic livestock can graze in the more accessible pastures at lower altitudes, thus, allowing species to coexist without competition for food or space. A study by Bagchi et al. (2004) shows that the co-occurrence of ibex and free-ranging horses was unexpected, suggesting a possible facilitative interaction between the two species—emphasis on further investigation on this.

Studies have been done looking at the occurrence pattern with blue sheep and Ladakh Urial at multiple scales (regional, landscape, habitat levels) and concluded that the presence of blue sheep appears to constrain the population and range expansion of Ladakh Urial (Namgail et al., 2010). Most rangelands in Spiti are overstocked, where domestic herbivores reach biomass levels up to ten times higher than that of wild herbivores (Mishra et al., 2001). Research by Mishra et al. (2002) investigated whether the low diversity of wild herbivores in Spiti Valley results from the high diversity of livestock. The close match between the body weights of livestock species compared to wild herbivores in Spiti Valley implies that competition may have driven out the missing wild herbivore species. Further, a study by Mishra et al. (2004) indicates that livestock grazing reduces forage availability. There was a considerable overlap in the diet of blue sheep and livestock. During summer, the diet of the blue sheep is a component of the diets observed in three different livestock species. This decreased blue sheep's population density and led to poorer performance with a low ratio of young to adult females. Previous research has focused on explaining resource selection in ungulates by examining their dietary patterns (Bagchi et al., 2004; Namgail et al., 2007; Suryawanshi et al., 2009). Suryawanshi et al. (2009) explored the dietary transition of blue sheep from primarily composed of graminoids in the summer to one dominated by browse during winter due to low graminoids availability. This can have nutritional costs and impact life history parameters such as body mass and vital rates. The findings of the study by Koetke et al. (2020) indicate that during autumn, blue sheep appear to consume fewer graminoids.

A review on food plants and feeding habits of Himalayan ungulates by Awasthi et al. (2003) listed the forage plant species documented from studies on blue sheep, ibex, musk deer, goral, and domestic ungulates. Diets of ungulates (wild and domestic) were studied using dung analysis (Hussain et al., 2010; Bhattacharya et al., 2012; Manjrekar et al., 1997) and direct observations (Bagchi et al., 2004; Liu et al., 2007) and a combination of both (Shrestha et al., 2005). Habitat selection by ibex (*Capra ibex*) (Bagchi et al., 2004), Argali (*Ovis ammon*) (Namgail et al., 2007), and livestock were analyzed using Non-Metric Multidimensional Scaling (NMDS) (Bagchi et al., 2004; Namgail et al., 2007), while Bagchi et al. (2004) used chi-square tests of association to determine the association of kiang (*Equus kiang*) with habitat categories. Correspondence analysis was carried out by Shrestha and Wegge (2008) to look at seasonal and cross-seasonal patterns of association between animal groups and habitat categories. The overlap in the diets of different species pairs was assessed using Pianka's overlap index (Bhattacharya et al., 2012) and Schoener's index (Hussain et al., 2010). A research study by Bhattacharya et al. (2020) is the first to apply a point process framework to analyze resource selection based on data gathered without radio-telemetry. Incorporating spatial data on blue sheep and livestock locations and topographic covariates, the researchers constructed a resource selection probability model using an intensity function method. The study found that blue sheep actively avoid the optimal areas, a behaviour that could alter their foraging habits and diets. Bhattacharya et al. (2012) prove the theory of the Jarman-Bell principle, which states that “Larger herbivores can subsist on less nutritious food than smaller ones”. Namgail et al. (2004) investigated the ecological separation between Tibetan Argali and blue sheep by examining their preferences for specific physical habitats and plant communities in Hemis High Altitude National Park. The coexistence of two species is attributed to distinct habitat preferences aligning with their unique anti-predator strategies. Research by Fox et al. (1992) identified a distinct movement pattern of ibex during winter, strategically positioning themselves in relation to escape terrain based on their activity. Ibex exhibited the most significant distance from escape terrain during the morning feeding period, were nearest during the midday bedding period, moved away again in the evening feeding period, and returned to the proximity of cliffs at dusk. In a study carried out by Namgail et. al (2009), blue sheep had a wider habitat width in Kibber, where it shares its resources with one sympatric species (Ibex) than in Gya-Miru (with Ladakh urial), and a narrower habitat width in Hemis, where resources are shared with two sympatric species (Ibex and Ladakh urial). Research by Manjrekar (1997) signifies that ibex adjusts their feeding approach based on the presence and abundance of different plant species. During late summer and autumn, they exhibit a generalist feeding behaviour, showing adaptability to shifts in the timing and availability of vegetation. In spring and early summer, periods of abundant food availability, they become selective feeders. In the winter, when both the quantity and quality of food are limited, ibex adopts an opportunistic feeding strategy.

Only one study has been conducted on differential habitat use between blue sheep and ibex in Ladakh during winter by Namgail (2006). Asiatic ibex and blue sheep prefer habitats near cliffs, indicating a shared preference for rugged terrain. They also exhibit similar slope angle, elevation, and snow cover preferences. However, ibex distinctly avoids gentle slopes and snow-free areas, while blue sheep steer clear of very low elevations. These distinct habitat preferences suggest that the two species have evolved to utilize different niches within the shared mountainous environment. The research also indicates that the substantial overlap in habitat utilization may be attributed to the potential for mutual protection against predators.

1.3 Bharal or blue sheep (*Pseudois nayaur*)

A medium-sized ungulate, group living, belonging to the family Bovidae, sub-family Caprinae, and tribe Caprini, widespread and locally abundant herbivore in Trans-Himalaya and the Tibetan Plateau (Miller & Schaller, 1996; Johnsingh et al., 2006).

The Kunlun and Nanshan mountains delineate its northern range boundary. The majestic Himalayas form the southern boundary (Schaller, 1977). However, the blue sheep has proven its adaptability by venturing into the Tibetan marginal mountains and navigating through some gorges within the main Himalayan range. The eastern boundary of the blue sheep's range lies in western Sichuan and Gansu, characterized by a rugged terrain punctuated by deep river gorges, including those of the Yangtze and Min rivers. The western boundary is less defined, extending northward from around the town of Kargil across Ladakh and up the Nubra Valley. It then curves around the eastern end of the Karakorams before continuing as far west as the Hunza district of Pakistan (Schaller, 1977). They are found in alpine and steppe, mountain pastures, and subalpine slopes devoid of tree cover, in elevations between 2,500 to 5,500 m (Prater, 1980; Sathyakumar & Bhatnagar, 2002). They prefer open grassy or boulder-strewn ground, often with high cliffs and crags. While they utilize these rocky areas for shelter and escape from predators, their primary foraging grounds are alpine meadows (Menon, 2014). blue sheep choose steep terrain close to exposed rocks or cliffs to minimize predation risk by snow leopards (Wilson, 1981; Harris & Miller, 1995; Oli, 1996; Namgail et al., 2004).

Indeed, the blue sheep exhibits a fascinating blend of goat and sheep-like characteristics. Their horns, with their pronounced curvature, resemble those of goats, while their overall body structure and social behaviour bear similarities to sheep (Schaller, 1977; Menon, 2014). It lacks a beard and possesses foot glands, similar to other sheep family members. It also exhibits traits that align it more closely with goats (Schaller, 1977; Menon, 2014). Notably, the blue sheep's horns are smooth and lack the distinct ridges seen in sheep. Additionally, they lack facial glands, a feature characteristic of goats. This intriguing combination of traits highlights the blue sheep's unique evolutionary position, bridging the gap between sheep and goats (Schaller, 1977; Menon, 2014). However, recent genetic studies have provided a clearer picture, placing the blue sheep more closely related to goats (genus Capra) than sheep (genus Ovis) (Schaller, 1977; Menon, 2014).

Adult males have slate-blue coats that darken in winter. Females and young have red-brown coats in summer for camouflage. Interestingly, they are found in the Trans-Himalayan region and tend to have lighter, almost cream-colored coats, while those in the Himalayas have darker coats. This variation in coloration suggests that blue sheep have adapted to the specific environmental conditions of their respective regions. Adult male blue sheep have dark markings on the neck, chest, and legs, a white rump patch, and distinctive crescent-shaped horns (Schaller, 1977; Menon, 2014).

The species is categorized as Least Concern by the International Union for Conservation of Nature (IUCN) (Reading et al., 2020) and listed under Schedule I of the Wild Life (Protection) Amendment Act, 2022.

1.4 Himalayan ibex (*Capra sibirica*)

A large mountain goat, well-adapted for climbing, and belongs to the family Bovidae, sub-family Caprinae, and tribe Caprini (Bhatnagar, 1999).

The Asiatic ibex, a wild goat species, boasts an extensive range from the Hindu Kush mountains in Afghanistan to the Sayan Mountains in Russia's north, encompassing diverse mountainous landscapes. Their southernmost reach extends to the Pir Panjal range in Himachal Pradesh, India. Their habitat encompasses the Pamirs, Tien Shan, Kara Tau, Tarbagatay, and Altai mountains. The Asiatic ibex has established itself across all major mountain ranges in North-

Western India and Pakistan. In Ladakh, the upper Shyok River and Leh's vicinity mark the species distribution's eastern boundary. However, the animal's range extends eastward to the Sutlej River along the Himalayan chain (Schaller, 1977; Roberts, 1977; Prater, 1980; Fox et al., 1992; Bhatnagar, 1997).

The Asiatic ibex thrives in the harsh environments of high-altitude mountains, primarily between the tree line (approximately 2,500 to 3,000 m.s.l) and the upper limit of vegetation, which extends up to around 5,000 meters (Schaller, 1977; Prater, 1980; Bhatnagar, 1977). However, in its more northerly range, particularly in the Tien Shan and Altai mountains, the Asiatic ibex demonstrates remarkable adaptability, venturing as low as 500 meters above sea level. In these areas, it predominantly utilizes habitats between 1,000 and 2,000 meters (Bhatnagar, 1977). The Asiatic ibex grazes on alpine pastures, wet meadows, and dry grassland steppe, always near steep terrain (Menon, 2014).

It can be easily distinguished from other members of the Caprid family by its distinct horns and beard (Menon, 2014). Asiatic ibex exhibit sexual dimorphism in their coat color and pattern. Male Asiatic ibex has a striking dark brown winter coat with a white saddle and markings, while females have a grey-brown coat with less conspicuous whites (Menon, 2014; Schaller, 1977).

Males are distinguished by their thick, scimitar-shaped horns that diverge and curve backward, giving them a formidable appearance. Males have long beards, and females have shorter ones. It has powerful forelimbs to propel itself up and over rocks. Its legs are short and robust, which gives it the stability it needs to climb in steep terrain (Schaller, 1977).

The species is categorized as Near Threatened by IUCN (Reading et al., 2020) and listed under Schedule I of the Wild Life (Protection) Amendment Act, 2022.

A study by Joshi et al. (2023) revealed a paraphyletic relationship between Himalayan and Siberian ibex through Bayesian-based phylogenetic analysis, indicating significant genetic divergence and allopatric speciation in the Himalayan ibex. The research examined the evolution of the Himalayan ibex over the past 100,000 years, identifying river systems as barriers that restrict gene flow and contribute to this divergence. These findings suggest that the Himalayan ibex is an evolutionarily distinct phylogenetic species, proposing a taxonomic upgrade to *Capra himalayensis* to enhance conservation efforts regionally and globally.

Initial observations of their habitat preferences suggest they share similar requirements, such as altitude, slope angle, and rock type (Mallon, 1991). It raises the possibility that the two species may compete, with one species potentially having a negative impact on the other. Unofficial reports of their distributions, particularly in the vast mountainous regions of the North-Western Tibetan Plateau, indicate clear boundaries between their ranges. This observation suggests a possible scenario of competitive exclusion, where one species may negatively influence the presence or distribution of the other (Schaller, 1998).

The evolutionary history and dispersal of ibex and blue sheep are significant. Ibex likely originated from the Mediterranean region, while blue sheep evolved near the Tibetan plateau (Schaller, 1977; Bhatnagar, 1997). Blue sheep may have colonized areas before the arrival of ibex, giving them an advantage. These species overlap in narrow strips in the Taxkorgan Reserve in China (Schaller et al., 1987) and near Leh in Ladakh (Osborne et al., 1983; Mallo, 1991). The Kibber region is another area of overlap, and more such regions are expected along the Pir Panjal range in Himachal Pradesh (Bhatnagar, 1997).

1.5 Threats

Threats include the introduction of livestock into wild habitats, which disrupts the natural balance of resources, as native species have not had enough time to adapt to the presence of these new competitors (Syed & Khan, 2017). When livestock and wild herbivores share similar habitats and food sources, overstocking livestock can lead to excluding wild herbivores from their natural environment (Mishra et al., 2002; Bagchi et al., 2004). It could also pose a risk to the wild ungulate population due to the potential transmission of infectious diseases (Bhatnagar & Rawat, 1999). Climate change is one of the major threats. Rising temperatures are causing an early bloom of spring vegetation, which may initially benefit some ungulate species. However, this early green-up also leads to earlier migration and increased resource competition, putting these animals under immense pressure. Recently, feral dogs are a serious threat to wildlife. Previously ibex and blue sheep were poached for meat (Fox et al., 1991).

Even though some studies have been conducted on blue sheep and ibex, ecological dynamics and interactions between the species need to be better known. The mechanism that leads to resource partitioning among wild ungulates needs to be better understood. Also, only one study has looked into the differential habitat use between blue sheep and ibex in Ladakh during winter (T. Namgail, 2006). The study says that more research is needed to fully understand the extent of overlap in their diet. This information is crucial for accurately assessing the degree of resource competition and identifying potential management strategies for their sustainable coexistence. Studies on resource partitioning have investigated the interaction between livestock and mountain ungulates for Asiatic ibex (Bhatnagar et al., 2000) and blue sheep (Mishra, 2001) in the arid region of the Indian Himalayas. However, apart from theoretical considerations (Mishra et al., 2002), there is limited exploration of niche segregation among wild species in that area (Namgail et al., 2004). Many studies have concentrated on competition as a likely element that influences the coexisting species to differ in resource use. However, the role of predation in differential resource utilization needs to be more comprehended. Predation may facilitate resource partitioning if species occupy different habitats for the safety of predators (Sih et al., 1985; Repasky, 1996).

There is a narrow overlap between blue sheep and ibex in their distribution. The study aims to unravel how the two species coexist through differential resource utilization (habitat and diet).

Thus, the following objectives are proposed to investigate the resource use and ecological separation between blue sheep and ibex.

1.6 Objectives

Objective 1: To assess the patterns of habitat selection by blue sheep and ibex during winter.

Objective 2: To evaluate niche overlap (time and diet) between blue sheep and ibex during winter.

Research Questions

Objective 1:

1. Do species differ in the use of space?
2. How do factors such as snow cover, snow depth, and proximity to escape terrain influence the habitat selection of blue sheep and ibex during peak winter?

Objective 2:

1. How similar or dissimilar is the selection and utilization of forage between ibex and blue sheep?
2. What is the temporal overlap between blue sheep and ibex during winter?

2.STUDY AREA

2.1 Location and Topography

The Indian Trans-Himalayas, covering parts of the Tibetan Plateau and the Greater Himalayas, extend over 186,000 km2 (Mishra et al., 2004), shared in 5 states on the Northern boundary of the country, viz., erstwhile Jammu and Kashmir (including Ladakh), Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh.

My study was carried out in Kibber Wildlife Sanctuary (32° 19′ 54″ N, 78° 0′ 32″ E) located in the Spiti sub-division of Lahaul & Spiti district, Himachal Pradesh. The elevation range is 3,600–6,800 m (11,800–22,300 ft) above mean sea level. The sanctuary was first established on 1st Nov 1999 with an area of 1,400 km^2. Later the area was increased to 2,220 $km^{2.}$ On 7th April, 2013. The Sanctuary lies on the Northern banks of the Spiti River, situated along the Plateau. This is classified under the "Trans-Himalayan Cold Desert" (Zone 1) biogeographic zone with Province 'Ladakh mountains (1B) by Rodgers and Panwar (1988).

Intensive study area

The intensive study area (57 km^2) is located around Kibber and Chicham areas. The altitude ranges from 3,800m to 5,400m above mean sea level. The terrain was mainly rolling hills, intermittently interrupted by rocky cliffs and outcrops.

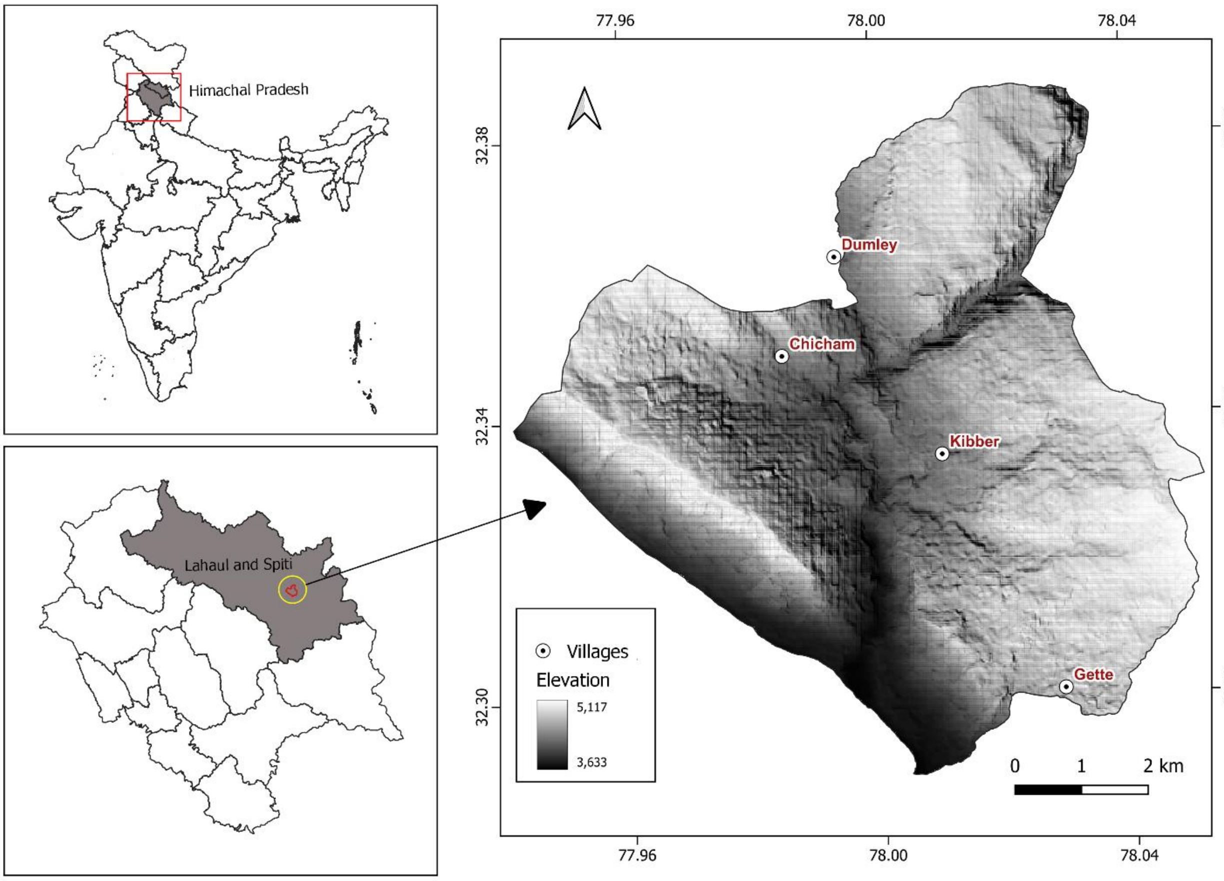


Fig 2.1 Study area map with locations of villages marked.

2.2 Climate and Seasons

Spiti Valley lies on the leeward side of the Pir Panjal range of the Himalayas, which blocks the monsoonal effects from the plains, making the region dry and cold. The annual precipitation, primarily in the form of snow, averages around 200mm. Winters are harsh with temperatures up to -40°C, while summer temperatures reach around 30°C. The minimum temperature remains sub-zero from September to April (Bhatnagar, 2016).

In spring (between April and May). The thaw begins, revealing patches of bare ground as snow and ice melt. Vegetation sprouts during this period. As summer arrives (from July to September), vegetation experiences its peak growth. By the end of August, senescence sets in, leading to dry conditions that persist until snowfall occurs in December or January (Bhatnagar, 2016,1997).

2.3 Rocks and Soils

The region exhibits a geological transition between quartzite, shales, limestones, and conglomerates. Fossils, including brachiopods, trilobites, ammonites, bivalves, corals, and algae, provide evidence of its Tethyan history (Bhatnagar, 2016). The high-altitude desert soils are shallow and sandy, shaped by diurnal and seasonal temperature fluctuations. Avalanches and streams transport substantial amounts of soil to lower valleys and alluvial fans, resulting in rich plant cover (Bhatnagar, 2016). These soils predominantly consist of silty loam to silty-clay loam, with a slightly alkaline pH and characterized by low organic matter and water retention capacity. Soils are rich in calcium but poor in other essential nutrients such as nitrogen, phosphorous, and potassium (Bhatnagar, 2016).

2.4 Flora

In summer, plant growth is limited to a short season from May to August due to low temperatures during the rest of the year. Soil moisture availability plays a crucial role during the growing season. The vegetation in the Spiti Valley is categorized as 'Alpine scrub' according to Champion and Seth (1968) and as 'Dry Alpine steppe' vegetation based on Schweinfurth (1957) and Puri et al. (1989). It is characterized by scattered and open bushland. Prominent shrubs include *Caragana versicolor*, *Ephedra geraradiana*, and *Rosa webbiana*. Herbs found in the region are *Christolea crassifolia*, *Arnebia euchroma*, *Heracleum pinnatum*, *Artemisia sp*., *Polygonum sp*., *Oxytropis sp*., *Cousinia thomsonii*. Grasses include *Stipa sp*., *Piptatherum sp*., *Festuca sp*., *Deschampsia sp.*

Cliffs and steep rocky slopes have *Ribes orientale*, *Rosa webbiana* etc and moist areas near river valleys, springs, and glaciers are frequently covered by sedge meadows, featuring species such as *Carex* and *Kobresia*. At elevations up to 4,600 meters, open or desert steppes predominately feature grasses such as *Stipa, Leymus, and Festuca* species, along with sedges such as *Carex* species. Between 4000 to 5000 meters, dwarf shrub species are common, including shrubs such as *Caragan*a. Lower to middle slopes have *Ephedra* and *Rosa sp*., while middle to higher slopes have *Lindelofia and Potentilla sp*. (herbs); *Festuca sp., Stipa sp., Piptatherum sp.* (grasses); *Caragana, Ephedra* (shrubs). Vegetation extends up to 5,200m, though it becomes sparse above 4,800m (Bhatnagar, 2016,1997). Vegetation is sparse, with herbage seldom exceeding 1 meter (Mishra et al., 2004).

2.5 Major Fauna

The diversity of large mammalian fauna in this region is lower compared to other Trans-Himalayan areas, as documented by Chundawat (1992), Mallon (1991), and Bhatnagar (1997). The large mammals include Snow leopard (*Panthera uncia*), Himalayan ibex (*Capra siberica himalayanus*), blue sheep (*Pseudois nayaur*), Himalayan wolf (*Canis lupus*), Red fox (*Vulpes vulpes montana*). Small carnivores include Stone marten (*Martes foina intermedia*), Mountain weasel (*Mustela altaica temon*), and Himalayan weasel (*Mustela siberica*). Pikas (*Ochotona sp.*) and Woolly hare (*Lepus oiostolus*) are also present in the study area.

There are 69 bird species recorded in my study area (Source: eBird). Avian fauna includes the Bearded vulture (*Gypaetus barbatus),* Golden eagle (*Aquila chrysaetos),* Himalayan Griffon (*Gyps himalayensis*), Himalayan Snow cock (*Tetraogallus himalayensis*) and Chukar partridge (*Alectoris chukar*).

2.6 Local people and land use

Agro-pastoralism has been practiced in the region for over 2,000 years. People are mainly Agro-pastoralists even though some men work as guides for mountaineers and trekking tourists. Inhabitants follow Tibetan Buddhism. Livestock grazing is prevalent, with stall-feeding during winter. Agricultural and rangeland production occurs between May and September. Cultivation is dependent on the snow melt, which is channeled from glacial ponds to the terraced fields around villages through long channels (several km) dug along the contours. The climatic challenges for agriculture are limited irrigation water and early autumn frost. Crops cultivated are Barley, Green peas, potato, and mustard. In low-lying villages, fruits such as apples and apricots are grown. Black pea (a local variety of green pea) is used as fodder and also for consumption. A single crop is raised during summer and the main agricultural activities begin around mid-April (Mishra, 2001). Livestock includes yak, cows, yak-cow hybrids (dzo-male; dzomo-female), horses, and donkeys constitute large livestock. Smaller livestock include sheep and goats. Dzomo, sheep, and goats are accompanied by herders, yaks and horses are free-ranging. Yaks and dzo are used for plowing, donkeys as draught animals, and horses are used for religious purposes and trade. All animals are used for meat and milk except for horses and donkeys. Sheep are used to extract wool; yak's hair is used to make ropes. During winter, all animals are kept in pens and are stall-fed (Mishra, 2001).

In Kibber village, decisions on collective work, dispute resolution, and access to common resources such as grazing, fuel, fodder, and irrigation water are made by a council comprising three group representatives (n*umberdaars*) from *Dhontoth, Dhonsham,* and *Dhonhar* groups. Additionally, there is a 'head' *numberdaar* who rotates annually. Majority rule governs decision-making, while major decisions are consulted with 5-10 village elders (Mishra, 2001).

3 METHODOLOGY

The study follows Type I design where the measurements were made at the population level. Used, unused, and available resource points were collected within the study area and for the collection of all animals within the study area (Manly et al., 1993). The assessment for resource use was carried out based on the use-availability framework (Marcum & Loftsgaarden, 1980). The availability of a component refers to its accessibility to the consumer and the usage of a component by the consumer is the amount of that component used by the consumer within a specific period (Johnson, 1980).

Resource selection by species follows a hierarchical process, starting from the geographical range down to the individual home range, then to general habitat features within that range, and finally to the selection of specific elements such as food items (Manly et al., 1993).

3.1 Field methods:

A preliminary reconnaissance was carried out at the beginning of the study between (15 January to 22 January 2024) to determine the optimal sampling methods (vantage points or line transects or trails) and to identify areas that fall in my study area, while considering the logistical constraints.

Monitoring trails and vantage points were utilized as the primary methods for systematic sampling. Trails were laid in the study area to gather information on_spatial distribution and study resource selection for the ungulates. A total of 10 monitoring trails were walked in the study area (ranging from 0.4 to 1.8 km2). Two vantage points were chosen.

Transects were walked uniformly, and areas on both sides of the transect were scanned. 10×42 binoculars were used to look for animals. Once the animals were sighted, Hawke spotting scope of 25 - 75× magnification was used to observe them and classify them into different age classes.

For each sighting, information such as the date and time of the observations, site, GPS locations, species, group ID, group size, group type, age and sex composition, dominant activity, distance from the observer to the animal, bearing (animal and transect) and habitat type were recorded.

Ibex and blue sheep populations were categorized into three distinct group types: all-male, female-young (including class 1 sub-adult males), and mixed groups (comprising adult males, females, and young) (Bhatnagar, 1997).

Each herd sighting was considered as one observation despite the number of individuals in the herd. If a herd is separated from another herd by approximately 150 meters, then it is considered a separate group. GPS locations of the animals were recorded by visiting the exact locations where they were seen feeding, after they moved out of the area or by projecting GPS locations, ensuring that the recorded location was within 30-40m of their actual locations.

Scan sampling was conducted for five minutes, followed by ten minutes of focal sampling. After a five-minute break, the cycle of scan and focal sampling was repeated, ensuring that animals of various age classes and sexes were included in the focal observations. Behavioral observations of ibex and blue sheep were conducted during daylight hours, from 9:00 AM to 5:00 PM, to align with the diurnal activity patterns of these ungulates, as documented in previous studies (Schaller, 1977; Namgial, 2006).

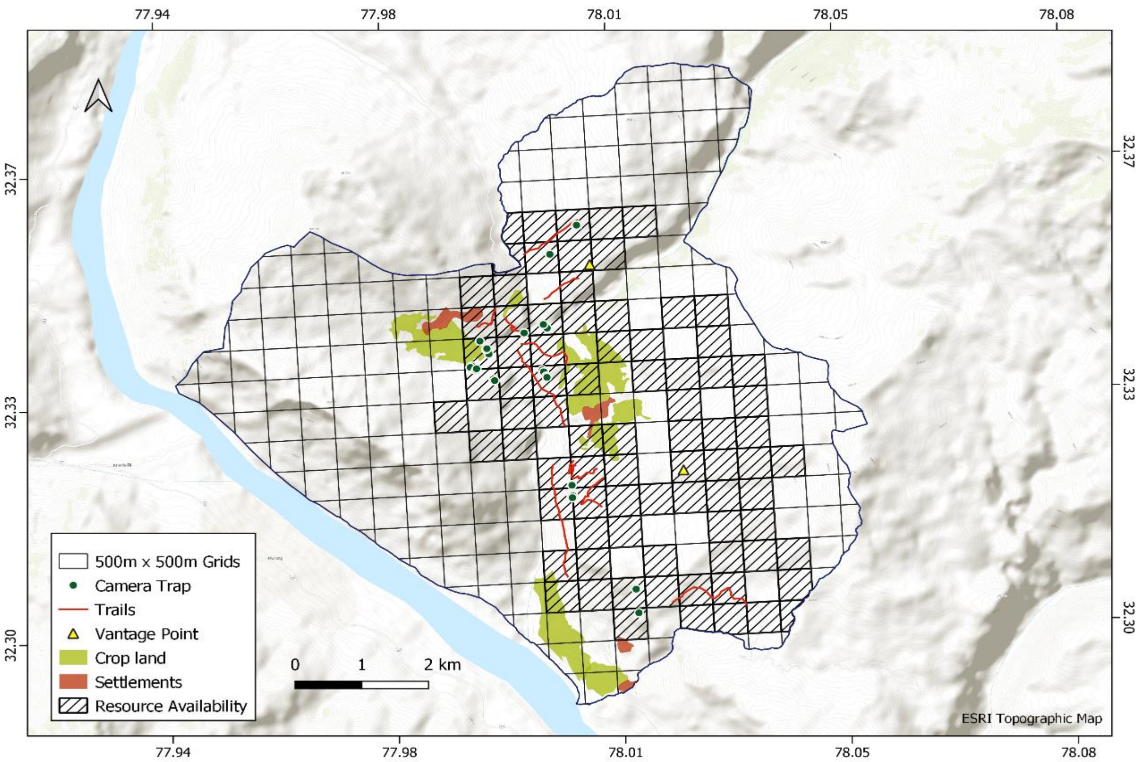


Fig 3.1 Various monitoring trails, vantage points, CT locations, settlements, croplands, and resource availability grids are marked.

Table 3.1: Ethogram of Ungulate species – ibex and blue sheep.

Sl. No	Behaviour	Definition
1	Foraging	Feeding on the plants or lowering its head or oriented towards the food plant.
2	Resting	Inactive and stationary; eyes may be open or closed; maybe standing, sitting, or lying down.
3	Movement	Locomotion of different types such as walking, jumping, running, etc.
4	Aggression	Display of hostile behaviour towards another individual such as chasing, physical confrontations.
5	Grooming	Cleaning and maintaining the body includes licking, rubbing, etc.
6	Vigilance	Alert and attentive behaviour, scanning the surroundings with head raised above the horizontal plane and also ears raised.
7	Sniffing	Using the nose to investigate the environment, objects, or other animals.
8	Defecating	Act of expelling feces from the body.
9	Cratering	Digging into the ground using its hooves to unearth food.
10	Ruminating	Repeatedly Chewing the cud.

3.1.1 Resource Utilization by ibex and blue sheep

a. Habitat availability and selection

<u>Availability:</u>

The study was carried out in four locations - Chicham. Kibber, Gette, Dumley. A grid (1minute × 1minute, 500m × 500m) was overlaid on a satellite image of my study area downloaded from Google Earth Pro 7.3.6. These grids were utilized to sample for forage and habitat availability. Since the area of my study site was 57.3km2 and half of the grids in the study area were inaccessible due to terrain type and high snow cover, So, systematic sampling was done to record the resource availability in the accessible areas to ensure comprehensive coverage throughout the study area.

Within each grid, ten Random points were laid and points were chosen based on the accessibility and ensuring coverage of different habitat types within the grid. The Availability of habitat features was recorded within a 30-meter radius plot around the point. Variables such as elevation, terrain type, distance to the cliff, vegetation type, vegetation cover, rock cover, soil cover, snow cover, snow depth, and the number of directions in which escape terrain is available were estimated using a Non-Mapping technique (Marcum and Loftsgarden, 1980). The topographic variables such as aspect, slope, and terrain ruggedness index were extracted from a 12.5 m resolution Digital Elevation Model (DEM), downloaded from Alos Palsar, in ArcGIS Pro 3.3. Elevation was recorded using Garmin 72 GPS and extracted from DEM (Bhatnagar, 1997; Raghavan, 2003). Distance to the cliff was recorded using a Hawke 400 range finder.

Utilization and Selection

To quantify and detect patterns in habitat use and selection by ungulates, I employed focal species plot sampling, wherein, habitat variables were recorded at the animal's location (during the transect walks) after the herd left the area. Habitat variables such as elevation, terrain type, distance to cliff, vegetation type, vegetation cover, rock cover, soil cover, snow cover, snow depth, number of directions in which escape terrain is available were collected around a 30-meter radius plot and topographic variables such as aspect, slope, terrain ruggedness index were extracted (Bhatnagar, 1997; Raghavan, 2003; Hussain, 2010; Chanchani, 2007).

Table 3.2: Habitat variables and categories used in quantifying habitat utilization by ibex and blue sheep.

Habitat Variables	Categories	Description
Elevation (m)	Lower Elevation	≤4000m
	Middle Elevation	≤4500 < 5000m
	Higher Elevation	≥5000m
Aspect	North	(0º - 22.5º)
	Northeast	(24º - 68º)
	Northwest	(294º - 337º)
	South	(159º - 203º)
	Southeast	(114º - 158º)
	Southwest	(204º- 248º)
	East	(69º - 113º)
	West	(249º - 293º)
	North	(337.5º - 360º)
Slope (angle measured in degrees at every 5° intervals)	0-10°	Very gentle slopes
	11-20°	Gentle slopes
	21-30°	Intermediate slopes
	>30°	Steep slopes
Terrain type	1. Interspersed Rocky Slopes 2. Rocky slabs 3. Cliffs 4. Rocky slopes 5. Smooth slopes 6. Scree 7. Valley bottom	1. Interspersed Rocky Slopes- Steep areas, > 40° inclination, characterized by broken terrain, usually beneath large rocky slabs & cliffs. 2. Rocky slabs - Parallel rocky slabs with intermittent patches of vegetation 3. Cliffs - Rocky slopes with inclination >50° 4. Rocky Slopes - Slopes with an exposed rock cover of >20 %, often forming stony fields. 5. Smooth Slopes - Gentle slopes with <20% rock cover, typically featuring good vegetation.

		6. Scree - Loose rocky slopes spreading out below rocky slabs and cliffs. 7. Valley bottom - Usually rocky and flat land at the base of the valley, occasionally featuring shrubby patches.
Distance to the cliff (escape terrain)		Measured in units of meters
Cover values for vegetation, snow, rock, soil		Within a 30m radius plot, recorded in % in units of 5
Snow depth		Measured in cm at 5m intervals
Number of Directions in which ET is available within 100m (8 directions are identified w.r.t both observer's position and ibex)	1 2 3 4 5 6 7 8	above above right right below right below below left left above left
Vegetation type		Classified based on the dominant species present in the plot

b. Forage availability and selection

Availability

Analogous to habitat selection, food selection was evaluated using a use-availability framework. Forage availability was recorded around the point where habitat availability was recorded.

To assess forage availability, vegetation sampling was conducted using the quadrat method. A circular plot with a radius of 10m was laid around the point. Within this area, five (1 x 1m) quadrats were randomly selected and sampled (without replacement) to quantify forage (Rawat and Adhikari, 2004). Quadrats for sampling were chosen randomly by tossing a stone in the direction indicated by the second hand of a dial watch (Chanchani, 2007). Within each quadrat, plant species and several individuals were recorded and the height of significant forage species was measured. Additionally, vegetation cover, soil cover, and rock cover were recorded for each quadrat. The vegetation type for the entire circular plot was recorded (Manjrekar,1997).

Utilization and Selection

For assessing use, several sites where animals had been feeding were sampled same as the initial forage availability sampling. This was done after the animals vacated the area, typically on the same day or within the subsequent 48 hours. When the area was covered with snow, snow was removed within the quadrats, additionally, snow cover, snow depth, and cratering depth (when possible) were recorded.

Pellets of ibex and blue sheep were collected for fecal analysis to determine the percentage of monocots and dicots in their diet. Dung analysis has been a commonly employed method for studying the feeding habits of ungulates (Holechek et al., 1982; Green, 1987; Mishra, 2001; Shrestha et al., 2005). Micro histological analysis is the most commonly used method (Sparks

& Malechek, 1968; Green, 1987) for determining the botanical composition of range herbivore diets (Hansen, 1969; Holechek et al., 1982; Alipayo et al., 1992).

Fresh pellet groups were collected when the animal was seen defecating primarily from the use plots. Each pellet group's location (GPS coordinates), size, number, and characteristics were recorded. Vegetation type, elevation, slope, and aspect were noted. The pellet samples were collected in zip-lock bags and labeled. It was then sun-dried and stored with silica gel. A total of 40 independent pellet samples of ibex and 36 samples of blue sheep were collected between January and April 2024.

3.1.2 Temporal overlap using camera traps

Camera traps were deployed in clusters at sites frequented by ibex and blue sheep. A total of 31 camera traps were deployed. Of these, 29 camera traps were used for the analysis. Ibex was detected by 12 cameras and blue sheep by 7. However, logistical challenges and heavy snowfall impeded proper monitoring, resulting in fewer detections.

3.2 Laboratory methods

From the collected independent pellet samples, 15 out of 40 from ibex and 15 out of 36 from blue sheep were selected for the analysis. All 30 samples (15 of ibex and 15 of blue sheep) were oven-dried at 55° to 60° C for 48 hours, then stored and labelled in paper bags.

Hoyer’s solution, known as gum chloral, emerged as one of the initial mounting mediums commonly utilized for bryophytes (Anderson, 1954; Conard & Redfearn, 1979; Schofield, 1985). Hoyer’s medium was prepared by dissolving 7.5g of Gum Arabic crystals in 12.5 ml of distilled water while continuously stirring. This might take some time and can be aided by gentle heating (do not boil) to speed up the process. Then 50g of chloral hydrate crystals was added to the gum Arabic solution while continuously stirring. The solution becomes somewhat thick and syrupy. 5ml of glycerine was added to the mixture and the solution was stirred thoroughly until all the components were completely mixed and dissolved. Then store the medium in an airtight container. Hertwig's solution was prepared by slowly adding 10ml of 1N HCl to 50ml of distilled water while stirring gently to ensure proper mixing. Then 10ml of Glacial acetic acid was added to the mixture. The solution was stirred thoroughly until all the components were completely mixed and dissolved (Green, 1987).

The oven-dried pellet samples were broken into pieces by hand and ground into powder in a CT 293 Cyclotec ™ mill fitted with a 1mm screen. The ground sample was then sieved through 1mm mesh sieves to remove dust and other coarse material (Sparks & Malechek, 1968). Then, a small quantity of powder was taken on the slide. Hertwig's solution was added to clear the pigments from plant tissues (Cavender & Hansen, 1970). The slide was gently boiled using a spirit lamp for 3-4 minutes. Then, Hoyer's solution was added. Hoyer's solution is used for making permanent slides. The solution is Hygroscopic and should be kept in a low-humid environment (Johnson et al., 1980). A coverslip of size 22×50mm was placed. Slides were prepared and viewed under a microscope and 100 identifiable fragments were counted at 40X magnification from 3 replicate slides prepared from each fecal pellet sample. The frequency of monocot fragments and dicot fragments was estimated (Manjrekar,1997; Shrestha et al., 2005).

4. ANALYSIS

a. Spatial overlap

To evaluate spatial overlap, the entire study area was divided into 1×1 cm grids overlaid on the study area shapefile (500×500 m on the ground). Direct Sightings, camera trap detections, and pellet collection locations of Ibex and blue sheep were plotted on the grids. This comprehensive data enhances the accuracy of identifying the grids utilized by ibex and blue sheep.

The spatial overlap between the two species was assessed using the Jaccard Similarity Index (Magguran, 2004; Kittur, 2010), calculated as:

$$S = A/(A + B + C)$$

Where A – represents the number of grids occupied by both ibex and blue sheep

B – represents the number of grids occupied only by ibex

C – represents the number of grids occupied only by blue sheep

To determine if the observed index value differs significantly from random expectation, the associated probability P (A, B, C) was calculated using the formula:

$$P(A, B, C) = N!/(A!\ B!\ C!) \times 3\text{^}(-N)$$

Where A, B, and C are the same as the Jaccard similarity Index and N = A+B+C

b. Activity pattern and temporal overlap

The “Overlap” package (version 0.3.9) was used in R-4.3.2 (R Core Team, 2014) to estimate the overlap of temporal activity patterns of ibex and blue sheep.

c**. Habitat selection and utilization**

TWINSPAN (Two-Way Indicator Species Analysis) is a hierarchical clustering technique that categorizes samples by progressively splitting them into smaller groups based on shared species composition. Starting with two groups, it continues to divide them into four, eight, sixteen, and so on. This method relies on the input of species abundance data from various sample plots (Hill, 1979). This technique was performed on the 750 quadrats from 150 vegetation plots using TWINSPAN codes in R 4.3.2 (Manjrekar, 1997).

Non-metric Multidimensional Scaling (NMDS) is an ordination method that simplifies complex multivariate data, allowing us to visualize sample relationships through their dissimilarities. NMDS was performed to reduce the dimensionality of habitat features and to visualize the separation between ibex and blue sheep based on differential use of habitat features (Bagchi et al, 2002), using the 'metaMDS function' in vegan package (version 2.6-6.1) and Bray-Curtis dissimilarity index in R 4.3.2. To verify if the observed differences are statistically significant, a Multi-Response Permutation Procedure (MRPP) was employed using the 'vegdist' function in the vegan package (version 2.6-6.1).

Logistic regression, implemented through Generalized Linear Models (GLMs), was utilized to identify the factors influencing the presence or absence of animals at specific locations. This approach is employed to understand how various habitat and vegetation factors affect the presence of ibex or blue sheep at the plot level, offering insights into local selection patterns (Chanchani, 2007). The predictor variables include the habitat variables. The quadratic elevation function was explored as a predictor to assess whether there were any peaks at the intermediate levels. To ensure relative importance, predictor variables were appropriately scaled before analysis. The models were selected based on the least AIC value (Akaike's Information Criterion).

Hypothesis testing was also done to compare the significant effect of each habitat variable for both species based on the p-value.

d. Diet selection and utilization

Ivelev's selectivity index (E) (Ivelev, 1961) was used to compare the use and availability of vegetation types and monocots & dicots.

$$E = \frac{P2A - P1A}{(P2A + P1A)}$$

Here, E value ranges from -1 to +1, values between 0 to +1 indicate preference, -1 to 0 indicate avoidance and 0 indicates no selection.

5. RESULTS

5.1 Vegetation communities

Flora in my study area was represented by 28 families, 67 genera, and 95 species. A list of plant species is given in Appendix A. Family Poaceae represented largest number of species (17 species), followed by Asteraceae (12 species), Cyperaceae, Brassicaceae, Polygonaceae, Rosaceae (8 species each), Boraginaceae (7 species), Fabaceae (5 species), Amaranthaceae (4 species), Caryophyllaceae, Lamiaceae and Crassulaceae (3 species each), Apiaceae, Primulaceae, Rubiaceae, Scrophulariaceae, Ranunculaceae, Gentianaceae and Crassulaceae (2 species each), Amaryllidaceae, Apocynaceae, Saxifragaceae, Ephedraceae, Orobanchaceae, Rhamnaceae, Grossulariaceae, Tamaricaceae and Violaceae (1 species each).

Eight distinct vegetation clusters were identified through TWINSPAN analysis, utilizing data from 150 vegetation plots and a total of 750 quadrats. The dendrogram in Figure 5.1 illustrates the clustering of quadrats to form these communities and Table 5.1 lists major communities from TWINSPAN analysis.

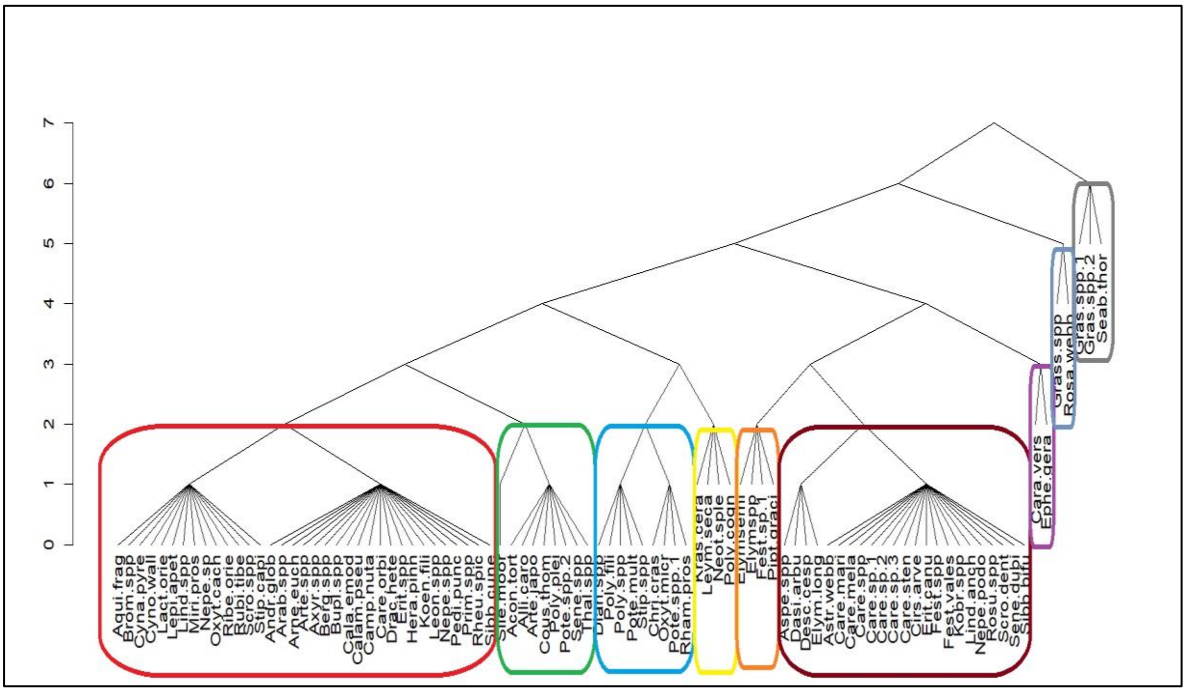


Fig 5.1: Dendrogram of vegetation communities based on TWINSPAN classification

Table 5.1: List of major vegetation communities

Sl.no	Vegetation communities
1	*Aquilegia – Arnebia – Nepeta*
2	*Silene – Cousinia – Potentilla*
3	*Kraschennikovia – Christolea - Polygonum*
4	*Caragana - Ephedra*
5	*Elymus spp – Piptatherum*
6	*Deschampsia – Carex – Festuca*
7	*Rosa webbiana*
8	*Sea buckthorn*

<u>Description of Vegetation communities</u>

Major vegetation communities are described in terms of indicator species, dominant species, and associated species, and influenced by a combination of habitat characteristics.

1. *Aquilegia – Arnebia– Nepeta* (Mixed herbaceous meadows)

This association represented 7.6% of the sampled area and was made of a number of herbaceous species including *Aquilegia fragrans, Bromus sp., Calamagrostis pseudophragmites, Cynanchica pyrenaica, Lactuca orientalis, Lepidium apetalum, Lindelofia sp., Miricaria prostrata, Nepeta sp., Ribes orientale, Rubia tibetica, Stipa capillata, Androsace globifera, Arabidopsis sp., Arnebia euchroma, Artemisia sp., Axyris sp., Bergenia sp., Bupleurum sp., Calamogrostis emodensis, Campeiostachys nutans, Carex orbicularis, Dracocephalum heterophyllum, Eritrichium sp., Heracleum pinnatum, Koenigia filicaulis, Leontopodium sp., Nepeta sp., Oxytropis cachemiriana, Pedicularis punctata, Primula sp., Rheum spiciforme, Scrophularia sp., and Sibbaldia cuneata*.

Most of the species here prefer cool and moist environment and a few species such as *Arnebia euchroma* prefer Arid and Semi-arid conditions. Vegetation cover varied from 5-60%, averaging 20.4%, occurring at altitudes ranging from 3859 – 4877m, on NW, W, SW, E, and

NE aspects, on Slopes ranging from 7-37.5°, occurring at terrain types of Scree, Rocky slopes, Rocky slabs, Interspersed rocky slopes, and Smooth slopes.

2. *Silene-Cousinia-Potentilla sp 2*

This association represented 8.9% of the sampled area, consisting of species such as *Silene moorcroftiana, Aconogonon tortuosum, Allium carolinianum, Artemisia japonica, Cousinia thomsonii, Polygonum pleibeium, Potentilla sp., Senecio sp., and Thalictrum sp.*

Species such as *Silene moorcroftiana, Aconogonon tortuosum, Cousinia thomsonii, and Polygonum pleibeium* indicate disturbed soils and *Potentilla sp* indicate soil health. Vegetation cover varied from 5-50%, averaging 19%, occurring at altitudes ranging from 3913 – 4648m, on N, NW, S, SW, and W aspects, on slopes ranging from 8-34°, occurring at terrain types of Scree, Rocky slopes, Valley bottom, Interspersed rocky slopes, and Smooth slopes.

3. *Krascheninnikovia-Christolea-Polygonum*

This association represented 27.3% of the sampled area, consisting of species such as *Christolea crassifolia, Dianthus sp., Oxytropis microphylla, Polygonum filicaule, Polygonum sp., Potentilla multifida, Potentilla sp.1, Rhamnus prostrata, Stipa sp., Cynoglossum wallichii, Grass sp., Krascheninnikovia ceratoides, Leymus secalinus, Neotrinia splendens, and Polygonum cognatum.*

Oxytropis microphylla is found in dry rocky soils, *Polygonum sp* is found in moist and disturbed areas, *Krascheninnikovia ceratoides* is found in dry and saline soils and *Leymus secalinus* is grown in steppe and semi-desert conditions. Vegetation cover varied from 5-50%, averaging 21.8%, occurring at altitudes ranging from 3864 – 5392m, without any obvious preference for aspect, on slopes ranging from 4-42°, occurring at terrain types of Scree, Rocky slopes, Valley bottom, Interspersed rocky slopes, Smooth slopes, and Rocky slabs.

4. *Caragana-Ephedra*

This association represented 14% of the sampled area, consisting of species such as *Caragana versicolor, and Ephedra gerardiana.* Both the species denote dry and steppe vegetation.

Vegetation cover varied from 5-70%, averaging 20.6%, occurring at altitudes ranging from 3823 – 4718m, on N, E, NE, S, SE, SW, and W aspects, on slopes ranging from 4-43°, occurring at terrain types of Scree, Rocky slopes, Interspersed rocky slopes, Smooth slopes, and Valley bottom.

5. *Elymus spp-Piptatherum*

This association represented 18.4% of the sampled area, consisting of species such as *Elymus semicostatus, Elymus sp., and Piptatherum gracile.* Elymus indicates a steppe environment with soil moisture.

Vegetation cover varied from 5-40%, averaging 18.6%, occurring at altitudes ranging from 3982 – 4722m, without any obvious preference for aspect, on slopes ranging from 5-35°, occurring at terrain types of Scree, Rocky slopes, Interspersed rocky slopes, Smooth slopes, and Rocky slabs.

6. *Deschampsia-Carex-Festuca*

This association represented 18.4% of the sampled area, consisting of species such as *Asperula sp., Dasiphora arbuscula, Deschampsia cespitosa, Elymus longearistatus, Festuca sp.1, Scrophularia dentata, Astragalus webbianus, Carex maritima, Carex melanantha, Carex sp.,* *Carex sp.1, Carex sp.2, Carex sp.3, Carex stenophylla, Cirsium arvense, Eritrichium canum, Festuca sp., Festuca valesiaca, Kobresia sp., Lindelofia anchusoides, Nepeta podostachys, Rosularia sp., Senecio dubitabilis, and Sibbaldianthe bifurca.*

Most of the species such as *Deschampsia cespitosa, Carex sp., Kobresia sp., and Scrophularia dentata* indicate moist conditions. *Festuca sp* indicate grassland and steppe conditions.

Vegetation cover varied from 10-55%, averaging 28.6%, occurring at altitudes ranging from 3883 – 4637m, on NW, S, SE, SW, and W aspects, on slopes ranging from 9-32°, occurring at terrain types of Scree, Rocky slopes, Interspersed rocky slopes, Smooth slopes Rocky slabs and valley bottom.

7. *Rosa webbiana*

This association represented 3.18% of the sampled area and consisted of a single species - Rosa webbiana. It is found in moist soils, indicating good soil quality and health. Vegetation cover varied from 10-15%, averaging 12%, occurring at altitudes ranging from 3887 – 4271m, on SW and SE aspects, on slopes ranging from 15-43°, occurring at terrain types of Interspersed rocky slopes, Scree, Rocky slopes, Scree, Rocky slabs, and Smooth slopes.

8. *Sea buckthorn*

This association represented 3.18% of the sampled area and consisted of a single species of Sea buckthorn. It is found in disturbed soils, often indicating erosion or river banks. Vegetation cover varied from 10-60%, averaging 30%, occurring at altitudes ranging from 3934 – 4031m, on S and SE aspects, on slopes ranging from 14-30°, occurring at terrain types of Interspersed rocky slopes, Scree, Rocky slopes, and Smooth slopes.

5.2 Spatial overlap between ibex and blue sheep

The study area encompassed 457 grids. Ibex were observed in 6 grids (n=75), and blue sheep in 17 grids (n=69). Only 5 grids were shared by ibex and blue sheep, indicating a low level of overlap between the species (Jaccard Similarity Index, S = 0.17, probability P=0.015). This implies that both species use 17% of the grids occupied by either species, suggesting that ibex and blue sheep largely occupy distinct areas due to their differing habitat preferences. The remaining blank grids had high snow cover (inaccessible), human habitation, and croplands.

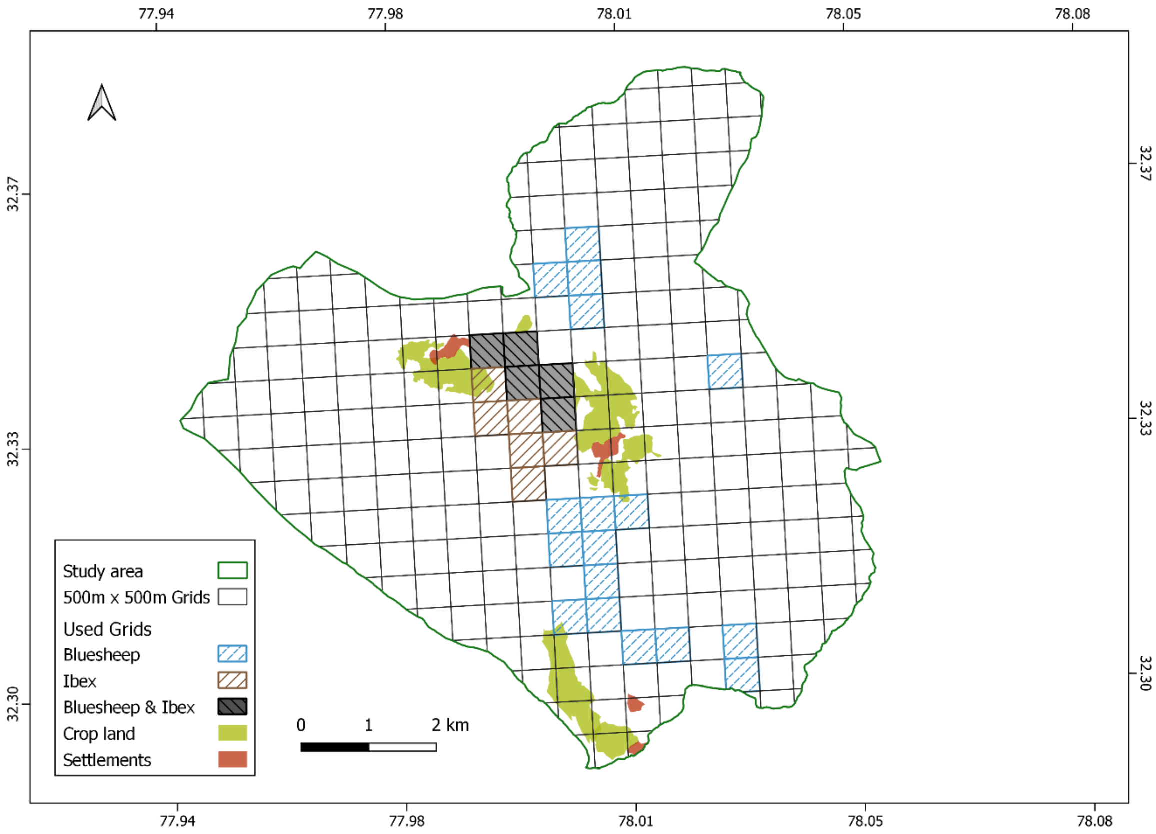


Fig 5.2 Study area showing grids used by ibex, blue sheep, by both groups, croplands, and settlements.

5.3 Temporal overlap between ibex and blue sheep

A total of 31 camera traps were placed in my study area. 29 camera trap data was analyzed for the activity pattern of ibex and blue sheep. The camera trap effort changes for each set of cameras. There was a total of 990 captures of ibex and 218 captures of blue sheep.

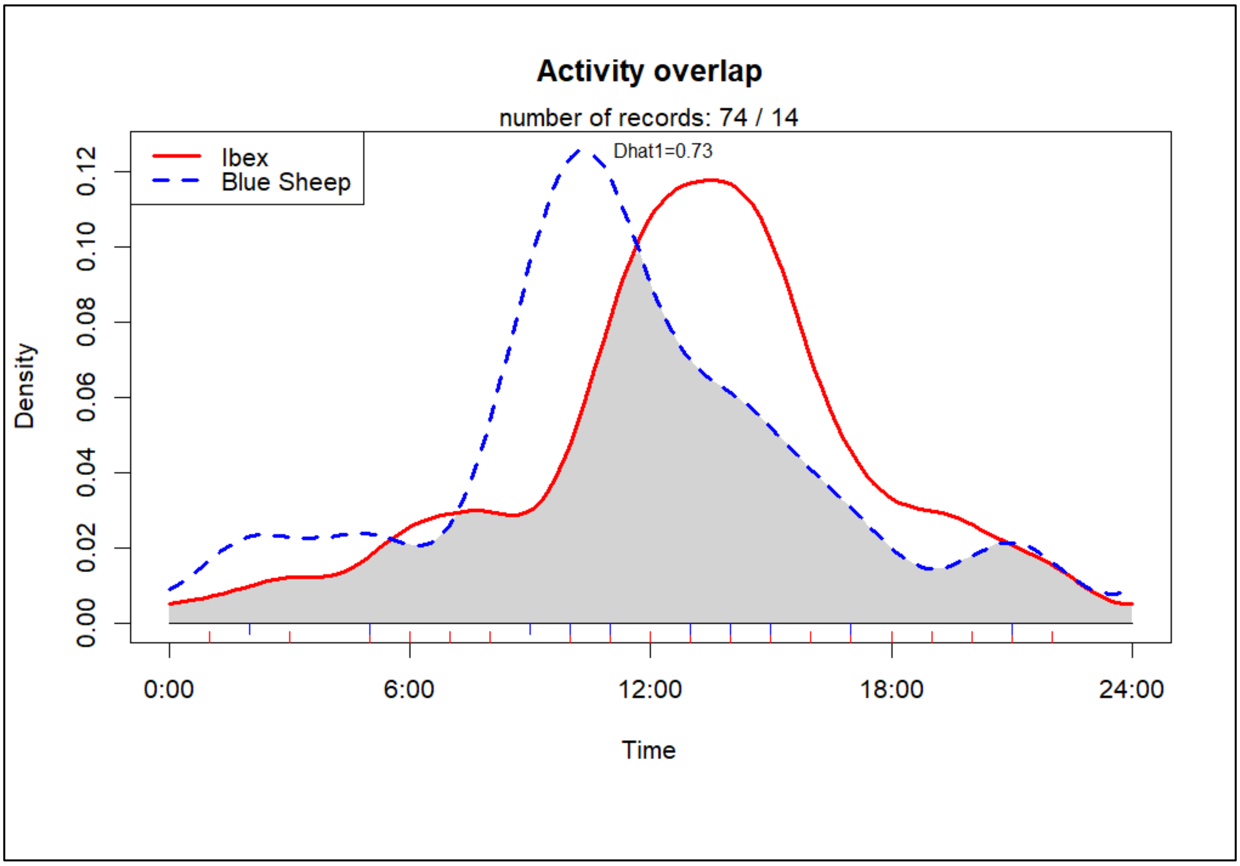


Fig 5.3 Activity overlap of ibex (n=74) and blue sheep (n=14).

Both species are diurnal, with peak activity occurring in the morning and late afternoon, corresponding to their foraging times. The peak activity pattern of blue sheep at around 1000-1100 h and that of ibex is around 1400-1500 h. There is substantial overlap in their activity patterns (Dhat1= 0.73), indicating they are active during the same periods for most of the time with 73% overlap in their activity patterns.

5.4 Habitat use and Selection by ibex and blue sheep

5.4.1. Habitat utilization patterns

Non-metric multidimensional scaling (NMDS) identified two axes based on all habitat variables considered for both ibex and blue sheep. Plotted using Bray-Curtis dissimilarities and several dimensions ($k = 3$), the stress value of 0.07264836 indicates a good fit model. Moreover, the high R-squared values for the non-metric fit (0.995) and linear fit (0.974) indicate strong explanatory capability. In terms of the MRPP (Multi-Response Permutation Procedure), the analysis reveals significant dissimilarities ($\delta = 0.001$, $p < 0.05$) between the two species based on the derived axes.

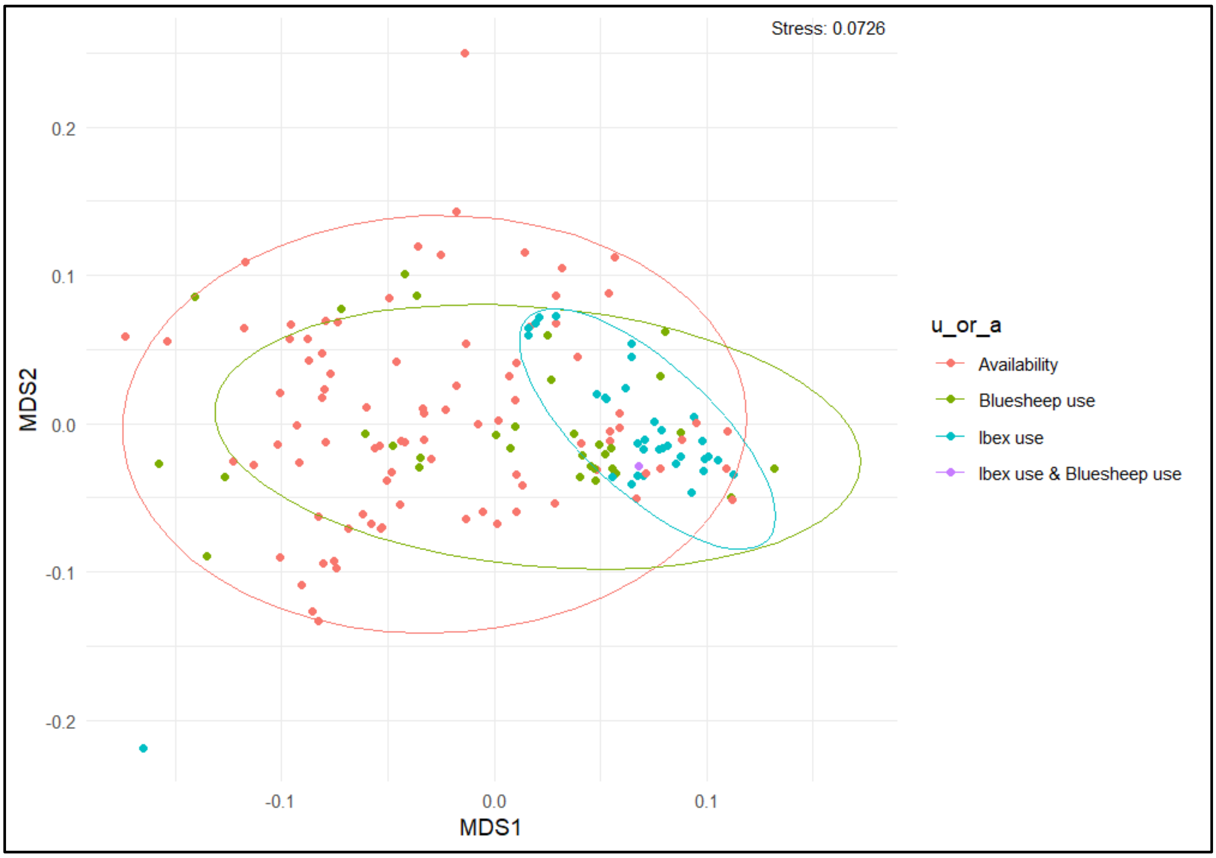


Fig 5.4: Non-metric multidimensional scaling (NMDS) ordination of habitat variables at Kibber and Chicham areas of Spiti Valley. Axes MDS1 and MDS2 represent the dimensions. The points on the plot are color-coded to represent different categories and form distinct clusters. Availability plots are coded in red, plots used by blue sheep are coded in green, and ibex use plots are coded in blue. Additionally, a plot (coded in purple) was used by both ibex

and blue sheep. Ellipses are drawn around the clusters of points (indicate 95% confidence intervals), suggesting similarities within the data. Stress value = 0.0892 indicating goodness-of-fit for the model. Dominating variables on the MDS1 axis are slope (+0.99930, p value=0.001) and snow cover (+0.87831, p value=0.001), and for the MDS2 axis – distance to the cliff (+0.91221, p value=0.001) and average snow depth (+0.88821, p-value =0.001).

The data in Figure 5.4 illustrates the habitat utilization patterns of blue sheep and ibex. The overlapping areas between the blue sheep's habitat (green ellipse) and the available habitat (red ellipse) suggest that blue sheep exploit a broad range of habitats that are available. The larger ellipse representing blue sheep indicates their extensive habitat selection, covering a wide variety of habitat conditions. In contrast, the ibex's habitat is characterized by smaller and more specific habitat conditions (blue ellipse), reflecting their specialized habitat requirements and preferences. The purple-coded areas on the plot indicate that there is some overlap in habitat use between ibex and blue sheep. However, this overlap is neither extensive nor confined to particular regions within the NMDS space, highlighting that while both species share some habitats, they also have distinct habitat preferences.

5.2.2 Predicting Habitat selection through logistic regression

Logistic regression for modeling

Factors influencing the probability of use by ibex and blue sheep were different.

a. Ibex

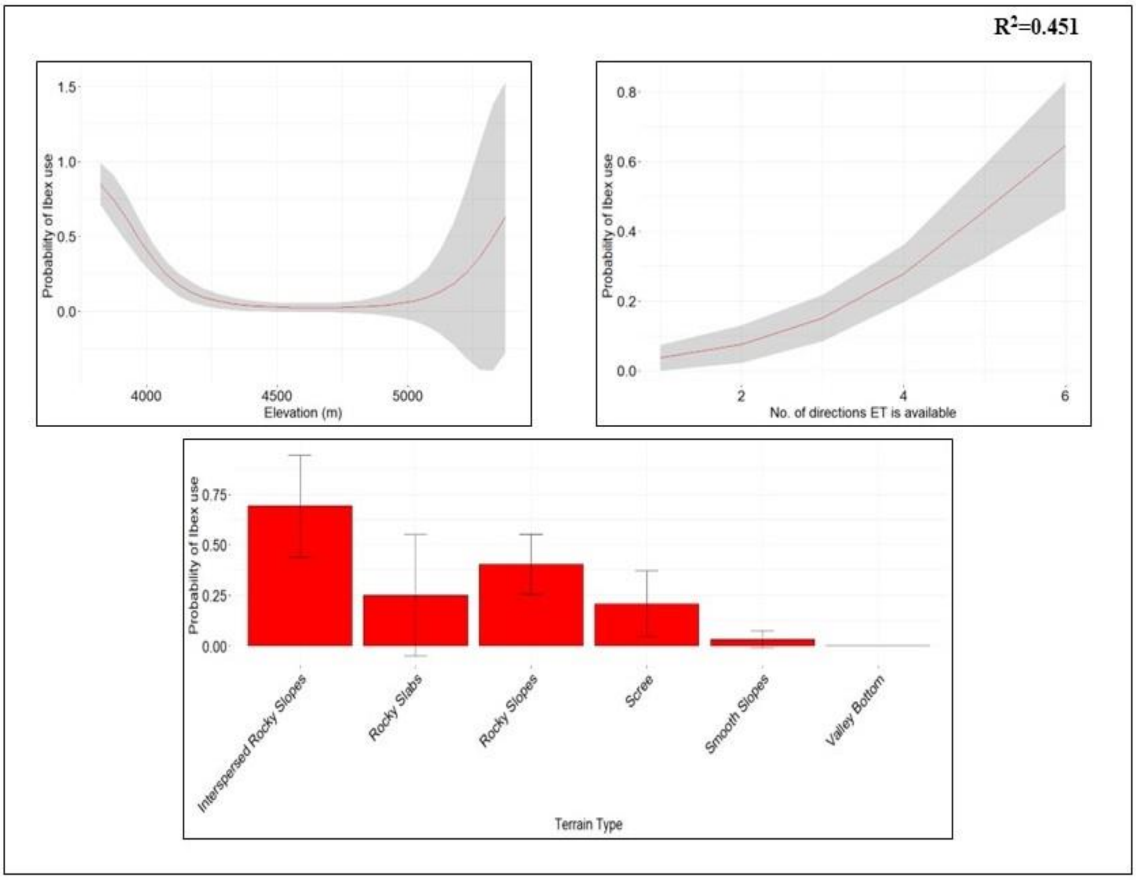
Probability of use was positively influenced by quadratic term of elevation (β = 0.0000083 (0. 0000025), $p<0.05$), no of directions in which escape terrain is available (β = 0.493 (0.231), $p<0.05$), terrain type – interspersed rocky slopes – intercept (β = 178 (51.37), $p<0.05$), negativel y influenced by elevation (β = - 0.077 (0.022), $p<0.05$), terrain types - rocky slabs (β = -2.521

(1.285), p<0.05); scree β = -3.69 (1.04),p<0.05); smooth slopes (β = -3.516 (1.066), p<0.05). Below Table 5.2 shows that the probability of use by ibex is influenced by the factors mention ed above.

Table 5.2 Comparison of best-fitting models with the Global model. The best-fitting model is selected based on the lowest AIC value.

Sl. No	Model	df	AIC	*R^2
1	Ibex ~ elevation + I(elevation^2) + no_of_directions_in_which_et_is_available + terrain_type	9	109.5035	0.451
2	~ elevation + aspect + no_of_directions_in_which_et_is_available + terrain_type	9	112.7388	0.4315
3	~ elevation + I(elevation^2) + aspect + no_of_directions_in_which_et_is_available + terrain_type	9	114.0184	0.4237
4	~ elevation + I(elevation^2) + aspect + no_of_directions_in_which_et_is_available	5	114.8372	0.371
5	~ elevation + I(elevation^2)+ aspect	4	119.8024	0.329
6	~ elevation + slope + aspect + no_of_directions_in_which_et_is_available + terrain_type + dist_to_cliff + snow_depth + vegetation_cover + vegetation_type + rock_cover + snow_cover + tri (Global model)	22	117.8956	0.5563

*R^2 is McFadden's R^2 value; et = Escape terrain; tri = terrain ruggedness index



Model = prob (ibex use) ~ Elevation + I(Elevation^2) + No of directions in which escape terra in is available + Terrain type

Fig 5.5 Habitat correlates of the relative probability of use by ibex. The parameters used are from the best-fitting model. The variables include elevation (Left), No. of directions escape terrain is available (Right), and Terrain type (Below).

a. <u>Blue sheep</u>

The probability of use was positively influenced by the slope (β = 0.0499 (0.023), $p<0.05$) and negatively influenced by the directions in which escape terrain is available (β = -0.417 (0.181), $p<0.05$). Vegetation cover has a positive non-significant effect (β = 0.0223(0.0142), $p>0.05$) and Distance to cliff has a negative non-significant effect (β = -0.0020 (0.0013), $p>0.05$),

Table 5.3 below shows that the probability of use by blue sheep is influenced by the factors m

entioned above.

Table 5.3 Comparison of best-fitting models with the Global model. Best best-fitting model is selected based on the lowest AIC value

Sl.No	Model	df	AIC	*R^2
1	BS ~ slope + vegetation_cover + distance_to_cliff + no_of_directions_in_which_et_is_available	5	157.0809	0.054
2	~ slope + vegetation_cover + no_of_directions_in_which_et_is_available	4	157.7483	0.073
3	~ no_of_directions_in_which_et_is_available + slope	3	158.4351	0.056
4	~ slope + vegetation_cover + no_of_directions_in_which_et_is_available + rock_cover + soil_cover	6	159.0638	0.090
5	~ vegetation_cover + slope	3	159.3151	0.050
6	~ elevation + slope + aspect + no_of_directions_in_which_et_is_available + terrain_type + dist_to_cliff + snow_depth + vegetation_cover + vegetation_type + rock_cover + snow_cover + tri (Global model)	22	170.2658	0.2180

*R^2 is McFadden's R^2 value; et = Escape terrain; tri = terrain ruggedness index

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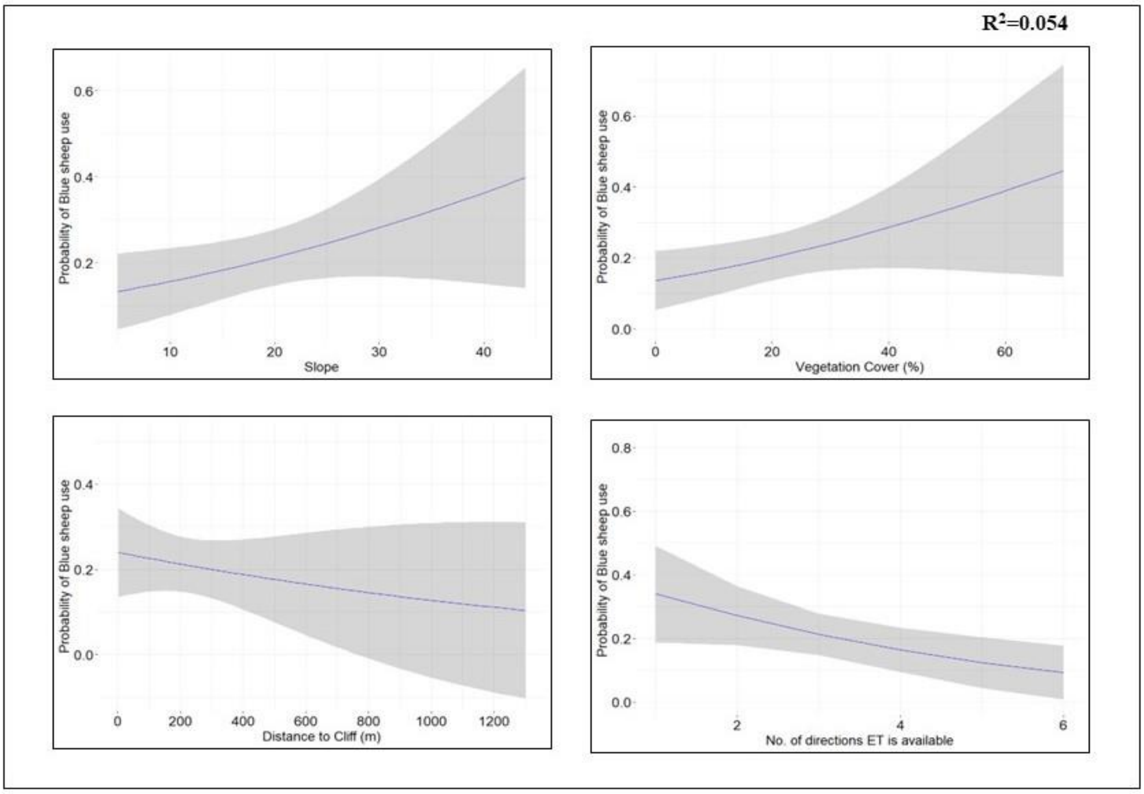


Model = prob (blue sheep use) ~ Slope + Distance to cliff + Vegetation cover + No of directions in which escape terrain is available.

Fig 5.6 Habitat correlates of the relative probability of use by blue sheep. The parameters used are from the best-fitting model. The variables include slope (left) and No. Of directions escape terrain is available (right).

Logistic Regression for Hypothesis testing

For comparing the significant effect of each habitat variable on ibex and blue sheep based on the p-value.

a. Elevation:

Elevation had a negative effect on both ibex and blue sheep but had a significant effect on ibex (β = -0.0055 (0.0013), $p<0.05$) but a non-significant effect on blue sheep (β = -0.00044 (0.00079), $p>0.05$).

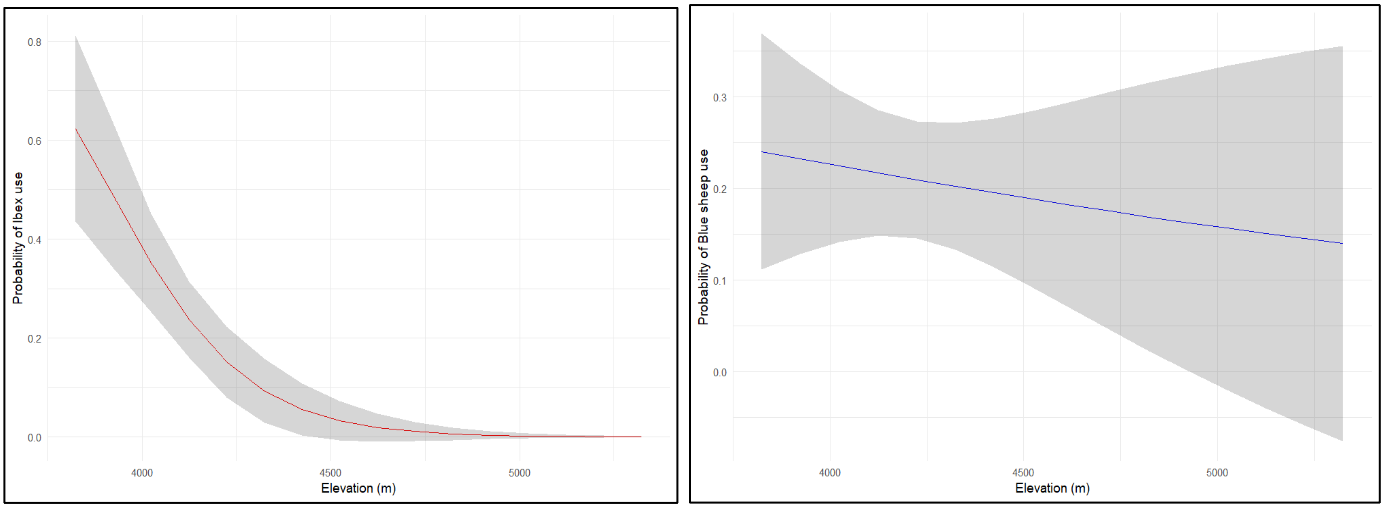


Fig 5.7 Effect of elevation on the relative probability of use of ibex and blue sheep.

b. Slope:

The slope had a positive influence on both the species but a non-significant effect on ibex (β = 0.02327 (0.02130), $p>0.05$) and a significant effect on blue sheep (β = 0.0373 (0.0215), $p<0.05$).

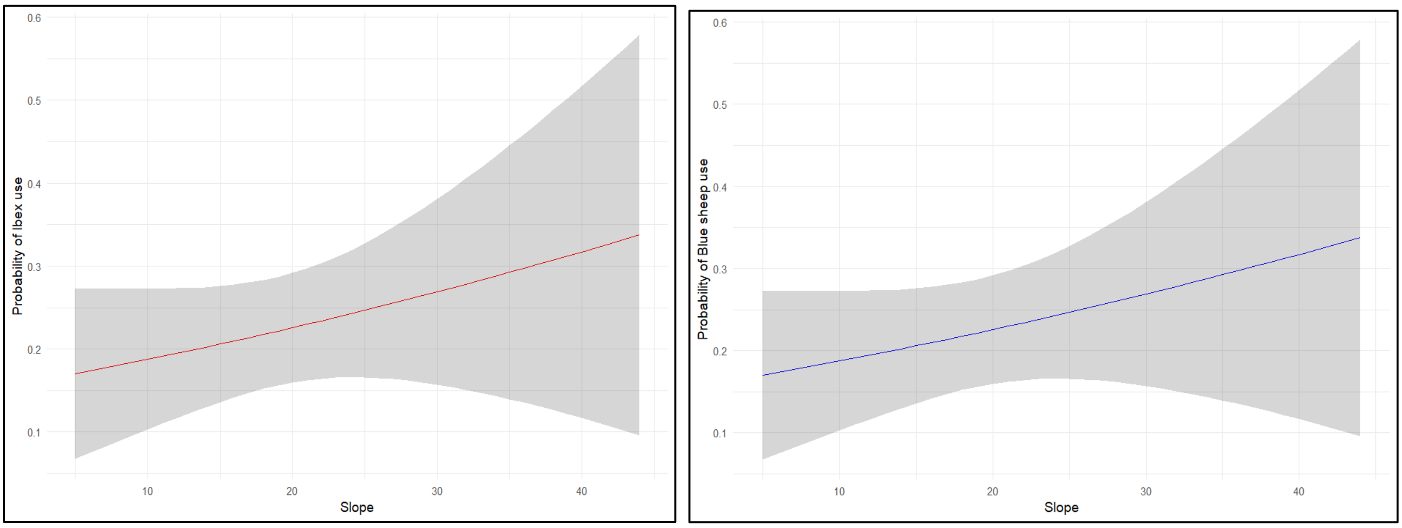


Fig 5.8 Effect of slope on the relative probability of use of ibex and blue sheep.

c. Aspect

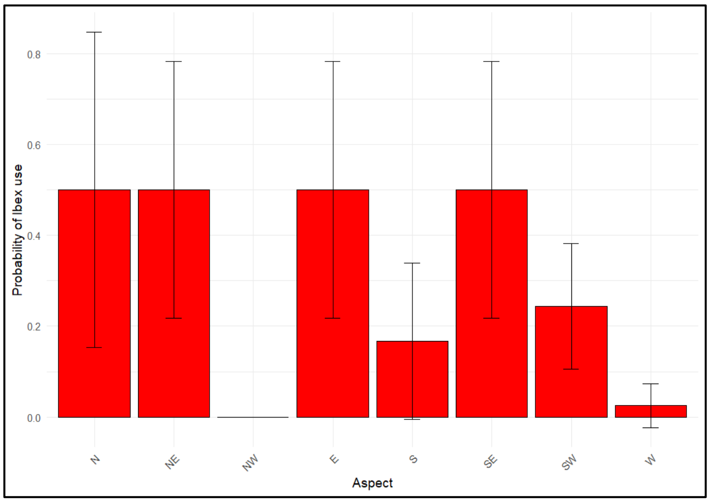
The eastern aspect had a non-significant positive influence on ibex but a significant negative effect on blue sheep. Western aspect had a significant negative effect on ibex but a non-significant positive effect on blue sheep.

Table 5.4 Summary of coefficients of aspect for ibex.

Coefficient	Estimate	Std. Error	p-value
(Intercept)	0.000	0.577	1.000
aspectN	0.000	0.913	1.000
aspectNE	0.000	0.817	1.000
aspectNW	-18.570	1537.0	0.990
aspectS	-1.609	0.856	0.060
aspectSE	0.000	0.817	1.000
aspectSW	-1.135	0.693	0.101
aspectW	-3.664	1.166	0.0016**

Table 5.5 Summary of coefficients of aspect for blue sheep

Coefficient	Estimate	Std. Error	p value
(Intercept)	-2.398	1.044	0.0217*
aspectN	1.887	1.274	0.1387
aspectNE	0.000	1.477	1.0000
aspectNW	0.789	1.221	0.5185
aspectS	0.789	1.221	0.5185
aspectSE	1.299	1.239	0.2944
aspectSW	0.943	1.126	0.4024
aspectW	1.551	1.100	0.1586



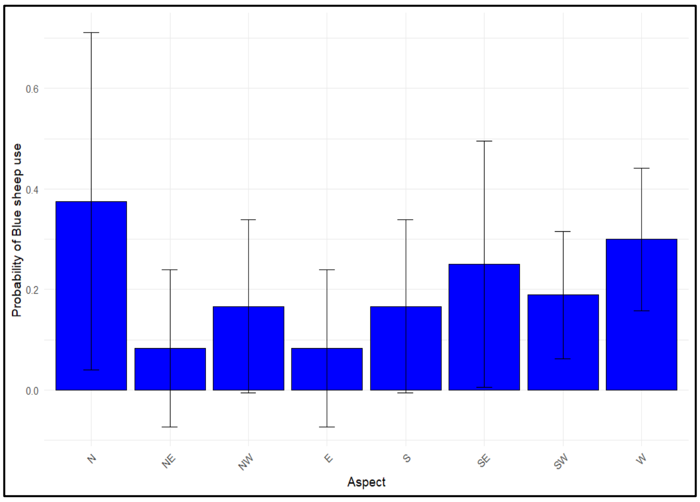


Fig 5.9 Effect of aspect on the relative probability of use of ibex and blue sheep.

d. Terrain type

Scree and Smooth slopes have significant negative effects on ibex. Other terrain types do not have a significant effect on ibex. None of the terrain types have a significant effect on blue sheep.

Table 5.6 Summary of coefficients of terrain types for ibex.

Coefficient	Estimate	Std. Error	p value
Intercept	0.8109	0.6009	0.17719
Rocky Slabs	-1.9095	1.0138	0.05962
Rocky Slopes	-1.1966	0.6782	0.07766
Scree	-2.1459	0.7834	0.00616 **
Smooth Slopes	-4.2449	0.9366	0.00000584***
Valley Bottom	-18.3770	1615.1040	0.99092

Table 5.7 Summary of coefficients of terrain types for blue sheep

Coefficient	Estimate	Std. Error	p value
Intercept	-18.570	-1809.000	0.992
Rocky Slabs	0.000	2931.000	1.000
Rocky Slopes	16.770	1809.000	0.993
Scree	17.230	1809.000	0.992
Smooth Slopes	17.780	1809.000	0.992
Valley Bottom	17.870	1809.000	0.992

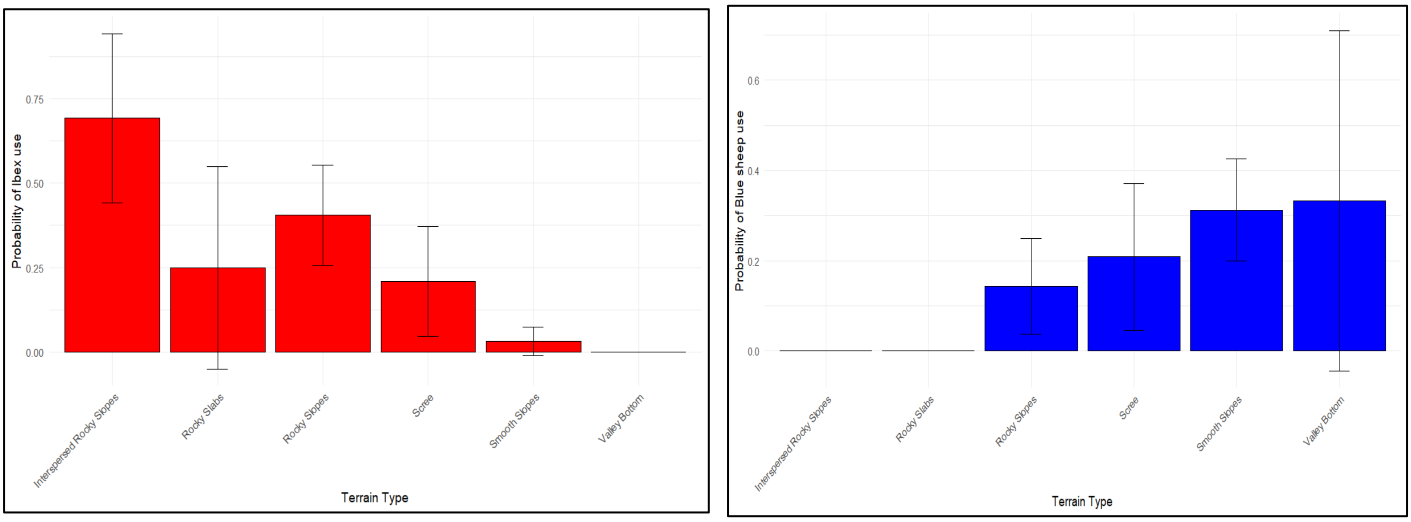


Fig 5.10 Effect of terrain types on the relative probability of use of ibex and blue sheep.

e. Soil cover

Soil cover has a significant negative effect on ibex (β = -0.0422 (0.0111), $p<0.05$) and a non-s ignificant negative effect on blue sheep (β = -0.0014 (0.0089), $p>0.05$).

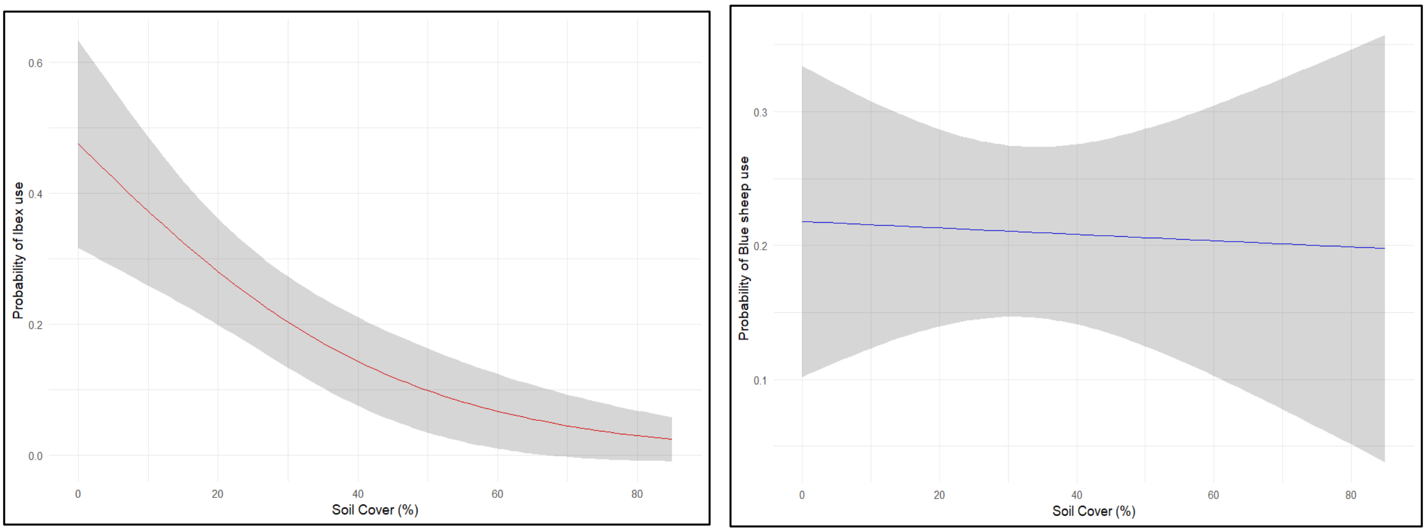


Fig 5.17 Effect of soil cover on relative probability of use of ibex and blue sheep.

e. Distance to the cliff

Distance to cliff has a significant effect on ibex (β = -0.0041 (0.0014), $p<0.05$) and has a non-significant negative effect on blue sheep (β = -0.0007 (0.0010), $p>0.05$).

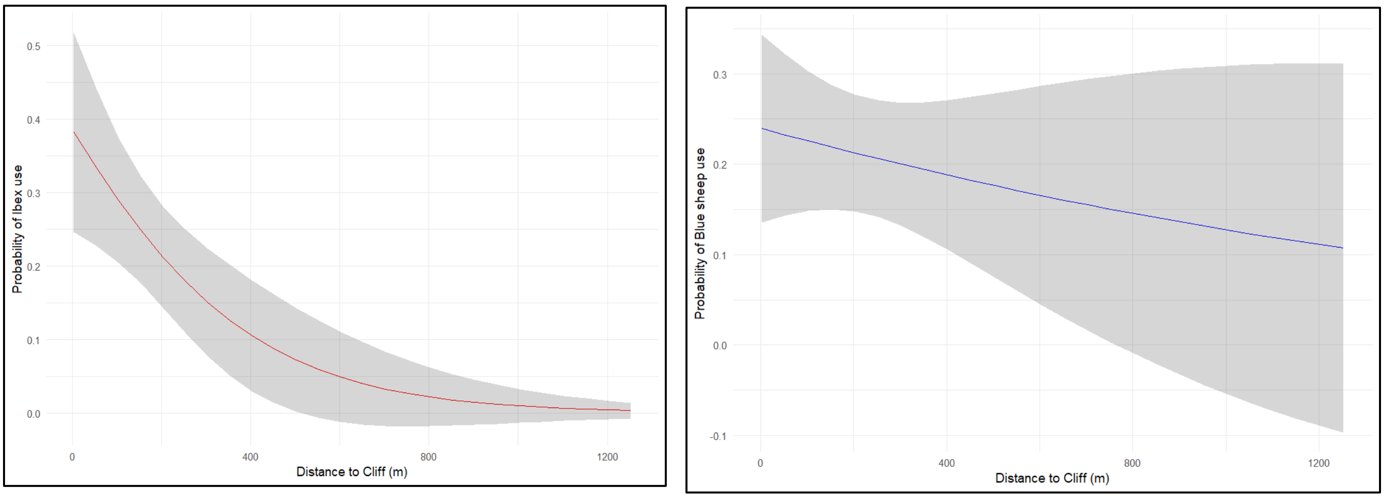


Fig 5.11 Effect of distance to the cliff on the relative probability of use of ibex and blue sheep

f. Snow depth

Snow depth has a positive non-significant effect on ibex (β = 0.00271 (0.0436), $p>0.05$) and negative non-significant effect on blue sheep (β = -0.0298 (0.0460), $p>0.05$).

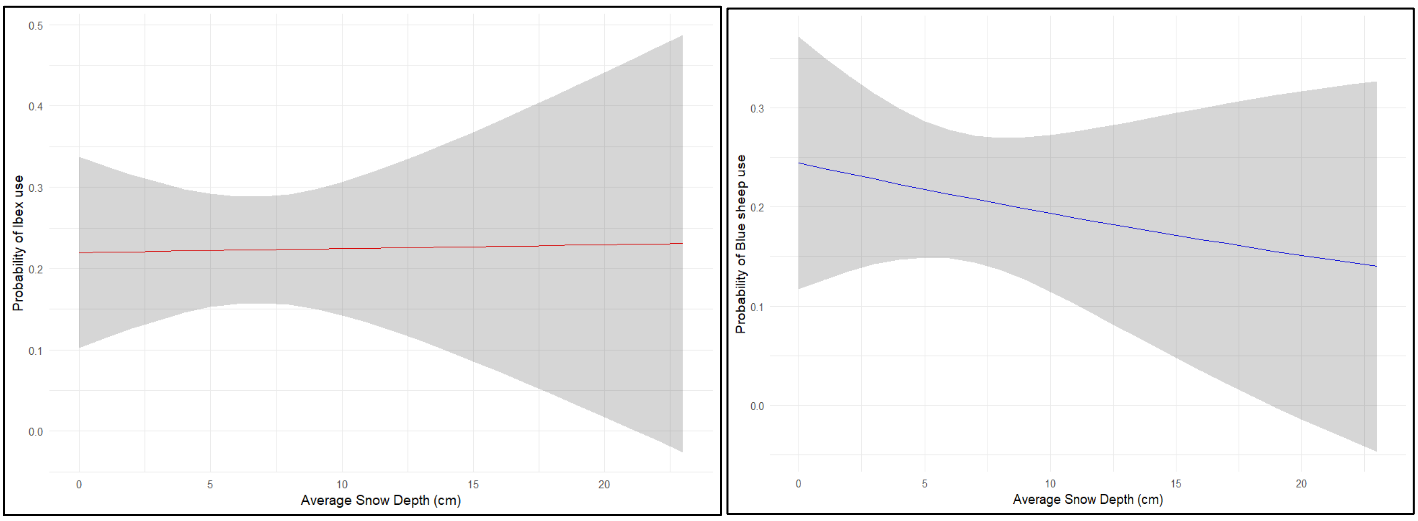


Fig 5.12 Effect of Snow depth on the relative probability of use of ibex and blue sheep.

g. No. of Escape terrain directions

It has a positive significant effect on ibex (β = 0.776 (0.1705), $p<0.05$) and a negative significant effect on blue sheep (β = -0.3218 (0.1497), $p<0.05$).

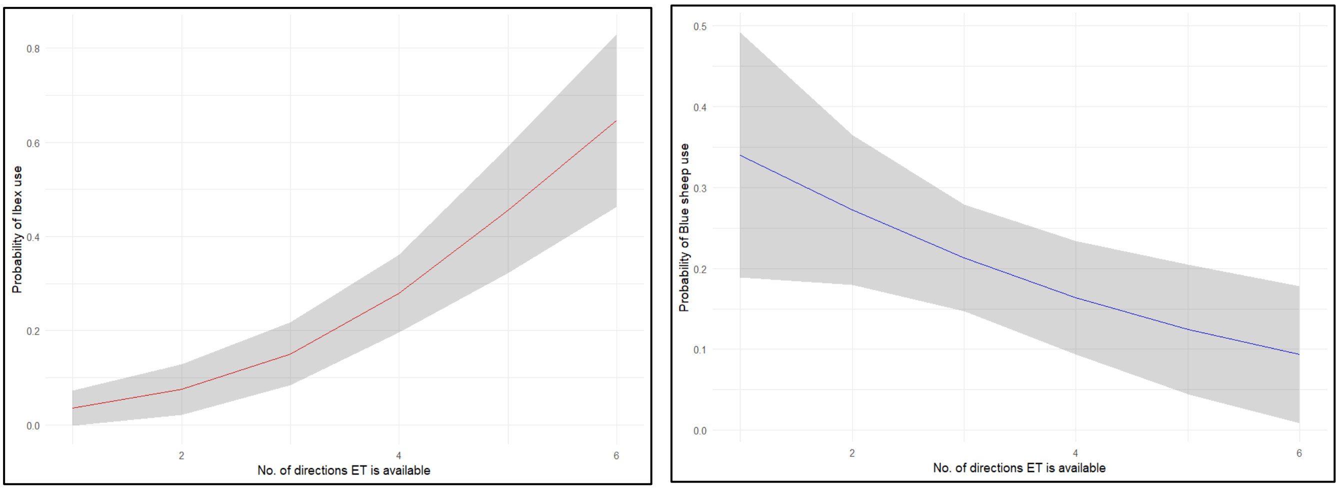


Fig 5.13 Effect of No. of ET directions on the relative probability of use of ibex and blue sheep.

h. Vegetation cover

Vegetation cover has a negative non-significant effect on ibex (β = -0.0293 (0.0162), $p>0.05$) and a positive non-significant effect on blue sheep (β = 0.0232 (0.0126), $p>0.05$).

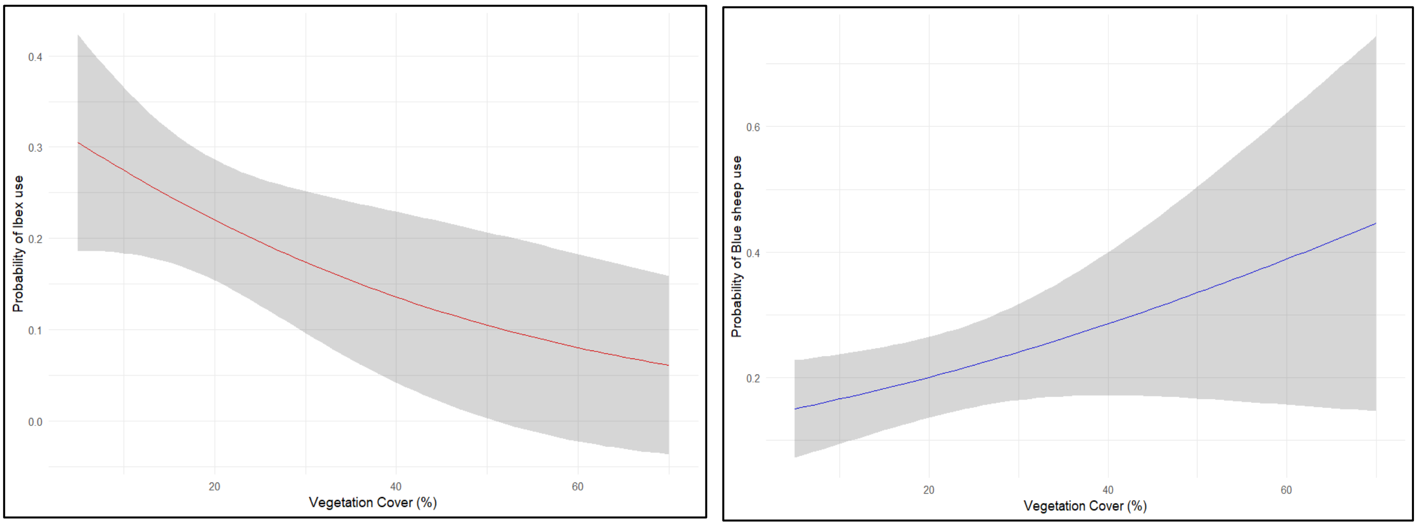
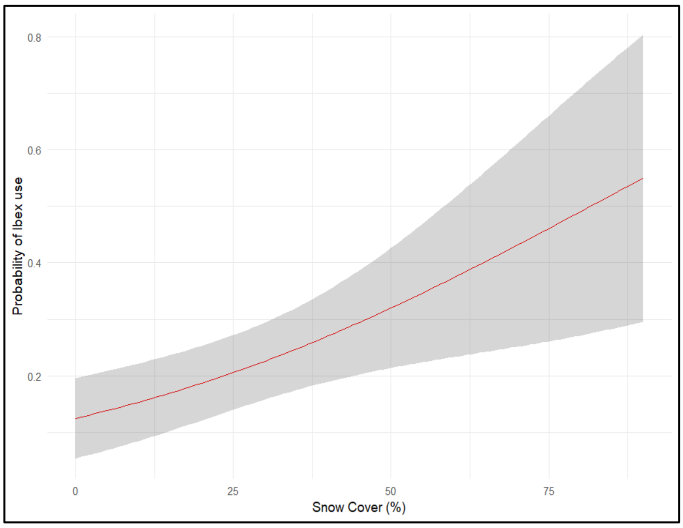


Fig 5.14 Effect of vegetation cover on relative probability of use of ibex and blue sheep.

i. Snow cover

Snow cover has a significant positive effect on ibex (β = 0.0238 (0.0083), $p<0.05$) and a non-significant positive effect on blue sheep (β = 0.0010 (0.0087), $p>0.05$).



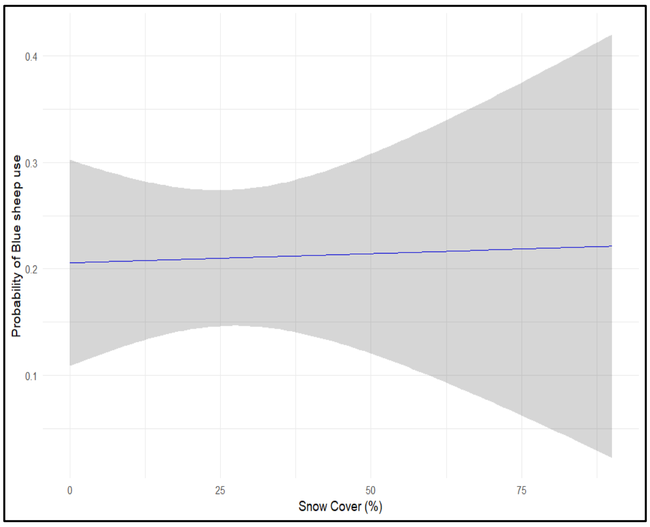
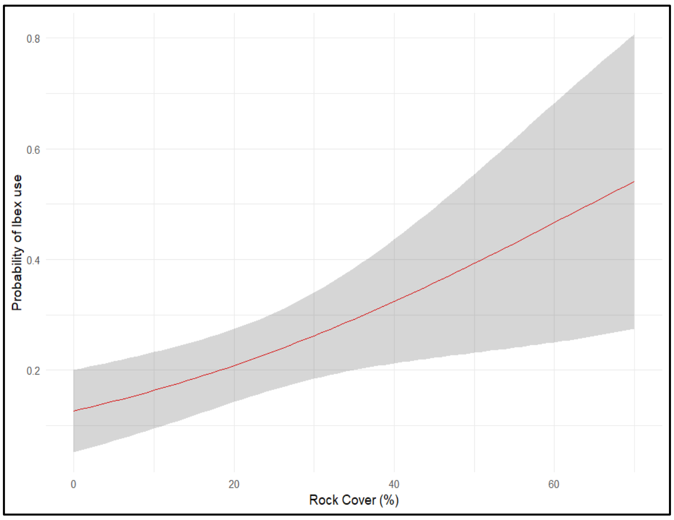


Fig 5.15 Effect of snow cover on relative probability of use of ibex and blue sheep.

j. Rock cover

Rock cover has a positive significant effect on ibex (β = 0.0299 (0.0112), $p<0.05$) and a non-significant negative effect on blue sheep (β = -0.0206 (0.0132), $p>0.05$).



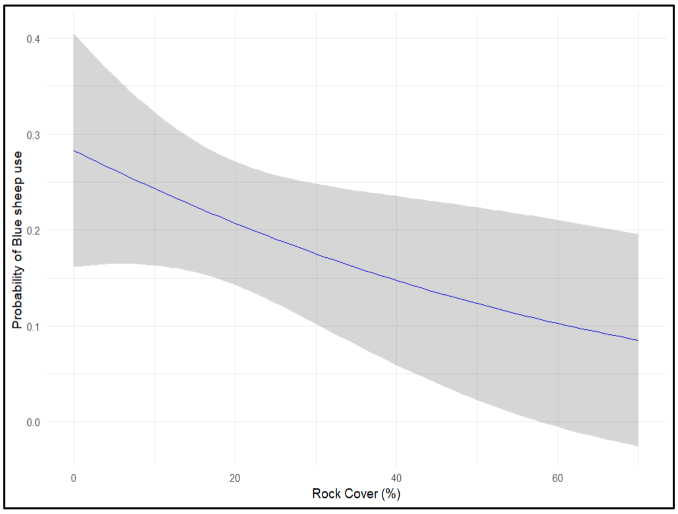


Fig 5.16 Effect of rock cover on the relative probability of use of ibex and blue sheep.

5.2.3 Comparison of availability and use of habitat variable categories among species during winter.

a. Elevation

Both species utilized lower elevations and medium elevations more than their availability, exhibiting more preference to lower elevations, while avoiding higher elevations. This can be influenced by factors such as food availability, and temperature.

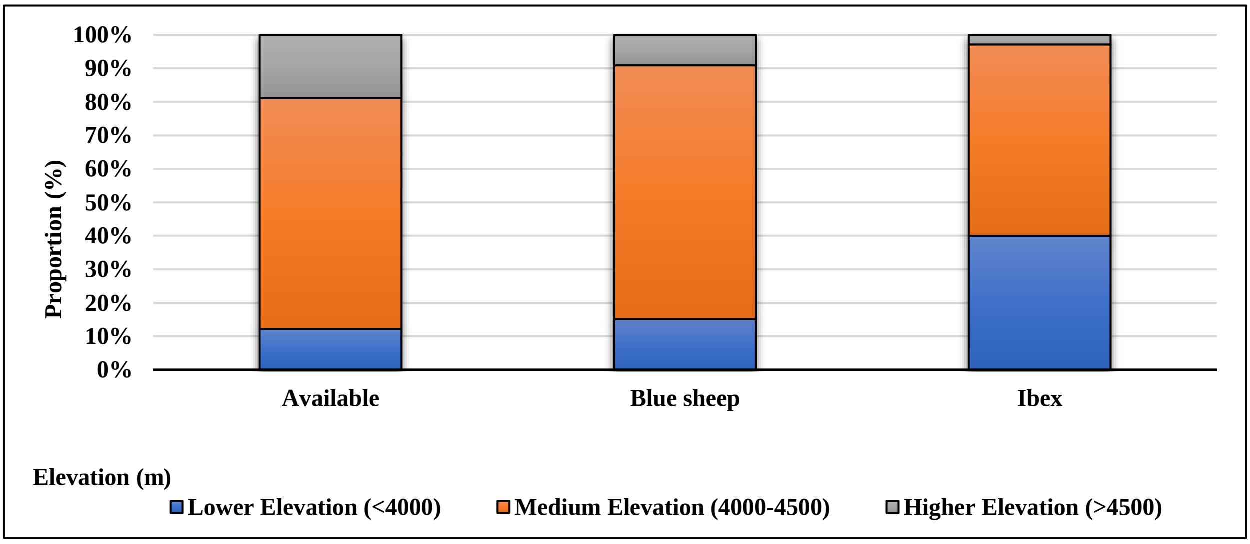


Fig 5.18 Use of elevation categories by blue sheep and ibex.

b. Slope

Very gentle slopes were used more than availability comparatively more by ibex than blue sh eep. Gentle slopes were used more than availability by blue sheep more than ibex. Intermedia te slopes were used more than availability by ibex more than blue sheep. Both species used st eep slopes more than availability, with blue sheep exhibiting a stronger preference.

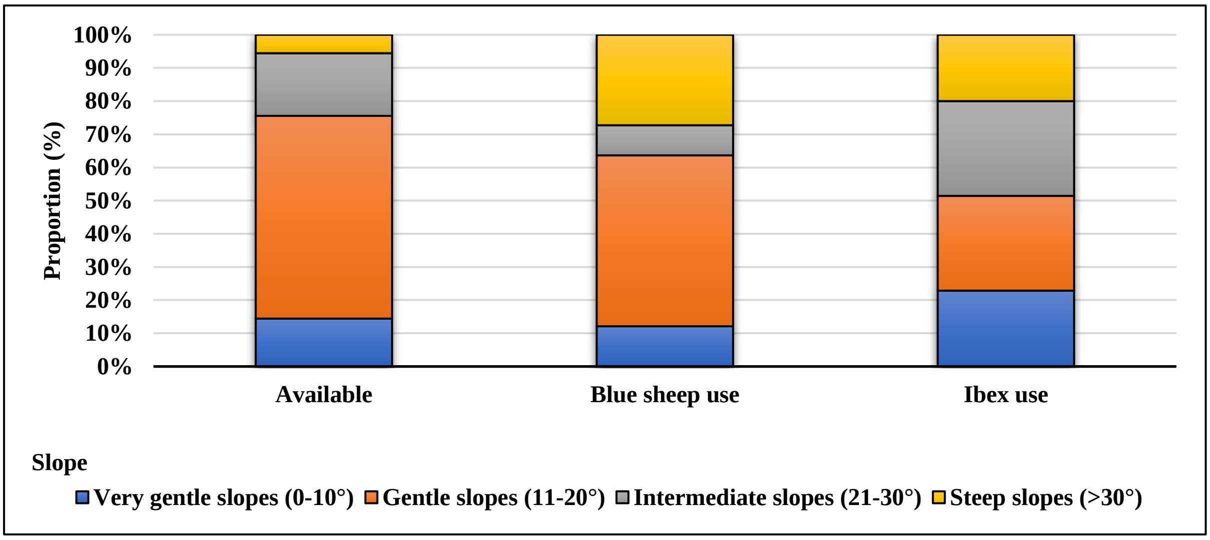


Fig 5.19 Use of slope categories by blue sheep and ibex.

c. Terrain type

Interspersed rocky slopes and rocky slabs were used more than available by ibex, with no records of blue sheep. Rocky slopes were used more than availability by ibex over blue sheep. Scree was used more than availability by both species. Smooth slopes were used more than availability by blue sheep than ibex. Valley bottoms were used by blue sheep, with no records of ibex.

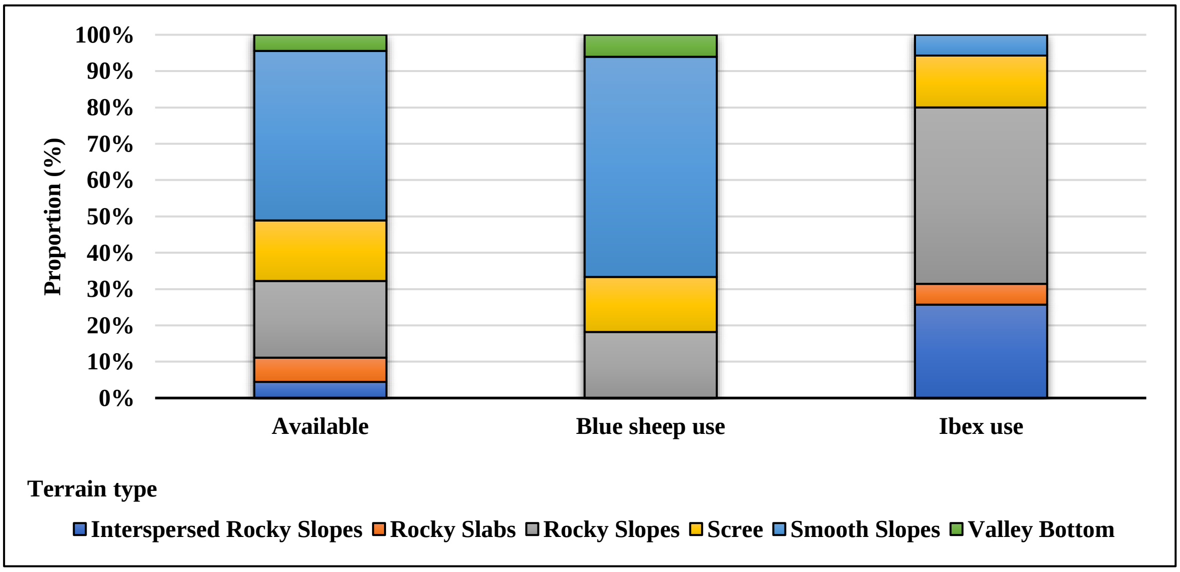


Fig 5.20 Use of terrain type categories by blue sheep and ibex.

d. <u>No. of escape terrain directions</u>

Ibex used areas wherein more than three directions of escape terrain are available. Five directions of escape terrain were used more than availability. Blue sheep used areas wherein two directions of ET are available more than available. Blue sheep did not show much preference for the directions of ET available though.

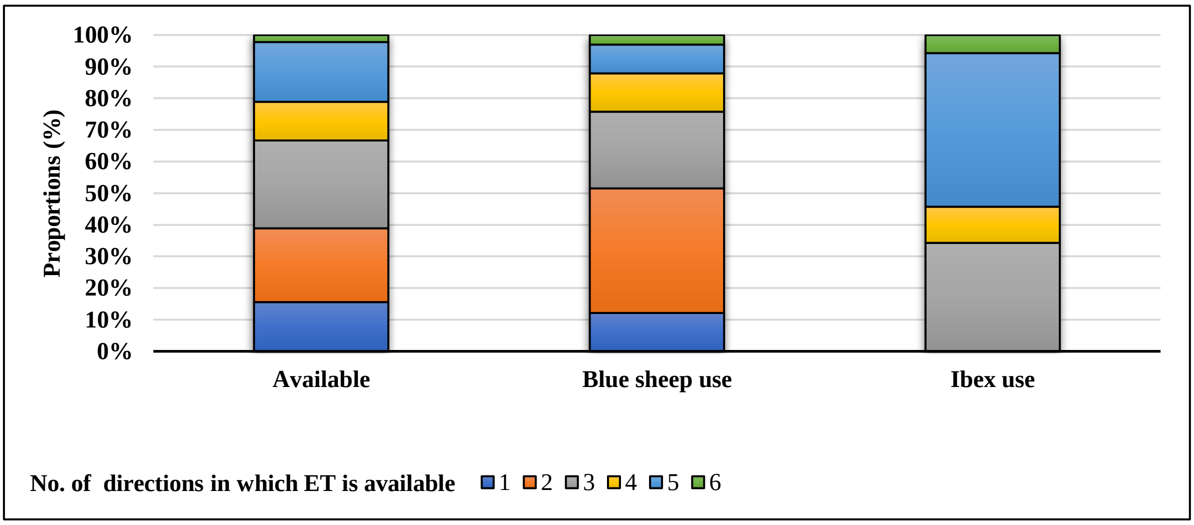


Fig 5.21 Use of ET directions by blue sheep and ibex.

e. <u>Distance to the cliff</u>

Ibex uses areas with a distance to cliff <100m more, with less use within 200m. Blue sheep uses distances within 300m and also used areas of >500m distance, while no records of ibex at such distance.

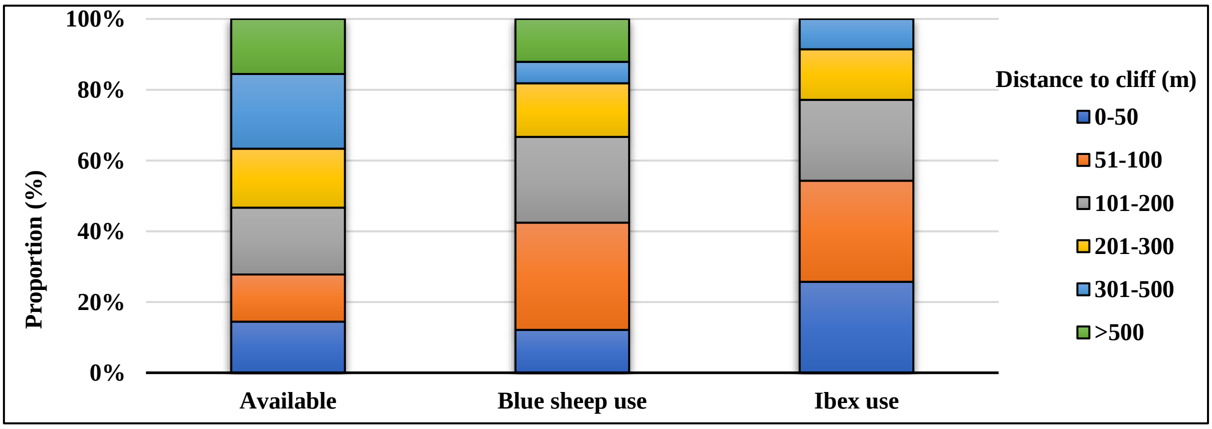


Fig 5.22 Use of distance to cliff categories by blue sheep and ibex.

f. Snow depth

Blue sheep uses a wide range of snow depth. Blue sheep use areas with low snow depth and also snow depth up to 20cm, whereas ibex avoids higher snow depth areas.

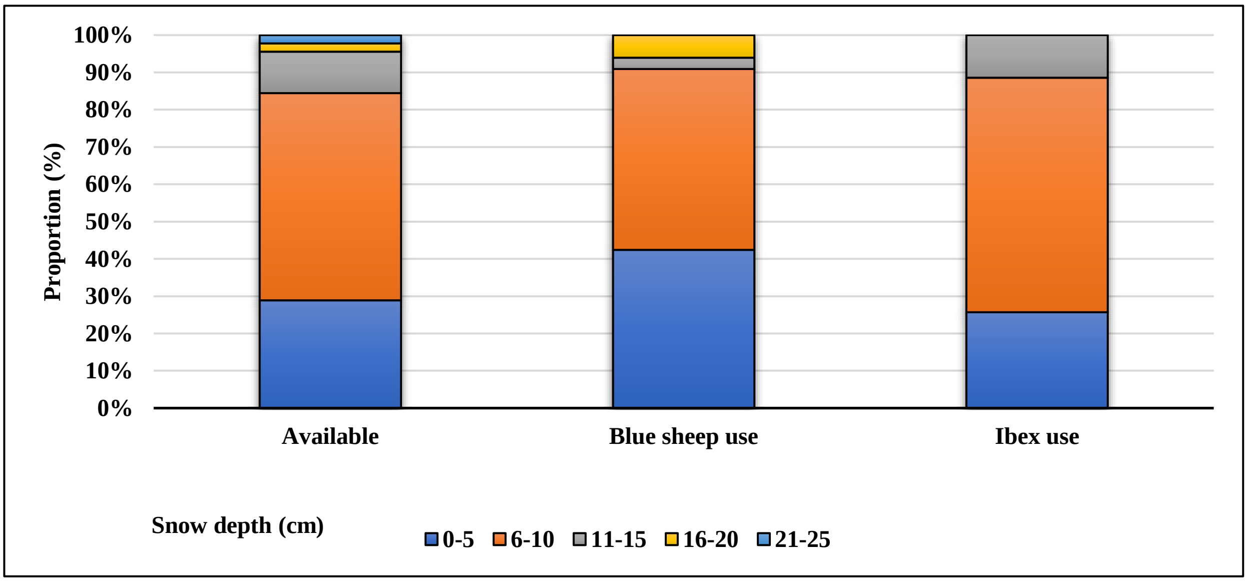


Fig 5.23 Use of snow depth categories by blue sheep and ibex.

g. Vegetation cover

Blue sheep uses areas with high vegetation cover compared to ibex, as vegetation cover is a surrogate for food availability. Ibex uses low vegetation cover areas since rocky slopes have sparse vegetation.

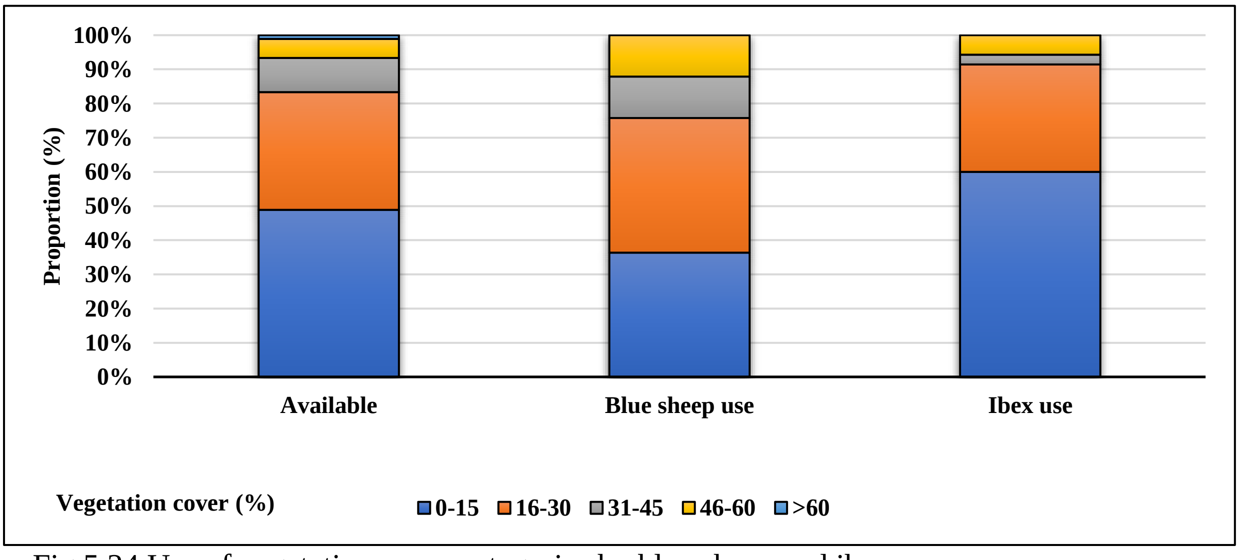


Fig 5.24 Use of vegetation cover categories by blue sheep and ibex.

h. Snow cover

Blue sheep uses areas with minimal snow cover, whereas ibex uses areas with high snow cover, compared to blue sheep.

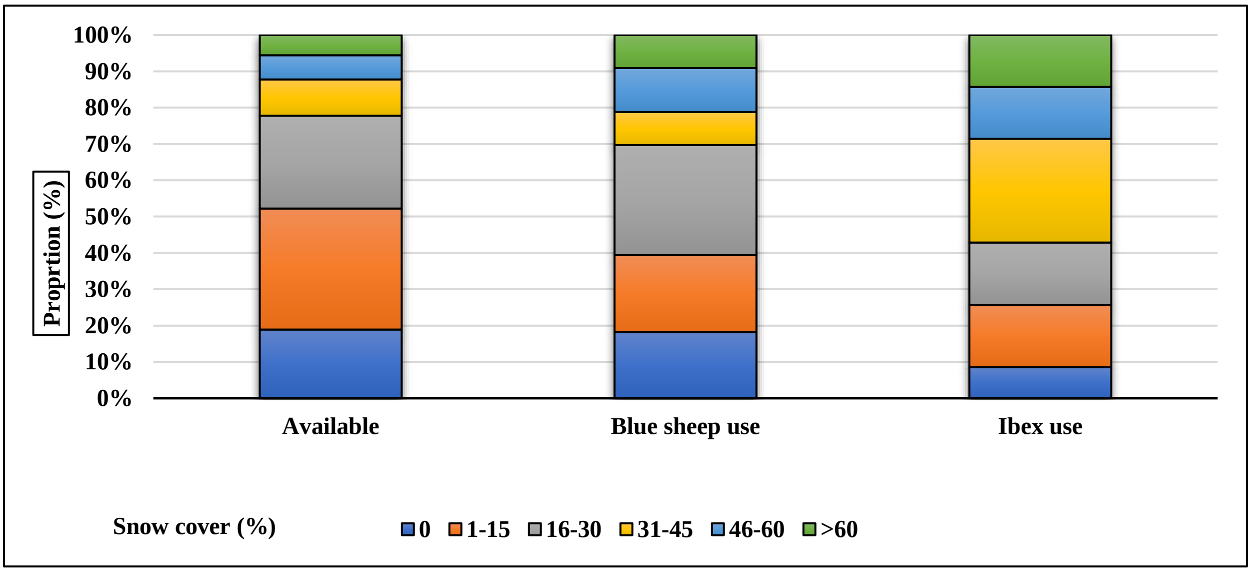


Fig 5.25 Use of snow cover categories by blue sheep and ibex.

i. Rock cover

Blue sheep uses areas with minimal rock cover, while ibex tend to use areas with higher rock cover, thus explained by the terrain type they use.

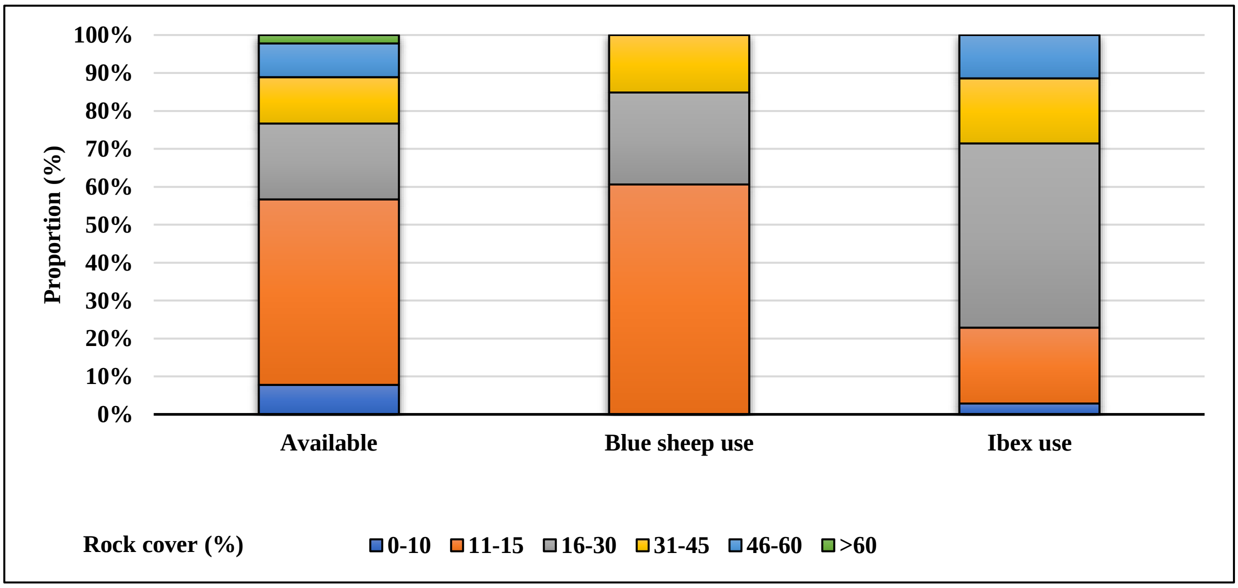


Fig 5.26 Use of rock cover categories by blue sheep and ibex.

j. Soil cover

Blue sheep uses areas with a wide range of soil cover, although they tend to avoid regions with high soil cover, which may explain low vegetation cover. In contrast, ibex uses areas with low soil cover, which, consequently aligns with their preference for habitats characterized by high rock cover and sparse vegetation.

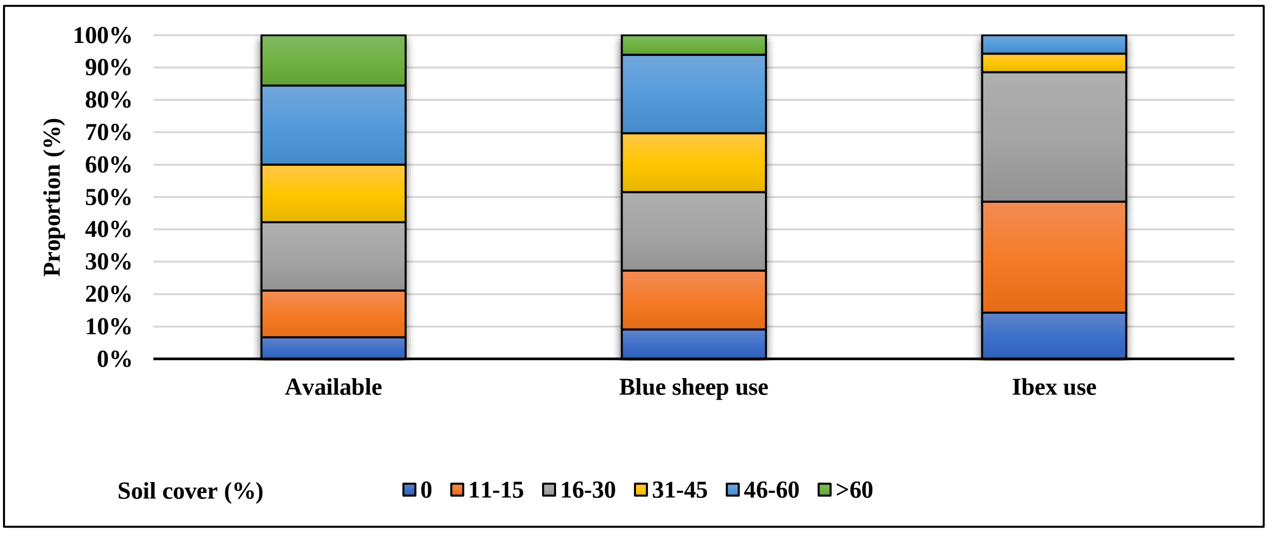


Fig 5.27 Use of soil cover categories by blue sheep and ibex.

k. Terrain ruggedness index

Blue sheep use less rugged areas compared to ibex. Ibex uses moderate ruggedness and high ruggedness areas.

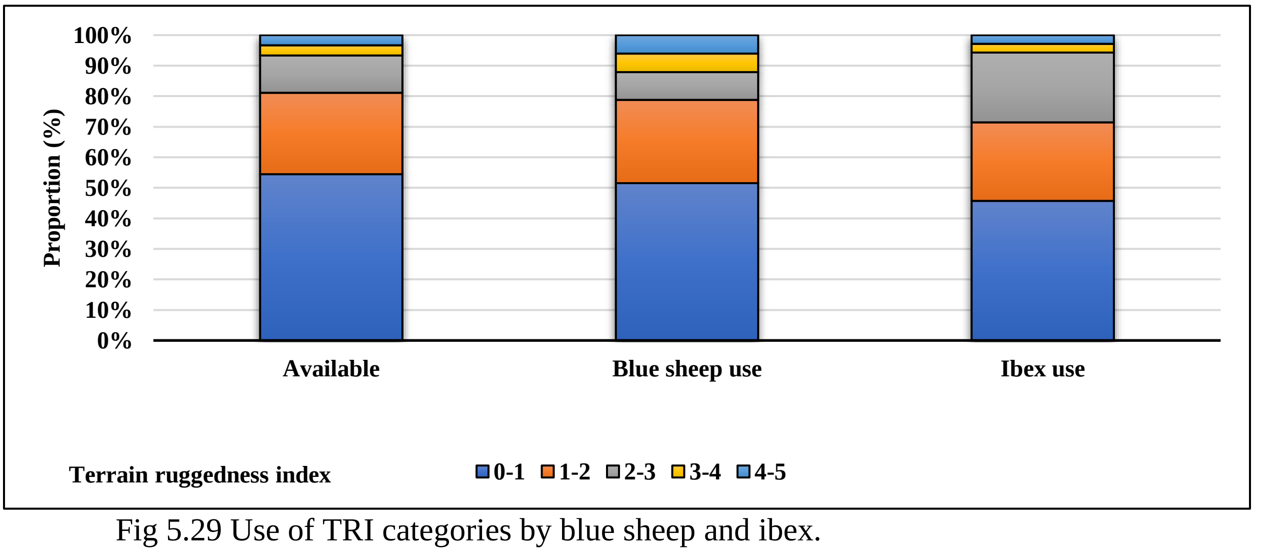


Fig 5.29 Use of TRI categories by blue sheep and ibex.

l. Aspect

Northern aspects were used more than availability by both species, North-Eastern aspect was used more than availability more, by ibex than blue sheep. The north-western aspect was completely avoided by ibex but used less than availability by blue sheep. The eastern aspect was used more than availability by ibex and used less than availability by blue sheep. The southern aspect was used more less availability by both species. The southeastern aspect was used more than availability by both, with more preference for ibex. The southwestern aspect was used more than availability by both species. The western aspect was used less than availability by ibex but more by blue sheep.

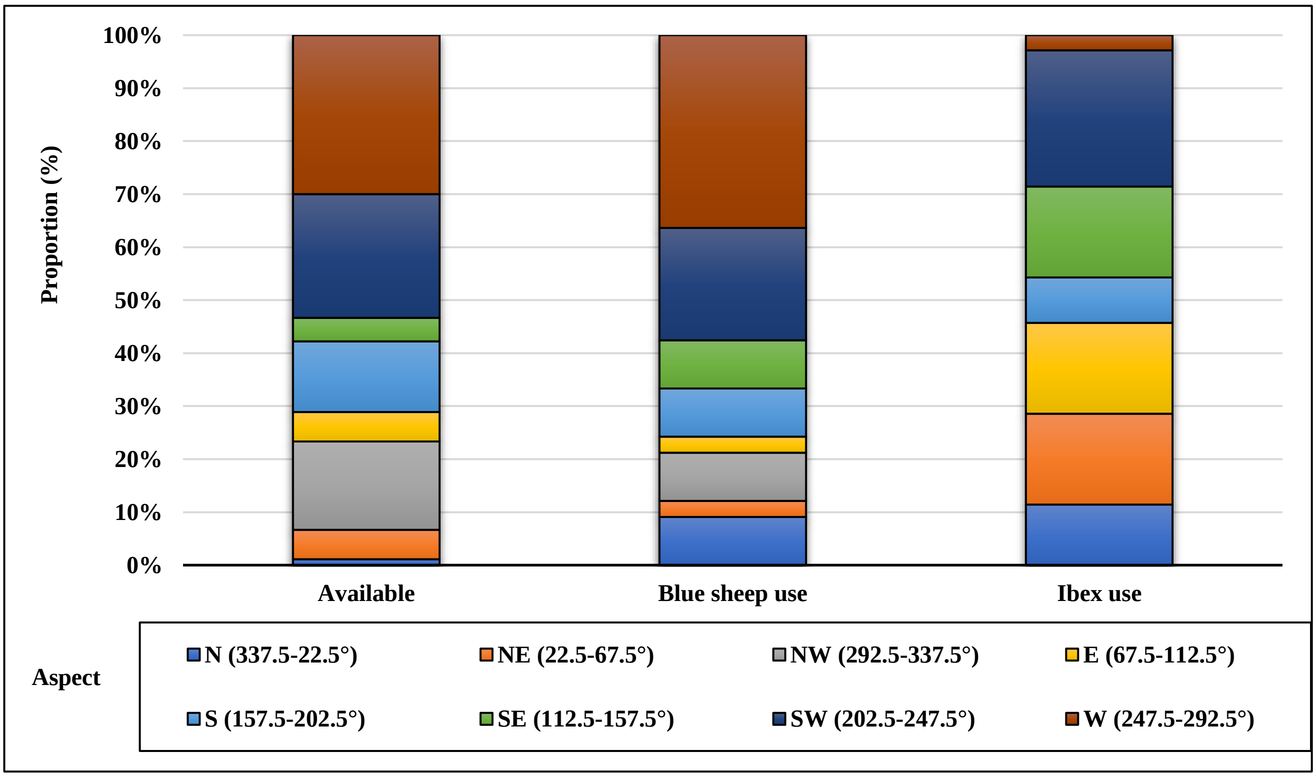


Fig 5.28 Use of aspect categories by blue sheep and ibex.

5.5 Diet selection and utilization

Selection for vegetation communities was evaluated using Ivelev's index. Fig 5.29, Fig 5.30, and Table 5.8 illustrate the selectivity of vegetation types by ibex and blue sheep. The vegetation communities preferred by blue sheep are *Kraschennikovia-Christolea-Polygonum, Elymus spp-Piptatherum, and Caragana-Ephedra.* Ibex preferred *Aquilegia- Arnebia-Nepeta, Caragana-Ephedra, Rosa webbiana,* and *Sea buckthorn,* communities.

Table 5.8 Preference indices for vegetation types for blue sheep and ibex.

Vegetation type	Blue sheep	Ibex
Silene-Cousinia-Potentilla sp 2	0	-
Aquilegia- Arnebia-Nepeta	-	+
Kraschennikovia-Christolea-Polygonum	+	-
Deschampsia-Carex-Festuca	-	-
Elymus spp-Piptatherum	+	-
Caragana-Ephedra	+	+
Rosa webbiana	-	+
Sea buckthorn	-	+

(where, '+' used more than available, 0 means proportional use, '-' used less than available)

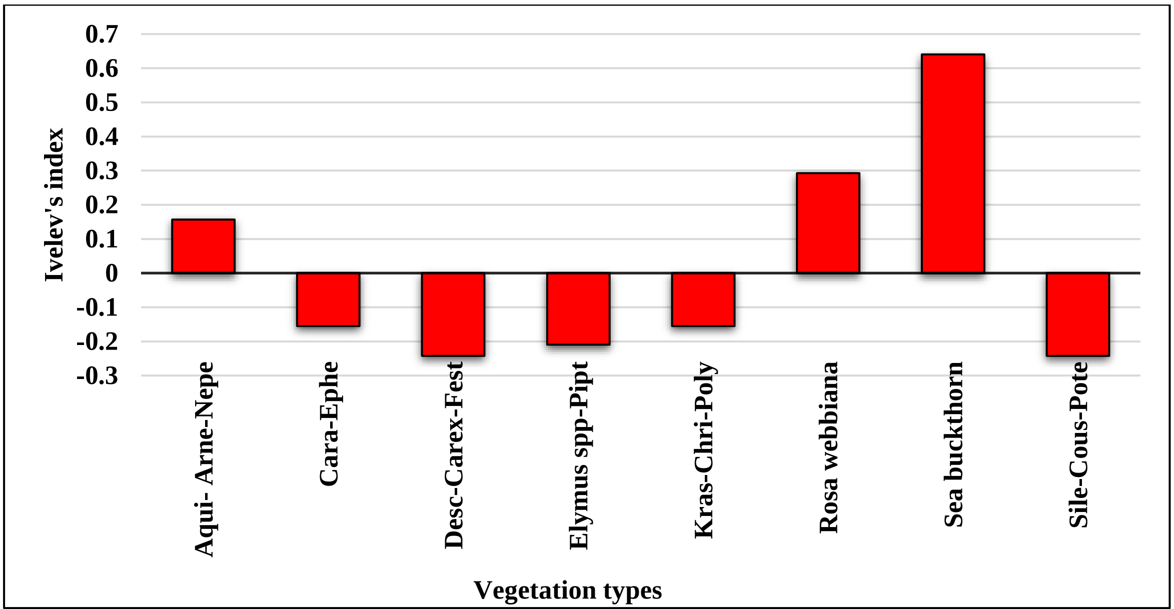


Fig 5.29 Selection for vegetation types by ibex.

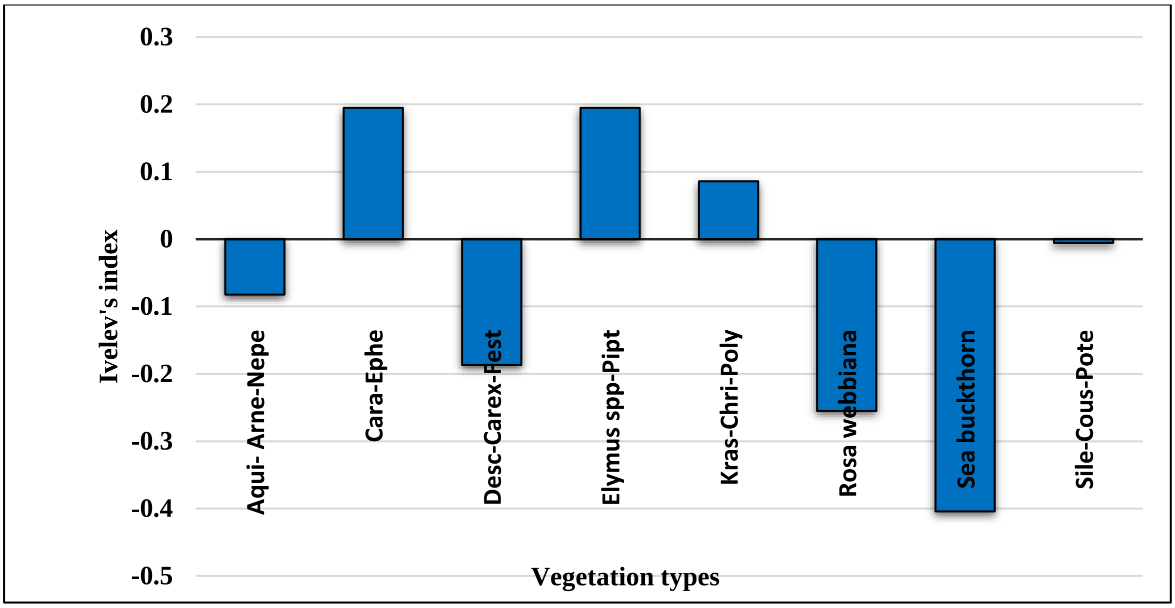


Fig 5.30 Selection for vegetation types by blue sheep.

<u>Faecal analysis of blue sheep and ibex for monocots and dicots</u>

Selection for monocots and dicots was evaluated using Ivelev's index. Both the species had higher proportions of dicots in their diets, with blue sheep consuming a slightly higher proportion of monocots compared to ibex. Conversely, ibex seems to rely slightly more on dicots than monocots. Even though the availability of monocots was more, both of them preferred dicots.

Overall, the differences in proportions of monocots and dicots in the diet of blue sheep and ibex are not significant.

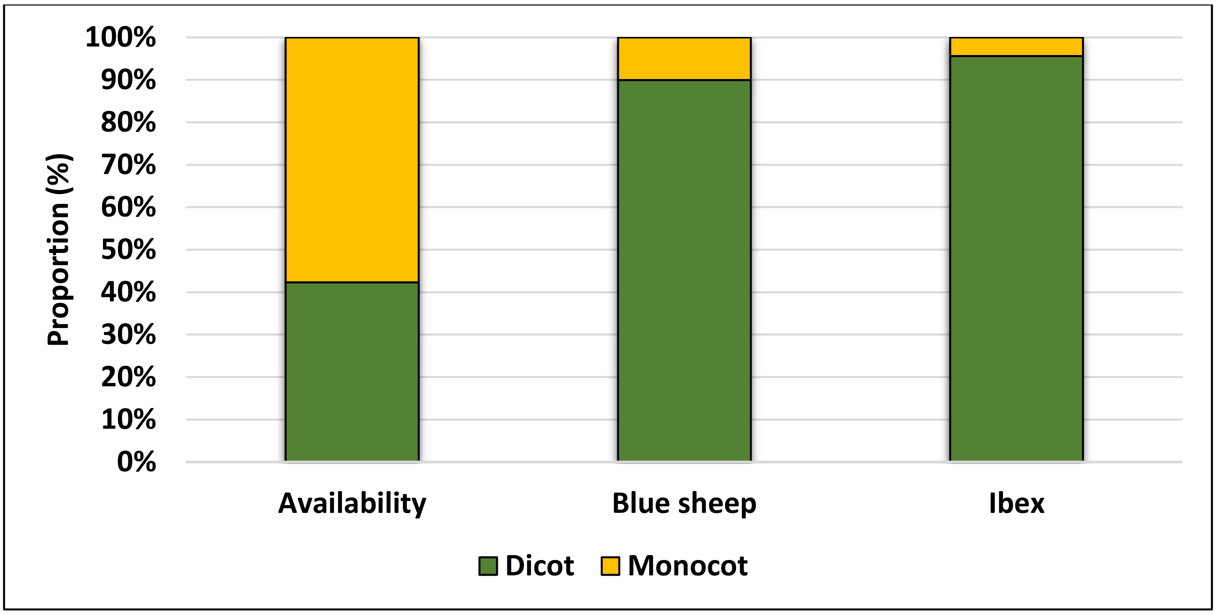


Fig 5.31 Percentage composition of monocots and dicots in pellet samples vs availability (N=30).

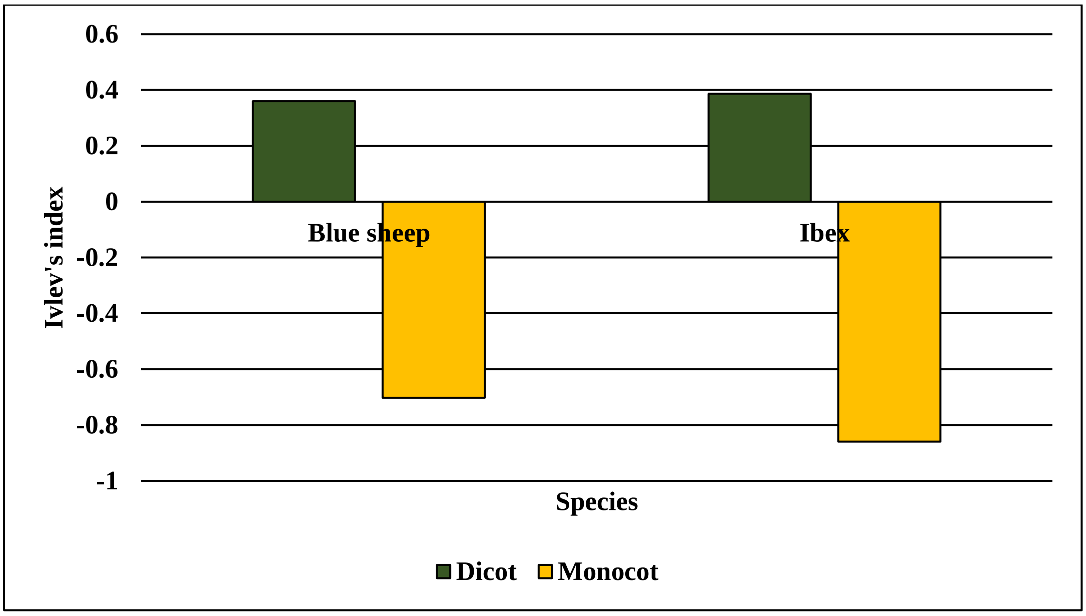


Fig 5.32 Selection for monocots and dicots by blue sheep and ibex.

6. **DISCUSSION**

The aim of the study was to understand the ecological separation between ibex and blue sheep and also to understand the patterns of resource use and species interaction. The study was carried out during the winter to understand habitat-use patterns and diet of ibex and blue sheep and how they segregate in terms of habitat, diet, space, and time during harsh winter months. The results of the study broadly suggested that ibex and blue sheep segregate in terms of habitat use and space they occupy. Although there are not much differences in the diet. This study deviates from the findings of a previous study by Namgail (2006), revealing that high overlap in the habitat use between ibex and blue sheep in Zanskar mountains, may be influenced by their proximity to the escape terrain for protection against predators.

6.1 Spatial and Temporal overlap

Ibex and blue sheep showed less spatial overlap i.e. only 5 grids were shared ($S = 0.17$, $P=0.015$). This indicates that despite limited forage availability during the winter season, ibex and blue sheep segregate in their selective habitat use. There were two incidences where Ibex and blue sheep were seen foraging together. A study conducted by Sinclair (1985), reveals that group living observed in ungulate communities across Eastern Africa is often considered as a strategic response to high predation pressure. Approximately, based on my observations there was a total population of 50 ibex (a total 54, out of which 4 yearlings were killed by the 2 snow leopard siblings which were directly observed) occupying the Chicham area and a very small part of Kibber. Blue sheep in the area occupy spatially distinct zones so that there is little overlap between ibex and blue sheep. Blue sheep occupied areas such as Dumley, Kibber (also near Kibber-Langza road), Gette, and a very small part of Chicham. Blue sheep was quite good in number in my study area (1 adult male near Dumley region was predated by Snow leopards).

There is a 73% overlap in the activity pattern of ibex and blue sheep (Dhat1 =0.73), signifying that both species segregate in their space and habitat utilization.

6.2 Habitat use and separation between ibex and blue sheep

Habitat use was explained by broad topographical and environmental variables. Ibex and blue sheep showed segregation in terms of space and on the basis of preference for habitat categories. Blue sheep being generalists, exploit a broad range of habitats that are available. The broad distribution of the animal may be linked to its versatility in utilizing resources based on the availability of biotic and abiotic factors. Specifically, its flexible diet and habitat use allow it to thrive in different kinds of environments (Namgail et al., 2009). For example, blue sheep preferred cliffs as anti-predator habitat (Namgail et al., 2004), so when the cliffs were scarce, they were adapted to use boulders as escape terrain on the Tibetan plateau (Harris & Miller, 1995; Namgail, 2006).

However, ibex has a narrow niche, more of a specialist, whose habitat is characterized by smaller and more specific habitat conditions. Ibex uses steep slopes ranging from 31° to 60°, prefers areas within 1-50m from escape terrain, and selects locations with escape routes available in three to six directions (Bhatnagar, 1997). Hence, ibex space is clustered near the rugged areas that have easier accessibility to forage and escape terrain. They avoid deep snow areas, choosing sites based on physical characteristics that minimize snow coverage (Bhatnagar, 1997). Their distribution is clustered near Kibber and Chicham areas because of more availability of escape terrain (rocky areas), more directions of escape routes, and steep slopes.

Research on habitat association (Namgail et al., 2007; Shrestha & Wegge, 2008) has utilized Generalized Linear Models (GLMs) to examine resource selection. Ecologists have long viewed habitat segregation as a strategy that minimizes interference and exploitation competition, thereby facilitating the coexistence of ecologically similar species (Pianka, 1978; Namgail et al., 2004)

Factors that influence the probability of use by ibex and blue sheep were different. Elevation (linear effect + quadratic effect), number of directions in which escape terrain was available, and terrain type influenced the probability of use by ibex. The quadratic effect was considered because not all the variables have linear effects, some have quadratic effects such as elevation. It was considered to assess whether there was a peak in the intermediate levels, which did not happen in my case. There was a decrease in the mid-elevations and an increase at lower and higher elevations, although the confidence interval was too large. Bhatnagar (1997) noted the use of higher elevations in the winter. Higher elevations were found to have a great number of snow-free sites (wind-blown sites and avalanche chutes) (Bhatnagar, unpubl. data; Bhatnagar,1997). Ibex might have chosen to remain at higher altitudes despite chilly weather conditions. Animals show altitudinal migration because of better forage availability at lower elevations (Namgail, 2009).

Ibex prefers areas where escape terrain is available in 3-4 directions or even more, suggesting that these directions are used more frequently. Stocky legs and strong knees, adapted for climbing (saltatorial legs), make them adept at swiftly climbing cliffs rather than running long distances (Schaller, 1977; Geist, 1987; Bhatnagar, 1997). Interspersed rocky slopes were used higher during the winter season because of proximity to the cliffs (escape terrain), high rocky, and characterized by sparse vegetation. These steep and rocky areas shed snow early and expose forage (Bhatnagar 1997; Beecham et al, 2007).

The factors influencing the probability of use for blue sheep were slope, number of directions in which escape terrain was available, vegetation cover, and distance to the cliff. A study by Oli (1996), reveals that blue sheep use moderate slopes (<40°). In the regions where both the ibex and blue sheep coexist, blue sheep tend to frequent open slopes near cliffs more than ibex do (Namgail, 2006). The preference for steeper slopes and rocky areas is likely an adaptation related to their use of cliffs as escape terrain (Namgail et al., 2004). Since cliffs have sparse forage, blue sheep move away from the cliffs to feed, thus balancing the need for food and avoiding predators (Namgail et. al, 2004; Namgail, 2001; Wegge, 1979).

Vegetation cover is surrogate to forage availability and blue sheep prefer areas with more vegetation cover. More the number of directions of escape terrain, rockier, proximity to cliffs, and a higher degree of slopes resulting in sparse vegetation. Thus avoids more directions of escape routes. Also, blue sheep can run down the slope and then reach escape terrain (Bhatnagar pers comm). Many studies have recorded blue sheep habitat use in the proximity of cliffs. In a study conducted by Namgail et.al (2004), blue sheep were observed within 250 meters of cliffs. Blue sheep remain close to broken landforms such as cliffs landslides or boulders (150 meters) even when they are not directly observed from these features (Oli, 1996). Research by Wegge (1979) and Oli (1996) indicates that the group size of blue sheep increases as the distance from escape cover increases.

<u>Comparison of the use of habitat variable categories between ibex and blue sheep during winter.</u>

a. Elevation: Both the species preferred lower and medium elevations and avoided higher elevations. In response to improved forage availability, ibex tend to occupy the lowest part of their range (Manjrekar, 1977). Higher elevations were snow-covered with little vegetation available.
b. Slope: Not many differences in the use of slopes between the species, although blue sheep used steeper slopes more than availability compared to ibex. Slopes can be used for forage quantity and security purposes, as steep slopes have lower snow accumulation (Fox et al, 1989).

c. Terrain type and Terrain ruggedness Index: Ibex prefer Interspersed rocky slopes, rocky slabs, and rocky slopes because of high rocky areas (escape terrain) and sparse vegetation as they trade food for security. They are adapted for climbing and cannot run along the slopes like blue sheep. On the other hand, blue sheep prefer smooth slopes with high vegetation cover, maintaining a considerable distance from the escape terrain (Bhatnagar, 1977). Thus, ibex uses more rugged areas than blue sheep,

d. No. of directions in which escape terrain is available: This factor is more important for ibex compared to blue sheep. Ibex prefers areas where there are escape routes available in 3 to 6 directions (Bhatnagar, 1977). This is not necessary for the blue sheep as evidenced in this study.

e. Distance to the cliff: ibex prefers areas where escape terrain is available within 100m, with less preference for 200m. Blue sheep, on the other hand, prefer distances within 300m and are also found in areas more than 500m away. Blue sheep can forage farther away from the cliff compared to ibex (Bhatnagar, 1977).

f. Snow depth and snow cover: Both species avoid deep snow areas. Blue sheep primarily feed on vegetation protruding from the snow and refrain from creating snow craters (Suryawanshi et al., 2008), whereas ibex dig out snow craters and feed on the erect plants (Bhatnagar et al., 2000).

g. Vegetation cover: blue sheep prefer areas with high vegetation cover than ibex. Vegetation cover is related to the terrain type. Snow accumulation is greater on smooth slopes because they are less steep. As the snow recedes, more moisture is available to the plants, thus supporting vegetation. Most of the vegetation types in my study area grow on smooth slopes.

h. Rock cover: ibex prefers rockier areas than blue sheep, given that rock cover is more abundant on Interspersed rocky slopes and Rocky slopes (Escape terrain).

i. Soil cover: blue sheep prefer areas with varied soil cover but avoid high soil cover areas, which may explain low vegetation cover. In contrast, ibex favors areas with low soil cover, aligning with their preference for habitats characterized by high rock cover and sparse vegetation.

j. Aspect: Ibex appeared to use aspects and vegetation types without showing preference in the winter, choosing crests and cliffs, which were relatively free of snow and exposed to wind, for their easier access to vegetation (Manjrekar, 1997).

   But based on my study, preference for Northern slopes by both the species can be due to less snow cover and snow depth, despite sparse vegetation and less availability of escape terrain. North-eastern aspects and Eastern aspects were preferred by ibex because of the availability of important terrain type - Interspersed rocky slopes. South-eastern and South-western aspects were more preferred by ibex than blue sheep because of low vegetation cover and high rock cover and also the availability of favored terrain type. Western aspects were preferred by blue sheep due to high vegetation cover and low rock cover. Southern slopes were avoided by both species due to high snow cover and depth, despite good vegetation cover and rock cover. The north-western aspect was avoided by blue sheep, but no records of usage by ibex, which can be due to moderate vegetation cover, low snow cover & depth, and low rock cover.

6.3 Diet selection and utilization

Ungulates select their food at various scales, known as a foraging hierarchy (Bailey et al., 1996; Chanchani, 2007). Ungulates choose specific plants based on their intrinsic value related to palatability and availability, rather than selecting entire plant communities. The spatial separation of foraging areas plays a crucial role in minimizing conflicts among ungulates over preferred foraging sites (Sheehy & Varva, 1996). Vegetation communities offer only broad insights into preferences, so interpreting them at large scales should be approached with caution and a thorough understanding of the plant community (Chanchani, 2007).

Here, in my study, both species appear to prioritize terrain features over vegetation types, although there is likely some relationship between the two.

Rosa webbiana and Sea buckthorn communities were predominantly found in areas used by ibex, which led to blue sheep avoiding these communities. *Rosa webbiana* was mainly restricted to rocky slopes. The *Aquilegia – Arnebia- Nepeta* community was found in all terrain types, preferred by ibex and avoided by blue sheep. *Caragana – Ephedra* was prevalent in areas of intensive livestock grazing. Since blue sheep were foraging in areas where livestock grazed during summers (Mishra et al., 2004), these communities showed a high preference for blue sheep. Communities such as *Kraschennikovia – Christolea – Polygonum* and *Elymus spp – Piptatherum* were favored by blue sheep and avoided by ibex due to their high vegetation cover. Blue sheep showed no specific preference for *Silene – Cousinia – Potentilla sp 2* but was avoided by ibex. *Deschampsia – Carex – Festuca* was avoided by both species because sedges grew close to the streams, and during winter, the water froze to ice, which might have led to less availability of sedges.

Many herbivores exhibit considerable seasonal variation in their diet composition, with varying contributions from graminoids and browse plants (Bodmer, 1990; Brown & Doucet, 1991;

Suryawanshi et al., 2009). These dietary changes may occur from seasonal variations in forage quality (Hulbert et al., 2001; Iason & Wieren, 1999), competition with sympatric herbivores (Hulbert & Anderson, 2001), or heightened predation risk (Morgantini & Hudson, 1985).

This study indicates that both ibex and blue sheep consume a higher proportion of dicots in their diets. This was confirmed by Suryawanshi et al. (2009), who found that blue sheep rely more on browse plants in rangelands with low graminoid availability. The study also revealed that graminoid availability strongly influences the diet composition of blue sheep during winter, whereas the quality of non-graminoids has minimal impact. A similar dietary shift was observed in Mishra et al.'s (2004) study. A study by Bhattacharya et al. (2012) in Uttarkashi district, Uttarakhand, suggests that decreased graminoid availability may result from livestock grazing or the presence of relatively nutritious dicots.

During winter, ibex shift their diet from graminoids to specific parts of shrubs, often favoring fruits. During winter, the availability of forage significantly influences the diet of ibex, leading them to forage with minimal selectivity (Manjrekar, 1997). They exhibit a generalist feeding strategy due to the limited availability and quality of food.

These ungulates build up fat reserves during seasons of abundant and high-quality food, which helps support their physiological needs throughout harsh winter months. However, low-quality food during winter only allows maintenance, not growth. Therefore, large-scale movements would not be cost-effective for these animals during the season (Arnold et al., 2020; Parker et al., 2009).

Some possible biases in the study:

The results of species' higher utilization may indicate that a small number of features were widely covered during trail monitoring.

7. CONCLUSION

The habitat overlap between ibex and blue sheep indicates significant potential for competition, as overlapping habitats can result in both exploitation and interference competition (Namgail, 2006; Begon et al., 1996).

However, in my study, blue sheep and ibex segregate in their use of terrain, slope, and physical features such as escape terrain, snow cover, and depth. Blue sheep, more in number, compared to ibex, and occupy distinct regions within the study area, have a competitive advantage over ibex, which are present in few numbers and restricted to a specific region. The variation in their distribution can be attributed to their ecological and evolutionary factors. Nevertheless, increasing livestock pressure and winter-induced plant senescence impact both species.

3.3 Conservation interventions:

Understanding the threats to these species and their habitat and addressing them with the help of local people and involved agencies is important and these threats should be monitored periodically.

1. During the winter season, the area attracts numerous tourists and wildlife photographers. It is crucial to implement measures that ensure minimal disturbance to wildlife. I have observed people approaching animals too closely, disturbing them, and even causing them to flee for the sake of capturing videos.
2. Areas where these ungulates occur at high densities, must be demarcated and zoned and should be free from livestock.
3. During winter, wild ungulates use grazing lands used by the livestock during summer. Thus, the availability of forage becomes limited. Therefore, rangeland-based effective management interventions are required. Controlled grazing and a decrease in anthropogenic disturbances or shall be helpful.

4. Efforts should be made to curb the population of feral dogs and regulate their movement, as they have emerged as a serious threat to wildlife, with many instances of ibex being chased by dogs having been witnessed (on 4 occasions), where the females and the yearlings retreated to the nearby cliff and climbed down.
5. More research should be conducted to focus on monitoring the long-term impacts of climate change on their habitat use and resource availability, and conservation strategies should be developed to address the issue.

PLATES

Plate 1: Trans-Himalayan landscape in Spiti Valley during winter. This photo shows scree slopes and rugged terrain with layered cliffs in Kibber and Chicham. Ibexes are encircled.

Plate 2: Snow-covered Kibber village with settlements and people filling water into their cans.

Plate 3: Chicham Bridge, Asia's highest suspension bridge at an altitude of 4037m (13,596 feet) connecting Kibber and Chicham villages in Spiti Valley (Source: Times of India).

Plate 4: Adult Class IV male ibex, 2 adult females (left and right to the male), a female sub-adult (right corner), and 2 yearlings (resting).

Plate 5: Adult Class III male ibex cratering to feed on the vegetation buried under the snow.

Plate 6: Ibex herd feeding and resting near the cliffs (escape terrain) on scree slopes.

Plate 7: Adult class V male blue sheep cratering to feed on the vegetation buried under the snow. Adult class IV male towards its left and adult female on its right.

Plate 8: Yearling blue sheep walking on the snow.

Plate 9: Adult female blue sheep feeding on the grass species.

Plate 10: Blue sheep herd feeding on rocky slopes.

Plate 11: The blue sheep herd is feeding in close proximity to ibex (adult male and female); the blue sheep adult female and ibex adult female are looking at each other.

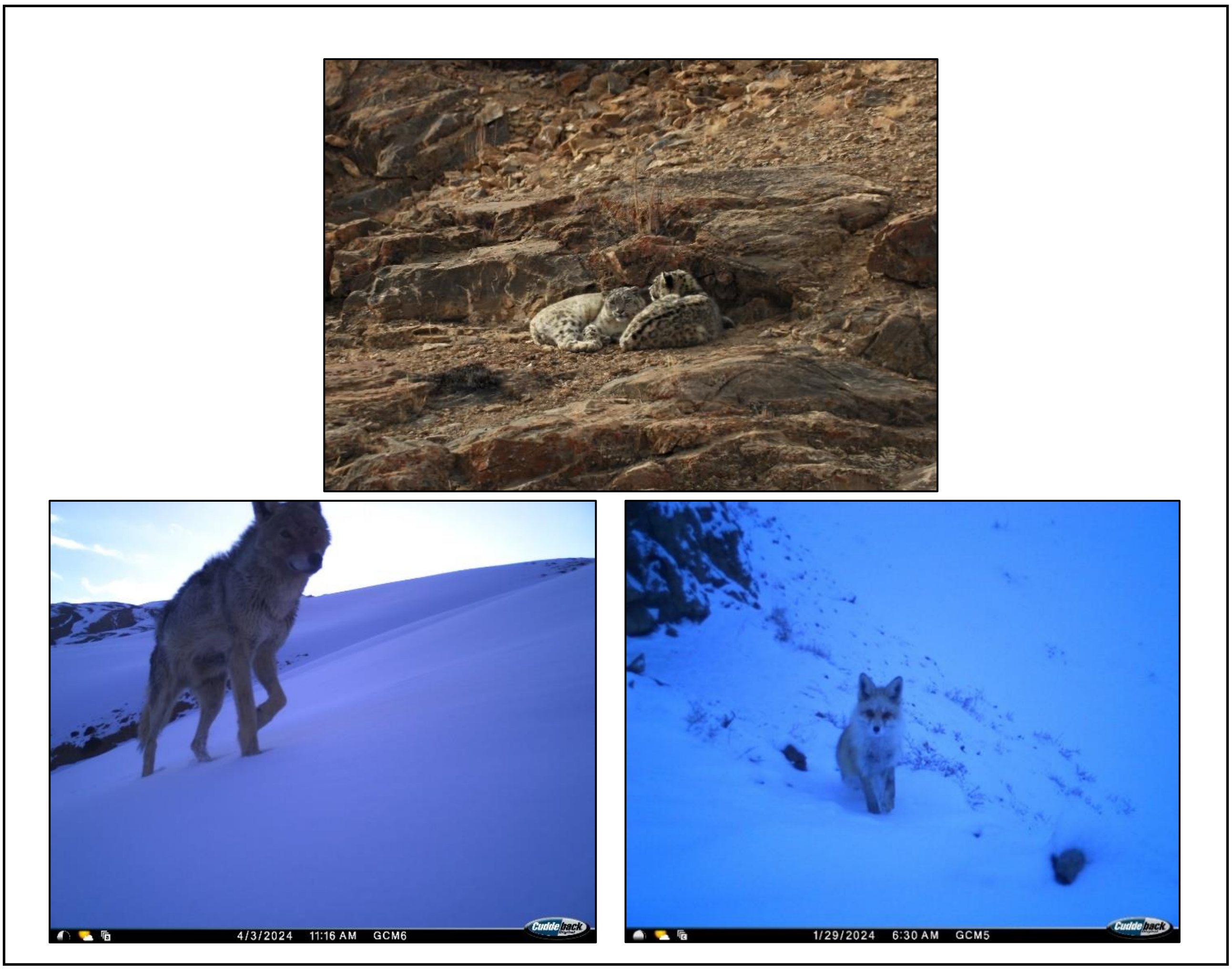


Plate 12: Apex predators and a meso predator of my study area: Snow leopard siblings (top left), Himalayan wolf (top right), Red fox (below).

Plate 13: Blue sheep pellets.

Plate 14: Ibex pellets.

Blue sheep pellets are more rounded and spherical, while ibex pellets are generally oval, elongated, and larger than blue sheep pellets.

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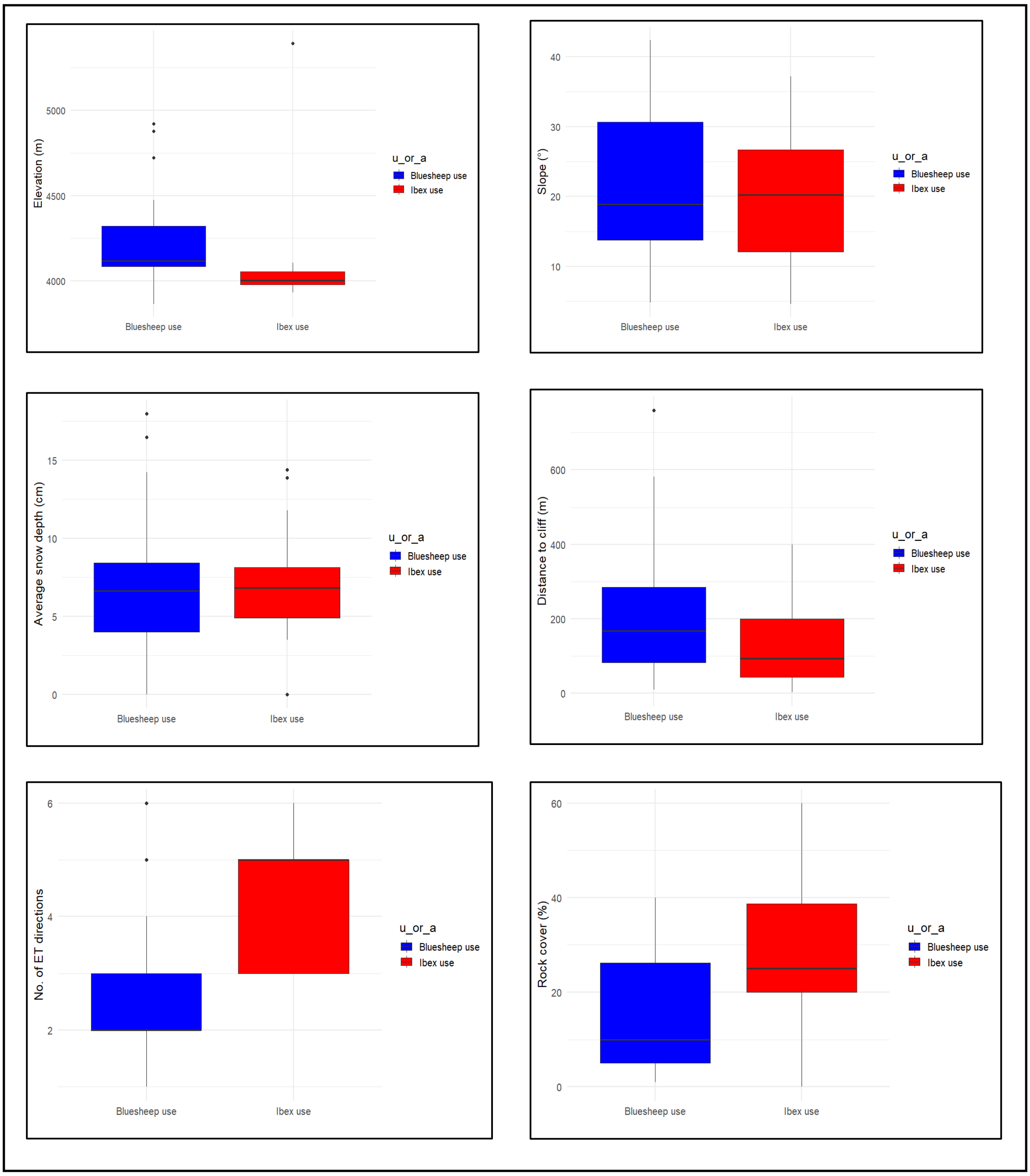
APPENDICES

APPENDIX 1

Exploratory analysis



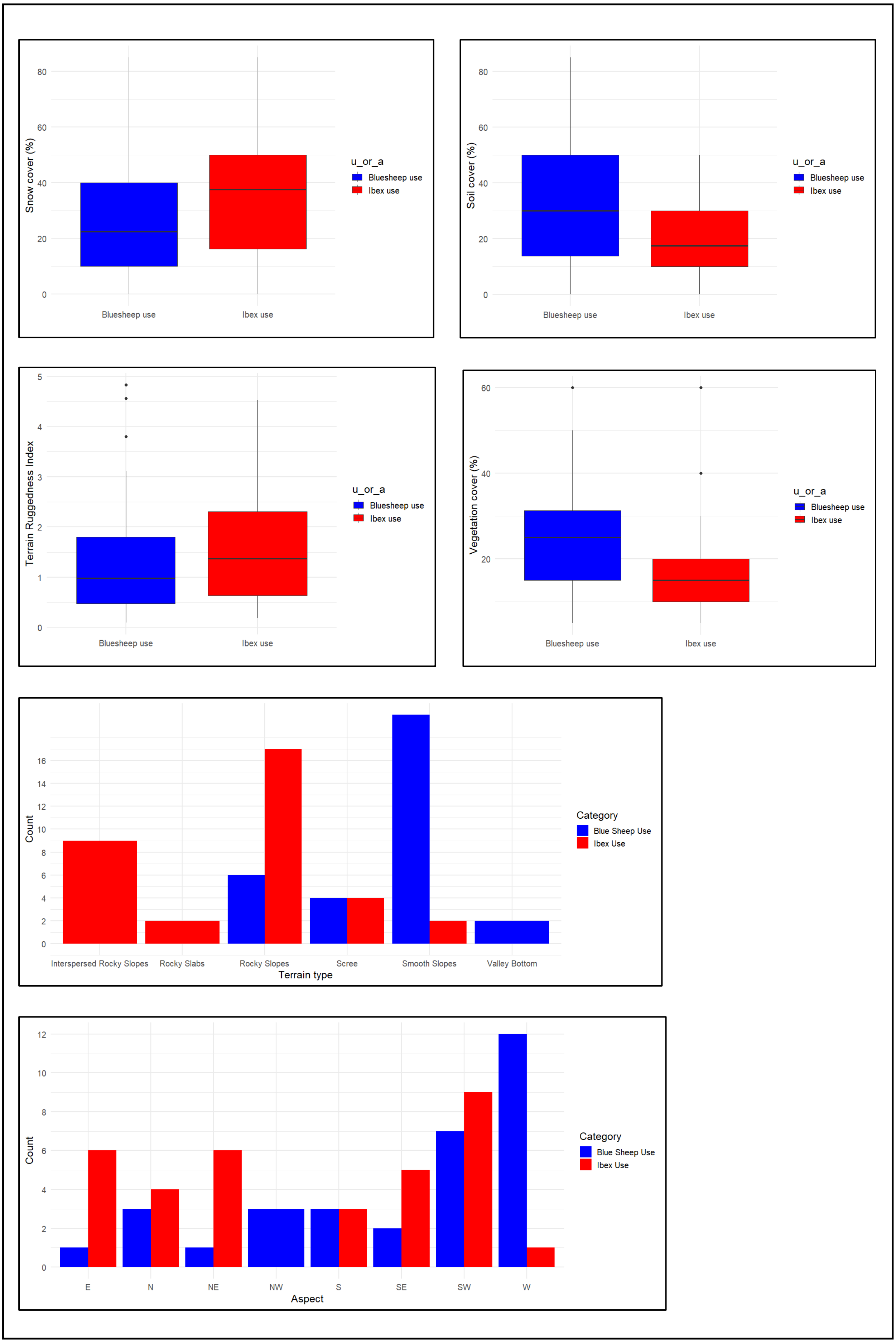


Fig A: Exploratory graphs of habitat variables

APPENDIX 2: Correlation matrix for habitat variables

	Elevation	Slope	Distance to cliff	Vegetation cover	Snow cover	Rock cover	Soil cover	Snow depth	ET directions	TRI
Elevation	1	-0.31	0.13	0.29	-0.35	-0.14	0.29	-0.24	-0.26	-0.02
Slope	-0.31	1	-0.15	-0.23	0.1	0.24	-0.11	0.18	0.11	0.21
Distance to cliff	0.13	-0.15	1	0.15	-0.06	-0.12	0.04	0.13	-0.39	0.03
Vegetation cover	0.29	-0.23	0.15	1	-0.44	-0.24	-0.01	-0.4	-0.32	0.08
Snow cover	-0.35	0.1	-0.06	-0.44	1	-0.14	-0.65	0.48	0.28	-0.12
Rock cover	-0.14	0.24	-0.12	-0.24	-0.14	1	-0.4	-0.02	0.31	0.03
Soil cover	0.29	-0.11	0.04	-0.01	-0.65	-0.4	1	-0.23	-0.32	0.07
Snow depth	-0.24	0.18	0.13	-0.4	0.48	-0.02	-0.23	1	0.12	-0.05

ET directions	-0.26	0.11	-0.39	-0.32	0.28	0.31	-0.32	0.12	1	0.05
TRI	-0.02	0.21	0.03	0.08	-0.12	0.03	0.07	-0.05	0.05	1

ET – Escape terrain; TRI – Terrain Ruggedness Index

Here, soil cover and snow cover are highly correlated. Soil cover was not considered for the analysis. The variables used for the analysis are elevation, aspect, slope, distance to the cliff, vegetation cover, ET directions, snow depth, snow cover and rock cover.

APPENDIX 3: Age and Sex classes of blue sheep and ibex

Criteria used for age and sex classification of blue sheep

Age class	Sex class	Description			
		Age	Body size	Horn size/ Curvature	Other description
Young	Young	<1 yr	small	Very small and stubby	
Yearling or Sub adult	Male	1-2 yrs	2/3rd the size of Adult Female	15cm long	
	Female	1-2 yrs	medium		
Adult males	Class I	2 ½ yrs old	As large as female	25 cm long	
	Class II	3 ½ yrs old	Bulkier than Class I Males	35 cm long	
	Class III	4 ½ yrs old	Have a powerful physique, trimmer than full adults		
	Class IV	5 ½ - 6 ½ yrs old with some 7 ½ years.	Bulky in looks.	Stout horns sweeping out and far back.	Black neck and chest. Their necks are much swollen during the rut and the skin around the penis forms a prominent bulge.
	Class V	Atleast 7 ½ years old. Their age is most readily ascertained by counting horn rings.		50 cm or more long	

APPENDIX 4: Criteria used for age and sex classification of ibex

Age class	Sex class	Description			
		Age	Body size	Horn size/ Curvature	Coat colour
Kid	Kid	First year		Stubby horns	
Yearling	Females	Second year	3/4th of the size of Adult Female	Less than 5cm	Resemble females except for a darker pelage
	Males		Close to but smaller than that of adult female.	Less than 20 cm Horns are laterally wide with 1 or 2 frontal knobs	Relatively darker than adult females and yearling females.
Adult males	Class I	Third year		35 cm long. Short horns with little curvature	Do not develop dark brown markings on body during rut and winter
	Class II	Fourth & fifth year		50 – 60cm long. Horns curved slightly backwards.	Dark brown markings with a distinct silvery 'saddle' appears during rut and winter
	Class III	Sixth & seventh year		60 – 70cm, Horns curve back in a semi-circle	Dark black coloration with silvery saddle appeared during rut and winters.
	Class IV	>seventh year		>70cm, horns curve in a semi-circle and curve outward	Dark black coloration with silvery saddle appeared during rut and winters.

APPENDIX 5:

NMDS axes fitted to the habitat variables.

Variable	NMDS1	NMDS2	R_squared	P_value
elevation	-0.89335	-0.44936	0.9668	0.001
slope	0.9993	0.03748	0.1241	0.001
distance_to_cliff	-0.40972	0.91221	0.9517	0.001
vegetation_cover	-0.99514	-0.09847	0.1101	0.001
snow_cover	0.87831	0.47809	0.1827	0.001
rock_cover	0.96823	-0.25008	0.0332	0.077
soil_cover	-0.86234	-0.50632	0.1311	0.001
avg_snow_depth	0.45943	0.88821	0.099	0.001
et_directions	0.7993	-0.60093	0.2673	0.001
tri	0.56841	0.82275	0.0021	0.841
ibex	0.98926	-0.14615	0.2163	0.001
bs	0.0000	0.00000	0.0000	1.0000
availability	-0.98286	0.18435	0.1837	0.001
irs	0.99936	-0.0358	0.0189	0.242
rslopes	0.96318	-0.26884	0.0675	0.004
ss	-0.95797	0.28686	0.1485	0.001
rslabs	0.24292	0.97005	0.0078	0.531
sc	0.89964	-0.43663	0.0644	0.009
vb	-0.99446	-0.1051	0.0208	0.168
caragana_ephedra	-0.77303	0.63437	0.0079	0.545
kras_christ_poly	-0.66558	-0.74633	0.034	0.067
aqui_arne_nepe	0.57396	0.81888	0.0123	0.39
elym_pipt_elysemi	0.96169	-0.27416	0.0031	0.775
grass_sp	0.99035	0.13859	0.0057	0.627
desc_carex_fest	-0.46255	0.88659	0.0462	0.038
sil_cou_pot2	0.01561	-0.99988	0.0029	0.805
seabuckthorn	0.92595	-0.37765	0.058	0.01
rosawebbiana	0.89728	-0.44145	0.0241	0.146
north	-0.93295	0.36	0.0184	0.224
northwest	-0.96979	-0.24392	0.0456	0.023
northeast	-0.15868	0.98733	0.006	0.612
south	0.83824	-0.5453	0.0116	0.408
southwest	0.0000	0.0000	0.0000	1.000
southeast	0.98644	0.16414	0.0754	0.004
west	-0.94407	-0.32974	0.0466	0.024
east	0.9819	0.1894	0.0939	0.001

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Permutation: free
Number of permutations: 999

Here, the values under NMDS1 and NMDS2 columns represent the directions and strengths of the vectors for each variable in the ordination space.

APPENDIX 6: lists favoured plant species recorded from direct observations and based on the literature (Manjrekar, 1997; Mishra, 2001).

List of favored plant species

Sl. No.	Plant Species
1	*Aconogonon tortuosum*
2	*Arnebia euchroma*
3	*Artemisia sp*
4	*Bupleurum sp*
5	*Carex maritima*
6	*Carex sp*
7	*Carex sp 1*
8	*Carex sp 2*
9	*Carex stenophylla*
10	*Deschampsia cespitosa*
11	*Elymus longearistatus*
12	*Elymus semicostatus*
13	*Elymus sp*
14	*Ephedra geraradiana*
15	*Eritrichium canum*
16	*Festuca sp*
17	*Festuca sp 1*
18	*Festuca valesiaca*
19	*Heracleum pinnatum*
20	*Krascheninnikovia ceratoides*
21	*Leontopodium sp*
22	*Leymus secalinus*
23	*Lindelofia anchusoides*
24	*Lindelofia sp*
25	*Nepeta podostachys*
26	*Nepeta sp*
27	*Oxytropis cachemiriana*
28	*Oxytropis microphylla*
29	*Polygonum filicaule*
30	*Polygonum pleibeium*
31	*Polygonum sp*
32	*Potentilla multifida*
33	*Potentilla sp 1*
34	*Potentilla sp 2*
35	*Rosularia sp*
36	*Sibbaldianthe bifurca*
37	*Silene moorcroftiana*
38	*Stipa capillata*
39	*Stipa sp*
40	*Thalictrum sp*
41	*Polygonum cognatum*
42	*Grass sp*

APPENDIX 7: List of Plant species recorded in my study area.

Sl.no	Species	Sl.no	Species
1	*Aconogonon tortuosum*	43	*Festuca sp 1*
2	*Allium carolinianum*	44	*Festuca valesiaca*
3	*Androsace globifera*	45	*Gentiana kirilowii*
4	*Aquilegia fragrans*	46	*Gentiana sp*
5	*Arnebia euchroma*	47	*Heracleum pinnatum*
6	*Artemisia japonica*	48	*Kobresia sp*
7	*Artemisia sp*	49	*Koenigia filicaulis*
8	*Asperula sp*	50	*Krascheninnikovia ceratoides*
9	*Astragalus webbianus*	51	*Lactuca orientalis*
10	*Axyris sp*	52	*Leontopodium sp*
11	*Bergenia sp*	53	*Lepidium apetalum*
12	*Bromus sp*	54	*Leymus secalinus*
13	*Bupleurum sp*	55	*Lindelofia anchusoides*
14	*Calamogrostis emodensis*	56	*Lindelofia sp*
15	*Calamogrostis pseudophragmites*	57	*Miricaria prostrata*
16	*Campeiostachys nutans*	58	*Neotrinia splendens*
17	*Caragana versicolor*	59	*Nepeta podostachys*
18	*Carex lemmonii*	60	*Nepeta sp*
19	*Carex maritima*	61	*Oxytropis cachemiriana*
20	*Carex melanantha*	62	*Oxytropis microphylla*
21	*Carex orbicularis*	63	*Pedicularis punctata*
22	*Carex sp*	64	*Piptatherum gracile*
23	*Carex sp 1*	65	*Polygonum filicaule*
24	*Carex sp 2*	66	*Polygonum pleibeium*
25	*Carex stenophylla*	67	*Polygonum sp*
26	*Christolea crassifolia*	68	*Potentilla multifida*
27	*Cirsium arvense*	69	*Potentilla sp 1*
28	*Cousinia thomsonii*	70	*Potentilla sp 2*
29	*Cynanchica pyrenaica*	71	*Primula sp*
30	*Cynoglossum wallichii*	72	*Rhamnus prostrata*
31	*Dasiphora arbuscula*	73	*Rheum spiciforme*
32	*Deschampsia cespitosa*	74	*Rhodiola heterodonta*
33	*Dianthus sp*	75	*Rhodiola sp*
34	*Draba sp*	76	*Ribes orientale*
35	*Dracocephalum heterophyllum*	77	*Rosa webbiana*
36	*Elymus longearistatus*	78	*Rosularia sp*
37	*Elymus semicostatus*	79	*Rubia tibetica*
38	*Elymus sp*	80	*Salsola sp*
39	*Ephedra geraradiana*	81	*Scrophularia dentata*
40	*Eritrichium canum*	82	*Scrophularia sp*
41	*Eritrichium sp*	83	*Senecio dubitabilis*
42	*Festuca sp*	84	*Senecio sp*
85	*Sibbaldia cuneata*	91	*Tragopogon gracilis*

86	*Sibbaldianthe bifurca*	92	*Viola kunawarensis*
87	*Silene moorcroftiana*	93	*Arabidopsis sp*
88	*Stipa capillata*	94	*Dianthus sp*
89	*Stipa sp*	95	*Polygonum cognatum*
90	*Thalictrum sp*		