PATTERNS OF GRAZING, NATURAL RESOURCES USE BY LOCAL COMMUNITY AND THEIR INFLUENCE ON WILD UNGULATE (IBEX) HABITATS IN PIN VALLEY NATIONAL PARK, HIMACHAL PRADESH

A THESIS

Submitted by

KALZANG TARGE

for the award of the degree of

DOCTOR OF PHILOSOPHY

in

WILDLIFE SCIENCE

Under the guidance of

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&

Co-guidance of

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August 2023

DECLARATION

I hereby declare that the work conducted under this thesis titled "**Patterns of grazing, natural resources use by local community and their influence on wild ungulate (Ibex) habitats in Pin Valley National Park, Himachal Pradesh**" is a record of original and independent research work done by me and subsequently submitted for the award of the degree of **Doctor of Philosophy in Wildlife Science** to the **Saurashtra University, Rajkot (Gujarat)**. This research work has been carried out under the guidance and supervision of Dr. B. S. Adhikari and co-guidance of Dr. Salvador Lyngdoh, Wildlife Institute of India, Dehradun. 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 own work, analysis, observation, understanding and the particulars given in it are true to the best of my knowledge.

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Mr. Kalzang Targe has worked on the thesis for more than six terms under our supervision and guidance. The work presented in this thesis has not been submitted for any other degree. It meets all of the specifications stated forth in the ordinances of Saurashtra University in Rajkot, Gujarat, and the Wildlife Institute of India.

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Mr. Kalzang Targe has put more than six semesters 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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It certifies that the research work was appreciated by all who were present, and no major comments made by the faculty and researchers in the thesis.

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I dedicate this work to the cherished memory

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my elder brother (Acho) late Sh. Sangay Rinchen,

as well as to my loving family, relatives, and the people of Spiti Valley

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I dedicate this thesis to the loving memory of my late elder brother, Teacher, and Social activist Sh. Sangay Rinchen Alias Ram Lal. He has always been the pillar of strength for our family, shouldering all responsibilities alongside sister Yangchen Gatuk.

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Executive Summary

The Trans-Himalaya region, located in the cold desert area of Pin Valley, boasts remarkable natural values, including diverse floral and faunal species such as the iconic Snow leopard and Himalayan Ibex, which led to its designation as a National Park (NP) in 1987. However, a significant portion of the Pin Valley National Park (PVNP) is utilized by historically resource-dependent communities, including eight villages from Pin Valley and six groups of migratory herders from the Shimla and Kinnaur districts, for purposes such as livestock grazing, fuelwood collection, dung, fodder, medicinal plants, and other non-timber forest products (NTFP).

This thesis endeavours to conduct a comprehensive study in response to the imperative need for a deeper understanding of the impact of pastoralism on wildlife. The research is centered on the high-altitude rangelands of the Trans-Himalaya, which have a grazing history spanning millennia. The primary goal of this research is to analyse an agropastoral system and investigate its conflicts with wildlife, particularly in relation to the Himalayan ibex. The study is summarized into the following objectives.

- To study the changing aspects of local and migratory herders in Pin Valley,
- To study grazing patterns of livestock and wild ungulate (Ibex) in Pin Valley, and
- To document the natural resource dependency of local agropastoral community in Pin Valley.

The study on agropastoral practices and their influence on the wild ungulate ibex in the Trans-Himalaya area employed a variety of methodologies and data analysis techniques. The primary data collection took place between September, 2017 and December, 2019. The research conducted for social aspects in all thirteen villages but only villages dependent on National Park were considered for the analysis. Semi-structured interviews in thirteen villages ensuring representation from different strata, age groups, and genders. Additionally, two focused group discussions were organized in the villages that related with migratory herders with the aim of raising awareness about overstocking and over-grazing's impact on range land resources.

To analyse changes in the traditional agropastoral system, data were collected for both the past (pre-2000, before green pea commercialization) and present (post-2017) periods. Informal discussions with local community members were held to understand trends in livestock numbers and composition. Data on agriculture practices were also

recorded. The potential factors responsible for livestock and agriculture changes were recorded.

Locations (GPS) of agriculture and settlements were recorded to generate change detection maps. High-resolution satellite imagery from Google Earth Pro and ArcGIS 10.8 were utilized to map the study area and determine the area of resource dependency on the National Park by different strata.

Descriptive statistical analysis and paired two-sample t-tests were used to analyse changes in agriculture cropping patterns and livestock composition numbers between the past and present periods.

The resource dependency by the local community study included surveys of 80 households from eight villages with a focus on comparing strata-1 (fully dependent on the National Park) and strata-2 (partially dependent on the National Park) villages. Data on the use of natural resources like fodder, fuelwood, livestock dung, and non-timber forest products (NTFPs) were collected using semi-structured questionnaires with open and closed-ended questions. Change in resource use was compared between past and present data using descriptive statistical analysis.

Vegetation study was conducted using quadrats (1x1m) to measure vegetation composition and availability. TWINSPAN analysis was used to analyse plant association in the vegetation plots. The study also compared vegetation composition and structural patterns between grazed and ungrazed areas. Within those areas different landforms categorised and vegetation composition change detected using Mann-Whitney U test, Kruskal-Wallis test, and Dunn's test to evaluate significance differences.

The employed various methods to assess Ibex and livestock feeding habits, including direct and indirect observations, bite counts, and microhistological techniques. Chemical analysis was performed to estimate crude protein, phosphorus, potassium, and ash content in Ibex faecal samples using Microhistology techniques. Diet overlap between ungulates analysed using Pianka's index, Levin's index for diet width and Ivlev's index used for selectivity/preference using software packages "spaa" and "Electivity" in R version 4.2.2 (2022) and R Studio (2022).

Spatial use analysis utilized encounter rates of Ibex to understand their habitat use, population dynamics, and interactions with other ungulate species in grazed and ungrazed areas.

Kernel density estimation was employed to estimate the probability density function of Ibex's spatial utilization based on observed data points.

The agropastoral study revealed changes in the agricultural system from traditional self-sustaining crops to commercial green peas have improved the financial status of local families but have resulted in decreased crop diversity and self-sustaining use of crops. Pasture lands have been converted to agriculture lands. The livestock numbers have significantly decreased over the period of time in the valley. Free ranging dogs and modernization was the major cause of decreased livestock number. The study revealed important findings regarding the interaction between human activities and the natural environment in the area.

Local communities' dependency on the park for natural resources has decreased over time. Which is a good from the wildlife conservation point of perspective but on the other hand the modernized lifestyle of the people of valley and increased agricultural land use due to commercialised cash crop green pea have led to conversion of more and more pasturelands in to the agriculture lands resulting in habitat degradation and threats to the some of the rare and endangered medicinal plants of the valley.

The decline in local livestock diversity and numbers also may impact agricultural quality due to reduced manure availability. Medicinal plant collection and use have decreased, likely due to a decrease in the number of traditional healers (*Amchis*). Three high conservation value (HCV) sites have been identified for future medicinal plant conservation.

Vegetation analysis revealed that overall species richness, diversity and density was observed significantly higher in the livestock ungrazed areas as compared to the livestock grazed areas. Total six types of landform broadly classified and vegetation cover percentage found maximum in the Meadow (MD) landform and least cover percentage was in the riverbed landform. The Bray-Curtis vegetation dissimilarity between grazed and ungrazed areas is 0.62.

The resource competition between livestock and wild herbivores is explored, with many forage species being common for both Ibex and domestic ungulates. Ibex is confined to certain parts of the national park, as the southern part of the Parahio catchment is grazed by migratory livestock during the peak summer season, while the northern part is free from grazers except for local free-ranging livestock.

Microhistological analyses revealed that Ibex diets are high in dicots during the summer and monocots during the winter. In spring and autumn, there is no substantial difference as both dicots and monocots are consumed in equal amounts.

Ibex has broader niche availability in terms of diet and space in ungrazed areas compared to grazed areas.

Ibex primarily consumes grasses and forbs, showing a preference for forbs during the summer and a shift towards grasses and shrubs in winter. There is diet overlap between Ibex and livestock in grazed and ungrazed areas. Ibex shows a preference for rocky habitats and least preference for riverbeds.

The Ibex encounter rate in the livestock grazed areas showing significantly less as compared to the ungrazed areas during summer. But, onset of winter when migratory livestock left the areas the encounter rate in both grazed and ungrazed areas was more or less similar showing statistically no significance difference. Which conclude that the presence of livestock clearly showing impact on Ibex population when livestock was present.

The insights gained from this study are intended to guide conservation policy and management strategies.

The findings of this thesis hold practical relevance for land use planning and conservation management strategies. The research findings contribute valuable insights into the interactions between agropastoral practices and wild ungulate Ibex in the Trans-Himalaya area, providing a foundation for guiding conservation and management implementations strategies in the region.

Chapter 1

Introduction

1.1 Background and review of literature

Pastoralism refers to a livelihood system centred around the extensive herding and management of livestock, such as cattle, sheep, or goats. Pastoralists rely primarily on grazing natural vegetation for their animals and often have a nomadic or semi-nomadic lifestyle, moving their herds in search of suitable grazing lands (Galvin, 2009). Agropastoral on the other hand, is a traditional land use system that combines agricultural practices with livestock herding. It involves the cultivation of crops and the rearing of livestock, with the two activities complementing each other within the same land area. This integrated approach allows for the utilization of both plant-based and animal-based resources to sustain human communities (Scoones, 1994).

The association of domestic livestock with wild herbivores is a common phenomenon in various regions where pastoral and agropastoral practices are carried out around the world.

Understanding an animal's feeding habits, including food availability and preference, is crucial for evaluating and managing its habitat (Nelson, 1982). The availability and quality of forage significantly influence an animal's habitat use and behaviour (Putman, 1988).

Globally, the impact of livestock grazing on native animals is a significant conservation concern (Prins, 1992; Fleischner, 1994; Voeten, 1999).

This problem is particularly pronounced in India, which houses the world's largest livestock population of 520 million individuals (FAO, 2001), and this number continues to grow (a 6% increase between 1984 and 1994) (WRI, 1996). Despite covering less than 5% of India's land, wildlife reserves are not exempt from human activities and livestock impacts. More than 3 million people reside within Indian wildlife reserves, and approximately three-quarters of these reserves support livestock populations (Kothari *et al*., 1989).

As a result, the influence of local human resource use on indigenous species remains poorly understood (Mishra & Rawat, 1998). The Tibetan plateau and Tibetan marginal mountains, covering 26 million km², are situated in the dry Trans-Himalayan region, sheltered in the rain shadow of the Greater Himalayan range. This region boasts a rich pastoral heritage dating back millennia (Handa, 1994; Schaller, 1998) and is home to various endemic large wild herbivores, some of which are globally threatened. Both livestock and wild herbivore diets lack comprehensive understanding (Harris & Miller, 1995), impeding effective Trans-Himalayan wildlife management.

The Spiti Valley, situated in the Indian Trans-Himalayas and spanning 12,000 km², has been used for pastoral purposes for thousands of years (Handa, 1994). Currently, more than four-fifths of the rangelands in the Spiti Valley are overstocked, meaning they are grazed by an excessive number of animals, posing a threat to cattle productivity (Mishra *et al*., 2001). In these overstocked rangelands, adult female livestock perform poorly due to a density-dependent reduction in resource availability (Mishra *et al*., 2001).

While supplemental feeding sustains livestock populations during resource scarcity, its impact on Trans-Himalayan wild herbivores remains unknown (Mishra, 2001). Livestock-induced competitive exclusion may have caused the extinction of four wild herbivore species in Spiti over the past three millennia (Mishra *et al*., 2002).

Understanding an animal's feeding habits in terms of food availability and preference is critical for evaluating and managing its habitat (Nelson, 1982). One of the most significant factors affecting the patterns of habitat use and behavior of an animal is the availability and quality of forage (Putman, 1988).

Globally, the effects of livestock grazing on native animals constitute a significant conservation issue (Prins, 1992; Noss, 1994; Fleischne, 1994; Voeten, 1999). This is especially true in India, which is home to highest livestock population in the world, with 520 million individuals. (FAO, 2002), and this number continues to grow 6% increase between 1984 and 1994 (WRI, 1996). Only 5% of India's area is covered by wildlife reserves., and even these areas are not exempt from the impacts of human activities and livestock. According to estimates, more than 3 million people reside inside Indian wildlife reserves, and livestock grazing is one of the most common land uses, with approximately three-quarters of Indian wildlife reserves supporting livestock populations (Kothari *et al*., 1989).

As a result, the issue of how local human resource use affects indigenous species remains poorly understood (Mishra & Rawat, 1998). The Tibetan plateau and Tibetan marginal mountains, spanning 26 million km2, are located in the dry Trans-Himalayan region, nestled in the Greater Himalayan range's rain shadow. This area has a long history of pastoral farming (Handa, 1994; Schaller, 1998). The region also sustains a variety of endemic large wild herbivores, some of which are globally threatened. Both livestock and wild herbivore diets are poorly understood (Harris & Miller, 1995). Consequently, we have limited knowledge about how livestock affect wild herbivores, which impedes our capacity to efficiently manage Trans-Himalayan wildlife.

The Spiti Valley, which is 12,000 km² in size and is located in the Indian Trans-Himalayas, has been used for pastoral purposes for more than three millennia (Handa, 1994). Currently, more than four-fifths of the pasturelands in the Spiti Valley are overstocked, meaning that they are being grazed by an excessive number of animals, posing a threat to cattle productivity (Mishra *et al*., 2001). In overstocked pastures, adult female livestock exhibit significantly poorer performance compared to rangelands with lower stocking density, owing to a reduction in resource availability influenced by density-dependent factors (Mishra, 2001; Mishra *et al*., 2001). Supplemental feeding helps to sustain livestock population during resource scarcity, but its effect on Trans-Himalayan wild herbivores remains unknown (Mishra, 2001). Livestock-induced competitive exclusion potentially caused the extinction of four wild herbivore species in Spiti over the past three millennia (Mishra *et al*., 2002).

The Spiti Valley hosts three wild medium-to-large herbivore species: *Lepus oiostolus* Hodgson (woolly hare), *Pseudois nayaur* Hodgson (bharal) and *Capra ibex* Linnaeus (ibex) (Mishra *et al.,* 2002).

A comprehensive review of literature has revealed that certain areas within the Trans-Himalayan region are recognized as biodiversity hotspots due to their rich flora and the presence of endangered faunal species, including the snow leopard (*Panthera uncia*) and the Himalayan ibex (*Capra sibiricia*). Livestock grazing effects in the trans-Himalaya pastures vary with terrain and history. Research is needed to understand vegetation composition, grazing patterns, and the relationship with wild herbivores (Rawat & Adhikari, 2006). Transhumant pastoralist routes in pasture landscapes are heavily influenced by human activities like livestock grazing and tree lopping, emphasizing the need for preliminary documentation to assess the extent and effects of these anthropogenic disturbances needed (Mitra *et al*., 2013).

Literature highlights specific areas in the Trans-Himalayan region as biodiversity hotspots, characterized by some rare flora and faunal species like the snow leopard (*Panthera uncia*) and Himalayan ibex (*Capra sibiricia*). Pin Valley National Park (PVNP), located in the region, is vital for the surrounding communities. Eight villages in the valley depend on the park for fuelwood, fodder, livestock grazing, and farming (Bhatnagar, 1996). Traditional utilization practices in these communities, including uprooting shrubs, intensive livestock grazing by migratory grazers, and local grazing, exceed sustainable limits (Bhatnagar, 1996; Bhatnagar, 1997; Johnsingh *et al*., 1999; Manjrekar, 1997; Mishra, (2000, 2001, 2002); Bagchi *et al*., 2004). Livestock grazing, competition, and disturbances pose significant threats to species (Mallon *et al*., 1997; Clark *et al*., 2006). Historical livestock grazing patterns have impacted wild ungulate distribution and abundance (Mishra, 2001; Bagchi *et al*., 2002; Raghavan, 2003). Herder's livestock along with guard dogs and habitat degradation may impact the low abundance of wild ungulates (Bhattacharya & Sathyakumar, 2011).

The genesis of this study is rooted in significant research findings regarding the interaction between livestock and wild herbivores, particularly focusing on Ibex. Previous studies have shed light on various aspects of this interaction. Bhatnagar (1997) and Manjrekar (1997) highlighted the potential role of migratory livestock as carriers of diseases that can impact Ibex populations. In contrast, Bhatnagar *et al*., (2000) found that resident livestock did not interfere significantly with Ibex resource selection, suggesting a lack of direct competition for resources between resident livestock and Ibex.

Moreover, Mishra *et al*., (2001) revealed a negative relationship between livestock stocking density and fecundity, indicating that high livestock stocking density resulted in reduced reproductive capacity among wild herbivores. Another study by Mishra *et al*., (2004) explored the impact of livestock grazing and diet overlap on Bharal populations, demonstrating how livestock grazing led to resource limitation and subsequent decline in Bharal density.

Furthermore, Bagchi *et al*., (2004) discovered that migratory Goat and Sheep had a greater impact on Ibex populations by imposing resource limitations and spatially excluding Ibex, while local livestock did not exhibit the same effect. These findings highlight the differential threats posed by migratory versus local livestock on Ibex and the consequent resource limitations faced by this species. Additionally, Ghoshal *et al*., (2017) examined the impact of grazing on forage biomass, underscoring the ecological consequences of livestock grazing on the availability of essential forage resources. The social dynamics affecting stocking density and herding behavior as well as the ecological effects of livestock grazing on wildlife conservation are topics that are little understood but are hotly contested (Saberwal, 1996, 1998; Mishra & Rawat, 1998). Considering these significant research findings, this study aims to delve further into the intricate dynamics between livestock and wild herbivores, with a specific focus on Ibex. The study seeks to investigate the spatial and resource interactions between migratory and local livestock and Ibex. Through this comprehensive examination, the study intends to provide valuable insights into the complex relationship between livestock contributing to a broader understanding of livestock wildlife interactions within the research area.

Considering the aforementioned concerns, the current study aimed to assess the biological diversity of the national park by quantifying the dependence of local communities on the park and raising awareness among them. The study also focused on the recommendations put forth by Manjrekar (1997) and Bhatnagar (1997), particularly regarding the impact of migratory livestock grazing and the historical extraction of fuelwood by the local residents in the PVNP.

Himalayan Ibex is a crucial prey species for the flagship Snow leopard in high altitude Himalayas. Previous studies have highlighted the issues of livestock grazing and its impact on Ibex habitats. This study specifically examines the impact of migratory livestock grazing and community resource use patterns to better comprehend the pressure on Ibex habitats and resource overlap between Goat, Sheep, and Ibex. The study's rationale lies in the imperative to conserve Ibex populations, address habitat fragmentation, manage resource competition, maintain appropriate vegetation composition, and consider socio-economic factors.

In this study, the availability of resources in terms of diet and habitat between livestock-grazed and ungrazed pastures in two adjacent rangelands was compared to evaluate variations in resource availability. The extent of resource (diet) overlap among three species goat sheep and ibex was analyzed. Additionally, the encounter rate of ibex in two rangelands with different livestock grazing history was analysed to determine the spatial use difference and influence of livestock during peak summer and winter seasons. Two predictions were tested: (i) a low encounter rate of ibex in the presence of livestock grazing during peak summer in the historically grazed area, and (ii) a high encounter rate of ibex in the livestock ungrazed area during the same period. Similar tests were conducted in the winter season without livestock in the grazed and ungrazed areas. The research aims to evaluate pastoralism practices and resource utilization patterns in Pin Valley National Park.

Nomadic pastoralism has been a traditional subsistence strategy closely linked to settled societies. The transition from nomadism to sedentarization is influenced by factors such as ecological events, economic prospects, urban development, and governmental measures (Bradley, 2012). Modern pastoralist societies in East Africa (Kenya, Tanzania, Uganda) encounter significant challenges, such as population growth, land loss to farmers, ranchers, and game parks, urbanization, increased commercialization of livestock, out-migration of impoverished pastoralists, and displacement due to droughts, famines, and conflicts (Fratkin, 2008).

Grazing management practices, like stocking numbers and systems, substantially influence plant variety and abundance, impacting grassland community stability and ecosystem functioning (Hickman *et al.,* 2004).

Grazing practices have a positive impact on grasslands dominated by tall grasses, as they help control the dominance of certain plant species, thus promoting diversification (Kooijman & de Haan, 1995). However, the unregulated grazing of livestock can lead to overgrazing, making it imperative to implement land and livestock management practices based on scientific principles. It is anticipated that the implementation of such policies through various government-sponsored schemes will encourage greater community involvement in grassland management (Roy, 2009).

The Indian trans-Himalayan region is characterized by sparse vegetation cover, low primary productivity, and a short growing season. Despite high livestock densities, these rangelands support diverse populations of wild ungulates and other faunal groups (Rawat *et al*., 2015). The vegetation composition of trans-Himalayan rangelands is influenced by various factors, including topography, altitude, pastoral and agropastoral practices. Understanding the diversity and richness of plant communities across various landforms is essential. (Rawat & Adhikari, 2015).

Other challenges to the Ibex population in PVNP include migratory livestock and the consumption of natural resources (fuel, fodder, etc.) by the local agropastoral community (Bhatnagar, 1996).

In the Spiti landscape of the trans-Himalayan region, socioeconomic and ecological changes have resulted in a reduction in livestock numbers, which may benefit wildlife conservation efforts (Singh *et al*., 2015). The alpine zone of the greater Himalayas, with its higher seasonal primary productivity, contrasts with the cold arid trans-Himalayan pasture, which experiences relatively low primary productivity. As a result, the impacts of livestock grazing in these zones are expected to differ based on microtopographic features and the history of livestock grazing. To understand these variations better, comprehensive studies are required to explore the connections among vegetation structure, composition, grazing patterns by domestic livestock, and wild herbivores. (Rawat & Adhikari, 2005). Anthropogenic pressures, including livestock grazing and tree lopping for fuelwood, affect the pasture landscape areas along the routes of transhumant pastoralists. It is essential to document these routes and evaluate the effects of anthropogenic disturbances (Mitra *et al*., 2013).

Socioeconomic changes have probably led to extensive overstocking, even within wildlife reserves. To address this, conservation managers should prioritize establishing grazing-free areas and effectively managing livestock densities (Mishra *et al.,* 2001). The transition in agropastoral lifestyles, socioeconomic factors, uncontrolled tourism in wildlife reserves, and changes in land use by local communities can result in complex conservation problems (Mishra, 2000). The utilization of resources by the local residents in PVNP, including fuelwood, fodder, and uprooting and collection of shrubs and herbs, along with intensive livestock grazing by both local and migratory herders, may be exceeding sustainable limits (Bhatnagar, 1996).

There is limited scientific evidence to support the notion that heavy grazing by migratory herders has no effect on rangelands. On the contrary, it can increase species richness and plant diversity. However, human land use for subsistence purposes leads to degradation and is incompatible with maintaining high levels of biological diversity (Saberwal, 1996). In the trans-Himalayan region of Spiti Valley in Himachal Pradesh, livestock compete with Bharal for forage, resulting in a decline in graminoid availability during winter (Suryawanshi *et al*., 2010). There is a significant overlap in the diet of Bharal and trans-Himalayan livestock, leading to competition, particularly at high livestock densities (Mishra *et al*., 2004). The niche of Blue sheep varies across areas with different numbers of sympatric species, suggesting that biotic interactions play a role in the distribution of mountain ungulates (Namgail *et al*., 2009). Wild ungulate populations are facing declines primarily due to livestock grazing and the resulting habitat degradation (Kittur *et al*., 2010). Null model analysis suggests that competitive interactions have influenced the structure of the trans-Himalayan wild herbivore assemblage (Mishra *et al*., 2002). In Ladakh, the population of goats and sheep may increase due to rising demand for pashmina. However, in the future, this population may decrease as more individuals adopt vegetarian diets due to religious campaigns. Such changes in livestock holding patterns can affect rangeland resources and ecosystems (Namgail *et al*., 2007). The overuse of food resources by livestock during the summer and habitat damage brought on by anthropogenic pressures may have a negative effect on the populations of wild mountain ungulates. (Bhattacharya *et al*., 2011).

In Pin Valley, migratory livestock grazing has resulted in rangeland degradation and resource limitations for wild ungulates, such as the Ibex. Currently, resident livestock do not significantly limit Ibex resources. However, changing agropastoral practices in the region could pose future conservation concerns (Bagchi *et al.,* 2004).

Migratory livestock have the potential to carry diseases that could affect Ibex (Bhatnagar, 1997; Manjrekar, 1997). Resident livestock, on the other hand, were observed not to interfere with Ibex in terms of resource selection (Bhatnagar *et al*., 2000). Additionally, the fecundity of certain wild herbivores showed a negative correlation with high livestock stocking density, and overstocking led to a reduction in their population, as reported by (Mishra *et al*., 2001). Furthermore, livestock grazing and high diet overlap with Bharal caused resource limitation, resulting in a decrease in the Bharal density (Mishra *et al*., 2004). Migratory Goat and Sheep were found to impose resource limitation and spatially exclude Ibex, whereas local livestock did not have a significant impact on Ibex, as stated by (Bagchi *et al*., 2004). Finally, the grazing activities had an impact on forage biomass, as highlighted in Ghoshal *et al*.'s work in 2017.

1.2 Justification of the study

The justification for this study stems from the pivotal role of the Himalayan Ibex as a prey species for the flagship species, the Snow leopard. Previous research has already highlighted the detrimental effects of livestock grazing on Ibex habitats. However, to further our understanding of the pressures facing Ibex populations, this study focuses specifically on the impacts of migratory livestock grazing and resource utilization patterns within the local community. By delving into these aspects, we aim to gain insights into the challenges posed to Ibex habitats and the extent of resource overlap between Goat, Sheep, and Ibex.

The rationale behind investigating pastoral and agropastoral practices lies in its multifaceted nature. Through this investigation, the study seeks to contribute significantly to the conservation of Ibex populations, address concerns related to habitat fragmentation, alleviate resource competition, promote a favourable vegetation composition, and consider socio-economic factors associated with pastoral and agropastoral practices. By delving into these dimensions, we aim to provide valuable information and recommendations that can guide effective conservation measures to safeguard the Himalayan Ibex and its vital ecological role in sustaining the Snow leopard population.

1.3 Objectives and research questions

1. To study the changing aspects of local and migratory herders in Pin Valley,
2. To study grazing patterns of livestock and wild ungulate (Ibex) in Pin Valley, and
3. To document the natural resource dependency of local agro-pastoral community in Pin Valley.

Questions

1. What are the past and present livestock herding patterns of local and migratory herders in Pin Valley?
2. What are the patterns of grazing, habitat use and feeding habits of the wild ungulate (Ibex) and domestic livestock in Pin Valley?
3. What is the consumption pattern of natural resources (fuel, fodder and medicinal plants) by the local agropastoral community in Pin Valley?

1.4 Thesis organization

Thesis is organised in to six chapters each addressing different objectives as follow:

Chapter 1: Understanding Pastoralism and its Recent Trends in Pin Valley National Park:

This chapter provides a comprehensive exploration of pastoralism, focusing on its recent trends and changes comparison with past within the context of Pin Valley National Park

Chapter 2: Understanding Natural Resource Use by the Spiti Bhot Community in Pin Valley National Park:

Here, the emphasis is on gaining insights into the utilization of natural resources by the Spiti Bhot community residing in Pin Valley National Park;

Chapter 3: Understanding Resource Availability with Respect to Ibex (Capra sibirica) and Its Habitats:

This chapter delves into the study of resource availability specifically concerning the ibex species and its habitats;

Chapter 4: Understanding Interactions and Resource Use between Wild (Ibex) and Domestic Ungulates:

Examining the interactions and resource utilization patterns between wild ibex and domestic ungulates constitutes the core of this chapter;

Chapter 5: Conclusion and Management Implications:

The final chapter encompasses a conclusion drawn from the findings and presents management implications concerning the conservation threats faced by the study area.

Each chapter dedicates attention to the specific objectives and results through the presentation of distinct methodologies, study areas, and statistical analyses. The thesis primarily serves as a documentation of various aspects of ibex ecology, shedding light on human anthropogenic pressures imposed on its habitats.

1.5 Study area

1.5.1 Location and topography description

The Pin Valley National Park is present in the South-East of the Lahaul-Spiti district, Himachal Pradesh (Lat: 31°6'40'' to 32°2'20''N and Lon: 77°41'21'' to 78°6'19''E; Figure 1). The park received official notification from the Government of Himachal Pradesh in January 1987 (Singh & Gupta, 1990; Pandey, 1991). Located in the rain shadow of the Pir Panjal range, Pin Valley falls under the trans-Himalayan zone-1 (Biotic province-B) according to the bio-geographic classification by Rodgers & Panwar (1988). This region is characterized by extreme cold, semi-arid to arid conditions, low plant productivity, and a relatively short plant growth season lasting approximately four months, from May to August. The park encompasses a core area of approximately 675 km², including most of the Pin-Parahio catchments, while the buffer zone spans around 1150 km² encompassing most of the Pin catchments. The buffer zone extends east of the national park until the Spiti river. The major areas of the national park lie in the Parahio catchment, and the drainage system consists of six rivulets, namely Khaminger, Debsa, Killung, Gocho, and Kidul Chhu, all fed by glaciers.

The lowest point in the national park, at approximately 3600 m, is near the confluence of Kidul Chhu and Parahio rivers, while the highest point is Shigri peak in the North, standing at 6632 m (Bhatnagar, 1997). The region is characterized by high mountain ranges and narrow river valleys, with flat land being uncommon. It exhibits the typical traits of a mountain desert, with massive glaciers covering a significant portion of the park, but no major lakes. Precipitation primarily occurs in the form of snowfall. The general topography is rugged, featuring high-altitude barren areas and an arid climate. However, the valleys of the park are highly disturbed due to extensive grazing activities. The PVNP represents a typical cold desert ecosystem.

1.5.2 Climate

In the span of a year, the temperature in the area exhibits significant variations, with a maximum of approximately 33°C during summer and a minimum of around -40°C in winter (Bhatnagar, 1997; Manjrekar, 1997). The daily minimum temperature remains below freezing for over half of the year, from October to May, and even the daily maximum temperature drops below zero during January and February (Bhatnagar, 1997). These extreme temperature fluctuations result in distinct seasonality.

Pin Valley experiences severe winters, characterized by heavy snowfall from November/December to March/April. The annual snow precipitation was typically around 300 cm (Bhatnagar, 1997; Manjrekar, 1997). However, at present snowfall has drastically decreased. Spring brings patchy snow melt and sprouting between April and May. The peak vegetation pulse aligns with the peak of summer, spanning from July to mid-September. With the onset of autumn, there is a gradual decline in daily temperatures. Dry conditions and the senescence of most plants persist until snowfall occurs in December/January.

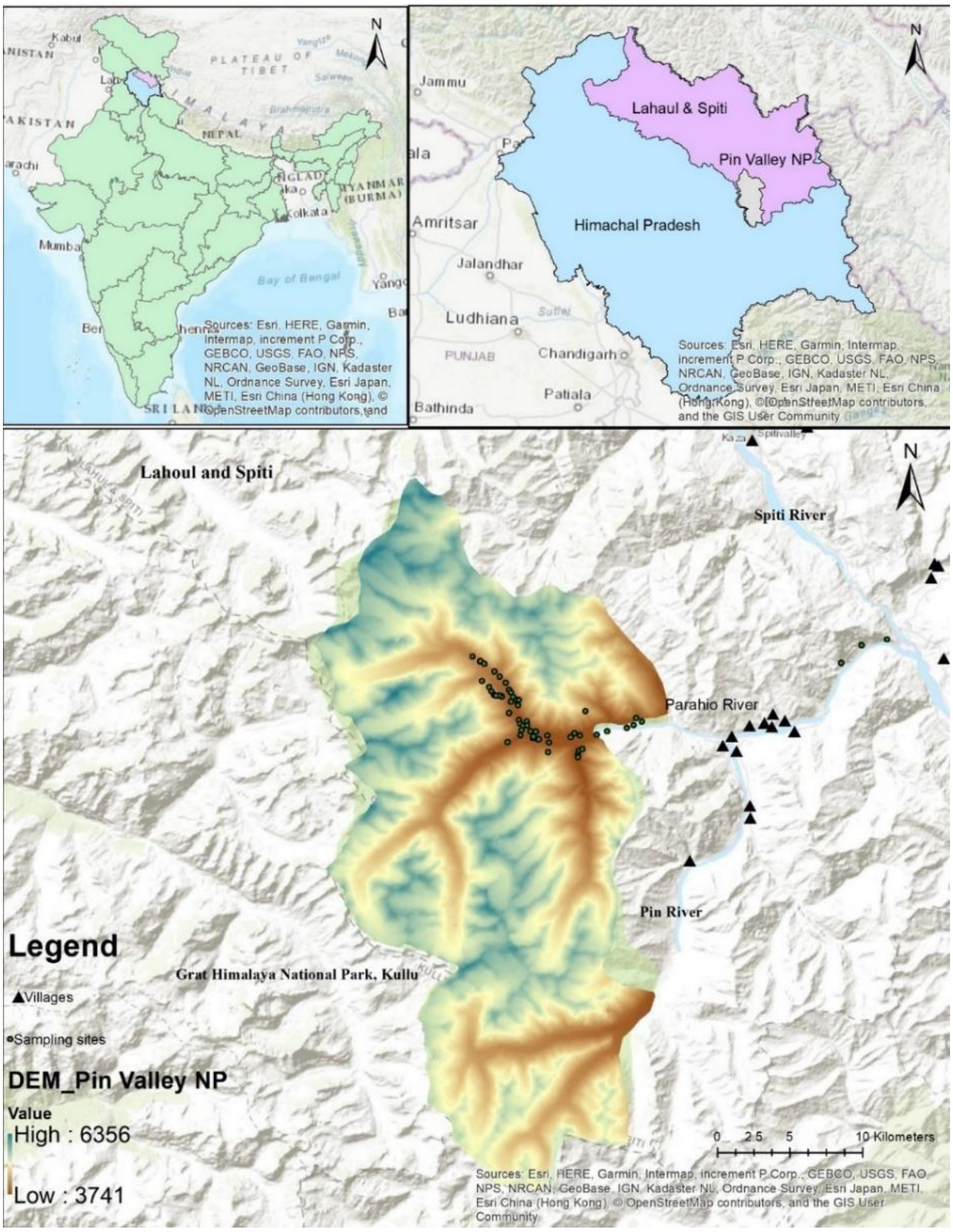

Figure 1.1: Study area map Pin Valley National Park, Himachal Pradesh.

1.5.2 Climate

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1.5.3 Flora and fauna

The terrain and climate are not conducive to the growth of forests. According to Champion and Seth's classification (1968), the vegetation falls under Dry Alpine Scrub and Dwarf Juniper species. Important shrubs include *Rosa webbiana* and *Lonicera spinosa*. Previous classifications by Puri *et al*., (1989) labelled the region as "Dry Alpine Steppe," while Schweinfurth (1957) categorized it as "*Artemisia* Steppe and Meadows." The area features sporadic patches of trees, such as *Juniperus* spp., *Salix* spp., and *Betula utilise*, which are now mostly limited to remote locations or religiously protected areas. Additionally, sparse scrub, meadows, and grasslands can be found. Prominent shrubs include *Rosa webbiana*, *Lonicera spinosa*, *Caragana versicolor*, *Ephedra gerardiana,* and *Artemisia* spp. Noteworthy herbs consist of *Lindelofia* spp., *Cicer microphyllum* and *Cousinia thomsonii*, while *Festuca* spp., *Oryzopsis* spp. and *Poa* spp. dominate the prominent grasses. Rare tree and shrubs like *Juniperus* spp., *Rose s*pp., and *Ribes orientale* grow on cliffs and steep, rocky slopes. In the valley bottoms and near river bed, patches of *Salix spp., Myricaria spp., and Hippophae spp. are dominant*.

The flora of PVNP included 53 families, 196 genera, and 378 distinct species (Manjrekar, 1997). The majority of the plants in this region are classified under threatened categories. Despite their vulnerable status, many of these plants possess valuable medicinal properties and are actively utilized in the traditional healthcare system by local *Amchies* (Targe *et al*., 2022).

When it comes to fauna, the region exhibits a relatively lower diversity of large mammals compared to other trans-Himalayan areas. Within the national park, one can find a limited number of large wild mammal species, which include the Himalayan ibex (*Capra sibirica*), Snow leopard (*Panthera oncia*), Himalayan brown bear (*Ursus arctos isabellinus*), Tibetan wolves (*Canis lupus chanco*), and Red fox (*Vulpes vulpes*). Smaller carnivores such as the stone marten (*Martes foina*), Himalayan weasel (*Mustela sibirica*), and pale weasel (*Mustela altaica*), along with various rodents and the mouse hare (*Ochotona* spp.), also inhabit the area, as documented by Bhatnagar (1993).

In terms of avifauna, the study area has recorded around 60 bird species, including the golden eagle (*Aquila chrysaetos*), lammergeier (*Gypaetus barbatus*), Himalayan griffon (*Gyps himalayensis*), Himalayan snow cock (*Tetraogallus himalayensis*), and chukar partridge (*Alectoris chukar*) (Bhatnagar, 1997; Manjrekar, 1997).

1.5.4 Elevation

The elevation ranges from 3,741m to 6,356 m asl. (Figure). The highest elevation ranges that contributed to the study area were 4828-5178m and 5178-5517m (28% each) of the total area. The lowest contributing range was between 3741m and 4408m (11%) (Figure 1.2). According to Bhatnagar's findings in (1997), the lower slopes are relatively gentle, sloping at approximately 30° to 35° and often featuring a lower steep bank, which is an old moraine leading to the valley bottom. On the other hand, the middle to higher slopes is characterized by a rugged terrain with a steeper gradient, exceeding 40°, and frequent rocky projections.

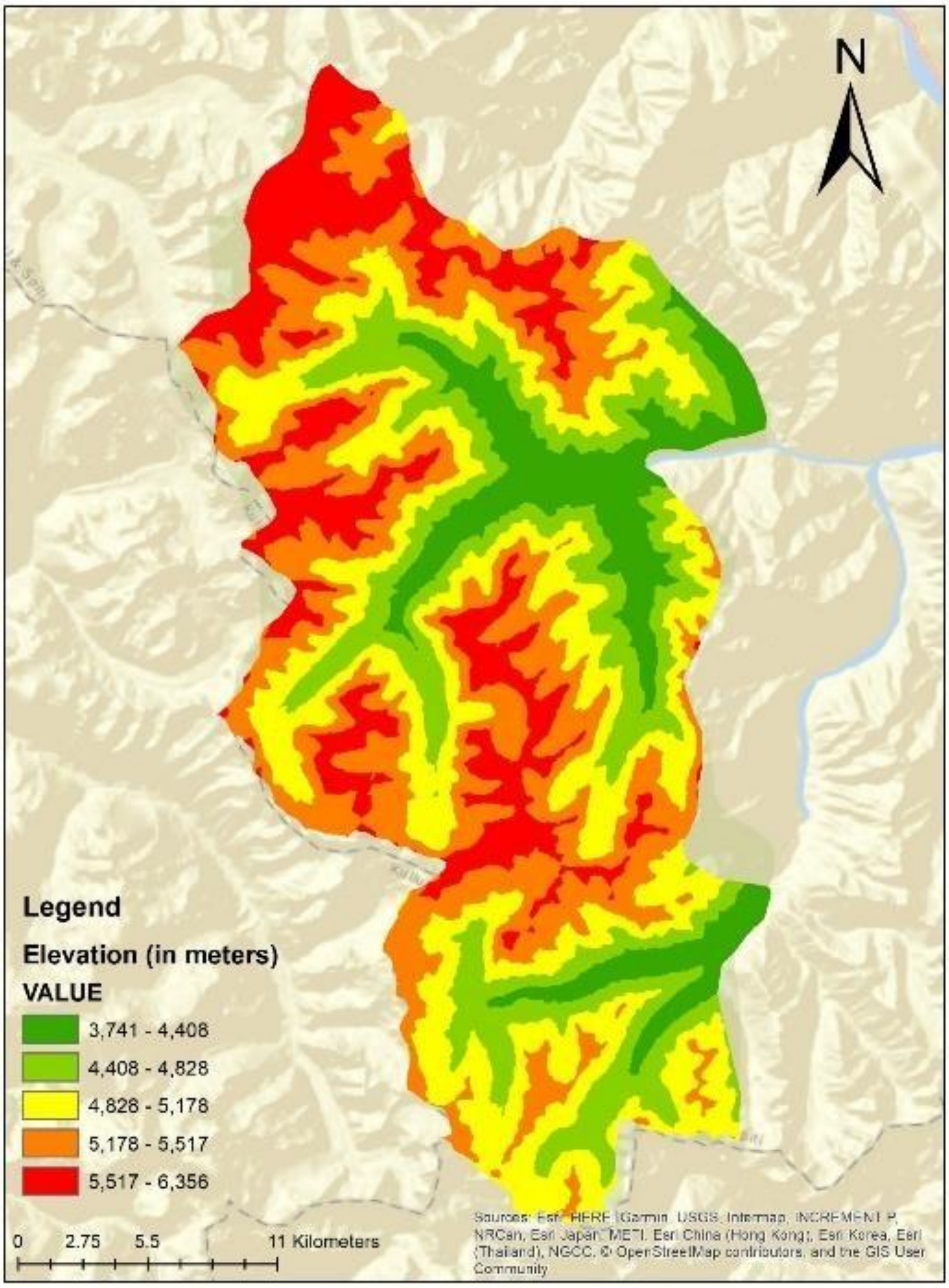


Fig 1.2: Map showing altitudinal range in PVNP.

1.5.5 Aspect

The aspect of study area was classified into ten categories (Figure1.3). The maximum aspect area covered by the aspect categories was the east and southeast area, which contributed (25%) of the overall research area. The smallest aspect area covered by the aspect categories was north which contributed (6% each) to the total aspect area (Figure 3).

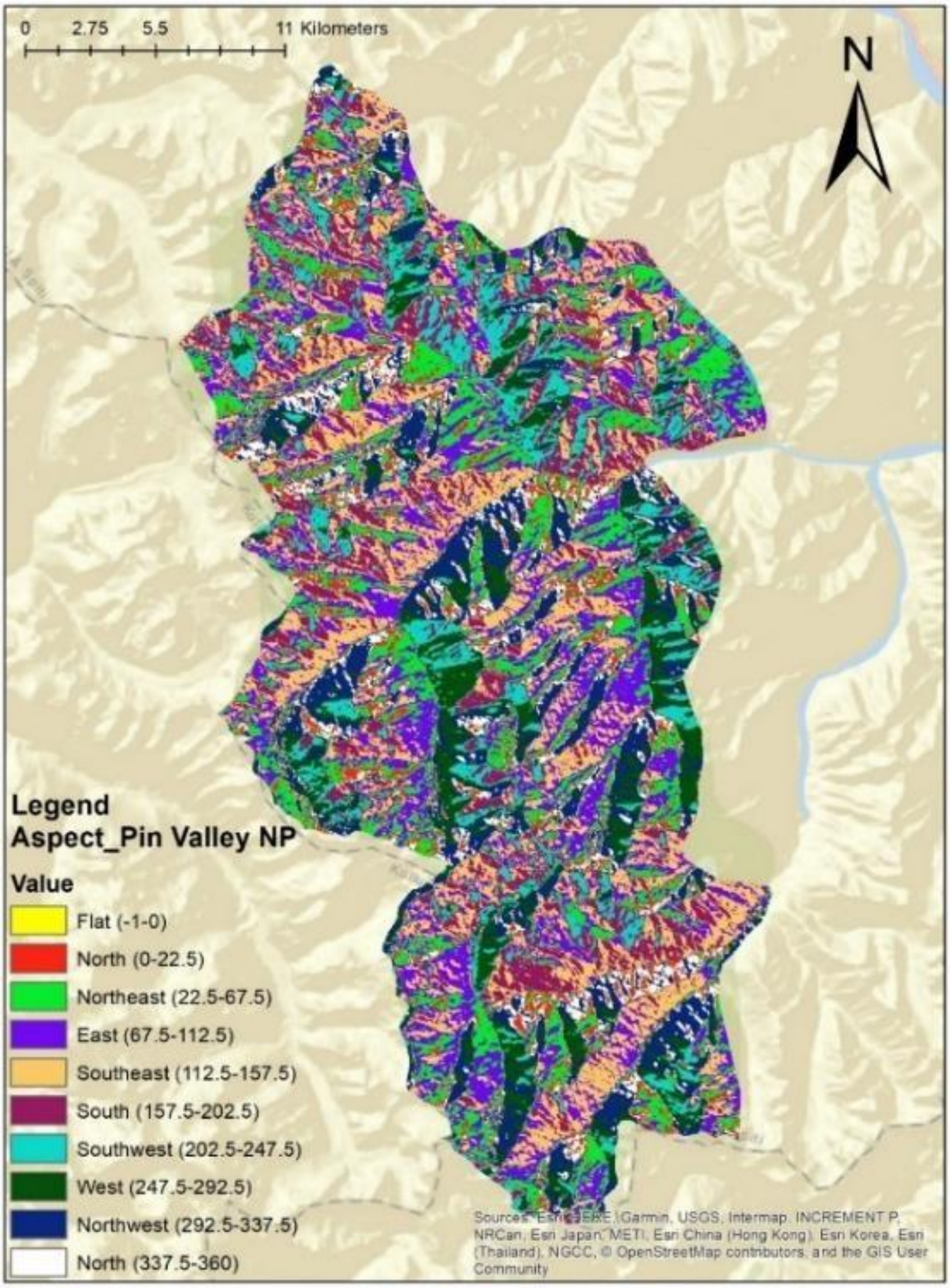


Fig 1.3: Map showing different aspects of PVNP.

1.5.6 Slope

Slope of the study area was classified into three categories i.e., low (0-20), medium (20-45) and high (45-75) (Figure). Area availability under different slope classes was maximum under medium slope (59%), followed by low slope (35%) and high slope (6%) (Figure 1.4).

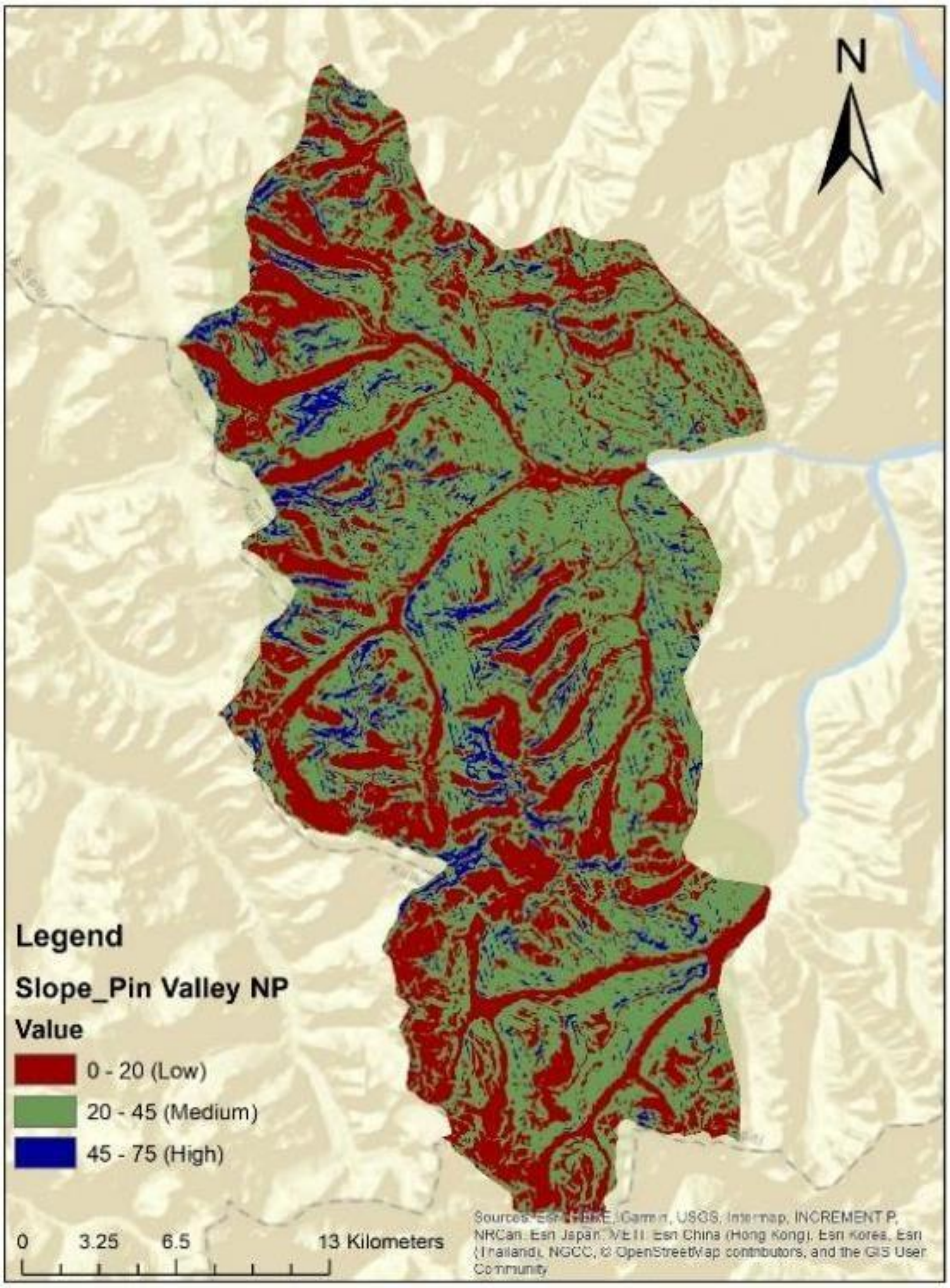


Fig 1.4: Map showing different slope categories in PVNP.

1.5.7 Local inhabitants and their dependency on Pin Valley National Park

The people living in and around the PVNP are sparsely populated and predominantly agropastoral Buddhist community. They mostly rely on the buffer zone of the NP for agriculture and other natural resources for their livelihood. They graze their livestock in the park, collect medicinal plants and herbs, and use the wood and other forest products for fuel and other agriculture purposes. In addition, the park is also an important source of water for irrigation and domestic use. However, the dependence of the local communities on the park's resources has led to overexploitation and depletion of some of these resources (Bhatnagar, 1996; Mishra *et al*., 2003; Bhagchi *et al*., 2007).

The region is renowned for its distinctive culture, a beautiful amalgamation of Indian and Tibetan traditions. The local inhabitants are known for their warm hospitality and friendliness towards visitors. Their traditional homes, constructed from stone and mud, exemplify their unique way of life. On special occasions, the locals don traditional attire, reflecting their rich cultural heritage.

In recent times, tourism has become a flourishing source of income for the residents living near the PVNP. The allure of Pin Valley lies in its appeal to trekkers, mountaineers, and nature enthusiasts who seek to immerse themselves in the breath-taking natural beauty of the area.

A notable attraction within the region is the Kungri Monastery, a significant Buddhist establishment. Founded by H. E. Yomed Tulku Rinpochhe, the monastery has become a popular destination for tourists. The presence of the monastery has fostered a deeper sense of spirituality among the locals, leading to a commitment to nonviolence and peace. As a result, wildlife conservation efforts have thrived, with no hunting reports in the area for millennia.

The people take great pride in sharing their cherished traditions with visitors who come to explore the region, making the experience all the more enriching and memorable.

Pin Valley comprises a total of 13 villages, excluding summer settlements (dogries), which are divided into two panchayats: Sagnam and Kungri panchayat. The Sagnam panchayat encompasses five villages, namely Mudh, Teling, Todnam, Khar, and Sagnam. Among these villages, only Sagnam, consisting of approximately 75 households on the ground, but recorded as 138 families in Panchayat records (Goshwara, 2021), relies entirely on the National Park for essential resources such as fuel, fodder, pastures, and farming needs.

On the other hand, the Kungri panchayat includes eight villages: Mikkim, Kungri, Chud, Gulling, Bhar, Seling, Tangti Yogma, and Tangti Gogma. Out of these, six villages have a partial dependence on the national park for resources, whereas Tangti Yogma and Tangti Gogma villages are exceptions, as they do not rely on the park for their needs.

The villages in the area are home to a total population of approximately 1315 individuals, residing in 318 households (Table 1). Among these villages, 28 families have summer settlement rights within the core area, historically granted. Interestingly, out of these families, three belong to the Kungri panchayat, while the rest are from Sagnam village under the gram panchayat Sagnam. During the onset of the cultivation season until its conclusion, these families reside in the dogries within the area.

The people of Sagnam village hold traditional rights over the National Park and engage in practices like agriculture, livestock grazing and gathering fodder and fuel from the park area. The other partially dependent villages have limited rights over a smaller section of the park, particularly in the vicinity of the kidul Chhu watershed, which is located at the intersection of the core and buffer area (as shown in the Figure). Only this designated area allows them to collect essential resources, but their free-ranging livestock continue to graze within the park throughout the year. The local residents take care of various animals, including yaks, cows, yak-cow hybrids (known as dzo for males and dzomo for females), horses, and donkeys. The free-ranging animals are allowed to graze from May until the onset of heavy snowfall in winter. In contrast, livestock such as milch animals, juvenile animals, goats and sheep are kept within their villages for daily rotational grazing.

Currently, there are only 12 to 13 families within the national park who remain engaged in agriculture, while the majority of others have abandoned cultivation.

Table 1.1: Demographic data showing population status of past and present in Pin Valley NP.

Villages		**Population (2021)**	**Population (1991)**	**Household (2021)**	**Household (1994)**
Strata-1	Sagnam	505	172	138	65
Strata-2	Fukchung	64	24	17	5
	Mikkim	32	25	8	5
	Kungri	232	45	54	23
	Uppar gulling	73	28	17	9
	Gulling	137	65	31	23
	Bhar	202	62	40	25
	Seling	70	18	13	4
Total Strata-1		505	172	138	65
Total Strata-2		810	267	180	94
Grand Total		**1315**	**439**	**318**	**159**

1.5.8 Migratory herders and their dependency on Pin Valley National Park

The migratory herders from the Shimla and Kinnaur districts in Himachal Pradesh, India, have a long history of practicing nomadic pastoralism in the Himalayan region, including the PVNP. They hold traditional grazing rights over the pastures within the park and follow a seasonal pattern of movement with their herds of sheep and goats, seeking suitable grazing lands and water sources. Their livelihoods heavily rely on the resources provided by the park, especially during the summer season (June to September), when vegetation growth is at its peak, ensuring sustenance for their livestock.

Around mid-June, six distinct groups of migratory herders, originating from Shimla and Kinnaur districts, embark on a journey to the region, covering distances of over 200 km. In total, they bring with them more than 7000 sheep and goats, along with 30-35 ponies and 25-30 shepherd dogs. Upon reaching the park, these groups disperse into the upper catchments of Killung, Debsa, Chhoham, and Khaminger, where they reside until mid-September. The herders have been practicing this tradition for generations, as it enables them to escape the heavy monsoon in their native regions and take advantage of the more nutritious forage available in the PVNP. Over time, local sources have observed a significant increase in their sheep and goat population.

Their sustainable use of the park's resources can help to promote conservation and ensure the long-term viability of the park and the communities that depend on it.

1.5.9 Intensive study area

An intensive study covered a total area of 118 km². Out of this, migratory herders occupied/grazed an area of 95.15 km² (81%) during summer, while un-grazed areas where migratory livestock was absent covered an area of (18%). The agricultural area was spread over 0.55 km² representing (1%) of the total area (Table). Six migratory herder groups used the area during the summer season. They graze their livestock in the area for about 2-3 months. The intensive study area was carried out within the core zone area (Figure 5). The core area encloses the watershed of the Barachhu as mentioned Parahio in the earlier studies (Bhatnagar, 1997; Manjrekar, 1997; Bagchi *et al*., 2004).

The Barachhu catchment originated from Barashigri glacier and its other sources are Ganla darvo I and Gangla darvo II glaciers. Other tributary streams are Debsa nala, Kilung nala, Gochok nala, Rajgaon nala and kidul Chhu nala which further meet pin river near Sagnam Mikkim and khar village.

However, the majority of the Pin River flows through the buffer zone, originating from the Pin Parvati glacier, and is fed by numerous tributaries, including Darbak Nala, Ensa Nala, Takshan Nala, and Sagnam Nala. From Sagnam, both the Barachhu and Pin rivers merge to form the Pin River, which is further nourished by other tributaries such as Gulling Nala, Tangti Nala, Chhidang Nala, and Kyidokpu. The Pin River eventually meets the Spiti River near Shushuna, and the Spiti River then joins the Satluj River near Khab in the Kinnaur district of Himachal Pradesh.

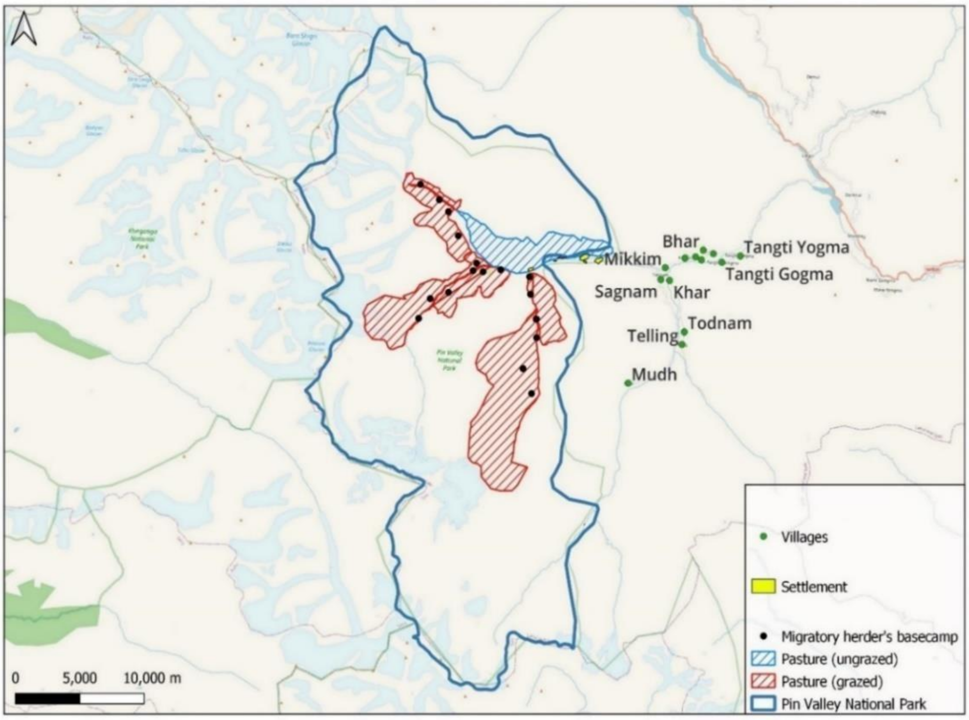


Fig 1.5: Intensive study area showing migratory livestock grazed (shaded red colour) and ungrazed (blue shaded) areas inside the Pin Valley National Park.

Table 1.2: A detailed area covered under summer settlements and migratory herders' pasturelands in PVNP.

Settlements	Area (km²)	Migratory herders Grazed pastures	Area (km²)
Thango	0.08	Changlung pasture	9
Gochok	0.04	Sumna pasture	45
Gyachang	0.22	Nur pasture	10
Settelment	0.18	Debsa I, II & Khamedngar pasture	19
Settelment	0.03	Tsoham pasture	13
Settlement	0.01	Ungrazed pastures	22
Total settlement area	**0.55**	**Total pastureland area**	118

1.6 Study design

The study was carried out both in the buffer and core areas. objective 1 and objective 2 was based on the social aspects therefore majority of survey was carried out in the buffer areas. Whereas, objective 3 and objective 4 purely based on the ecological aspects so the intensive study was carried out within the interested core area of the national park. The study design adopted for the different objectives were explained as below:

The study was conducted in both the buffer and core areas of the national park. Chapter 1 and 2 focused on social aspects, and thus, a majority of the survey work was conducted in the buffer areas. On the other hand, chapter 3 and 4 were centred around ecological aspects, leading to an intensive study conducted within the core area of the national park. The overall objectives of the study revolved around understanding how agropastoral and pastoral practices influence the Ibex and its habits. The study design for each chapter is explained as follows:

Chapter 1: Understanding Pastoralism and its Recent Trends in Pin Valley National Park

1. Initially, a reconnaissance survey was carried out to establish the study design. It was discovered that the entire Pin Valley comprised only two-gram panchayats: (1) Sagnam panchayat and (2) Kungri panchayat. Within these panchayats, villages dependent on National Park (NP) for essential resources such as grazing, fodder, fuel, and medicinal plants were identified and categorized into different strata following the approach proposed by Bhatnagar (1996). In total, eight villages were found to be reliant on NP resources. Among them, Sagnam village from the gram panchayat Sagnam was entirely dependent on NP (designated as Strata-1), while the remaining seven villages, namely Mikkim, Kungri, Chud, Gulling, Bhar, Seling, and Fukchung from the gram panchayat Kungri, were partially dependent on NP (stratified as Strata-2). The total

area utilized for resources by both strata was calculated using GIS mapping, as presented in Chapter 3.

2. The Participatory Rural Appraisal (PRA) method was employed to engage with local communities. Data was collected through a semi-structured questionnaire survey that included both open and closed-ended questions. 25% of each village was surveyed.

3. To assess agropastoral practice trends and changes, data were gathered from the same interviewees about the past and present. The "past" data encompassed information before the introduction of green pea cultivation (prior to the year 2000), while the "present" data pertained to the years from 2017 onwards. Secondary data on demography, land use in the region were collected from government office records.

Chapter 2: Understanding Natural Resource Use by the Spiti Bhot Community in Pin Valley National Park

1. The study design for objective two closely resembled that of objective one. To conduct the natural resource dependency survey, a combination of Participatory Rural Appraisal (PRA) and semi-structured questionnaire surveys was employed.

2. Moreover, within the collection sites, quantification was carried out to validate and pinpoint the areas with high resource dependency.

3. Furthermore, all the identified resource-dependent sites were mapped, and their respective areas were calculated.

Chapter 3: Understanding Resource Availability with Respect to Ibex (Capra sibirica) and Its Habitats

1. The study aimed to assess the resource availability for the key species Ibex in a specific area. The areas that were grazed by migratory livestock were identified as "grazed," at some points designated as "Experimental sites (E)." Conversely, the areas free from migratory livestock were labelled as "ungrazed" or "non-grazed," also at some points being referred to as "control sites (C)."

2. To evaluate the vegetation composition within these areas, 1x1 m quadrats were used for sampling. The data collected from these quadrats were then analysed using the TWINSPAN computer program to classify different vegetation patterns. Additionally, the extent of each community's coverage was calculated and mapped using Landsat data in ArcMap.

3. For quantifying the habitat, observations of landform types during vegetation sampling through the quadrat method were considered. Each landform type was categorized based on the total number of quadrats sampled, with the ones having a higher number of samples indicating greater availability.

Overall, the study focused on understanding the impact of grazing by migratory livestock on Ibex habitat and vegetation composition. By categorizing the grazed and ungrazed areas and quantifying the habitat, the research aimed to shed light on resource availability and its implications for the key species in the region.

Chapter 4: Understanding Interactions and Resource Use between Wild (Ibex) and Domestic Ungulates

In Chapter 3 resource availability with respect to Ibex was quantified and now in this chapter the resource used by livestock and ibex studied by the following methods:

1. The study involved extensive efforts, totaling 64 days of fieldwork and covering a trail walk distance of 832 kilometers. To examine the feeding habits of the Ibex, the researchers utilized three methods: Direct observation, Indirect evidence, and Microhistology (based on Manjrekar, 1997; Shreshtha *et al*., 2005).

2. For evaluating the forage quality consumed by the Ibex, the contents of nutrients such as Nitrogen (N), Phosphorus (P), Potassium (K), and Ash in their pellets were analyzed.

3. Habitat parameters observed during vegetation and feeding habits sampling.

4. The analysis primarily employed a resource selection function, utilizing the Adehabitat HS Package in R version 4.2.2 (2022) to study habitat and vegetation community use.

5. To understand the trophic niche overlap among different species, the Pianka's index employed. Niche width was assessed using Levin's index, and selectivity was measured using Ivlev's index. The statistical analysis involved using R version 4.2.2 (2022) and r studio (2022) along with packages spaa and electivity.

6. To determine the spatial distribution of Ibex, Kernel density estimation was utilized, distinguishing between summer and winter space utilization patterns in grazed and ungrazed areas.

7. Finally, to assess the Ibex area usage in grazed and ungrazed areas, encounter rates were measured.

Image1.1: Study area landscape view during winter season.

Image 1.2: Study area landscape view during summer season.

Chapter 2

Understanding pastoralism and its recent trends in Pin Valley National Park

2.1 Introduction

The Trans-Himalayan region, covering a vast expanse of approximately 2.6 million km², is crucial for both traditional livestock grazing practices and the conservation of various wildlife species, including the elusive snow leopard, ibex, and others. However, the coexistence of livestock and wildlife has sparked debates about their potential ecological impacts, necessitating a comprehensive study to address the complexities of this unique rangeland system.

The Trans-Himalayan region of the Indian sub-continent presents unique biophysical challenges, particularly in terms of agriculture due to its cold desert areas with limited arable land and rangelands. Traditional pastoral production systems, including nomadic, transhumant, and agropastoral practices, have sustained for thousands of years in this vast expanse (Handa, 1994; Bhasin, 2011).

Recent research has shown that socioeconomic changes in various parts of the Trans-Himalayan region have had significant impacts on local societies, land use practices, and ecological dynamics (Mishra, 2000; Mishra *et al*., 2003; Namgail *et al*., 2007). These changes have been associated with improved road connectivity and have been observed in other high-altitude regions across southern and central Asia, leading to transformations in livelihoods, land use practices, and livestock management (Ptackova, 2011; Aryal *et al*., 2014).

Of particular interest is the impact of these socioeconomic changes on livestock populations, which has become a subject of debate and concern. Some argue that the surge in livestock numbers and subsequent overgrazing have contributed to the degradation and desertification of high-altitude rangelands across the Trans-Himalayan region, affecting wildlife and wild herbivore populations (Harris, 2010; Weber & Horst, 2011; Singh *et al*., 2013; Singh *et al*., 2015). These changes have also raised concerns about potential human-wildlife conflicts arising from livestock depredation by endangered species such as snow leopards and wolves (Mishra, 1997; Namgail *et al*., 2007).

The Spiti region in the Trans-Himalaya has experienced various socioeconomic changes, particularly with the adoption of agricultural innovations, which have led to increased livestock populations and potential consequences for rangelands and wildlife conservation (Mishra *et al*., 2003; Bagchi *et al*., 2004).

This study aims to investigate the present status of agropastoral practices and their recent trends in the Trans-Himalayan region. The specific objectives include understanding patterns in livestock management and exploring the connections between traditional agriculture, social transitions, and ecological changes. The research will contribute to a better understanding of the impact of socioeconomic shifts on pastoral communities and wildlife conservation efforts in this ecologically sensitive area.

In conclusion, this research aims to shed light on the intricate relationship between socioeconomic changes, livestock management, and wildlife conservation in the Trans-Himalayan region. Understanding the dynamics of agropastoral transitions and their implications will be essential for sustainable land use practices and wildlife protection in this ecologically significant area.

2.2 Objectives and research questions

i. To study present and past agriculture cropping pattern and causes of changes if any,

ii. To identify and map area of agriculture and human settlement extension over the period of time,

iii. To study livestock composition pattern, changes if any over the period of time and factors affecting the composition pattern.

Questions

i. What is the current cropping pattern in the study area, and how has it changed over time?

ii. What are the main causes or factors that have led to changes in the agriculture cropping pattern over the study period?

iii. What are the key factors driving the extension of agriculture and human settlements in the study area?

iv. How has the composition of livestock in the study area changed over time?

v. What are the main factors influencing changes in the livestock composition pattern?

2.3 Material and methods

2.3.1 Data collection

Primary data were obtained between September, 2017 and December, 2018. A total of ninety-nine household across thirteen villages surveyed following semi-structured interviews to ensuring representation from various strata, age groups, and genders. These interviews comprised a mix of closed and open-ended questions, allowing participants to freely express their views and provide unrestricted responses. Information on past and present agriculture and livestock collected from the same interviewees. In addition, two focused group discussions were organized in the villages that collaborate with migratory herders for pasture rent i.e. Sagnam and Mudh. All the necessary information was gathered during survey and group discussion. The aim of the focused group discussion was to aware people of overstocking, overgrazing and their impact on range land vegetation. Demography data was collected from the Block Development Office (BDO) Kaza. Secondary data was collected through archival records.

For the agriculture and human settlement land use satellite imaginary year 2004 for past and year 2022 for the present was used. The reason behind choosing year 2004 was due to unavailability of clear image for digitization further.

2.3.2 Data analysis

The study utilized descriptive statistical analysis to investigate alterations in agriculture cropping patterns and livestock composition numbers. Moreover, a paired two-sample t-test was applied to determine the significance of discrepancies between past and present agropastoral practices.

To analyze changes in agriculture and settlement land use, historical and current satellite images were digitized through Google Earth Pro. Subsequently, the digitized satellite images were imported into ArcMap 10.3, and the "Calculate Geometry" tool was employed to quantify area changes, facilitating the assessment of agriculture and settlement land use modifications (Figure 2.1).

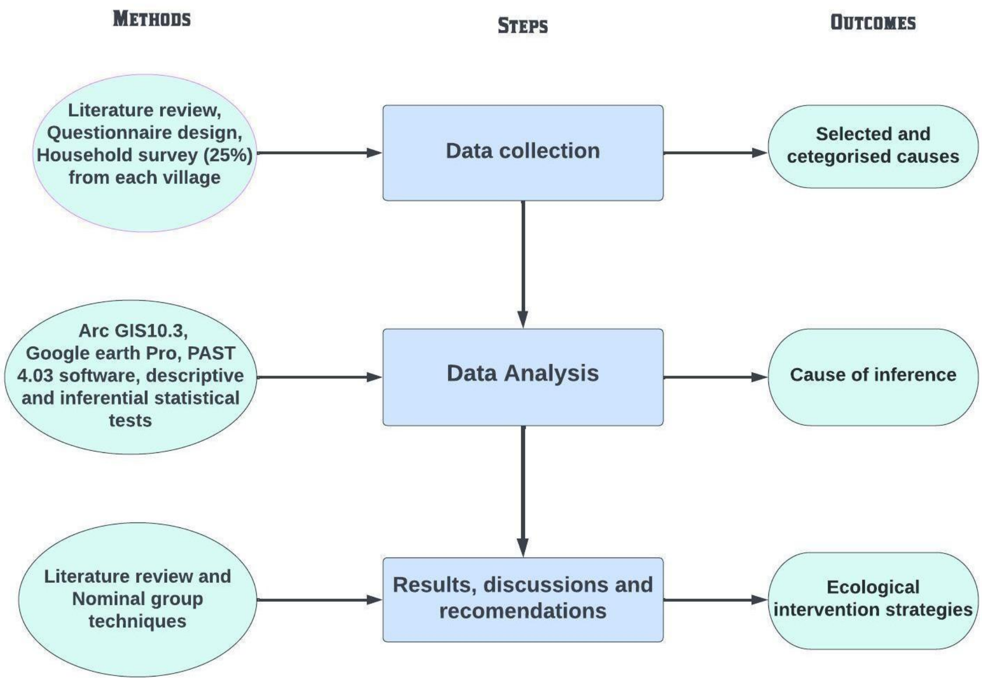


Figure 2.1: A visual roadmap to our research methodology.

2.4 Results

2.4.1 Demographic change

Population change in the two strata of the study area, Strata-1 and Strata-2, was observed over a 30-year period from 1991 to 2021. In 1991, Strata-1 had a total population of 172 individuals residing in 65 households, while Strata-2 had 267 individuals distributed among 94 households. By the year 2021, there was a significant change in population for both strata. Strata-1 experienced a substantial increase, with a population of 493 individuals living in 138 households. Similarly, Strata-2 also witnessed a notable rise in population, reaching 810 individuals residing in 180 households.

These findings indicate significant population growth in both Strata-1 and Strata-2 over the three-decade period, reflecting changes in the demographic landscape of the study area (Figure 2.2).

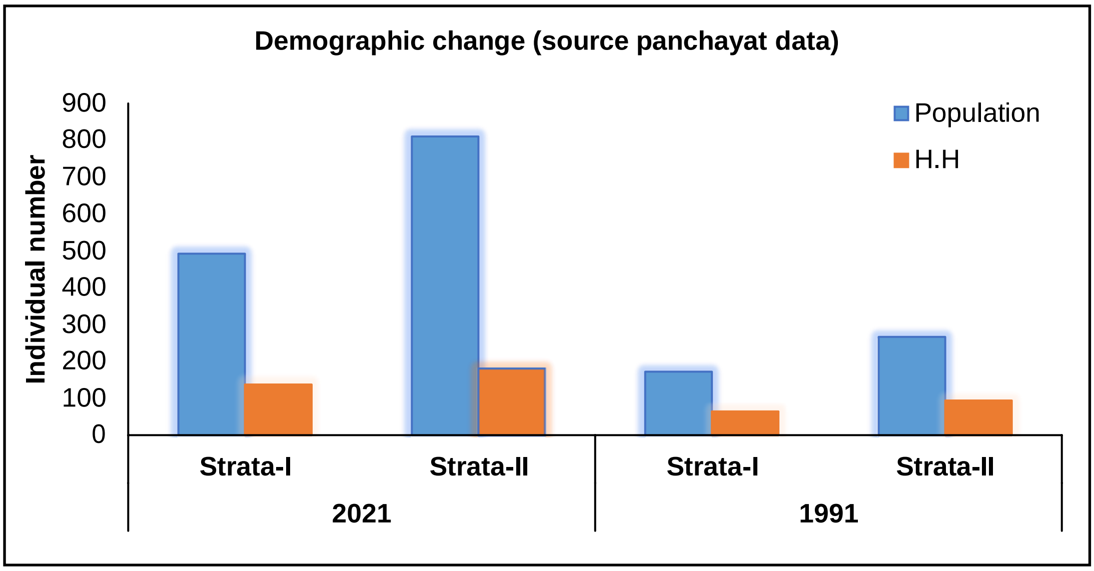


Figure 2.2: Change in demographic structure over the period of time in the PVNP.

2.4.2 Present and Past agriculture cropping pattern

In the past, as many as four varieties of crops were used to cultivate i.e., two types of barley locally called (*nyiu and sowa),* black pea *(tenma nakpo*), potato *(halu),* mustard *(nyuhar)*. Out of all these crops *nyiu* was the most preferred for consumption, used to prepare the local famous food "Sattu." It is a nutritious and versatile ingredient made from roasted barley (*nyivu*) locally called "*nyipe"*. The unroasted form is known as "Jenbe" kind of flour. The process of making sattu involves dry roasting the barley and then grinding it into a fine powder. The sattu is also prepared from two differently used barley (*sowa*) and black pea locally known as "*Sope*". Sattu which is prepared only from *nyiu* is locally called (*nyipe*) and sattu which is prepared from another barley sowa and black pea is known as (*sope*). But, at present only *nyipe* sattu is prepared because black pea and barley *sowa* cultivation are abandoned by the locals. The cropping pattern in Pin Valley varies from the cultivation of historical traditional cereals–Barley, Black pea, Mustard, and Potato to Present cash crops–Green pea and potato with high agroeconomic and low agrobiodiversity.

2.4.2.1 Change in cropping pattern over the specified time

The change in cropping pattern in the past and present shown in the Figure (2.3). People perception revealed that in the past maximum area used out of total agricultural land in all 13 villages cultivation, Barley covers 68.89±0.42%, Black pea 23.15±0.44%, Potato 5.98±0.27% and Mustard 1.98±0.23%.

Whereas, at present green pea covers 92.98±0.52%, Potato 6.06±0.35 and Barley 1.21±0.38% area. Other crops–pulses, and vegetables cultivated by very few people for self-use only which we did not consider for the analysis. At present the highest increase in crop cultivation was noted in commercialized cash crop green pea. Other crops have less cultivation just for the self-requirements.

The paired two-sample t-test revealed a significant difference between the past and present cropping patterns for barley ($p<0.05$), while no significant difference was observed for potato ($p=0.08$). Furthermore, the locals have completely abandoned the cultivation of black pea and mustard at present.

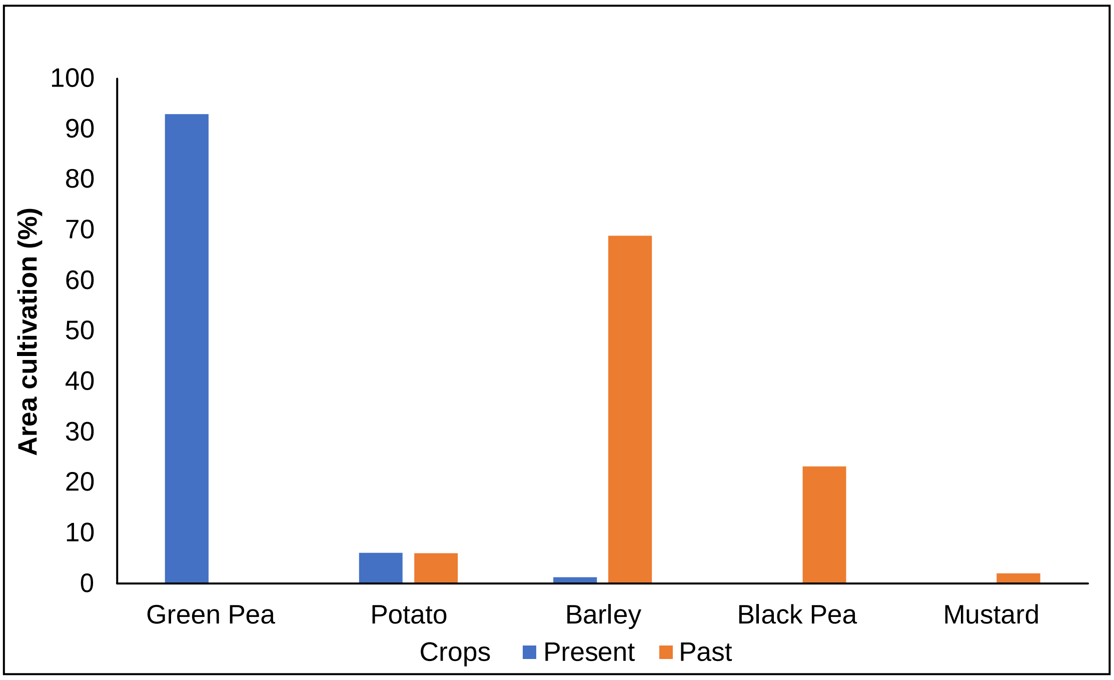


Figure 2.3: Agriculture cropping pattern change over the specified time period.

2.4.2.2 Locals perception on agriculture change

The cropping pattern has undergone a significant transformation, transitioning from a traditional non-commercial approach in the past to a present-day emphasis on commercial cash crops. In the bygone era, for roughly the last two decades, the cropping pattern was primarily rooted in traditional practices aimed at self-sufficiency. However, in the current scenario, this traditional cropping pattern has completely shifted towards a commercial orientation, largely driven by the introduction of green peas as a lucrative cash crop.

This shift towards commercial agriculture, specifically the adoption of green peas as a cash crop, has been instrumental in reshaping the agricultural landscape. Unlike other crops that were traditionally cultivated solely for self-consumption, the cultivation of green peas has become an economic imperative due to its potential for generating significant income margins.

The survey findings unequivocally reflect the impact of this change, as 100% of the respondents attributed the decline in traditional crop diversity and the increase in land use change to the predominance of the cash crop green pea. This shift to a commercial cash crop has not only transformed the economic dynamics of agriculture but also altered the traditional agricultural practices that were deeply ingrained in the community's way of life.

2.4.3 Present and past pastoral practices

Our study reveals a notable shift in the livestock composition pattern over time. In the past, the average individual household had a more diverse livestock composition. The highest numbers were observed for Sheep (6.23±0.14), followed by Goat (4.94±0.12), Horse (3.09±0.14), Donkey (3.04±0.12), Dzomo (1.83±0.09), Yak (1.20±0.07), and Dzo (0.42±0.06) (Figure 2.4).

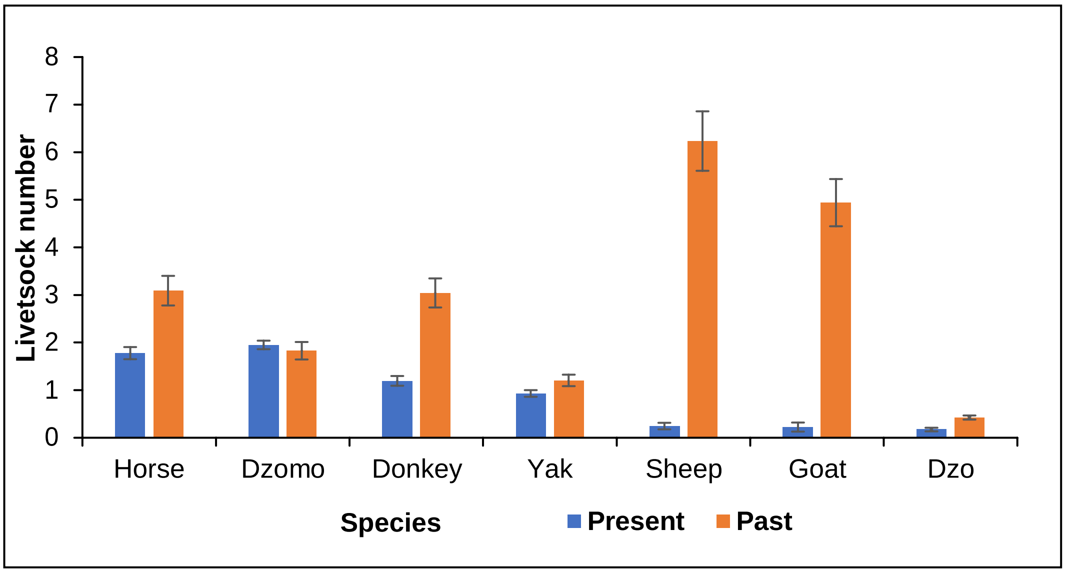


Figure 2.4: Change in local community livestock composition pattern over the period of time.

However, in the present scenario, the average household's livestock composition pattern has changed. The highest numbers now belong to Horses (1.78±0.13), followed by Dzomo (1.95±0.09), Donkey (1.19±0.10), Yak (0.93±0.07), Sheep (0.24±0.07), Goat (0.22±0.10), and Dzo (0.17±0.04) (Figure 5). There has been a decrease in the average livestock composition pattern from the past to the present. The numbers of goats and sheep have drastically decreased and are now near extinction in the area. Significant changes were observed in all other livestock categories ($p<0.05$), except for Dzomo, which showed non-significant changes ($p>0.05$).

2.4.4 Locals' response on decreased livestock number

The decrease in livestock numbers and the shift in livestock composition can be attributed to five main factors (Table 2.1). These factors include a scarcity of fodder due to reduced availability of wild grasses during winter for stall feeding, depredation by free-ranging dogs, increased education and job opportunities leading to changes in livelihood choices, improved village-to-village transportation through road connectivity, and the impact of religious beliefs on livestock management.

Among all the respondents surveyed, 100% believed that depredation by free-ranging dogs and the use of roads and vehicles for transportation were the primary reasons for the decline in livestock numbers. The depredation pattern of dogs is distinct from that of other wild carnivores, as they hunt in packs and can cause significant losses of livestock, especially goats and sheep (self-observation). Consequently, many households have stopped rearing goats and sheep altogether. This problem extends beyond domestic livestock, as free-ranging dogs also pose a threat to wildlife, as witnessed during an incident when they chased and almost killed a group of blue sheep near Glue village.

Furthermore, the introduction of road and vehicle infrastructure has reduced the reliance on traditional pack animals like donkeys, yaks, dzos, and horses. In the past, horses were the primary mode of long-distance travel, and donkeys were commonly used for transporting goods. However, with the advent of tractors and other vehicles, these animals have been replaced in agricultural practices and other activities. Horses, which were once essential, have been substituted with luxury cars.

Religious beliefs also play a significant role, with 87% of respondents indicating that they perceive a moral responsibility to take proper care of animals and avoid their unnecessary killing. When livestock numbers exceed sustainable limits, animals are often sold for meat purposes to meet the demand. Therefore, to avoid from killing and selling they better opted to abandoned rearing.

Overall, these five categories of factors have contributed to the decline in livestock numbers and the transformation of livestock-related practices in the region. The above perception discussed with the local experienced people during survey work and group discussions.

Table 2.1: Locals' perceptions on the major causes of decreased livestock numbers in pin valley.

People perception on decreased livestock	Yes (%)	No (%)	Can't say (%)
Shortage of fodder	90	7	3
Depredation by free ranging dogs	100	0	0
Education and job opportunities	95	0	5
Roads and vehicle for transport	100	0	0
Religious matter	87	3	10

2.4.5 Migratory livestock status in the Pin valley National Park

A total of five migratory herd groups were observed during the years 2017 and 2018. However, an additional group later invaded, resulting in a total of six herds. The present migratory livestock population was approximately 6,900 goats and sheep, along with 49 ponies and 27 dogs. These numbers were found to be more than double the Figures reported by Bhatnagar (1997), which was 2,900 individual sheep and goats.

Another study by Bhatnagar (1996), citing Pandey (1991), indicated a livestock count of 8,000. It is important to mention that the official government permit limit allows only 2,900 animals. Despite this, the study area currently experiences apparent high pressure, especially during the period of peak vegetation productivity.

To address this, a detailed examination of vegetation productivity in both grazed and ungrazed areas was conducted. Additionally, an analysis of the interaction between livestock and ibex in terms of feeding and habitat utilization was carried out in Chapter 3 and 4, respectively.

2.4.6 Agriculture and settlement land use change

The change in agriculture and settlement land use was compared through the Google earth images of past 2004 and present 2023 (Figure 2.5). The total arable land in 2004 was noted 4.10 km^2 Whereas, at present 2023 satellite image the total arable land (2004+2023) was noted 4.41 km^2 area. There is an increase in 0.31 km^2 in agriculture land use from 2004 to 2023 approximately in two decades.

In the recent years due to sudden hike in the cash crop market value people strongly willing to have more lands for agriculture and for that reason Government of Himachal Pradesh have regularized the Nautor Land Act, 1971 for the benefit of landless people. This policy resulted not only change in the cropping pattern but also changed in the agriculture land use pattern resulting more alpine pastures converted in to the agriculture land. The human settlement change was comparatively less than agriculture land use change. Total settlement area in 2004 was 0.30 km² and in 2023 it was 0.32 km². There is 0.02 km² increased in the settlement area in past two decades (Table 2.2).

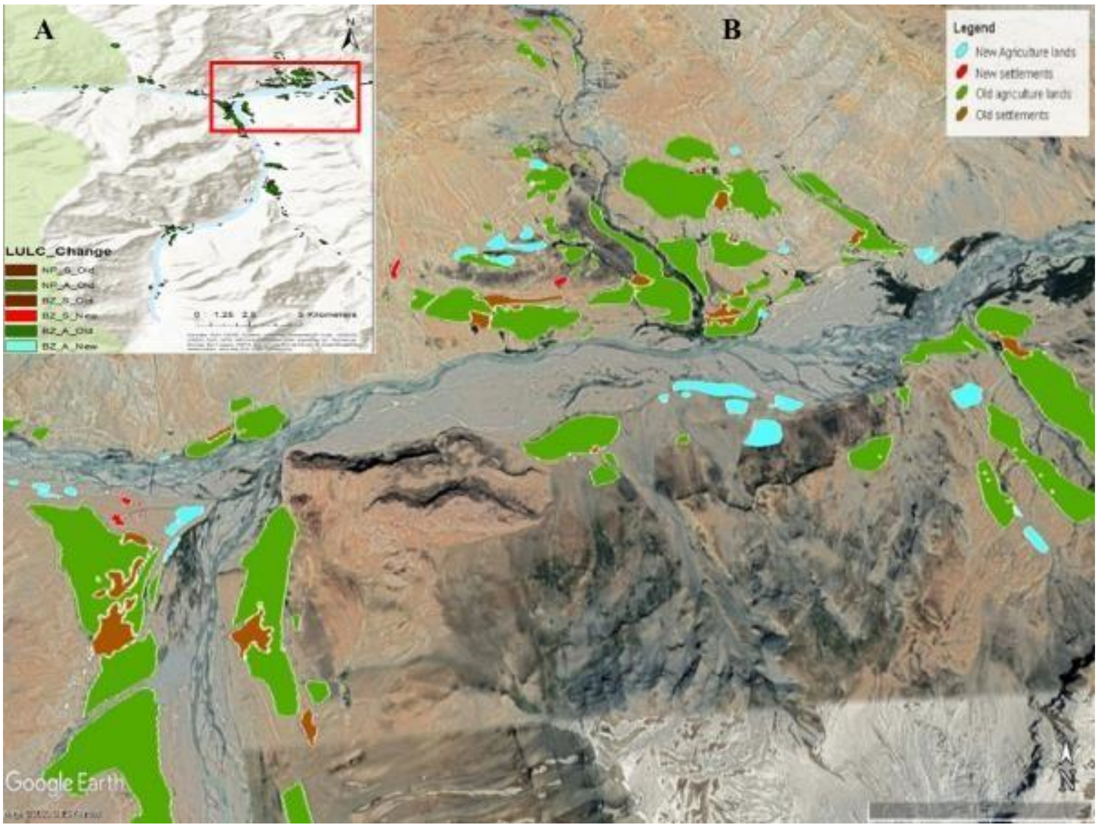


Figure 2.5: Agriculture and Settlement changes in PVNP from year 2004 to 2022 (Source: Digitized from high-resolution Google Earth imagery). Map (A) provides an overview of the entire core and buffer area, showcasing the changes in agriculture and settlement over the specified time period. Map B is a close-up view, focused on a specific area delineated by the red boundary in Map A, highlighting more detailed changes.

Table 2.2: Agriculture and human settlement land use change from 2004 to 2022.

Land use	**Location**	**Area past (km²)**	**Area present (km²)**	**Past + Present area (km²)**
Agriculture	NP	0.18	No change	0.18
Agriculture	BZ	4.096	0.31	4.41
Total				**4.59**
Human settlement	NP	0.004	No change	0.004
Human settlement	BZ	0.299	0.02	0.32
Total				**0.324**

2.5 Discussion

The cropping system in Pin Valley has undergone a significant transformation, shifting from historical self-sustenance to commercialization. The introduction of green pea brought about a revolutionary change, leading to improved economic conditions for the local community but also resulting in a decline in traditional ways of life and livestock diversity. Currently, a staggering 95% of the agriculture land is dedicated to cultivating cash crop green pea, while only 5% is allocated to self-use crops like barley and potato. Barley remains crucial as a staple food during harsh winter climates, while potato serves as a vital long-term food source, lasting over six months. Despite its importance, potato is often underrated. Unfortunately, the populations of goats and sheep are on the brink of extinction, with only a few families still rearing them, and their existence in the region is threatened. The main cause of their decline has been attributed to free-ranging dogs and other factors discussed in the results section. The surge in population and the appeal of cash crops have driven people to expand their agricultural lands, but this practice is venturing beyond sustainability.

The changes in the agricultural landscape raise concerns about the balance between commercial interests, traditional livelihoods, and the preservation of local biodiversity. However, a controversial debate revolves around the impact of pastoral livelihoods on rangeland health, particularly in high-altitude regions such as India, Tibet, Inner Mongolia, and parts of China (Harris, 2010; Singh *et al*., 2013; Mishra *et al*., 2001; Mishra *et al*., 2004; Bagchi & Ritchie, 2010; Thapa *et al*., & Yadav, 2016; Kakinuma *et al*., 2013; Wang & Wesche, 2016). Certain studies propose that pastoral communities might excessively exploit and degrade rangelands, citing the "tragedy of the commons" theory (Hardin, 2009, Dregne, *et al*., 1991; Beinart, 1996; Mishra *et al*., 2001). However, critics argue that these communities possess well-adapted resource management systems through TEK and local institutions (Scoones, 1994; Bilal Butt, 2011; Bhasin, 2012; Mapinduzi *et al*., 2003).

In the high-altitude pastoral communities of South Asia, significant socio-economic changes are occurring due to various factors. These include improved access to education, evolving aspirations, migration to urban centres, labour immigration, cash crop cultivation, and the growth of the tourism industry (Johnson *et al*. 2006; Namgail *et al*. 2007; Singh *et al*. 2013; Namgay *et al*. 2013, 2014; Bhasin 2011; Yamaguchi 2011; Aryal *et al*., 2018). Unfortunately, these changes have had adverse effects on pastoral livelihoods and traditional knowledge systems.

The Trans-Himalayan region in the Indian subcontinent is known for its harsh natural conditions that hinder primary productivity, particularly in agriculture. This area is mostly a cold desert with scattered rangelands and limited arable land, making cultivation opportunities limited. For thousands of years, the people in this region have relied on three main types of pastoral production systems: nomadic, transhumant, and agropastoral, as documented by Handa in

(1994) and further explored by Bhasin in (2011). These systems have been instrumental in sustaining life and culture in the face of challenging environmental factors.

The Pin Valley: A cold desert region in Spiti, Himachal Pradesh, India, is inhabited by a traditional agropastoral community over the past decades, the area has undergone rapid socio-economic changes, primarily attributed to improved road connectivity, enhanced market access, rising literacy rates, and the adoption of cash crops like green peas (Mishra 2000; Singh *et al*., 2015). These changes were further influenced by agricultural policy shifts at the national and regional government levels, which prioritized cash crop cultivation, leading to a significant transformation from a self-sustaining economy to market driven one (Mishra *et al.,* 2003; Singh *et al.,* 2015).

The livestock population and species distribution in the Valley have undergone significant transformations in recent decades, driven by a blend of natural, cultural, and economic factors. The primary objective has been to optimize livestock numbers, leading to a significant 57% surge in goat numbers and a remarkable threefold increase in yaks between year 1980s and 1990s (Mishra, 2000). However, the period between 2003 and 2011 witnessed a stark decline in livestock numbers by half, accompanied by a substantial reduction in the goat and sheep number (Singh *et al*., 2015). Several factors contributed to these fluctuations.

Increase in cash crop income, a lack of labour for managing livestock, the allure of tourism as a secondary source of income, incidents of dogs roaming free preying on livestock, and the effects of extreme climatic events, which have led to a decreased and shortage of grazing pastures (Singh, 2013); (Singh *et al*., 2015). The shift away from traditional resource management practices, increased resource exploitation, and dependence on immigrant workers for livestock management are alarming trends that need attention to ensure the region's long-term viability and ecological harmony (Ghoshal, 2017; Singh *et al*., 2013). Addressing above discussed challenges will be crucial to maintaining the delicate ecological and socioeconomic equilibrium in the PVNP.

2.6 Conclusion

Currently, a mere 8% of the available agricultural land is utilized for self-sustenance, with a significant 92% allocated to cash crops. Over the last 2-3 decades, the average number of livestock per family has significantly decreased (31%). Meanwhile, agriculture land has expanded by 8%, and human settlement areas have increased by 7% over the same period. The decline in goat and sheep populations is primarily attributed to the presence of free-ranging dogs. The overall drop in livestock population is linked to profound social, cultural, and economic changes on a large scale. The unchecked growth of agriculture poses a serious threat to pastureland, raising serious questions about the long-term viability of the ecosystem and the welfare of the neighbourhood.

Image 2.1: The Pin Valley experiences an intense winter characterized by abundant snowfall and a thick snow cover. During this season, the valley transforms into a winter wonderland, presenting awe-inspiring landscapes and challenging conditions for its inhabitants.

Image 2.2: Locals practices a unique tradition of storing ashes from their fires during winter. This traditional practice facilitates the snowmelt process in the onset of spring, especially when they need to catch up on their cultivation activities. They strategically scatter these ashes on selected areas of the heavy snow-covered fields. The ashes' dark colour absorbs sunlight and accelerates the snowmelt in those specific spots. It exemplifies the harmonious relationship between the people and nature in the Pin Valley, where age-old traditions continue to play a crucial role in sustaining their way of life.

Image 2.3: Historical traditional way of ploughing agriculture field using Yak and dzo.

Image 2.4: The modernization of agriculture has introduced advanced machinery like tractors and power trailers, replacing traditional manual labour and greatly improving work efficiency. However, this shift has also led to a decline in the number of livestock, such as yak and dzo, potentially impacting the traditional agropastoral practices. This could result in various imbalances, affecting the ecological, economic, and cultural aspects of the community's livelihoods in the future. Elderly perspectives suggest modernized agriculture may increase field weeds. Machinery may not eradicate them effectively as traditional methods, leading to chemical reliance.

Image 2.5: During the harsh winter climate, with temperatures plummeting to -35 to -40°C, the practice of water restoration from rivers and streams becomes essential. This is a reliable alternative when conventional water taps freeze. Drawing water from flowing sources ensures a steady supply, supporting the community's water needs and sustenance during the challenging winter months in some villages.

Image 2.6: During the Lavi fair in Rampur district, Himachal Pradesh, the age-old tradition of horse trading is still cherished. The fair, held from 11th to 14th November, now sees locals transporting horses by trucks, whereas in the past, they would journey on horseback through the entire route.

Image 2.7: The entire Spiti valley, faces a significant challenge with free-ranging dogs, posing threats to local livestock and wildlife. The increasing number of dogs is partly attributed to tourists and trekkers who bring and leave them behind during their journeys. This situation calls for attention and responsible practices to address the impact on the valley's delicate ecosystem and ensure the well-being of its inhabitants.

Chapter 3

Understanding natural resource use by the Spiti Bhot community in Pin Valley National Park

3.1 Introduction

Pastoralism has been practiced in the Himalayas for ages, albeit the amount of grazing varies significantly (Kala & Rawat, 1999; Bhattacharya & Sathyakumar, 2011). Anthropogenic disturbances, including livestock grazing, can lead to competitive exclusion of wild animals from high-quality habitats, compelling them to forage in less favorable areas and expend more energy to avoid disturbances that disrupt their nutritional balance (Schaller, 1977). In the trans-Himalayan region, ungulates play a crucial role in the mammalian fauna and serve as the primary prey base for large mammalian predators. These ungulates exhibit adaptable behavior by modifying their activity patterns in response to habitat variations, seasonal changes, and disturbances, making them sensitive indicators of habitat quality, protection, and management (Owen-Smith, 1979).

In a trans-Himalaya region of the cold desert area Spiti, the major part of PVNP, owing to its strong natural values of flora and faunal species like the Snow leopard and the Himalayan ibex led to the notification of this area as a National Park (NP) in 1987. A more cogent motive behind this notification was the fast-degrading ecosystem of the area through increasing human dependence on the natural resources from the park premises, a factor detrimental to the existing wildlife and the biological diversity of the area (Bhatnagar, 1996).

Intensive literature review revealed that the PVNP in the trans-Himalaya owing to strong natural values of flora and faunal species like the snow leopard (*Panthera uncia*) and the Himalayan ibex (*Capra Siberia*). A significant portion of PVNP flanked by historically natural resource-dependent communities, with eight villages from this valley depending on the national park for fuelwood, fodder, livestock grazing, and farming in varying degrees (Bhatnagar, 1996). This traditional pattern of resource utilization in terms of uprooting and collection of shrubs and herbs, intensive livestock grazing by migratory grazers, and, to a lesser extent local, and dung collection, is probably going beyond sustainable limits (Bhatnagar, 1996; Manjrekar, 1997; Bhatnagar, 1997; Mishra, 2000, 2001, 2002; Bagchi *et al*., 2004). Overstocking is the trans-Himalaya rangelands that outnumber the wild herbivores and reduce animal production (Mishra, 2000, 2001, 2002; Bagchi *et al.,* 2002, 2004). Local and migratory livestock cause a threat to Ibex through the transmission of contagious diseases and causing pasture degradation by overgrazing (Bhatnagar, 1997; Manjrekar, 1997).

Livestock grazing by a diverse assemblage is prevalent throughout the entire PVNP catchment. This raises concerns about the potential impact of livestock grazing on the Ibex population

(Bagchi *et al.,* 2004). The regions along the route of transhumant pastoralists face anthropogenic pressure, including livestock grazing and tree lopping for fuelwood. To assess the impact of these disturbances, it is essential to conduct preliminary documentation of the routes (Mitra *et al.,* 2013). Furthermore, more comprehensive investigations are required to understand the interplay between vegetation structure, composition, and grazing patterns of domestic livestock and wild herbivores (Rawat & Adhikari, 2005).

Considering the above issues, present study was designed to evaluate the biological diversity of the NP, by quantifying dependence on the park and developing awareness among local people. The present study will also focus on the livestock herding patterns of local and migratory herders and a natural resource consumption pattern. So, this study will help to generate information on the present status of the resource use pattern and livestock abundance in PVNP. Therefore, the prime objective of the current study was to document the natural resource dependency of the local agropastoral community in Pin Valley National Park.

3.2 Objectives and research questions

i. To document the natural resource dependency of the local agropastoral community in Pin Valley,

ii. To quantify the annual resource consumption pattern in terms of fuel, fodder, dung, and other NTFPs,

iii. To comprehend any changes in resource use patterns and the drivers of changes.

Questions

i. What is the extent of natural resource dependency among the local agropastoral community in Pin Valley?

ii. How much fuel, fodder, dung, and other non-timber forest products (NTFPs) are consumed annually by the local agropastoral community in Pin Valley?

iii. What are the drivers of changes in resource use patterns among the local agropastoral community in Pin Valley?

3.3 Materials and methods

3.3.1 Study design and data collection:

A total of 80 households from eight villages, representing 25.16% of the total sampled size, were surveyed. Out of these households, 43.75% belonged to the gram panchayat Sagnam. The village named Sagnam (strata-1) had complete traditional rights over the Pin Valley National Park for grazing and natural resource use. The remaining dependent villages (strata-

2) Mikkim, Kungri, Chud, Gulling, Bhar, Seling, and Fukchung had partial traditional rights over PVNP for resource use and accounted for 56.25% of the total surveyed households.

Data on the use of natural resources such as fodder, fuelwood (shrub), livestock dung, and non-timber forest products (NTFPs) were collected using a semi-structured questionnaire with open and close-ended questions, following the approach by Bernard (2006). The data was collected from June, 2017 to December, 2018, and information on both the present (after 2017) and past (before 2000) resource use was obtained from the same interviewees.

The consumption patterns of natural resources were quantified, and changes in resource use were compared between past and present data. The quantity of resources used was measured in kilograms, and the average load quantity (dry weight) for different resources was as follows:

Fodder 1 load = 55kg,

Dung 1 load = 55 kg,

Shrub 1 load = 35 kg.

The mean weights for each item (shrubs, dung, and fodder) were calculated by dividing the total consumption of the item from a village by the total number of families in that village.

The average annual resource use per household from the PVNP (core and buffer zone) was analyzed for both past and present periods, and separate analysis was done for the NP core area to assess the pressure on NP. The changes in the annual resource consumption pattern were depicted in Figures 4-9.

Google Earth Pro and Arc-GIS 10.3 were utilized to map the study area and calculate the area of resource dependency on NP by Strata-1 and Strata-2. The study design is illustrated through a flowchart diagram for a clear overview (Figure 3.1).

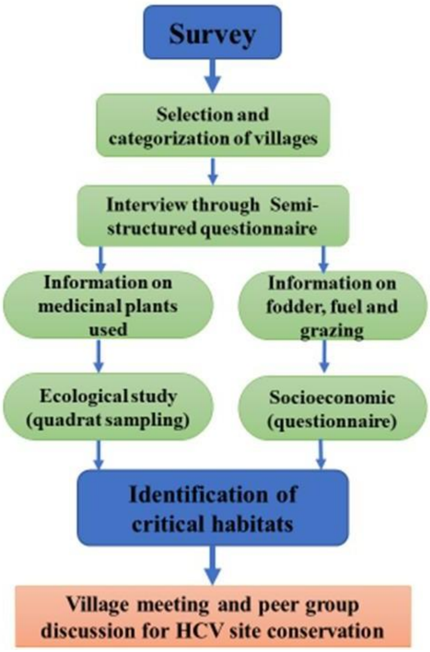


Figure 3.1: Flow chart diagram showing the study design.

3.3.2 Meetings and discussions

During the course of the survey and some informal meetings within the villages, a few motivated and interested individuals were identified to form a village group. With active support from these people, village meetings were conducted to elicit people's participation regarding the linking of conservation and development. Through this group's participation and the survey findings, a few basic issues were identified.

3.3.3 Stratification of grazing lands

Pre-reconnaissance survey was conducted to see the distribution pattern of migratory herders in the study area. After finding their distribution pattern a semi-structured questionnaire survey was conducted followed by a direct count to record the abundance of livestock, herd size, and group composition of each herd and their movement pattern into PVNP. Each base camp of the herders was recorded with help of GPS, to highlight their distribution pattern and area used during their grazing period.

The locals who brought their livestock from the dependent villages to National Park (NP) were interviewed and livestock numbers were recorded. The information generated from sampled surveys was pooled for each village.

3.4 Data analysis

Descriptive statistics were used to examine the alterations in resource utilization (fuelwood, shrub, fodder, dung, and depot wood) between the past and present periods. To evaluate the significance of these changes, two-sample paired tests were performed using the software Past 4.03.

3.4.1 Medicinal plants use analysis:

3.4.1.1 *Plant species density (per unit area)*:

Species density is a metric used to assess the abundance and distribution of medicinal plant species within a study area.

Species density = (Sum of individuals in all quadrats studied) / (Sum of quadrats studied)

This formula is used to calculate the species density, which is a measure of the average number of individuals of a particular species per quadrat in a given study area. By summing up the total number of individuals of the species across all quadrats and dividing it by the total number of quadrats studied, researchers can obtain an estimate of the density of that species in the area.

3.4.1.2 Use Value (UV)

The Use Value (UV) of a particular plant species is calculated as the sum of the number of uses mentioned by each informant for that species, divided by the total number of informants (n).

$$UV = \Sigma Ui / n$$

Where:

Ui = The number of times the plant species is mentioned as being used by each informant.

n = The total number of informants.

3.4.1.3 Fidelity Level (FL)

The Fidelity Level (FL) for a medicinal plant species used to treat a specific disorder is calculated as the ratio of the number of informants who used the plant for that particular disorder (Ip) to the number of informants who used the same plant for any disorder (Iu), multiplied by 100.

$$FL = (Ip / Iu) * 100$$

Where:

Ip = The number of informants who used the medicinal plant species for the particular disorder.

Iu = The number of informants who used the same medicinal plant species for any disorder.

In summary, the Use Value (UV) quantifies the overall usefulness of a plant species by considering the total number of times it is mentioned by informants, while the Fidelity Level (FL) assesses the specificity of a medicinal plant's use for a particular disorder by comparing the number of informants who used it for that disorder to the total number of informants who used it for any disorder.

3.5 Results

3.5.1 Area used by strata-1 and strata-2 in the National Park

The total land under cultivation inside the NP by strata-1 and strata-2 (Figure 3.2) was approximately 0.55 km² and for grazing and other resources strata-1 has a total land area of 158 km² with a perimeter of 80.2 km. While Strata-2 has only 21 km² with a perimeter of 25 km. As earlier mentioned, the partially dependent villages have their rights only in smaller portions inside the NP along the right bank of the Kidulchhu river.

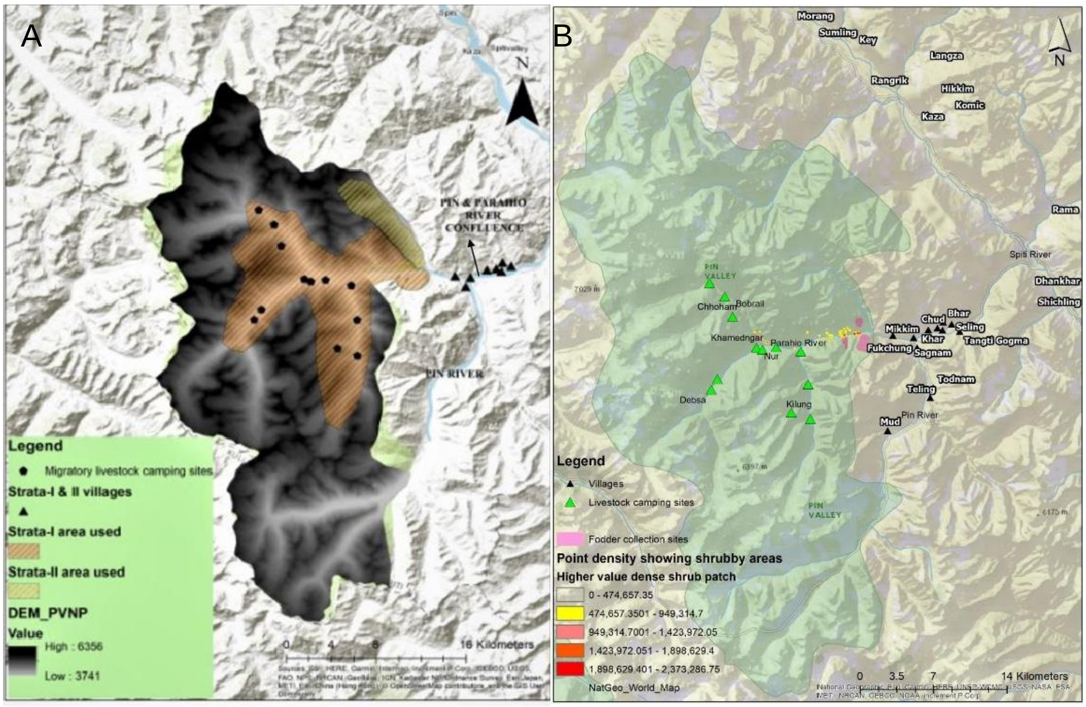


Figure 3.2 (A) Map showing areas under Strata-1 and Strata-2 and **3.2 (B)** showing resource dependency sites in the NP.

3.5.2 Resource extraction from the Pin Valley National Park's (core and buffer area)

3.5.2.1 Annual resource use pattern:

There are eight villages using the NP to varying degrees, for farming, collection of fuelwoods, fodder, livestock dung, and livestock grazing. Based on the quantities collected and the area used by different villages strata-1 and strata-2. Strata-1 has traditional rights in major portions of the Parahio catchment inside the NP. Strata-2 has rights in smaller portions inside the NP along the right bank of the Kidulchu river. The rights of both strata are traditional and were assigned to the villagers centuries ago.

Currently, the eight villages extract an average of approximately 99,110 kg of shrubs, dung, and fodder annually from the National Park. Among them, Strata-1 is responsible for 90,585 kg (91%), while Strata-2 extracts around 8,525 kg (9%) of these resources. Additionally, the annual depot wood usage for Strata-1 and Strata-2 amounts to 4,36,775.4 kg and 43,700 kg, respectively.

However, the same interviewees disclosed that in the past, the average annual consumption of shrubs, dung, and fodder by these eight villages was 2,55,918 kg. Within this consumption, Strata-1 accounted for approximately 2,12,465 kg (83%), and Strata-2 extracted around 43,453 kg (17%) of these resources. Furthermore, the depot wood used by Strata-1 and Strata-2 in the past was 2,20,587.7 kg and 20,500 kg, respectively.

According to a forest department Kaza report, the annual depot wood supply in Pin Valley in the year 1995 was 3,442 quintals, and it was 5,500 quintals in the year 2019. The depot wood usage in Pin Valley has increased by 60%. In comparison, the depot wood supply in the entire Spiti Valley sub division was 33,288 quintals in 1995 and 39,200 quintals in 2019. The depot wood usage has increased by 18% in the entire valley.

3.5.2.2 Strata-1 Annual resource extraction:

The annual average resource use per household by Strata-1 in past was observed fodder (1554.14±174.6), dung (3364.43±171.09), Shrub (1151.86±96.8), depot wood (714.3±146.8). While, the present annual resource use was fodder (799.86±89.1), dung (1676.28±149.9), Shrub (110±35.9), depot wood (1764.3±131.6) (Figure 3.3).

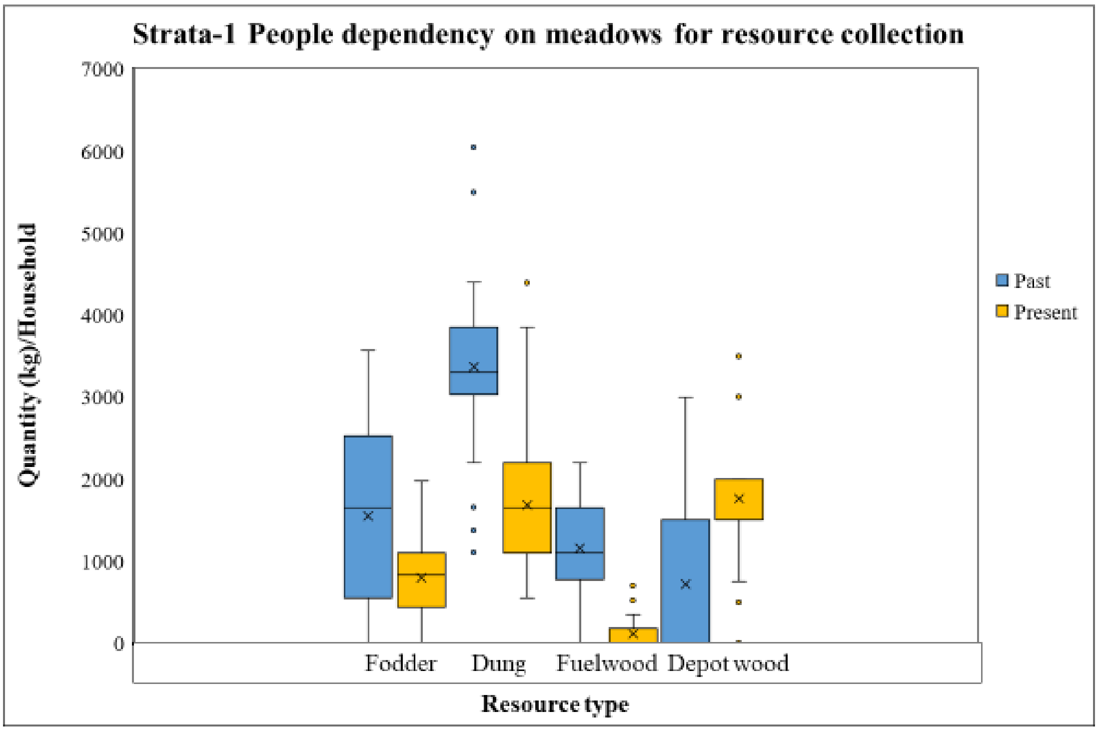


Figure 3.3: Box and whisker plot of Strata-1 past and present average annual/household resource collection pattern in Pin Valley National Park.

3.5.2.3 Strata-2 Annual resource extraction:

The annual average resource use per household by Strata-2 in past was observed with fodder (2852.7±85.9), dung (2135.2±97.1), Shrub (1041.4±70), depot wood (455.5±63.3). While the present study revealed that annual extraction of resources by Strata-2 was with fodder (413.1±82.61), dung (561±110.7), Shrub (8.6±5.93), depot wood (971.1±108.7) (Figure 3.4).

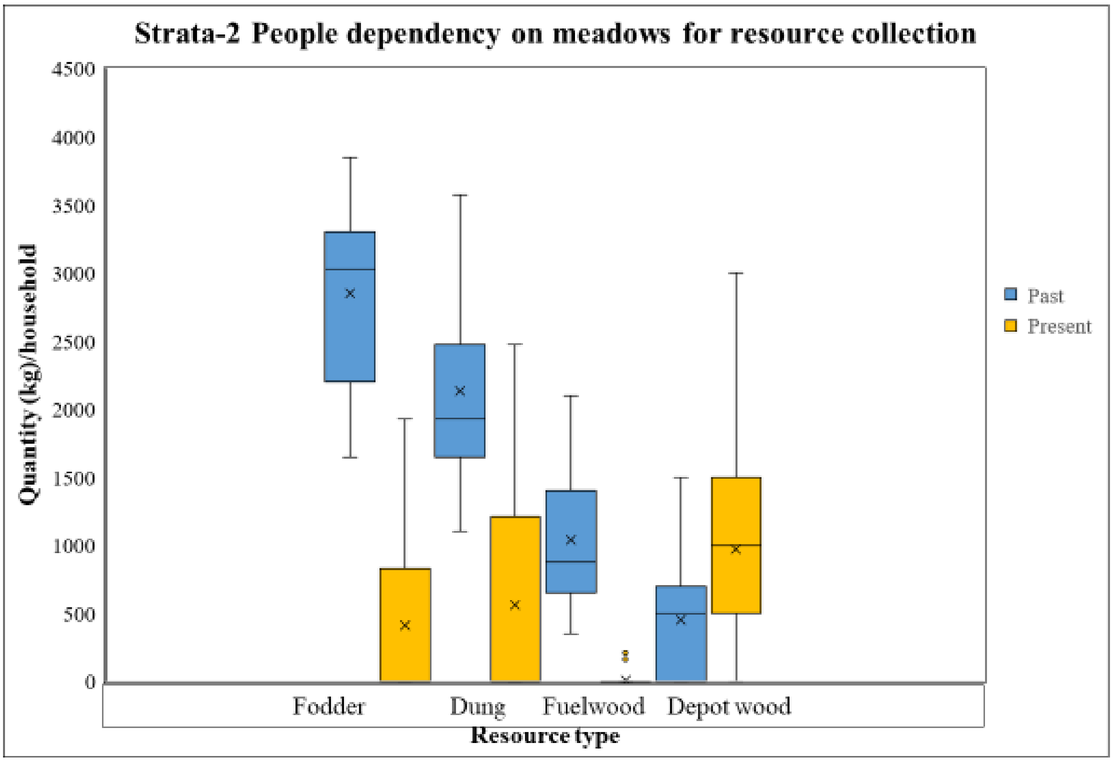


Figure 3.4: Box and whisker plot of Strata-2 past and present average annual resource collection pattern in Pin Valley National Park.

3.5.3 People resource dependency in the pin valley national park's (core area)

3.5.3.1 Annual resource collection Strata-1:

The annual resource dependence of Strata-1 at present was maximum on depot wood (41%) followed by dung (39%), fodder (18%), and shrub (2%) (Figure 3.5A).

While in the past the dependency was maximum on dung (50%) followed by fodder (23%), shrub (17%), and least on depot wood (10%) (Figure 3.5B).

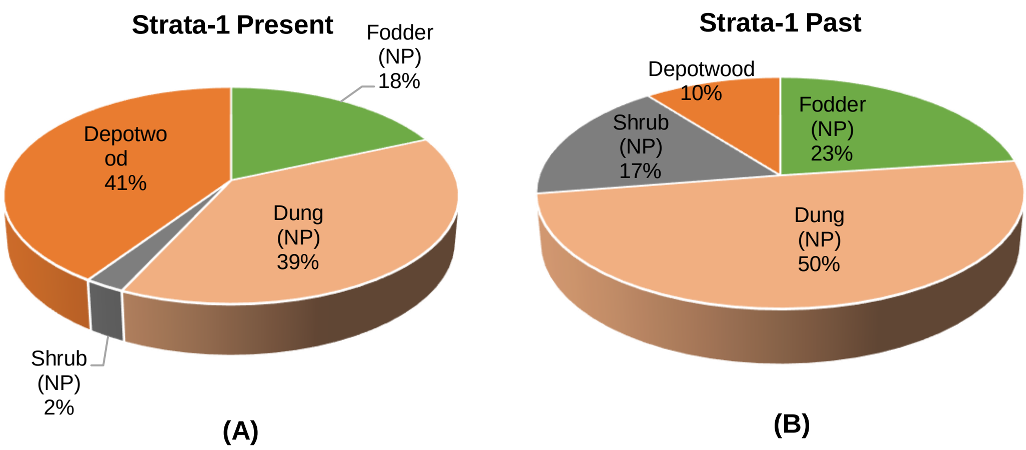


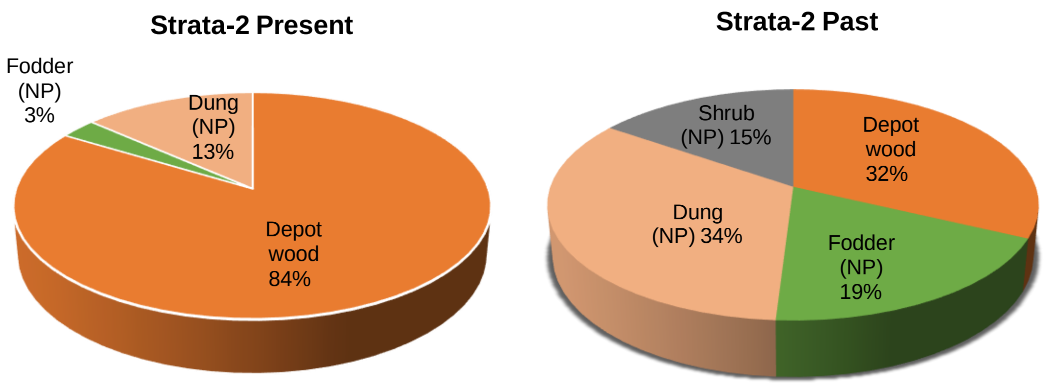
Figure 3.5 (A) & 3.5 (B): Illustrating the present and past annual resource extraction from the core area of the National Park by the Strata-1 village.

3.5.3.2 Annual resource collection Strata-2:

Currently, Strata-2 exhibits a significant reliance on maximum depot wood for its annual fuelwood consumption, accounting for 84% of the total usage. This is closely followed by fuel dung, constituting 13% of the consumption, while fodder alone contributes merely 3% (Figure 3.6A).

In contrast, the historical annual fuelwood consumption in Strata-2 displayed a different pattern. The primary source in the past was fuel dung, comprising 34% of the total consumption, followed by depot wood at 32%. Additionally, fodder contributed to 19% of the consumption, while shrub usage was the least prominent, accounting for only 15% (Figure 3.6B).

These findings demonstrate the dynamic changes in fuelwood utilization over time in Strata-2, with a notable shift in preference from dung and fodder-dominated consumption in the past to a prevailing reliance on depot wood in the present.



(A) **(B)**

Figure 3.6 (A) & 3.6 (B): Illustrating the present and past annual resource extraction from the core area of the National Park by the Strata-1 village.

3.5.3.3 Medicinal plant collection:

The collection of medicinal plants lasts only during the peak growing season and during this period *Amchies* collect medicinal plants from meadows, riverbeds, nearby agriculture fields ca. 13.20±2.93 kg (dry weight) annually.

Forty-seven rare and endangered medicinal plant species were used to treat twenty-seven different ailments (Targe *et al*., 2022). Some medicinal plants have high use value and high preference in the traditional healthcare system and they are uprooted for it (Table 3.1). The buffer zone of the National Park having rich source of medicinal plants and three high conservation value sites were identified for further conservation and management perspective namely Gangnam, Darbak and Solokyok. For more details on medicinal plants status and use refer to our published paper (Targe *et al.,* 2022).

Table 3.1. *Some rare and endangered medicinal plants used by the local community from buffer and core area of the PVNP.*

Species	**Core zone (density m-2)**	**Buffer Zone (density m-2)**	**UV index**	**FL values %**	**Parts used**
Bistorta affinis	0.69±0.29	3.25±1.71	1	100	Shoot
Crementhodium ellisii	-	0.4±0.4	1	65	Leaf
Saussurea bracteata **	-	0.43±0.18	1	100	Shoot
Waldhemia stoliczkai	-	0.22±0.02	1	65	Leaf
Hyssopus officinale	0.52±0.17	0.85±0.37	1	100	Flower, Leaf
Delphinium brunonianum *	0.05±0.07	0.9±0.9	1	67	Shoot
Picrorhiza kurroa **	-	0.5±0.5	1	100	Leaf, root
Aconitum heterophyllum ***	-	0.88±0.22	1	100	Shoot
Bergenia stracheyi	0.11±0.13	0.48±0.12	1	55	Root
Rheum webbianum	0.23±0.08	0.23±0.06	0.92	75	Shoot
Gentianella moorcroftiana	-	0.33±0.06	0.33	100	Shoot
Arnebia euchroma **	0.20±0.07	0.15±0.15	0.33	100	Rhizome
*Aconitum violaceum****	-	0.15±0.15	0.25	75	Shoot
Dactylorhiza hatagirea ***		0.10±0.04	0.67	90	Root
Ferula jaeschkeana *	0.13±0.0.5	-	0.92	85	Seed

*Vulnerable, **Endangered , ***Critical endangered, refered from (Targe *et al.,* 2022)

3.6 Discussion

Present study revealed that local community dependency on natural resources was declined in last 2-3 decades but dependency on depot wood increased by 60% in Pin valley. At present on an average annually around 99,110 kg of shrubs, dung, and fodder is being extracted from the NP by the eight villages. Strata-1 extracts around (91%) and Strata-2 extracts around (9%) of shrubs, dung and fodder.

Bhatnagar (1996) revealed on an average every year around 2,05,854 kg of shrubs, dung and fodder is being extracted from the NP by the eight villages. Stratum 1 extracts around (84%) and Stratum 2 extracts around (16%). There is significant decrease difference in resource use with (35%) over the period of time. This decrease in resource dependency was associated with an increase in household income from selling green peas, govt. jobs and road connectivity (discussed in the previous Chapter-1).

A decrease in dung collection is associated with the involvement of women who formed the primary workforce in government jobs as most of them engaged in Irrigation and Public Health (IPH) and Public Work Department (PWD). In the earlier period, they had to work only in the agriculture field and had time for resource collection till the harvesting period when cash crops and govt. employments wasn't in trends. But as the cash crop was introduced, people indulged in this business. Year by year cash crop income increased and now people growing 90-95% only green pea (Chapter-1). People began sending their children outside of the valley for better and higher education as soon as their income increased, leaving those who worked at home with a shortage of workforce. In addition, people no more collect shrubs from mountains as practiced in the past for use in rooftop cover and constructions. Now people absolutely rely on the availability of wooden kadi and well-furnished market woods locally called 'Takhta' for its use in roof construction and cover.

The decrease in fodder collection may be due to the decreased livestock number. People have abandoned rearing sheep and goats the reason was the free-ranging dog's massive killing (Chapter-1), lack of man power for rotational community livestock herding and religious sentiments. While the population of yak, horses, and donkeys has also decreased due to road connectivity and increased machinery use in agriculture practice (Chapter-1).

As a result, the cattle population has dropped, and humans are reliant on mountain resources to a lesser extent. Furthermore, elderly men and women do not stay in villages during the winter season; they migrate to big cities to avoid the harsh winter, and the young generation migrates to cities for education and to earn a living, resulting in a decrease in the use of traditional medicines and a decrease in the collection of medicinal plants from mountains.

A detail study on medicinal plants use by *Amchies* conducted and published (Targe *et al.,* 2022).

Winter is the period when most people get health issues due to the harsh winter climate. But the inhabitants are no more dependent on the traditional health care system i.e., the *Amchi* system as earlier because most of the people rely on allopathic treatment in present (Targe *et al*., 2022). The mass migration trend happened due to improvement in lifestyle and increased income. Thus, dependency on wild medicinal plants from mountains has decreased. Similarly, they are rarely dependent on other NTFPs collections from the mountains as most of the food items are available in the market and they have the monetary power to buy them due to income from cash crops and government jobs. In earlier periods they heavily depend on mountains for vegetables and spices during the summer period but now the use is minimum. This may be good sign from the wildlife conservation point of view.

3.7 Conclusion

The present study highlights and comes to conclude that from the above results and discussion it was found that the natural resource consumption pattern has decreased and people are less dependent on mountains for fodder, fuelwood, dung, Medicinal plants, and other NTFPs. While migratory livestock numbers reached beyond their limitations (see chapter one) grazing 81% of the total area sampled leaving only 18% un-grazed for wild animals. Local livestock herding numbers decreased as goat and sheep rearing was abandoned by the locals and the rest of livestock rearing practice was very limited (see chapter one). The unregulated livestock number, foot, and mouth diseases carried by goats and sheep, and free-ranging dogs are major threats to wildlife in the PVNP. Three HCV sites Gangnam, Darbak and Solokyok were identified for future medicinal plants conservation (Refer our paper Targe *et al.,* 2022 for more detail). Therefore, proper regulation of livestock numbers, vaccination, and dogs' management are very urgent for wildlife conservation in near future.

Image 3.1: Group discussion and awareness program with local community.

Image 3.2: The Pin Valley National Park boasts a rich diversity of rare and endangered plant species that hold significant value for medicinal purposes. These invaluable plants have been utilized by traditional healers and local communities for generations due to their unique medicinal properties. Some of the noteworthy species found in the park are shown in this image.

Image 3.3: Traditional way of fodder collection by the local people wearing locally called Hultum for fodder collection.

Image 3.4: Livestock Dung collection inside Pin Valley National Park.

Image 3.5: Medicinal plant collection by local *Amchi* during peak vegetation growth

Image 3.6: Many significant shrub species, including *Salix* spp., *Myricaria* spp., and *Hippophae* spp., which are the main riverine plants, degrade and are washed away with water during the peak summer season when river level reaches to its peak. When the river volume drops in the autumn, people gather such uprooted shrubs for fuel.

Image 3.7: Local woman preparing traditional basket from *Salix* spp. (saplings or young tree) locally known as 'Tsewu'. Tsewu are woven or crafted to hold and carry various items, ranging from dung collection and other necessities. Baskets are often crafted by hand, showcasing the skill and artistry of the individuals or communities that create them.

Chapter 4

Understanding resource availability with respect to Ibex (*Capra sibirica*) and its habitats

4.1 Introduction

Resource availability refers to the abundance and accessibility of essential resources, including food, water and shelter within an animal's habitat. Individual animal and population survival are dependent on the availability of sufficient life necessities or vital habitat resources (Manly *et al.,* 1993). Vegetation being animal resource selection and usage patterns are studied to better understand the ecology of the species and to assess the nature and dynamics of a species' interaction with biotic and abiotic elements and variables in its environment.

Prior knowledge of resource distribution allows analysis of species' spatial patterns and population using resource selection functions (RSFs). According to the habitat selection theory (Orians & Wittenberger, 1991), when multiple species coexist in the same area and share similar ecological niches, they tend to exhibit specific behavioral traits that lead to spatial or temporal separation within their shared habitat range (Namgail, 2001). This phenomenon helps us better understand how different species interact and adapt to their environment, shedding light on their coexistence and potential ecological implications.

The Trans-Himalayan and main Himalayan ranges are home to two of the Indian subcontinent's Ten major biogeographical zones (Rodgers & Panwar, 1988). The Trans-Himalayan biome is fragile, with poor primary productivity, high solar radiation

intensity, and a high degree of resource seasonality. With an area of 96,700 km², Spiti in northern India symbolizes the Trans-Himalayan zone. It is located in the Himalayan rain shadow region and receives very little precipitation (<100 mm. year–¹), forming high altitude cold desert (Singh & Gupta, 1990). The varying topography, edaphic and climatic conditions reflect on the natural vegetation found in the region.

The Trans Himalayan is dominated by graminoids and tiny herbs with perennial rootstocks and has a low vegetation density. The flora has adapted successfully to the hard-climatic circumstances, with most species having a limited population. Major landform types of regions include desert steppe, scrub steppe, and meadows, scree. Woody taxa such as *Juniperus spp*., *Betula utilis*, *Populus spp*., and *Salix spp*. is present in the partially dry temperate and dry alpine vegetation. Shrubby vegetation is also found, including *Hippophae* spp., *Artemisia spp., Ephedra geradiana*, *Rosa spp*., and *Lonicera spinosa.*

The study of vegetation structure, composition and ecological patterns in spatial variability relies heavily on the description of vegetation at the landscape level (Farina, 1998). Since the early nineteenth century, scientists have been studying the relationship between vegetation and altitude (Mani, 1978). The focus on vegetation studies in the trans-Himalaya is scarce (Chaurasia & Singh, 1996).

Pin Valley National Park supports less diverse, low populations of typical trans-Himalayan mammalian fauna, such as Himalayan ibex, Snow leopard, Tibetan wolf, Brown bear and Red fox. Besides, there are several other important wildlife species which are ecologically important. At the same time in the most of the part of national park historically permitted migratory herders are there for livestock grazing during peak summer season June to September months. Despite the region's harsh climate, scant vegetative cover, and low standing biomass, this area sustains high livestock population.

Therefore, the present study focusses only on resource availability in terms of vegetation and habitat with respect to the wild ungulate Ibex only, as it is key prey species of the flagship snow leopard in PVNP. We observed vegetation community association, composition and species heterogeneity with respect to landform type and altitudinal gradient.

The vegetation structure and composition study aimed to determine the diet composition and availability of the wild ungulate Ibex and its dietary overlap with the livestock. The vegetation description and quantification included in this study were not intended to be a thorough study of communities, but rather as a tool of understanding the food ecology of Ibex and livestock (goat and sheep).

4.2 Objectives and research questions

i. To determine vegetation community structure and composition in the study area,

ii. To identify vegetation composition in the various landform units and concerning grazing regimes (grazed vs ungrazed),

iii. To map identified vegetation communities and quantify the area covered by each community,

iv. To identify Ibex habitats with respect to different landform units and vegetation communities.

Questions

i. What are the major vegetation communities in the study area?

ii. How is the vegetation composition structure performing in relation to different landform units?

iii. Does the vegetation composition in grazed and ungrazed areas differ in any way?

4.3 Materials and methods

The study area was separated into grazed and ungrazed pastures based on the initial reconnaissance assessment. This split was formed primarily based on migratory herders' grazing history in the region, as well as physiognomy and broad vegetation types in relation to distinct terrain. The division of the region into grazed and ungrazed areas aided in the formation of "control site or ungrazed site" areas for those with no domestic migratory livestock use. The aim of the dividing area in to migratory livestock grazed and ungrazed was to check the vegetation composition pattern and difference in terms of species density, diversity and richness in both sites to understand the resource araciality for wild ungulate Ibex.

To measure vegetation composition and availability, a quadrat of (1*1m) size was utilized. The sampling took place during the peak summer season, from mid of June to September, 2019, when the vegetation is in full bloom. Vegetation sampling was done along the altitudinal gradients. Where ever possible the sampling sites divided in to three elevations as low, medium and high. After every 250 m of interval sampling was done deploying at least 5 quadrats at each point. Other parameters like aspect, slope, landform type, elevation etc. recorded. A total of broadly 81 sites were sampled, spanning a variety of terrain types and attributes. Total of 576 plots were laid for vegetation sampling following (Rawat & Adhikari, 2005). Out of the total in grazed areas, 326 plots were sampled while in ungrazed areas 250 plots were.

In ArcMap 10.3, conducted an estimation of the percentage area covered by grazed and non-grazed pastures, human settlements, and other vegetation communities. For supervised classification, GPS coordinates of 576 quadrats utilized. The Lansat-8 30m resolution clear summer satellite image was used from USGS earth explorer for community classification and mapping.

The study area being a cold desert, its appearance seems desolate due to the limited reflection of flora pigments from the earth's surface. Despite having unique vegetation characteristics, most of the vegetation in this area remained hidden with very low Normalized Difference Vegetation Index (NDVI) values. Consequently, only vegetation communities exhibiting high reflectance values were visible and distinguishable on the map.

4.4 Data Analysis

The vegetation analysis was carried out at three different levels to better understand the vegetation composition and structure concerning the Ibex food availability. The analytical tools and techniques used in this chapter shown in (Figure 4.1).

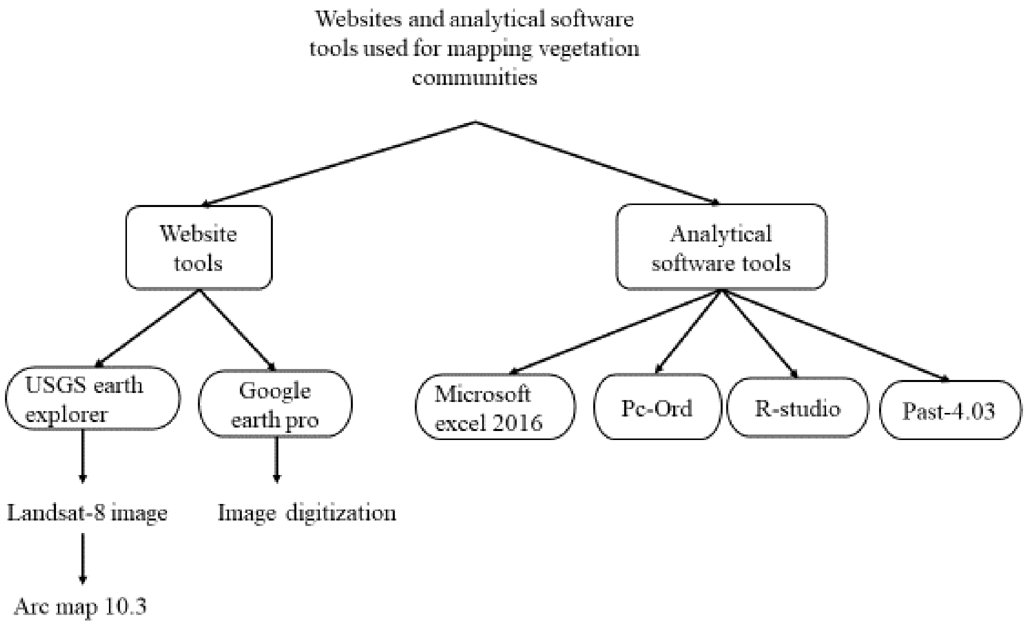


Figure 4.1: Analytical software tools used for vegetation classification

4.4.1 Vegetation community analysis

The vegetation plots were used to analyze plant association using TWINSPAN (Two Way Indicator Species Analysis) (Hill, 1979) in PC/ORD software. Classification of vegetation by TWINSPAN is based on the concept of dichotomy, in which samples are grouped based on similar species combinations, first into two groups, then four, eight, sixteen, and so on. The analysis requires an input of abundance values of different species in the sampled plots. DECORANA and CANOCO are popular computer packages that are widely used for the ordination of vegetation. The frequency data obtained from the vegetation plots were subjected to TWINSPAN analysis.

4.4.2 Vegetation analysis in grazed and ungrazed areas with respect to different landforms

At a broader scope, the study involved conducting an analysis on distinct livestock-grazed and ungrazed areas to gain deeper insights into variations in vegetation composition and structural patterns between these locations. The sample plots were categorized into either grazed or ungrazed sites. Subsequently, species density, diversity, and richness were computed using Past 4.03 software, along with descriptive statistics. To evaluate the significance of discrepancies between grazed and ungrazed areas across different landforms, the Mann-Whitney U test, Kruskal-Wallis test, and Dunn's test were applied.

4.4.3 Vegetation composition dissimilarity

The Bray-Curtis Dissimilarity is utilized because it considers abundance values, which are calculated using the formula:

$$BC_{ij} = 1 - (2 * C_{ij}) / (S_i + S_j)$$

Where:

Cij: Represents the sum of the lesser values for the species found in each site.

Si: Stands for the total number of specimens counted at site i.

Sj: Stands for the total number of specimens counted at site j.

The Bray-Curtis Dissimilarity always yields a value between 0 and 1,

where:

0 signifies that two sites have no dissimilarity, indicating they share the exact same number of each species.

1 signifies that two sites have complete dissimilarity, meaning they share none of the same species.

4.4.4 Ibex encounter rate in grazed and ungrazed areas

The Ibex encounter rate was assessed through systematic trail monitoring and simultaneous vegetation sampling. Each time an individual animal or a herd was spotted, detailed information, including time, location, number, age, and sex composition, was meticulously recorded. The start and end times of each monitoring walk were also documented, while the distances covered during transect monitoring were accurately measured using a Global Positioning System (GPS).

To determine the encounter rate of Ibex, each observed herd was treated as one sighting. The total number of herds encountered on a trail was divided by the distance walked (in kilometers) on that particular transect. Additionally, the standard error of the mean was calculated to assess the precision of estimating the encounter rate for each species.

4.5 Results

4.5.1 Descriptions of the various vegetation communities:

The major vegetation communities in the PVNP region occurred in distinct species associations and were governed by a combination of landform types, altitude, aspect, and slope. Ten vegetation communities were identified comprising data from 576 quadrats. These are *Mixed herbaceous* (higher), *Stipa-Oryzopsis, Mixed herbaceous* (lower), *Polygonum-Stipa-Oryzopsis, Ephedra* dominant, *Aconogonum-Potentilla argyrophylla, Cicer-Aconogonum, Carex-Artemisia, Oryzopsis* and *Polygonum-Stipa-Oryzopsis*. The vegetation communities classified are represented in the map (Figure 4.2) and percentage area coverage was described in (Table 4.1).

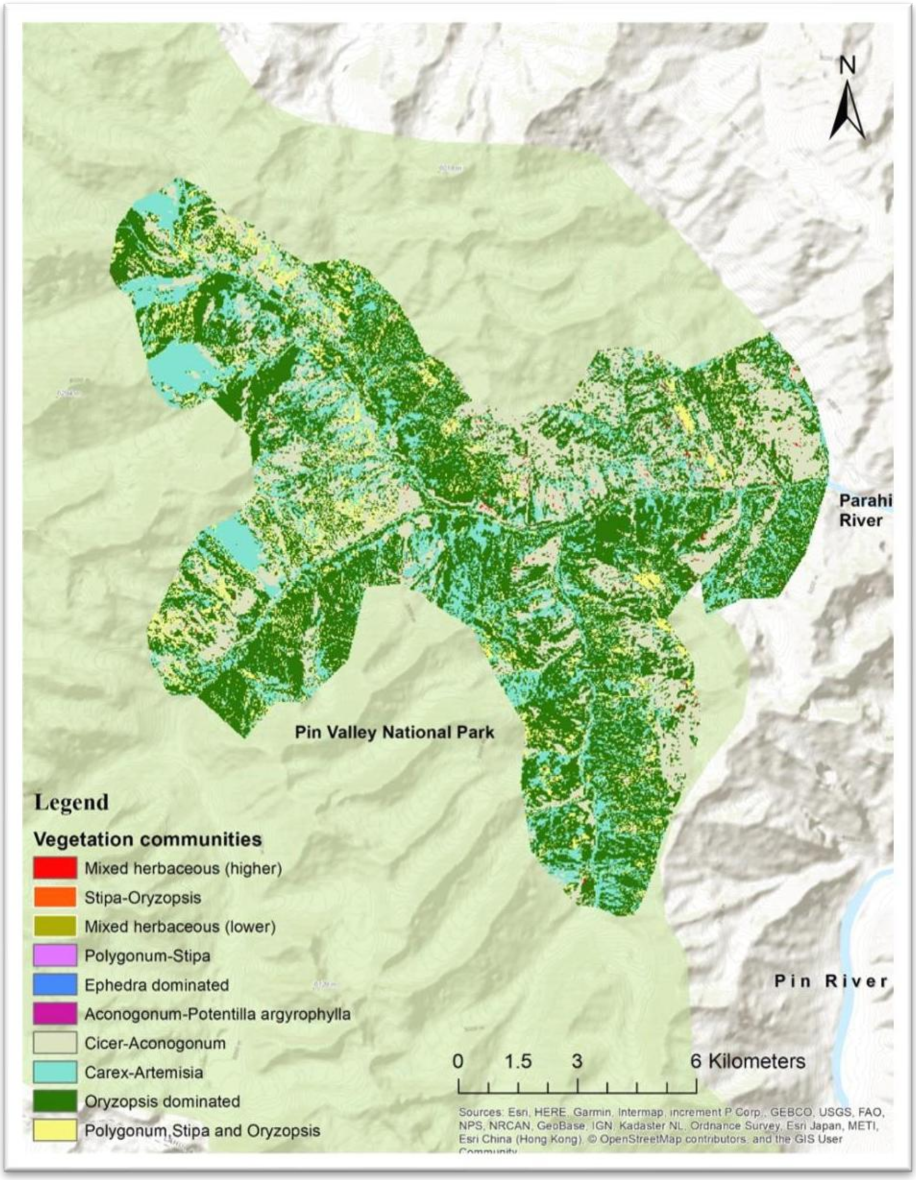


Figure 4.2. Map showing different vegetation communities in the Pin Valley National Park, Himachal Pradesh.

Table 4.1: Different vegetation communities and areas covered.

Communities	Area (%)	Area (sq. km)
Mixed herbaceous (higher meadow)	0.24	0.3807
Stipa -Oryzopsis	0.003	0.0045
Mixed herbaceous (lower)	0.004	0.0063
Polygonum-Stipa	0.004	0.0063
Ephedra dominated	0.02	0.03
Aconogonum-Potentilla argyrophylla	0.01	0.012
Cicer-Aconogonum	24.31	38.13
Carex-Artemisia	19.56	30.67
Oryzopsis	46.2	72.44
Polygonum,Stipa and Oryzopsis	9.7	15.2

Mixed herbaceous (higher meadow): This association covers a total area of (0.24%) of the sampled area with an average density of 0.24±0.05 m^{-2} and is made up of several herbaceous and Graminoid species, including *Geranium pratense, Potentilla argyrophylla, Bistorta affinis, Stipa sp. Oryzopsis sp., Poa alpina and Festuca kashmiriana* and *Lindelofia stylosa* etc. The vegetation composition generally formed above 4000 m altitudes and to the North (N), North East (NE), South West (SW) and East (E) aspects and relatively steep slopes.

***Stipa-Oryzopsis*:** The association covers an area of **(**0.03%) of the sampled area with an average density of 0.17±0.05m^{-2} and several grass species like *Poa* spp., *Lymus* spp., *Lindelofia stylosa*, *Polygonum cognatum*, *Nepeta* spp., *Hyssopus officinale*, *Arnebia euchroma* were the major species constituting this association. The association was widely distributed, occurring at altitudes between 3700-4500m and more on SW and N aspects. It occurred mainly on dry steep slopes and in flat and gentle slope areas.

Mixed Herbaceous (Lower): This association covers an area of (0.04%) of the sampled area with an average density of 0.26±0.08m^{-2} and is made up of species like Artemisia maritima, Ephedra gerardiana, Hyssopus officinale, Polygonum cognatum, Thymus serphyllum, Kobresia sp. Astragalus spp., etc. The association was widely distributed over N and S aspects and altitudes ranging between 3650-4700m. The landform type was old moraine and occurred mainly on lower slopes.

Polygonum-Stipa: This association covers an area of (0.04%) of the total sampled area with a density of 0.25±0.08m^{-2} and is made up of species constituting *Polygonum cognatum, Stipa capillata, Stipa orientalis, Melica persica, Poa* spp.*, Allium* spp.*, Lindelofia stylosa, Tragopogon gracile, Astragallus candolleanus, Rheum* sp. and *Linum perenne.* The association was widely distributed over Northern aspects and altitudes raging between 3700-4800m. Landform type was dry steep slopes and slopes ranged from medium to high.

***Ephedra* dominated:** This association covers an area of (0.02%) of the total area sampled with an average density of 0.14±0.05m^{-2} and was dominated by *Ephedra gerardiana*. This community dominated nearby riverbed areas and valley bottoms. The species association in this community were *Ephedra gerardiana, Saxifraga sp., Nepeta podostachyi, Polygonum cognatum, Lindelofia stylosa, Bupleaurum falcatum, Artemisia maritima,* etc. This community was restricted to the higher elevations above 3700m and generally found in all aspects mostly near riverine sites.

***Aconogonum-Potentilla argyrophyllai*:** This association covers an area of (0.01%) of the total area sampled and with 0.21±0.1m^{-2} density. The most frequent species in this association were *Ephedra gerardiana, Stipa orientalis, Saxifraga* sp.*, Rumex* spp.*, Eritrichium canum, Causinia thomsonii, Tanacetum gracile, Polygonum cognatum, Lindelofia stylosa,* etc. This association was found below 4200m altitude and distributed over riverbed areas, especially in the valleys and often in flat areas. It covered N, E, SE and S aspects.

***Cicer-Aconogonum*:** This association covers an area of (24.3%) of the total area sampled with an average density of 0.20±0.05m-² and species such as *Cicer microphyllum, Aconogonum tortuosum, Lindelofia stylosa and* Grasses were found in this community type. It was found mainly between 3,800m and 4,500m and the landform form type was scree. It was distributed more or less similar in all aspects with sandy and loose soil texture areas. It was rarely distributed at lower altitudes.

***Carex-Artemisia*:** This association covers an area of (19.5%) of the total area sampled with an average density of 0.22±0.05m-²and is covered by species of grasses, sedges and herbaceous plants like *Lindelofia stylosa* and *Ceratophyllum* sp. Altitude ranged between 3700-4500m. Steep slopes with moist areas are the characteristic feature of this community.

***Oryzopsis*:** This association covers an area of (46.2%) of the total area sampled with an average density of 0.40±0.13m-² and the associated species found were grasses, sedges and herbaceous species like *Aconogonum tortuosum, Silene* sp., *Artemisia* sp., *Arnebia euchroma*, *Geranium pretense*. This community was distributed mostly in the northern and southern aspects in the altitudinal range of 3700-4500 m. Landform characteristic was a dry steep slope and higher meadows.

***Polygonum-Stipa-Oryzopsis*:** This community association covers an area of (9.7%) of the total area sampled with an average density of 0.27±0.06m-² and is dominated by grass associated species such as *Stipa* spp., *Oryzopsis* spp., and herbaceous species such as *Polygonum cognatum*, *Geranium pretense*, *Aconogonum tortuosum, Silene* sp., *Artemisia* sp., *Arnebia euchroma*. This community was distributed mostly in the northern aspects in the altitudinal range of above 4500m. Landform characteristic was a dry steep slope and higher meadows.

4.5.2 Plant species richness, diversity and evenness with respect to various vegetation communities

Species diversity measures can serve as an index of habitat quality and may influence resource selection. Species richness pertains solely to the quantity of species within a community. Evenness measures control for species heterogeneity caused by a varying abundance of species in a community where a few are dominant and others are rare. Shannon-Wiener Index is a popular index to measure order or disorder in a community (Krebs 1999).

Richness was lowest in the *Aconogonum-Potentilla argyrophylla* community (S=6, H=1.5) and highest in *Cicer-Aconogonum* (S=62, H=3.1).

The lowest evenness (E=0.4) was shown by the *Cicer-Aconogonum and Ephedra in* each community and the highest evenness was shown by the (E=0.8) *Aconogonum-Potentilla argyrophylla* community. All other communities showed moderate evenness (E=0.5).

4.5.3 Vegetation structure and composition with respect to different landform units in the grazed and ungrazed pastures

To better understand the vegetation structure and composition further study was carried out on the basis of migratory livestock grazed and ungrazed pastures (Table 4.2). Overall vegetation composition tended to be dissimilar across ungrazed and grazed areas (Bray-Curtis Index of dissimilarity 0.62 and Morisita Index 0.83). The overall plant species richness was (S=90) in grazed areas and (S=95) in ungrazed areas. Density was 22.69±0.04 individual m^2 in grazed areas while in ungrazed areas it was 23.29±0.24 m^2. Species diversity was 3.63 m^2 in the grazed and 3.80 m^2 in the ungrazed areas. The overall difference in plant species density in grazed and ungrazed pastures was not statistically significant Mann Whitney U, P=0.052 (Figure 4.3).

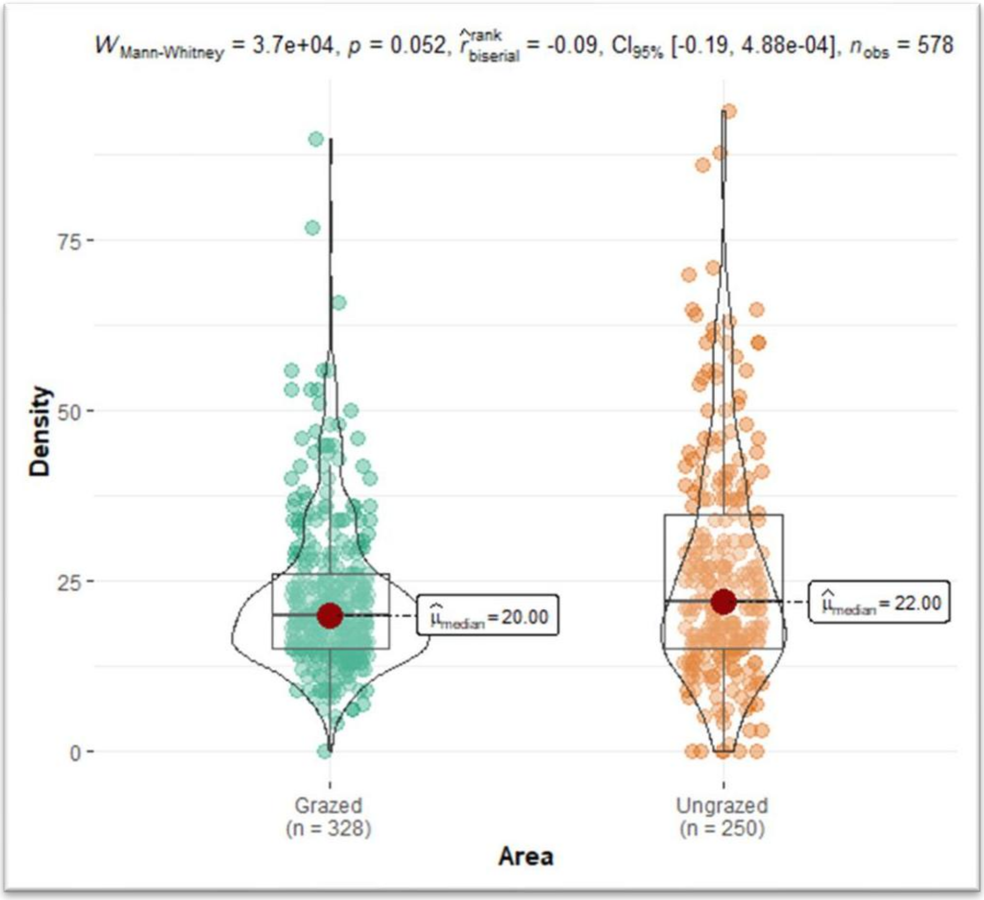


Figure 4.3: Violin plot comparing the significance difference between species density in grazed and ungrazed areas (Mann-Whitney U test).

Whereas, the difference in species richness was significant P=9.8e•08 (Figure 4.4).

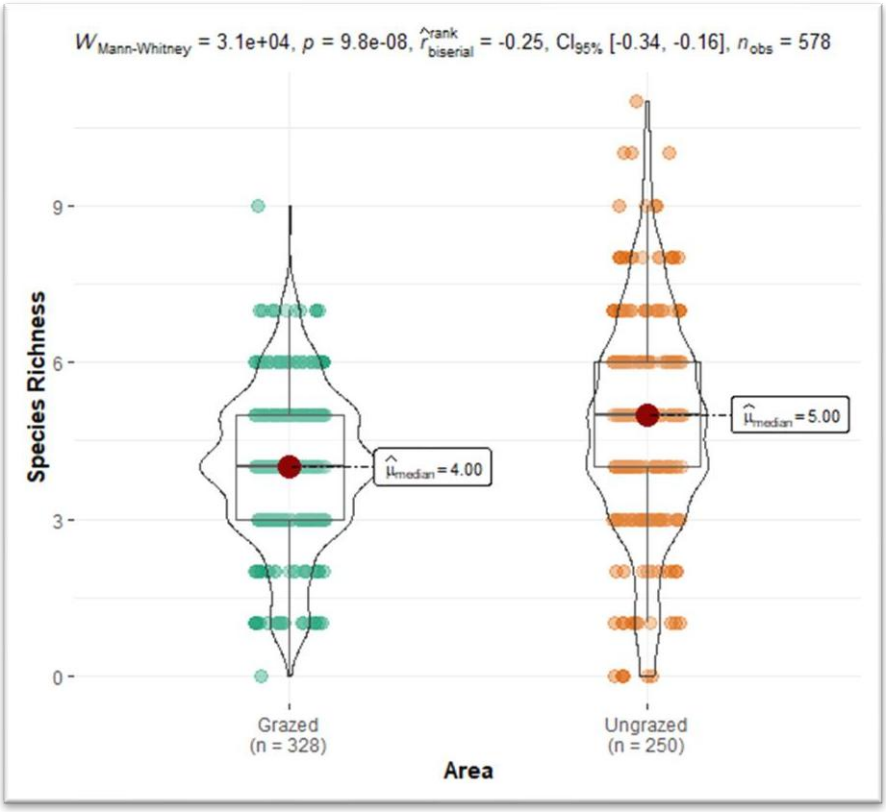


Figure 4.4: Violin plot comparing the significance difference between species richness in grazed and ungrazed areas (Mann-Whitney U test).

The vegetation composition in different landforms showed interesting patterns. Species density was higher in ungrazed areas except for meadow (21.57±0.06) and riverbed (16.32±0.05) landform types which had lower species density in comparison to the meadow (24.04±0.08) and riverbed (17.19±0.05) landform types in grazed areas. Likewise, species diversity was higher in ungrazed areas covering all landform types except for riverbed landform types. In riverbed landform type species diversity was (2.63±0.01) in grazed areas and (2.33±0.01) in ungrazed areas.

Overall, when comparing grazed and ungrazed areas across all landform units, the ungrazed areas consistently exhibited higher species richness, density and diversity (Table 4.2).

Table 4.2: Vegetation structure and composition pattern in the migratory livestock grazed and ungrazed areas.

Landform types	GRAZED				UNGRAZED			
	No. of quadrats	**Species richness**	**Density**	**Shannon Diversity (H')**	**No. of quadrats**	**Species richness**	**Density**	**Shannon Diversity (H')**
Meadow	71	31	24.04±0.08	2.76	47	42	21.57±0.06	2.92
Dry steep slope	83	45	20.63±0.05	3.20	37	56	37.65±0.08	3.38
Moraine	24	22	26.21±0.10	2.47	32	46	35.13±0.09	3.17
Riverbed	43	22	17.19±0.05	2.63	33	26	16.32±0.05	2.33
Rocky	10	14	24±0.10	2.20	21	30	30.57±0.06	2.85
Scree	81	35	23.86±0.06	3.19	80	44	23.10±0.05	3.24
Average	**326**	**90**	**22.69±0.04**	**3.63±0.01**	**250**	**95**	**23.29±0.24**	**3.80±0.04**

The significant statistical test value for overall landforms species density in grazed and ungrazed areas was P=7.26e-03 (grazed) and P=1.43e-12 (ungrazed) (Figure 4.5 & 4.6).

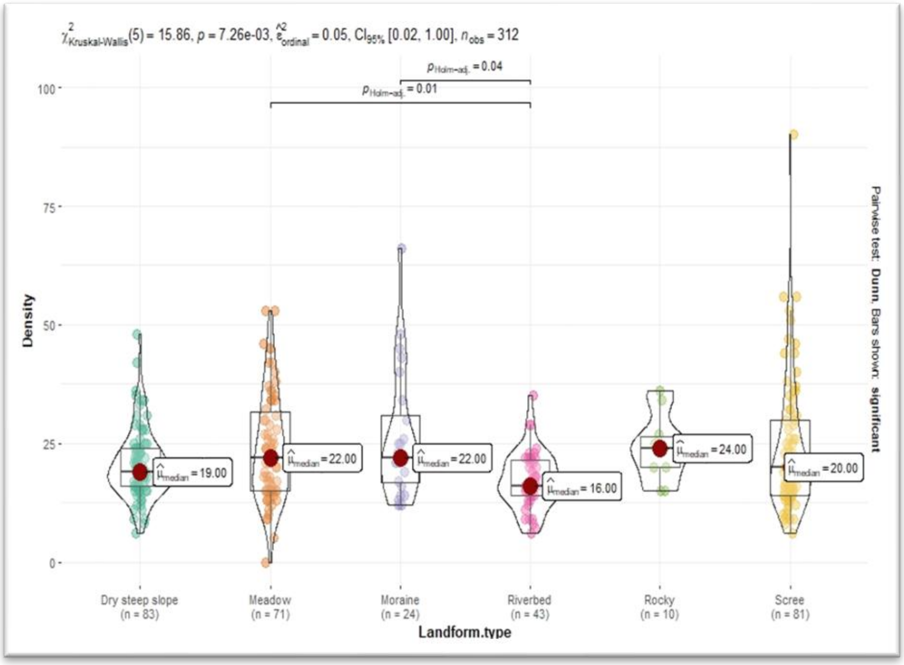


Figure 4.5: Violin plot comparing the significance difference between the species density within grazed pastures with respect to different landforms (Kruskal-Wallis test and Dunn pairwise test).

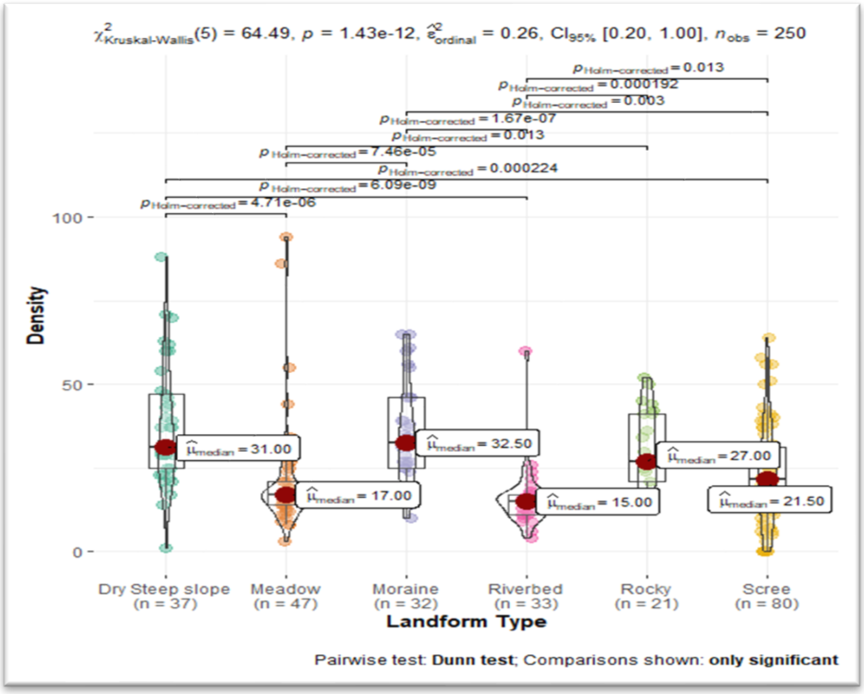


Figure 4.6: Violin plot comparing the significance difference between species density within ungrazed areas with respect to different landforms (Kruskal-Wallis test and Dunn pairwise test).

The pairwise Dunn test highly significant difference between the landforms in plant species density in the grazed area was observed between the meadow and riverbed landforms, P=0.01 (Figure 4.5). Whereas, the pairwise Dunn test highly significant difference between the landforms in the ungrazed area was between dry steep slope and riverbed landforms p=6.09e-09 (Figure 4.6).

Similarly, the significant difference in species richness between landforms was P=3.29e-04 in the (grazed area) and P=5.83e-10 in the (ungrazed area) (Figure 4.7 & 4.8). The pairwise Dunn test highly significant difference between the landforms in plant species richness in grazed landforms was between dry steep slope and riverbed p=5.31e-03 (Figure 4.7). Whereas, in ungrazed area it was between riverbed and rocky landforms p=7.7e-09 (Figure 4.8).

The species diversity was more or less similar in both grazed and ungrazed areas. Kruskal-Wallis test for diversity among different landforms was P=0.3 and there is no significant difference between samples.

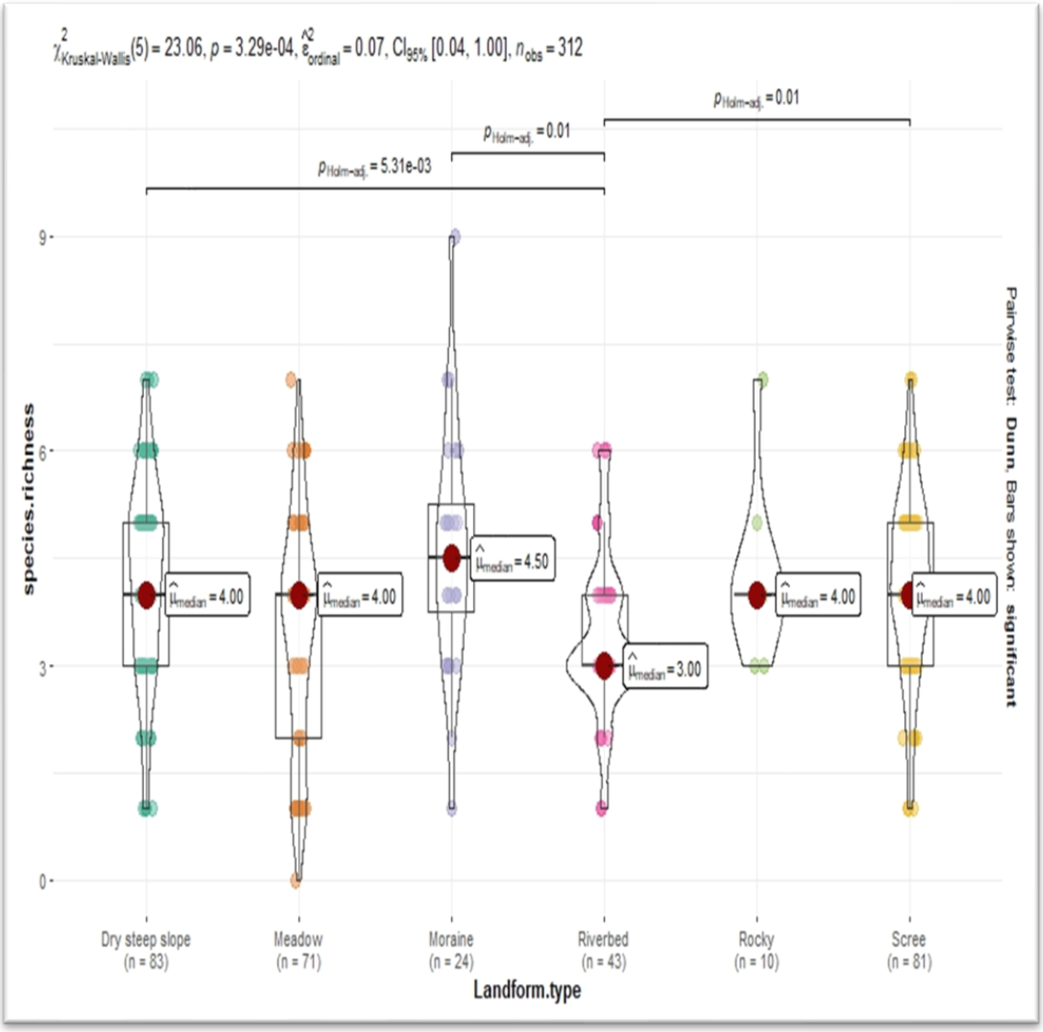


Figure 4.7: Violin plots comparing the significance difference between species richness within grazed pastures with respect to different landforms (Kruskal-Wallis test and Dunn pairwise test.

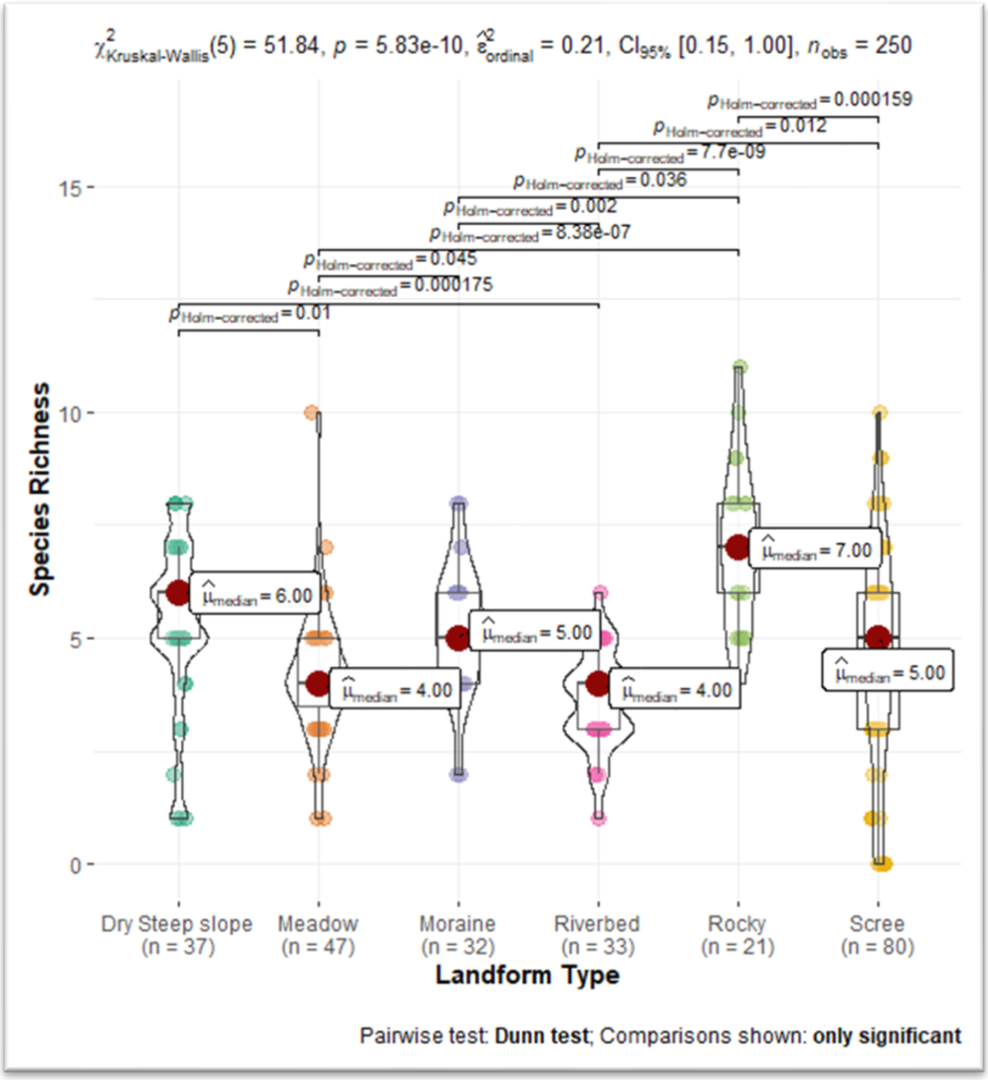


Figure 4.8: Violin plots comparing the significance difference between species richness within ungrazed pastures with respect to different landforms (Kruskal-Wallis test and Dunn pairwise test).

4.5.4 Vegetation, barren and rock cover percentage in the grazed and ungrazed areas with respect to different landform units

4.5.4.1 Grazed landforms

The area cover percentage of vegetation, rock and barren cover percentage in the grazed area was shown in (Figure 4.9). The vegetation cover in the grazed area was maximum in the Meadow (MD) landform (67%) followed by (DSS) (48%). Whereas, the lowest vegetation cover was observed in River bed (RB) (20%).

The barren land cover percentage was observed highest in the MO (51%) followed by RB (39%), DSS (25%) and Whereas, the lowest was observed in the Rocky interspersed (ROI) (5%) and scree (SC) (11%).

The rock cover percentage was maximum in the ROI (53%) followed by SC (51%). Whereas, minimum rock cover was observed in the MD (10%).

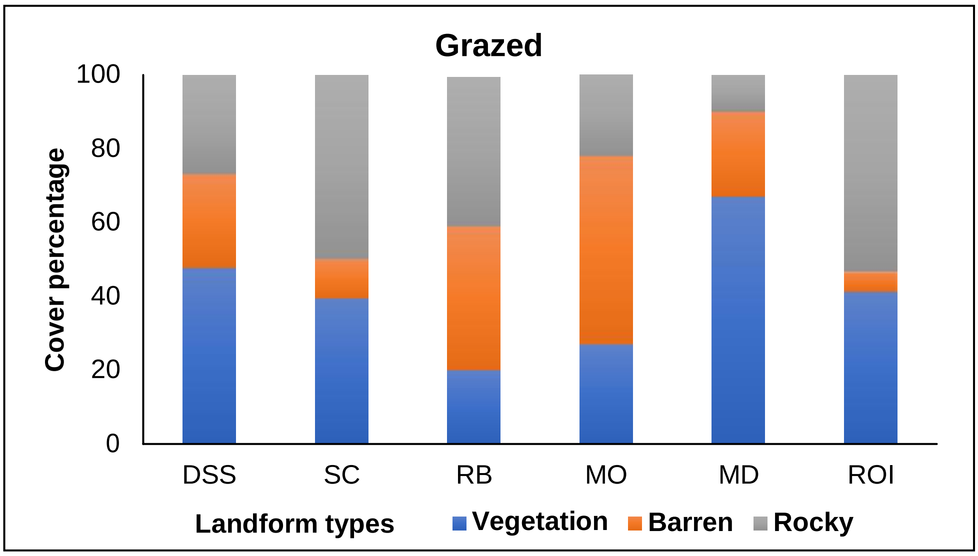


Figure 4.9: The percentage of vegetation, barrenness, and rock cover in grazed landforms.

4.5.4.2 *Ungrazed landforms*: The vegetation cover in the ungrazed area (Figure 4.10) was maximum in MD (65%) followed by DSS (41%). Whereas, the lowest vegetation cover was observed in RB (27%). The barren land cover percentage was observed highest in the DSS (44%) followed by RB (33%). Whereas, the lowest barren cover was observed in the SC (5%). The rock cover percentage was maximum in the SC (60%) followed by ROI (55%). Whereas, minimum rock cover was observed in the MD (15%). To test the significance difference in vegetation, barren and rock cover percentage between the grazed and ungrazed areas with respect to different landforms analyzed using the ANOVA and observed, there was a significant difference between the two (df=5, F=5.175, P=0.002).

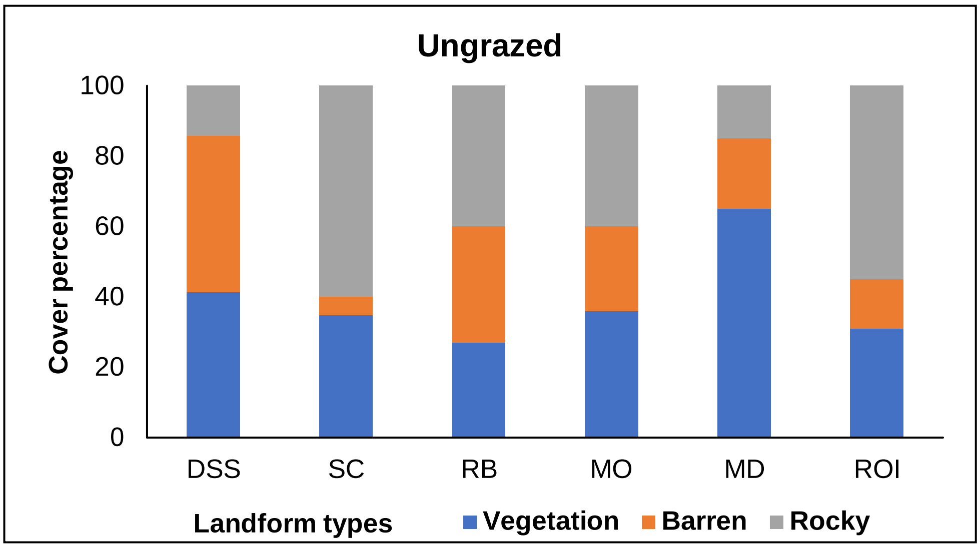


Figure 4.10: The percentage of vegetation, barrenness, and rock cover in ungrazed landforms.

4.5.5 Summer and winter Ibex sightings and group composition

Ibex classification was carried out based on distinctive characteristics from literature as well as those developed from preliminary observations. In many cases, identification was difficult on account of the large distance between observes and animals. Broad classification into different class categories is reported in.

Summer Ibex's total sightings were 15 with a total individual group size of 112 (Figure 4.11). The average herd size was 7.47±0.80 with the highest number percentage of Sub-adult females (SAF) (42%) and the lowest number of kids (9%). Whereas, in the winter the total sightings were 24 with a total individual number of 173 (Figures 4.12) and the average group size was 7.53±0.8. The SAFs were dominated with the highest percentage (33%) followed by adult males (AM) (23%) and Kids (21%). The smallest group size was sub-adult males (SAM) with only (5%).

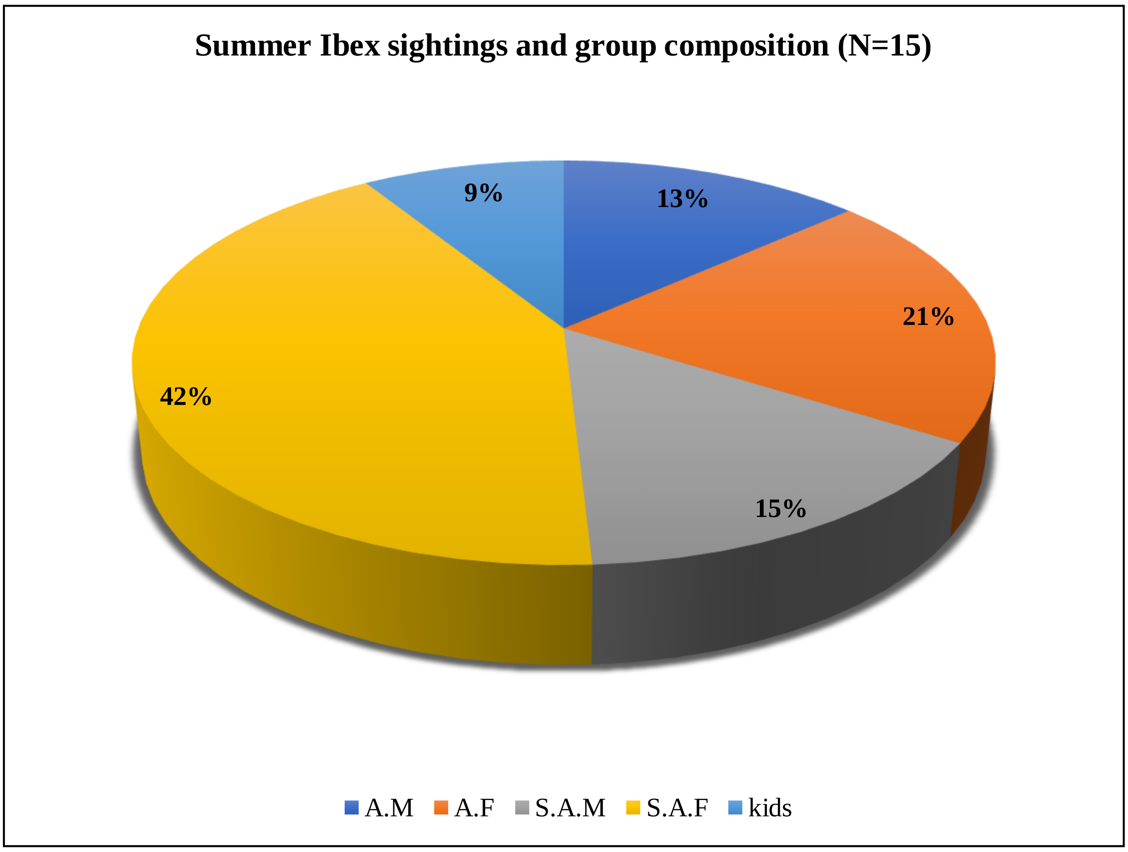


Figure 4.11: Summer Ibex group size composition in Pin Valley National Park. (A.M= Adult male, A. F=Adult female, S.A.M=Sub adult male, S.A. F=Sub adult female).

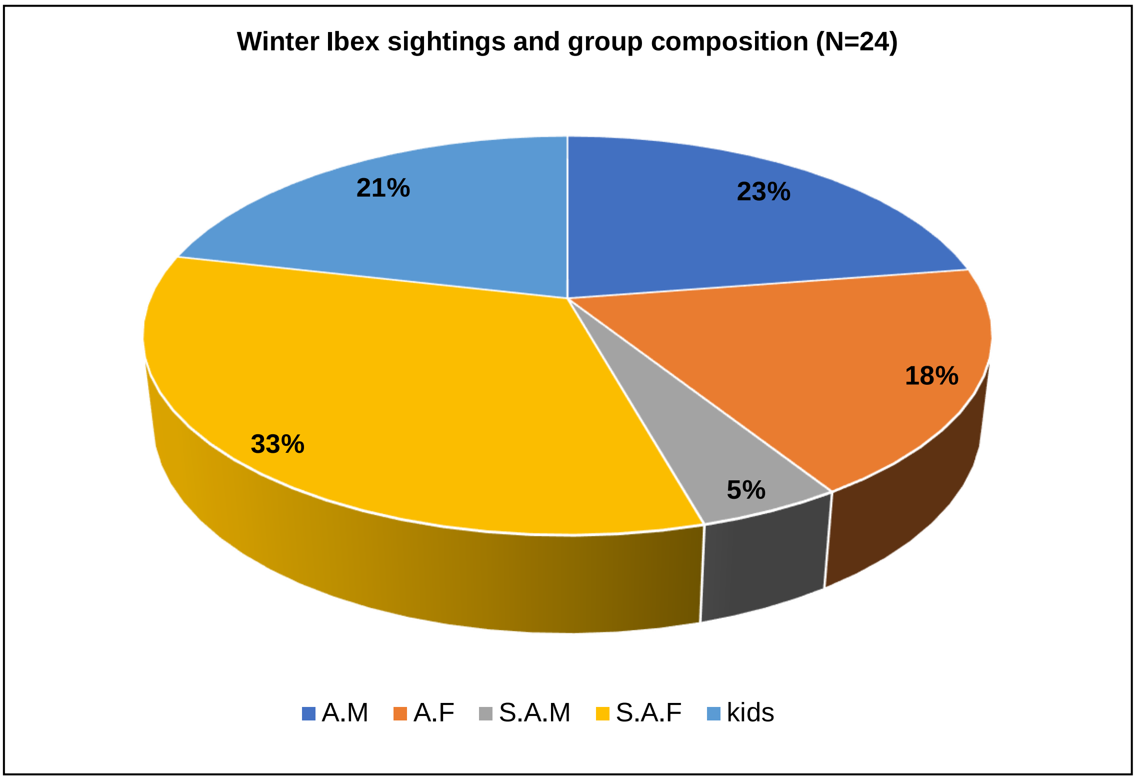


Figure 4.12: Winter Ibex group size composition in the Pin valley National Park.

4.5.6 *Ibex encounter rate*:

The encounter rate (one herd considered as one sighting) of ibex was recorded in two categories: grazed and non-grazed areas, as well as two seasons: summer and winter. During the peak summer season when migratory herders are present the average ibex encounter rate was 0.06 per km in the grazed areas, while the average encounter rate in the ungrazed areas was 0.27 per km.

In the winter season, the average encounter rate in the grazed areas was 0.22 per km. While, in the ungrazed area it was 0.32 per km. The encounter rate during winter in grazed and ungrazed areas were more or less similar and there was no significant difference between the two, ANOVA, F=0.5714, P=0.5.

During summer when migratory livestock were present there was a significant difference in ibex encounter rate between grazed and ungrazed areas, ANOVA, F=5.671, P=0.04 (Figure 4.13).

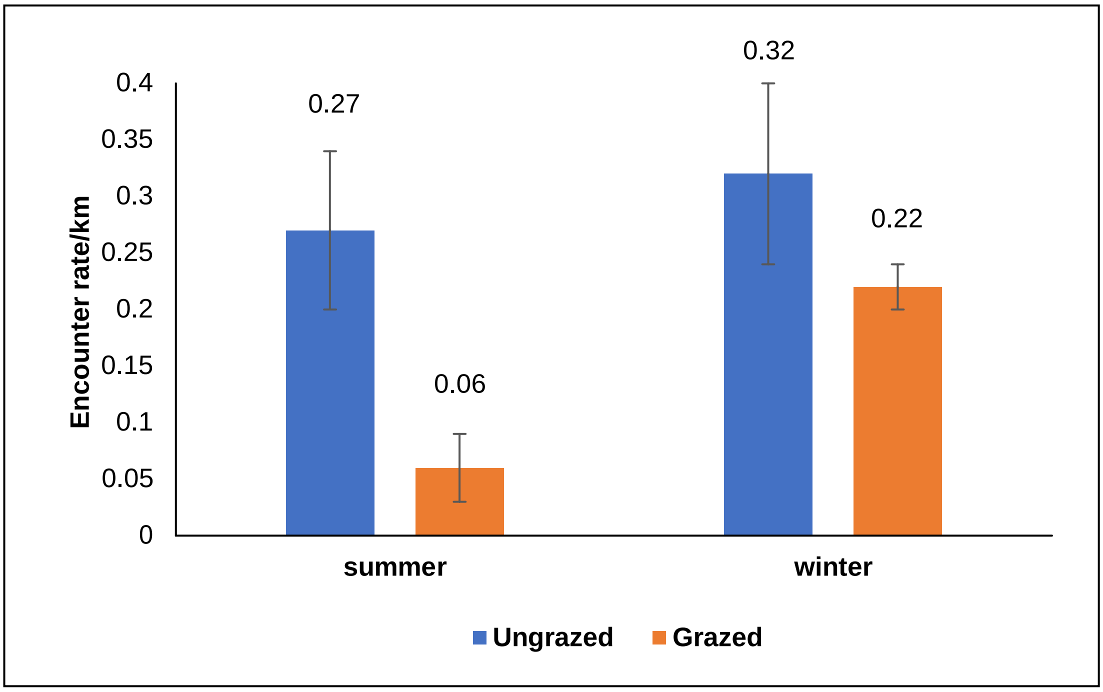


Figure 4.13: The significance difference in ibex encounter rate in the migratory livestock grazed and ungrazed areas during summer when livestock present and during winter when livestock absent.

4.5.7 Different habitat variables aspect, elevation and slope availability in Pin Valley National Park

Spatial habitat variables like aspect, slope, and elevation play a very important role in vegetation composition and heterogeneity improving the habitat quality of the area. The maximum cover percentage of the area by the aspect habitat variable categories was East and Southeast (17% each) followed by Northeast (14%) and South (12%). The lowest area percentage was covered by the North (6%) only.

The elevation ranges from 3741 to 6356 meters above sea level (asl). The maximum elevation range was between 4828-5178m asl. and 5178-5517m asl. with a percentage of (28% each) followed by 4408-4828m asl. (18%), 5517-6356m asl. (15%), and 3741-4408m asl. (11%).

The slope ranged between 0 to 75 degrees. The highest area cover percentage was in the range of 20-45 covering an area of (59%) followed by the 0-20 range with (35%) and the lowest 45-75 (6%) only.

4.6 Discussion

In order to anticipate the health of the environment for wild herbivores, vegetation is a key resource. Ibex and livestock both choose their resources based on the availability of food that meets their nutritional needs, both in terms of quality and quantity. In order to understand the feed availability for Ibex, the current study displays the pattern of vegetation composition in pastures that have been grazed by migratory livestock and those that have not. In contrast to pastures that were not grazed by livestock, we hypothesized that grazed pastures would exhibit lower plant species density, diversity, and richness.

The present study revealed ten major vegetation communities from both grazed and ungrazed pastures of the study areas. Out of the ten community types, the *Oryzopsis* community type was spread over a larger area followed by *Cicer-Aconogonum, Carex-Artemisia, Polygonum, Stipa and Oryzopsis.* Whereas, the rest had very low area coverage. Additionally, the *Oryzopsis* community was found in maximum landform types.

However, some vegetation community associations were restricted to certain landforms and altitudinal ranges. For example, like *Ephedra* community is most dominant in the lower altitudes near riverbeds and valley bottoms, while the *Oryzopsis* community associated with grass is dominant in the higher altitudinal ranges and seemed to be more preferred in the northern aspects.

The influence of slope was apparent in most vegetation associations. While the *Ephedra* dominants and mixed herbaceous associations preferred flat land and lower slopes. The mixed herbaceous (higher meadows), *Stipa- Oryzopsis* and *Aconogonum-Potentilla argyrophylla* were found on higher slopes. High altitude plant community distribution is primarily influenced by biological and environmental variables (Webber 1978; Chourasia & Singh,1996; Kala, 2000).

A total of six-landform types was broadly identified in the ungrazed and grazed areas. The highest species richness, diversity and density in the ungrazed areas were found in dry steep slopes while the least species richness, diversity and density were observed in riverbed areas. The reason may be due to the high rock cover percentage near riverbeds as these landforms are dominated by pebbles and the soil types are generally sandy soil with the dominant plant species *Ephedra gerardiana*. Likewise, in grazed areas species richness and diversity were high on dry steep slopes but high vegetation density was observed in moraine landform type. the soil type in the dry steep slopes was an intact soil system. Also, in dry steep slope areas plants are better exposed to sunlight. Additionally, in grazed areas least species richness and diversity were observed in rocky interspersed landform types. Whereas, the least density was observed in riverbed landform types. We observed heavy use of such areas by migratory sheep and goats. Livestock grazes in rocky areas in the daytime and rests in riverbed areas at night time. Therefore, species sensitive to trampling & grazing are likely absent from these areas (Rawat & Adhikari, 2005). Plant associations were more substantial in distinct landform units, and species associations had changed as landform units varied, regardless of aspect or elevation. As a result, the soil composition pattern could play a key role in better understanding the species connections in relation to other environmental gradients (personal observation).

The drainage moving from west to east, Pin Valley National Park demonstrates a decrease in atmospheric moisture from west to east, resulting in a change in flora with more xerophytic species occurring downstream abutting the Spiti valley (Manjrekar, 1997). The type of the terrain (Downes *et al.*, 1988) and elevation (Kala, 1998) have an impact on the variety of plant species in high-altitude areas like Ladakh. It exhibits a growth up to 4500m but drastically decreases at higher altitudes, mostly because of elements like craggy terrain with peaks and crags, nutrient-poor soils, and persistent snowfall. According to Fabienne *et al*., (1999), these difficult ecological conditions contribute to the existence of ecologically marginal conditions, which restrict the abundance and variety of plant species.

Present study revealed that the influence of aspect, elevation, and landform types was apparent in most vegetation associations. While the ephedra dominant community preferred lower altitude irrespective of aspects nearby the riverbeds. The plant community associations ranged between 3700m-4800m elevation. Manjrekar (1997) revealed that the influence of slope was apparent in most vegetation associations and the *Ephedra* dominant and *Carex* dominant associations preferred flatter and lower altitudinal terrain. While the alpine meadow, the *Oxytropis*-Grass-*Oryzopsis* and the *Geranium-Aconogonum*-Grass associations were restricted to the higher altitudes above 4000m. The aspect preferred associations were least and observed only in the Grass-*Lindelofia* association most in the S aspect, alpine mix, and *Oxytropsis*-Grass- *Oryzopsis* seemed to prefer the N, NE and E aspects (Manjrekar, 1997). The present study revealed that the preference for the aspect was mixed in most of the associations. The associations like *Polygonum-Stipa*, Mixed herbaceous (lower), and *Oryzopsis* were most represented in the Northern and Southern aspects and *Stipa-Oryzopsis* preference was in the SW and N aspects. Thus, the slope types, topographical characteristics, and altitudinal gradients all affect how the plant communities are composed. Species composition and heterogeneity are also significantly influenced by landform types.

The plant species which are sensitive to heavy grazing and trampling and also some common Trans-Himalaya plants are like *Rosa webbiana*, *Lonicera spinosa*, *Ephedra gerardiana*, *Juniperus* spp., and *Salix* spp. are absent from the overgrazed areas (Rawat & Adhikari, 2005). Ghoshal (*et al.,* 2017) revealed that the livestock grazing impact on the forage biomass. Whereas, in another study by (Rawat & Adhikari, 2005) revealed that high livestock camping sites vegetation are characterized by mostly unpalatable.

In a similar way an updated inventory of present study highlights that the vegetation in the livestock grazed areas have low species density, diversity and richness as compared to the livestock ungrazed areas in Pin Valley National Park. Therefore, our work offers valuable recommendations for maintaining rangelands at a landscape scale, which can be connected to food patterns at the microhabitat level, resulting in a more comprehensive strategy for appropriate conservation actions in the future.

4.7 Conclusion

In this study, we identified ten major vegetation communities within the research area. Among these communities, the *Oryzopsis* dominated community covered the largest portion of the total area, accounting for 46.2%. We observed that the ungrazed pastures exhibited higher plant species richness, density, and diversity compared to the grazed areas. This finding suggests that grazing activities may have a negative impact on vegetation composition and structure. By using the Bray-Curtis dissimilarity index, we quantified the vegetation dissimilarity between grazed and ungrazed areas, obtaining a value of 0.62. This indicates a noticeable difference in vegetation composition and species composition between the two areas. Additionally, among the top fifteen dominant species, *Stipa* sp. demonstrated the highest density.

In terms of vegetation cover percentage, both grazed and ungrazed areas exhibited maximum values in the MD landform, with percentages of 67% and 65% respectively.

Considering the resource availability for Ibex, it is noteworthy that the ungrazed areas offer higher dietary options and available space during the peak summer season compared to areas grazed by livestock.

Image 4.1: Into the wild documenting the beauty of nature's flourishing vegetation.

Image 4.2: Green meadow dominated by the *Landilofia stylosa*

Image 4.3: Overstocked migratory livestock in the historically grazed area.

Image 4.4: Trail of Ibex in the scree landform during summer season.

Image 4.5: Trail of Ibex in the search of food during winter season when landscape is covered with full of snow.

Image 4.6: Ibex feeding on *Rosa webbiana* during winter when all other vegetation is covered by the snow.

Chapter 5

Understanding interactions and resource use between wild (Ibex) and domestic ungulates

5.1 Introduction

The association of domestic livestock with wild herbivores is a common phenomenon in various regions where pastoral and agropastoral practices are carried out around the world. It is essential to comprehend feeding behaviour of an animal, in relation to forage preference and availability for the assessment and management of its habitats (Nelson & Leege, 1982). One of the most significant factors affecting the patterns of habitat use and behaviour of an animal is the availability and quality of forage (Putman, 1988).

Globally, the effects of livestock grazing on native animals constitute a significant conservation problem (Prins, 1992; Fleischner, 1994; Voeten, 1999). This holds especially true in India, which is the home to largest population of livestock in the world, with 520 million individuals (FAO, 2002), and this number continues to grow 6% rise in between years 1984 and 1994 (WRI, 1996). India's wildlife reserves occupy less than 5% of the country's land, and yet, even these areas are not immune to the influences of human activities and livestock. According to estimates, more than 3 million people reside inside Indian wildlife reserves, and livestock grazing is one of the most common land uses (Approximately three-fourths of India's wildlife reserves support livestock populations (Kothari *et al*., 1989). The ability to manage trans-Himalayan wildlife is hampered by a lack of knowledge and understanding of livestock and wild herbivore diets, as well as the effects of livestock on wild herbivores (Harris & Miller, 1995). The low abundance of wild ungulates observed may be attributed to the presence of livestock, shepherd dogs, and habitat degradation (Bhattacharya & Sathyakumar, 2011). As a result, the issue of how local human resource use affects indigenous species remains poorly understood (Mishra & Rawat, 1998). For millennia, the majority of the Indian trans-Himalayan landscape has been rooted in a pastoral heritage (Handa, 1994; Schaller, 1998).

Over three millennia ago, pastoral activities began in the Spiti Valley, which covers a surface area of 12,000 km² (Handa, 1994). According to Mishra *et al*., (2001), the rangelands in the Spiti Valley are currently overstocked, leading to an excessive number of grazing animals and posing a threat to livestock productivity. The overstocked rangelands cause a decline in resource availability, particularly linked to stocking density, resulting in significantly poorer performance of adult female livestock compared to rangelands with lower stocking densities (Mishra, 2001; Mishra *et al*., 2001).

Supplemental feeding enables the maintenance of livestock populations even when natural resources are scarce. However, the impact of overstocking density on the wild herbivores of the trans-Himalaya remains unknown (Mishra, 2001). Disturbances caused by livestock grazing pose significant threats to the wild species (Mallon, 1983; Mallon *et al.,* 1997; Raghavan, 2003).

Pin Valley National Park, situated in this region, is bordered by communities historically reliant on its resources. Eight valley villages depend on the park to varying extents for fuelwood, fodder, livestock grazing, and farming (Bhatnagar, 1996; Bhatnagar, 1997; Manjrekar, 1997).

Traditional resource utilization practices in these communities, including uprooting and collecting shrubs/herbs, intensive livestock grazing by migratory grazers, and to a lesser extent, local grazing and dung collection, likely exceed sustainable limits (Bhatnagar, 1996; Bhatnagar, 1997; Johnsingh *et al*., 1999; Manjrekar, 1997; Mishra, 2000, 2001, 2002; Bagchi *et al*., 2004). Historical livestock grazing patterns significantly impacted the distribution and population of wild ungulates (Mishra, 2001; Bagchi *et al*., 2002).

The genesis of this study is rooted in significant research findings regarding the interaction between livestock and wild herbivores, particularly focusing on Ibex. Previous studies have shed light on various aspects of this interaction. Bhatnagar and Manjrekar (1997) highlighted the potential role of migratory livestock as carriers of diseases that can impact Ibex populations. In contrast, Bhatnagar *et al.,* (2000) found that resident livestock did not interfere significantly with Ibex resource selection, suggesting a lack of direct competition for resources between resident livestock and Ibex.

Considering these significant research findings, this study aims to delve further into the intricate dynamics between livestock and wild herbivores, with a specific focus on Ibex and migratory livestock goat and sheep. The study seeks to investigate the trophic and spatial niche interactions between migratory and Ibex. Considering the aforementioned concerns, the current study aimed to assess the extent of resource (diet) overlap among these species. After assessing diet overlap, we proceeded to investigate further by analyzing the encounter rate of ibex in two different rangelands, each with distinct livestock grazing histories. The aim was to determine whether the presence of livestock had an influence on ibex during the peak summer season, characterized by high livestock stocking density and intense grazing pressure, as well as during winter when no livestock grazing occurred.

We formulated two straightforward predictions: (i) during the peak summer period in the historically grazed area, the encounter rate of ibex would be low in the presence of livestock grazing, and (ii) during the same period, the encounter rate of ibex would be high in the livestock ungrazed area. We conducted similar tests during the winter season when there was no livestock present in both the grazed and ungrazed areas.

5.2 Materials & methods

5.2.1 Tracking Ibex along the trails

Trail monitoring was employed to collect data on the trophic and spatial use of ibex. The method involved traversing both grazed and ungrazed pastures from the base camp, covering a total distance of approximately 832 km over 64 days between June, 2018 and January, 2019. The trails in the livestock-grazed sites included routes such as Rachegaon to Kinlung bridge (approximately 5.53 km), Kinlung bridge to Changlung (around 2 km), Kinlung bridge to Kinlung nala (approximately 3.16 km), Kinlung bridge to Nur (about 6.26 km), Khamedngar to Debsa (around 3.84 km), and Khamedngar to Chhoham (approximately 5.22 km). In total, approximately 26.01 km were covered in the grazed sites. On the other hand, the trails in the ungrazed sites comprised Kidulchhu to Gyachang (approximately 2.26 km), Gyachang to Gochok (around 2.1 km), Gochok to Thango (approximately 2.74 km), Thango to Shrim (about 3.11 km), and Shrim to Bobrail (around 9 km). In total, approximately 19.21 km were covered in the ungrazed sites.

In the summer period, additional information was gathered by conducting specific trail walks in the higher-altitude regions (>4000-5000m) between June and September. Due to uncertain snowfall, winter trail walks were limited and challenging to establish. However, whenever feasible based on weather conditions, regular surveys were conducted. Ibex groups encountered during the trail walks were classified by sex and age (Chapter 3), and feeding habits and habitat variables were documented.

Regarding migratory livestock, they had designated pasture lands for each herd group and were required to graze within their specified areas. The grazing pattern was entirely dependent on the owners, who herded the animals according to their own systems. Therefore, studying the habitat selection pattern of goats and sheep was not deemed significant. However, the same methodology employed for ibex was followed to assess their dietary habits.

5.2.2 Ibex and livestock food habits

5.2.2.1 Bite count (Direct observation):

This method required habituated Ibex individuals to human presence and enabled the quantification of utilization through bite counts. However, it did not simultaneously measure availability. One limitation of this approach was the tendency to overlook smaller plants growing within the microenvironment of larger plants, resulting in their underestimation (Manjrekar, 1997).

Despite attempts to track a group of Ibexes and record their feeding behaviour using focal animal sampling, it was challenging to approach the animals, especially during peak summer. Consequently, observations were primarily conducted from a distance using binoculars to enhance visibility. However, this method made it difficult to identify specific food items consumed by the ibex. Additionally, the shy nature of the ibex in the PVNP further complicated the observation and identification of their consumed plant species. Therefore, direct observation data was not included in the analysis.

5.2.2.2 Quantification of feeding signs (Indirect observation):

Indirect quantification of feeding signs was employed as an alternative method to study the feeding behaviour of shy and easily disturbed ungulates. This method allowed researchers to quantify the utilization of food resources by the studied species and provided an index of availability in the feeding area. However, it did not account for the initial choice of feeding sites by the animals.

To study ibex groups, visited feeding sites shortly after the animals had left, enabling the differentiation between fresh and old feeding signs. Randomly placed 1x1m quadrats were used to record the number of individuals of each species present and the number of feeding signs within each quadrat.

Livestock feeding was also quantified using the same method, with four randomly selected individuals from each herd group followed during the morning and evening for a total of two observation sessions. Direct focal observations were conducted to verify the feeding signs recorded in the quadrats. This method was employed for both ibex and livestock to compare their diet overlap. A minimum of five quadrats were placed at each site to assess the availability and composition patterns of vegetation used by the animals. The percent available and use of plant species were determined by following Manjrekar (1997):

Percent diet species available = (Total number of individuals of a specific species recorded) / (Total number of individuals of all species recorded) × 100

Percent diet species use = (Total number of individuals of a specific species fed) / (Total number of individuals of all species fed) × 100.

5.2.2.3 Microhistological techniques (Indirect observation):

This is a widely employed indirect method for studying the feeding habits of animals. This approach has proven particularly valuable in investigating the winter-feeding behaviours of Ibex. During the winter season, identifying forbs becomes challenging due to the senescence of vegetation. To avoid confusion with livestock faecal pellets, fresh Ibex faecal pellets were specifically collected from confirmed areas.

One of the advantages of microhistological analysis over examining feeding sites is that it allows for the identification of even those species consumed in small proportions. Often, small plant species are overlooked at feeding sites because they are entirely consumed, leaving no visible trace on the ground. Additionally, smaller plants might grow in close proximity to larger plants, making it more likely for them to be missed during recording.

Nevertheless, this method does have its disadvantages. The proportions of certain plants may be overrepresented or underrepresented due to variations in digestibility. This bias has been extensively discussed in the literature, and researchers have proposed using correction factors to account for the differences in digestibility. Correction factors require establishing the in-vitro dry matter digestibility of the food plant species and necessitate obtaining rumen fluid from the animal species under study. It is important to note that microhistological analysis provides information solely on seasonal utilization and does not indicate the animals' seasonal preferences in the absence of availability data.

5.2.2.4 Collection of Ibex faecal samples:

In terms of collecting ibex faecal samples, fresh pellets were gathered twice a month throughout the year from various aspects and altitudes during the vegetation sampling and trail monitoring. To avoid confusion with livestock faecal matter (goats and sheep), only fresh pellets of ibex and areas where no livestock grazing was allowed were sampled. Inaccessibility and time constraints did not allow the collection of samples from most of the areas. The collected samples tagged seasonally and kept separately. The samples were air-dried and kept in an oven overnight at 60°C before analysis. Subsequently, the well-dried samples were finely ground into a powder with a 1mm mesh using a Cyclotec electric grinder. The seasonal variations in crude protein, phosphorous, potassium, and ash content of the ibex faecal matter were analysed to observe changes in forage quality.

Laboratory protocols for the Microhistology method involve two main steps: The first step is the preparation of reference materials of food plant species to identify their epidermal and cellular structures. The second step is the microhistological examination of faecal samples to estimate the frequency of plant species fragments consumed by animals.

During vegetation sampling and feeding observations in the field, reference plant samples were collected. To preserve the plant form and facilitate later separation of different parts (e.g., leaf, stem, flower, and fruit), the collected samples were stored in newspapers or rough papers. Upon returning to the research station, all plant materials were oven-dried and stored in labelled, airtight plastic bags. The dried materials were then ground to a fine powder using a Cyclotec grinder, ensuring they would fit through a 1 mm mesh. The processed materials were subjected to microbiological examination following the methods described by Sparks and Malechek (1968) as discussed by Manjrekar (1997).

A small quantity of the powdered material was mixed with hot water for 1 minute to partially remove pigments that could obscure the characteristic epidermal and cellular patterns of the species. The material was then passed through a fine sieve to remove particles that were too small for identification. The remaining material was placed on a microscope slide, and a drop of Hertwig's clearing chemical solution was added (Manjrekar, 1997; & Scott & Dahl, 1980). The slide was gently heated until the liquid evaporated, allowing the clearing solution to remove the remaining plant pigments through its bleaching action. After cooling, a drop of Hoyer's mounting medium solution was added, and the plant material was evenly spread across the slide before covering it with a coverslip. Excess mounting medium was gently heated and removed, and air bubbles below the coverslip were eliminated by cooling the slide with a moist cloth. The slides were oven-dried at 60°C until the mounting medium hardened. This protocol was followed for all reference plant species collected. The slides were then viewed under a microscope at 100x magnification to observe characteristic epidermal patterns for later comparison with fragments found in faecal samples. Reference slides were prepared for 20 major forage plant species.

Similarly, faecal samples from Ibex were collected in the field every month. The faecal material was air-dried and stored in labelled plastic bags. Later, the samples were completely dried in an oven at 60°C before being ground into a fine powder using a Cyclotec grinder. In the laboratory, faecal pellet composites were created on a seasonal basis, with 10 pellet groups for spring, 14 for summer, 16 for autumn, and 16 for winter. The faecal material was prepared for microhistological analysis following the same method as the plant material. Five slides were prepared from each composite group. Due to logistical reasons, the plant species could not be identified at the species level. Instead, all composite group samples were identified as monocot or dicot. Fragments that could not be identified were grouped as unidentified, contributing to the diet.

A few assumptions underlie the procedure:

i. The faecal sample fragments were randomly distributed on the slide.

ii. The major fragments were equal in size.

iii. Twenty microscope fields were examined on each slide, and all identifiable fragments within these fields were recorded. The percentage of each species constituting the diet was determined by dividing the number of identified fragments by the total and multiplying by 100, following the approach outlined by Sparks and Malechek (1968).

5.2.3 Diet quality assessment through chemical analysis:

As mentioned earlier in the Microhistology section, the same dried and ground faecal samples were used for chemical analysis. The samples were stored in air-tight zip lock bags to maintain their integrity.

Crude protein estimation:

The nitrogen content in the samples was determined using the Kjeldahl method (AOAC 1975) to estimate the crude protein content. The percentage of crude protein, on a dry matter basis, was calculated by multiplying the total nitrogen content by a factor of 6.25.

Phosphorus (P) estimation:

A flame photometer was utilized to estimate the percentage of phosphorus (P) and potassium (K) in the ibex faecal samples.

Ash content determination:

The ash content was determined by combusting a known weight (0.5g) of the sample in a muffle furnace at 600°C for 6 hours. The proportion of residue remaining after the combustion of organic matter represented the ash content in the faecal sample.

Potassium (K):

The K content was also estimated, but due to errors in some readings, the results of the K content were not considered.

5.3 Analysis

5.3.1 Vegetation community preference by Ibex:

The broadly classified vegetation community detailed in Chapter 3 was utilized to gain a comprehensive understanding of Ibex feeding habits. To achieve this, the percentage of area covered by each vegetation community was calculated, and within those areas, the presence of Ibex was recorded. The vegetation was measured using quadrat methods, while Ibex presence was recorded through direct sightings and indirectly through pellets found during vegetation sampling. Using this data, the proportion ratio of community availability (area covered by each vegetation community) to Ibex use (presence of Ibex within each community) was calculated. This ratio provided insights into the selectivity of Ibex towards specific vegetation communities. Additionally, we analyzed the ratio between Ibex use and community availability to assess the extent to which Ibex utilized the available resources.

By employing these calculations and ratios, we evaluated the preferences of Ibex for specific vegetation communities and the availability of these communities for Ibex feeding (Figure 1 and 2).

The package "Adehabitat HS" in R version 4.2.2 (2022) was utilized to determine habitat and vegetation community preferences and calculate the use availability ratio.

For vegetation community use and forage species use overlap, the packages "spaa" and "Electivity" were employed in R version 4.2.2 (2022) and R Studio (2022). The "spaa" package provides miscellaneous functions for analysing species association, while the "Electivity" package includes indices for measuring the utilization of food types (r) relative to their abundance or availability in the environment (p). Preferred food types are those that constitute a larger proportion of the diet compared to their availability, while avoided food types are proportionately underrepresented in the diet. The following indices were used:

Pianka's index:

Used to analyse diet overlap between goat, sheep, and ibex. The index value ranges between 0 and 1, where 0 indicates no overlap and 1 indicates complete overlap.

Levin's index:

Used to calculate the niche width of the available resources (diet) for the three-ungulate species.

Ivlev's electivity index:

Ivlev's selectivity index (Ivlev 1961) used to describe the preference and selectivity of each plant species, concerning the abundance or availability of plant species in the environment (Brown *et al*., 2018).

$$Ei = (ri - ni)/ (ri + ni)$$

where Ei = species selectivity, ri = the proportion of a species in the diet, and ni = the proportion of that species available in the habitat. Values range from −1 to 1, −1 indicates total avoidance, 0 indicates that an item is taken in proportion to its abundance in the ecosystem, and 1 indicates total preference.

5.3.2 Spatial use:

Ibex encounter rate was used as a quantitative measure of animal behaviour, population dynamics, species interactions, and habitat use. It was employed to assess the significance of differences in ibex use between migratory livestock-grazed and ungrazed pastures, specifically during the presence of herders in summer and their absence in winter. The encounter rate comparison helps understand the utilization differences in grazed and ungrazed pasturelands. ANOVA was used to test the significance of the difference in Ibex use between grazed and ungrazed pastures.

To evaluate the spatial use by ibex, Kernel density estimation was employed as a statistical technique. It allowed for the estimation of the probability density function of ibex's spatial utilization based on observed data points, providing insights into their spatial distribution and extent of space utilized during the summer and winter seasons.

5.4 Results

5.4.1 Vegetation community preference:

The Ibex was shown to have a highest preference for PSO community followed by other positively preferred communities like APA, CA, Ory, and SO. Whereas, ED community was strongly avoided (Figure 5.1).

The communities like *Cicer Aconogonum*, *Aconogonum-Potentilla argyrophylla and Polygonum-Stipa-Oryzopsis* had the highest availability to usage ratio whereas, other communities had more or less similar usage availability ratio (Figure 5.2). The significance difference between availability and use ratio shown p=<0.05 in all communities except for *Stipa-Oryzopsis*, *Polygonum-Oryzopsis*, *Oryzopsis* communities p=>0.05 at Bonferroni classement based on 95 % confidence intervals on the differences of Wi (Table 5.1).

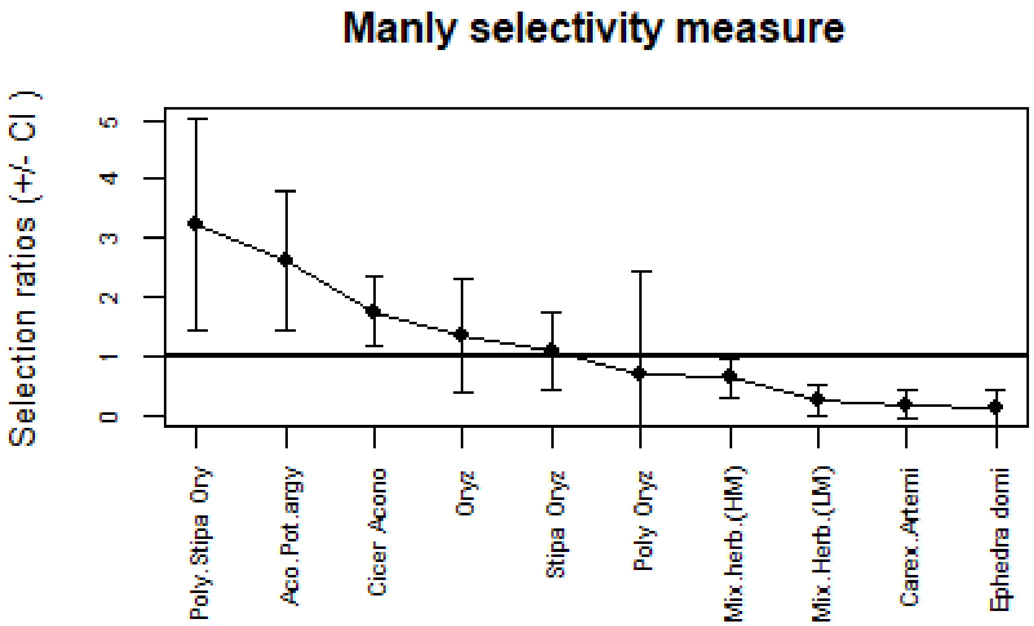


Figure 5.1: Manly's selection ratio of different vegetation community's preference of Ibex during the exploratory period.

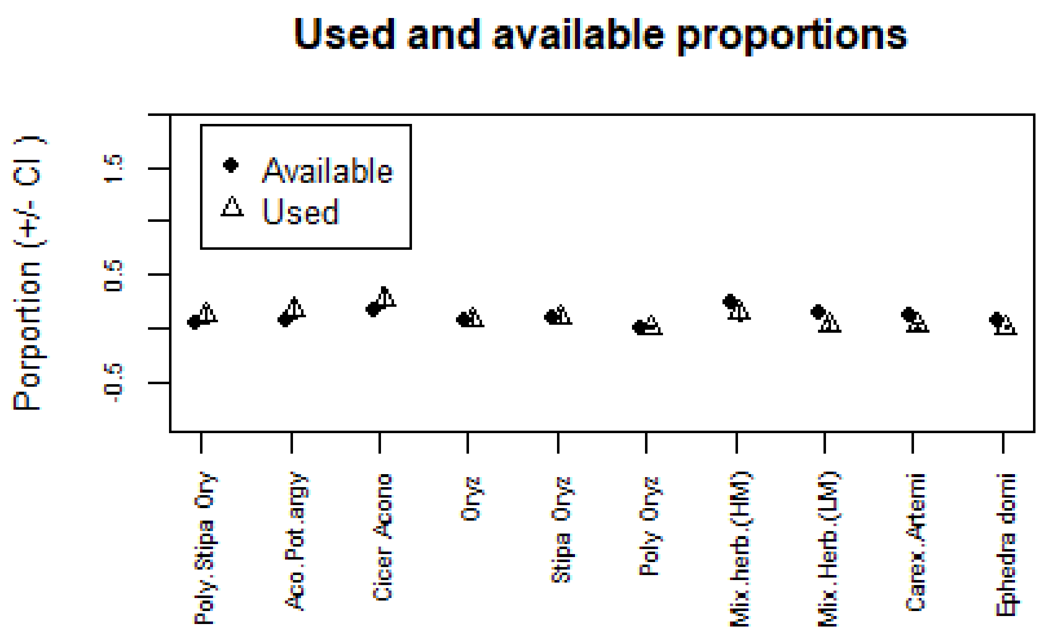


Figure 5.2: Manly's selection ratio of different vegetation community's availability and use ratio by Ibex in the Pin Valley National Park.

Table 5.1: Table of ratios (p-values should be compared with Bonferroni level= 0.005).

Vegetation communities	Used	Available	Wi	SE. Wi	P	Bi
Mixed Herbaceous (HM)	0.150	0.240	0.624	0.123	0.002	0.053
Mixed Herbaceous (LM)	0.034	0.140	0.243	0.107	0.000	0.020
Stipa-Oryzopsis	0.109	0.100	1.088	0.257	0.731	0.092
Polygonum-Oryzopsis	0.007	0.010	0.680	0.678	0.637	0.057
Ephedra dominated	0.007	0.060	0.113	0.113	0.000	0.010
Aconogonum-Potentilla-argyrophylla	0.184	0.070	2.624	0.456	0.000	0.221
Cicer-Aconogonum	0.279	0.160	1.743	0.231	0.001	0.147
Carex-Artemisia	0.020	0.120	0.170	0.097	0.000	0.014
Oryzopsis	0.082	0.060	1.361	0.376	0.338	0.115
Polygonum-Stipa-Oryzopsis	0.129	0.040	3.231	0.692	0.001	0.272

#Bonferroni classement Based on 95 % confidence intervals on the differences of Wi.

Global Manly's Selection ratio with ±95 percentage confidence intervals (CI) of the community types analysed in each category. Black dots (•) in (Figures 1) and (Figure 2) represent the mean selectivity rate of each community type. A community type can be considered as avoided if the global selection ratio is located in the 0-1 interval, while it can be considered positively selected if the value is larger than 1.

5.4.2 Summer forage species availability, use and preference:

Food selection and forage preferences are studied at multiple level to understand feeding habits of ungulates more in depth. At the broadest level, species preference for given vegetation types in terms of proportion of use v/s the proportion available are compared (Table 2). The following series of species list in the given table summarise food selection by ungulates. Major species that contribute to the ungulate's diet (based on the feeding sign observation) were only included for this comparative analysis. The diet comparative study was conducted between the ibex, goat and sheep. Ibex diet was analysed in to two parts as (Ibex C) diet observed in the livestock ungrazed or control sites and (Ibex E) diet observed in the livestock grazed areas. Goat and Sheep obviously comes under the grazed area only.

Use of forage species by Ibex in ungrazed area (Ibex C)

Ibex in the ungrazed areas appears to select total 28 (n=546) forage species of 50 (n=1716) species recorded in the quadrats. The top forage species used with respect to availability was *Aconogonum tortuosum* available (2.86%), use (7.51%). Some unpalatable forage species like *Polygonum cognatum* highly available (11.95%) but use was (0%).

Use of forage species by Ibex in grazed area (Ibex E): The Ibex in the grazed areas appears to select total 28 (n=337) forage species of 36 (n=811) species recorded in the quadrats. The top forage species used with respect to availability was *Aconogonum tortuosum* available (5.06%), use (10.39%). Unpalatable forage species *Polygonum cognatum* highly available (6.17%) but use was (0%).

Use of forage species by Goat: Goat appears to select total 37 (n=926) forage species of 47 (n=1712) species recorded. The top forage species used with respect to availability was *Oryzopsis* sp. available (23.31%), use (35.85%). Unpalatable forage species *Ephedra gerardiana* available (3.33%) and use (0%).

Use of forage species by Sheep: Sheep appears to select total 28 (n=945) forage species of 45 (n=1716) species recorded. The top forage species used with respect to availability was *Oryzopsis* sp. available (25.93%), use (42.96%). Unpalatable forage species *Mentha longifolia* available (1.96%) and use (0%).

5.4.3 Trophic niche overlap and niche width: The diet overlap between sheep and goat was maximum (0.97) followed by ibex ungrazed and ibex grazed (0.79), sheep and ibex ungarzed (0.23), sheep and ibex grazed (0.21). Least observed between the goat and ibex ungrazed and goat and ibex grazed (0.19 each).

Niche width was maximum in the ibex ungrazed diet (10.48%) followed by ibex grazed (9.13%), Goat (6.25%) and lowest in Sheep (4.57%) (Figure 5.3).

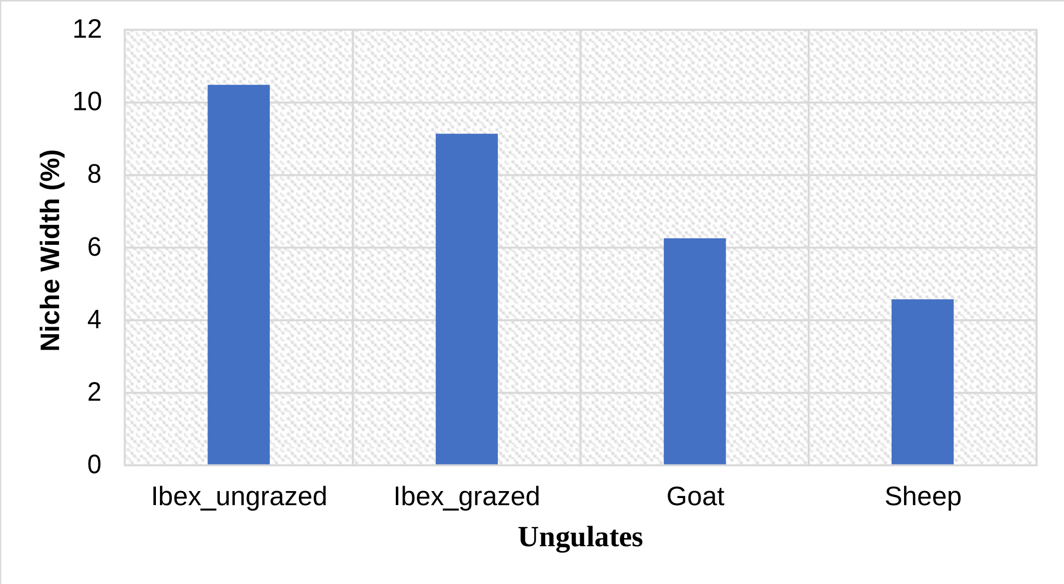


Figure 5.3: Trophic niche width between Ibex, Goat and Sheep.

5.4.4 Ibex seasonal diet use comparison through Microhistology: The diet selection by ibex through faecal sample revealed that during the spring and autumn seasons, the utilization of monocots and dicots were reported more or less similar (42% and 40%) respectively. Summer diet selection was more skewed toward dicots (42%) than monocots (35%), but winter diet selection was more biased toward monocots (67%) than dicots (17%) only. The logical explanation for what we observed was dicot senescence in the early phase in the beginning of Autumn season. Whereas, monocots, on the other hand, have a longer shelf life and are more widely available. The proportion of monocot, dicot, and unknown plant species found in the ibex diet help to understand in broader trophic niche in all seasons and help to minimize the errors in the indirect feeding signs method (Figure 5.4). Domestic livestock (goats and sheep) did not benefit from this strategy because they graze mainly during the peak summer season only.

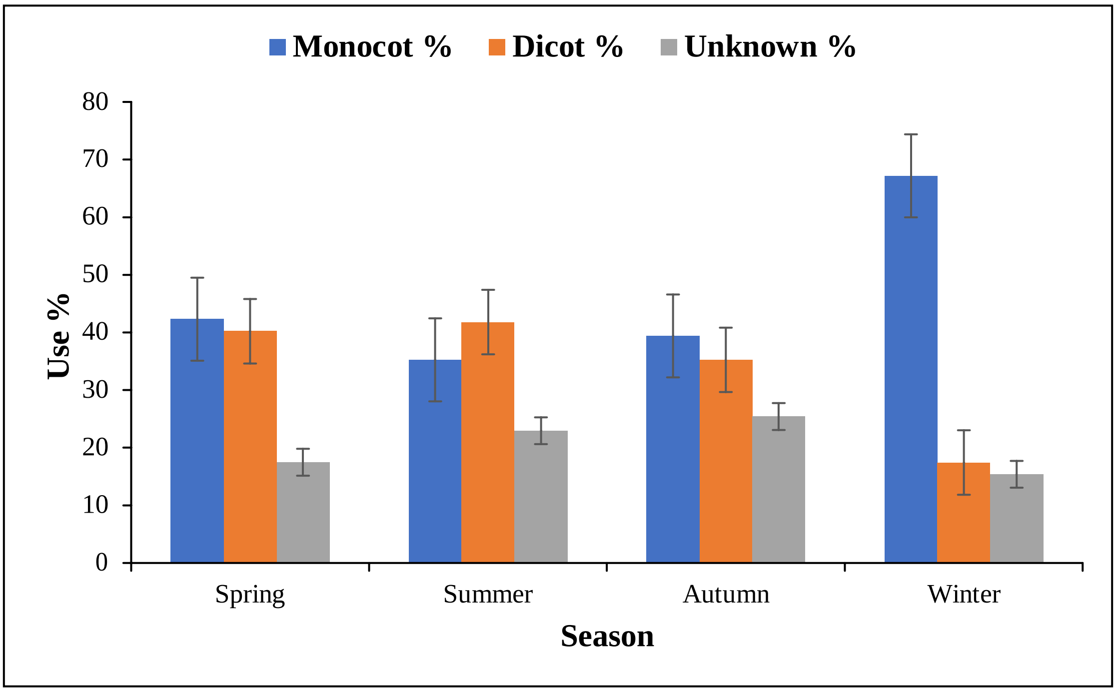


Figure 5.4: Microhistology based faecal feeding analysis showing Ibex seasonal feeding habits.

5.4.5 Ibex summer forage classes use:

During summer when vegetation growth is in peak ibex shown its preference highly in forbs (80%) followed by grasses (16%) and least shrubs only (4%) (Figure 5.5).

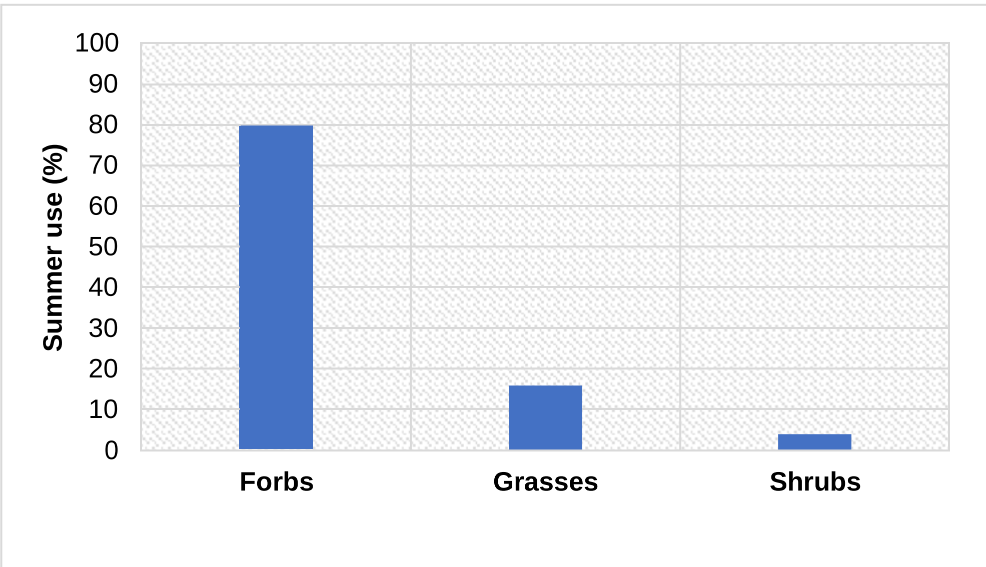


Figure 5.5: Ibex forage class use pattern during peak summer vegetation growth.

Table 5.2: Forage availability, use and selectivity index by wild and domestic ungulates. Here Ibex (C) denotes control or livestock ungrazed sites and Ibex (E) denotes experimental or livestock grazed sites.

Plants species	Percentage of diet available				Percentage of diet use				Ivlev's selectivity index			
	Ibex (C)	Ibex (E)	Goat	Sheep	Ibex (C)	Ibex (E)	Goat	Sheep	Ibex (C)	Ibex (E)	Goat	Sheep
Aconogonum tortuosum	2.86	5.06	5.32	4.52	7.51	10.39	8.96	7.62	0.4	0.3	0.3	0.3
Arabidopsis sp.	-	0.25	-	-	-	0.3	-	-	-	0.1	-	-
Arnebia euchroma	1.92	0.62	0.23	0.63	3.3	0.59	0.22	0.11	0.3	0	0	-0.7
Artemisia maritima	0.82	2.1	2.1	2.18	1.65	2.97	2.7	2.65	0.3	0.2	0.1	0.1
Artemisia salsoloides	-	-	1.46	2.18	-	-	1.08	1.16	-	-	-0.1	-0.3
Astragalus candoleanus	0.52	1.85	0.82	1.03	0	2.37	0.11	0	-1	0.1	-0.8	-1
Astragalus peduncularis	0.93	-	-	-	0.37	-	-	-	-0.4	-	-	-
Astragalus sp.	-	-	0.12	0.11	-	-	0.11	0	-	-	0	-1
Astragalus webberi	-	1.11	2.04	0.63	-	0.59	1.62	0.21	-	-0.3	-0.1	-0.5
Astragalus zanskarensis	1.75	1.23	-	0.4	2.75	0.3	-	0.32	0.2	-0.6	-	-0.1
Bergenia stracheyi	0.82	-	0.53	0.63	0	-	0	0.11	-1	-	-1	-0.7
Bistorta affinis	-	1.23	2.57	1.2	-	1.78	4	2.22	-	0.2	0.2	0.3
Bupleurum falcatum	1.46	-	-	-	2.01	-	-	-	0.2	-	-	-
Carex infuscata	-	4.32	-	-	-	5.34	-	-	-	0.1	-	-
Carex sp.	6.47	-	3.68	6.93	11.9	-	6.05	10.37	0.3	-	0.2	0.2
Cerastium cerastoides	-	-	2.1	0.52	-	-	1.19	0.74	-	-	-0.3	0.2
Chaerophyllum villosum	2.45	-	-	-	5.49	-	-	-	0.4	-	-	-
Cicer microphyllum	5.01	6.66	3.62	3.49	11.9	13.06	6.16	5.82	0.4	0.3	0.3	0.3
Codonopsis clematidea	0.17	-	-	-	0.18	-	-	-	0	-	-	-

Plants species	Percentage of diet available				Percentage of diet use				Ivlev's selectivity index			
	Ibex (C)	Ibex (E)	Goat	Sheep	Ibex (C)	Ibex (E)	Goat	Sheep	Ibex (C)	Ibex (E)	Goat	Sheep
Cousinia thomsonii	1.17	1.23	0.29	-	0.18	1.19	0.11	-	-0.7	0	-0.5	-
Crepis flexuosa	-	-	0.23	0.11	-	-	0	0.11	-	-	-1	0
Crepis sp.	-	0.49	-	-	-	0	-	-	-	-1	-	-
Cuscuta sp.	0.17	-	-	-	0	-	-	-	-1	-	-	-
Draba altaica	-	1.11	-	-	-	0.89	-	-	-	-0.1	-	-
Elymus nutans	-	1.73	-	-	-	2.67	-	-	-	0.2	-	-
Elymus sp.	1.05	-	0.41	0.92	0.73	-	0	0	-0.2	-	-1	-1
Ephedra gerardiana	4.66	-	3.33	3.21	0.18	-	0	0	-0.9	-	-1	-1
Epilobium angustifolium	1.57	-	1.11	-	0	-	0.54	-	-1	-	-0.3	-
Erigeron sp.	0.35	-	-	-	0	-	-	-	-1	-	-	-
Erimurus sp.	0.7	-	1.99	0.29	0.37	-	1.51	0	-0.3	-	-0.1	-1
Eritrichium fruiticulosum	0.76	2.34	0.18	-	0	0	0	-	-1	-1	-1	-
Ferula jaeshkeana	0.29	-	-	-	0	-	-	-	-1	-	-	-
Festuca kashmiriana	-	1.48	-	-	-	2.37	-	-	-	0.2	-	-
Galium aparine	2.16	-	1.23	-	0	-	0.43	-	-1	-	-0.5	-
Geranium pratense	0.35	2.71	0.29	0.29	0.73	3.56	0.54	0.53	0.4	0.1	0.3	0.3
Hyssopus officinale	3.44	5.55	2.22	2.75	0.37	0.59	0.65	0.42	-0.8	-0.8	-0.5	-0.7
Kobresia sp.	-	1.48	4.21	4.01	-	2.67	6.37	5.71	-	0.3	0.2	0.2
Leontopodium alpinum	-	-	-	0.4	-	-	-	0.53	-	-	-	0.1
Lindelofia stylosa	3.5	0.62	2.45	1.95	4.76	0.59	1.51	0.63	0.2	0	-0.2	-0.5
Linum perenne	1.34	-	0.18	0.29	0.37	-	0.11	-	-0.6	-	-0.2	-1

Plants species	Percentage of diet available				Percentage of diet use				Ivlev's selectivity index			
	Ibex (C)	Ibex (E)	Goat	Sheep	Ibex (C)	Ibex (E)	Goat	Sheep	Ibex (C)	Ibex (E)	Goat	Sheep
Linum sp.	0.64	-	-	-	0.92	-	-	0	0.2	-	-	-
Lotus corniculatus	-	0.37	-	-	-	0.3	-	-	-	-0.1	-	-
Melica persica	1.69	-	-	-	0	-	-	-	-1	-	-	-
Mentha longifolia	2.33	-	1.99	1.95	0	-	0	0	-1	-	-1	-1
Nepeta podostachy	0.35	1.73	3.21	-	0.37	1.19	2.05	-	0	-0.2	-0.2	-
Nepeta sp.	3.79	-	-	2.86	1.83	-	-	1.48	-0.3	-	-	-0.3
Oryzopsis munroi	6.53	0.99	-	-	17.22	1.48	-	-	0.2	0.2	-	-
Oryzopsis sp.	10.72	15.29	23.31	25.93	9.71	20.47	35.85	42.96	0.2	0.1	0.2	0.2
Parrya nudicaulis	0.47	-	-	-	0	-	-	-	-1	-	-	-
Pleurospermum sp.	-	-	-	0.11	-	-	-	0	-	-	-	-1
Poa allenuata	1.17	-	-	-	2.38	-	-	-	0.3	-	-	-
Poa sp.	-	3.58	5.55	5.38	-	3.26	7.45	6.67	-	0	0.1	0.1
Polygonum cognatum	11.95	6.17	7.24	10.36	0	0	1.4	0.53	-1	-1	-0.7	-0.9
Potentila desertorium	-	-	0.23	0.17	-	-	0.22	0.21	-	-	0	0.1
Potentilla multifida	-	0.99	0.47	0.29	-	0.89	0.22	0.11	-	-0.1	0.1	0
Potentilla argyrophylla	1.52	5.43	6.19	3.26	0	0	0.54	0.32	-1	-1	-0.9	-0.9
Potentilla pamirica	-	0.49	-	-	-	0.59	-	-	-	0.1	-	-
Potentilla sp.	0.76	-	-	-	0	-	-	-	-1	-	-	-
Primula microphylla	-	-	3.04	0.69	-	-	4.64	1.06	-	-	0.2	0.2
Rheum spicifome	-	0.25	-	-	-	0	-	-	-	-1	-	-
Rheum webbianum	0.58	-	-	-	0.37	-	-	-	-0.2	-	-	-

Plants species	Percentage of diet available				Percentage of diet use				Ivlev's selectivity index			
	Ibex (C)	Ibex (E)	Goat	Sheep	Ibex (C)	Ibex (E)	Goat	Sheep	Ibex (C)	Ibex (E)	Goat	Sheep
Rhodiola heterodonta	0.87	0.37	0.18	0.17	0	0	0	0	-1	-1	-1	-1
Ribes orientale	-	-	0.18	-	-	-	0.22	-	-	-	0.1	-
Rosa webbiana	-	0.25	0.12	0.11	-	0	0	0	-	-1	-1	-1
Rumex nepalensis	-	-	0.64	0.17	-	-	0	0	-	-	-1	-1
Rumex sp.	0.47	-	-	-	0	-	-	-	-1	-	-	-
Saxifraga sp.	0.23	-	-	0.86	0	-	-	0	-1	-	-	-1
Scrophularia stellaria	0.41	-	0.29	0.29	0	-	0.11	0	-1	-	-0.5	-1
Silene rechingeri	-	-	0.64	1.26	-	-	0	0	-	-	-1	-1
Sisymbrium sp.	-	0.25	0.58	0.11	-	0	0.54	0	-	-1	0	-1
Stellaria crispata	-	-	0.7	-	-	-	0.32	-	-	-	-0.4	-
Stipa capillata	0.41	-	-	-	0	-	-	-	-1	-	-	-
Stipa sp.	5.89	17.02	0.82	6.07	11.54	17.21	0.97	6.67	0.3	0	0.1	0
Tanacetum gracile	0.35	-	0.64	0.74	0.55	-	0.86	0.63	0.2	-	0.1	-0.1
Taraxacum officinale	0.23	-	-	-	0.37	-	-	-	0.2	-	-	-
Thalictrum platycarpum	-	0.37	-	-	-	0.59	-	-	-	0.2	-	-
Thermopsis inflata	1.34	-	-	-	0	-	-	-	-1	-	-	-
Thymus serphyllum	0.47	3.33	1.05	0.46	0	1.78	0.65	0.11	-1	-0.3	-0.2	-0.6
Verbascum thapsus	0.17	-	0.06	0.06	0	-	0	0	-1	-	-1	-1
Veronica ciliata	-	-	0.18	0.06	-	-	0	0	-	-	-1	-1

Green colour indicating the positive value from low (fade green) to high (fast green) and # Red colour indicating negative value from low (fade red) to high (fast red)

5.4.6 Diet quality

Chemical analysis revealed a seasonal change in forage quality through Ibex faecal samples (Figure 5.6). The different nutritional values observed in the chemical analysis discussed below:

Crude Protein: Percent Crude protein levels were observed highest in the summer and spring (11.94% and 10.63%) respectively and lowest in the autumn and winter season (8.60% and 7.94%). In summer and spring, levels of crude protein were highest (approximately similar) the reason may be due to its peak vegetation growing period, whereas in the autumn and winter i.e., after September the vegetation senescence starts and only dried summer vegetations are left over for the ibex grazing. The crude protein and phosphorous content of ibex faecal matter continued decreasing through autumn and winter whereas ash content was almost similar except in the spring season.

Phosphorous: The estimation of phosphorous in ibex faecal matter was highest in the summer (24%) followed by spring (14%), autumn (11%), and winter (10%). The decrease in the trend from summer to winter may be as early as mentioned the plant's senescence and dried vegetation composition in that area, whereas, there is a slight difference between autumn and winter the reason may be similar vegetation quality in these two seasons.

Ash content: The seasonal change in the ash content of the ibex faecal matter was highest in spring (81.51%), followed by summer (44.06%), autumn (39.62%), and winter (41%).

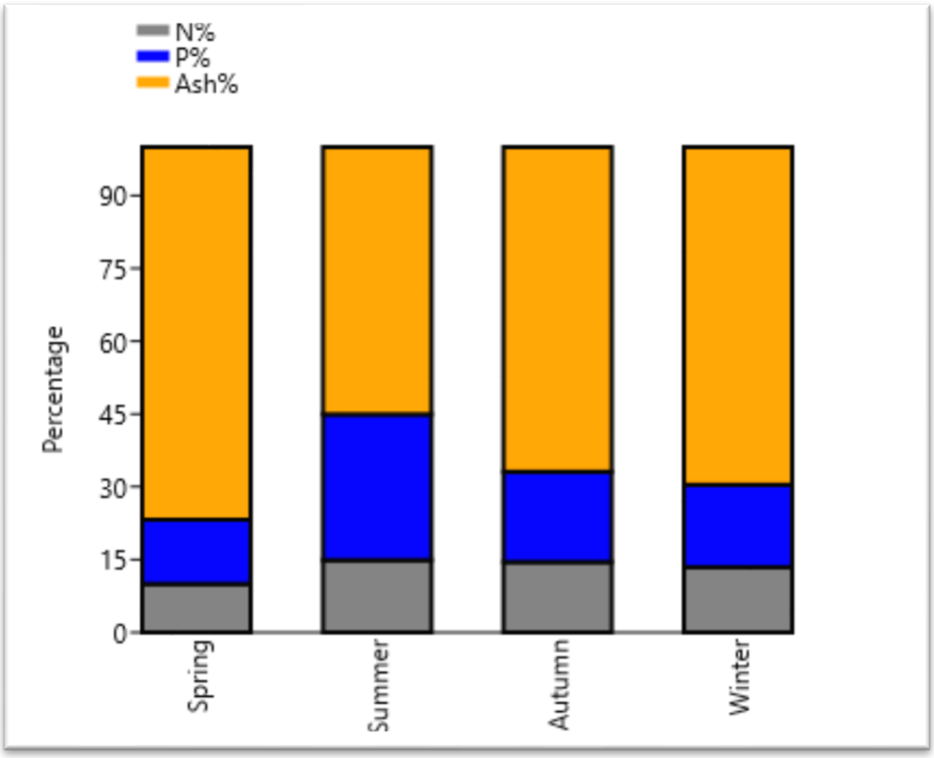


Figure 5.6: Ibex seasonal diet quality assessment through chemical analysis based on faecal samples

5.4.7 Habitat selection

The Ibex was shown to have a high preference for rocky habitat, whereas meadow and moraine habitats were avoided to a moderate extent and riverbed environment was strongly avoided (Figure 5.7). The habitat with a scree-like surface had the highest availability to usage ratio, followed by a dry steep slope and a meadow. Other habitats, such as rocky, moraine, and riverbed, had a lower usage availability ratio (Figure 5.8). Dry steep slope and meadow showing non-significant use availability ratio p=>0.05 and in other habitat types all showing significant p=<0.05 at Bonferroni classement based on 95 % confidence intervals on the differences of Wi (Table 5.3).

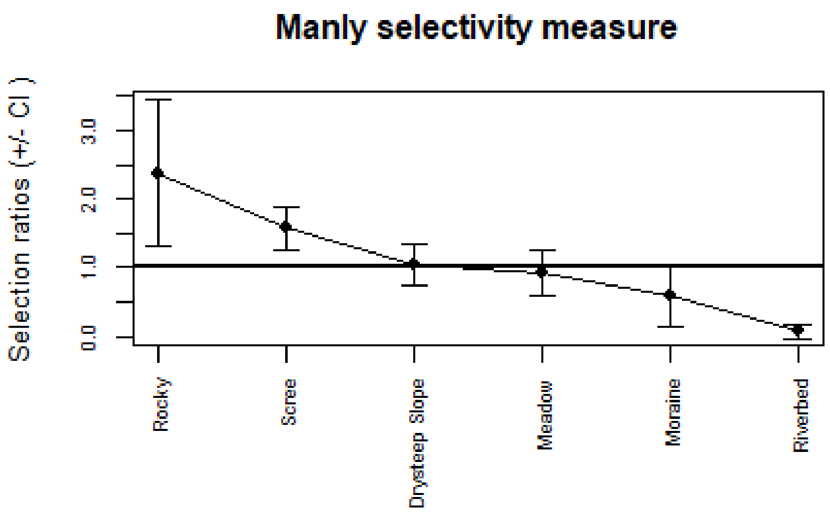


Figure 5.7: The pattern of habitat selectivity ratio exhibited by Ibex in Pin Valley National Park.

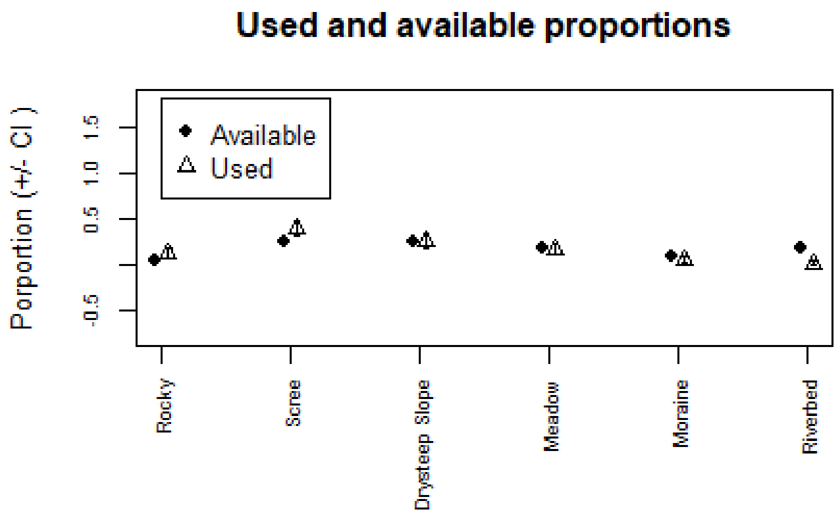


Figure 5.8: The ratio of habitat uses to availability by Ibex in Pin Valley National Park.

Table 5.3: Table of ratios (p-values should be compared with Bonferroni level= 0.0083)

Habitat	Used	Available	Wi	SE. Wi	P	Bi
Dry steep slope	0.261	0.250	1.043	0.121	0.724	0.159
Moraine	0.047	0.080	0.592	0.183	0.026	0.090
Meadow	0.166	0.180	0.922	0.142	0.581	0.140
Riverbed	0.014	0.190	0.075	0.043	0.000	0.011
Rocky	0.118	0.050	2.370	0.445	0.002	0.360
Scree	0.393	0.250	1.573	0.135	0.000	0.239

#Bonferroni classement Based on 95 % confidence intervals on the differences of Wi.

5.4.8 Ibex seasonal spatial use in grazed and ungrazed areas

5.4.8.1 Summer spatial use:

During the peak summer season, the study area experienced significant overexploitation due to the presence of migratory herd groups. These areas, which have traditionally been utilized by herders (refer to chapter 3), faced high levels of grazing pressure. As a result, Ibex tended to confine themselves to the northern aspects of the study area that were free from migratory livestock grazing. This distribution indicates the broader space availability and use in the livestock ungrazed areas for the ibex during the summer months (Figure 5.9). Whereas, in the livestock grazed areas ibex use was minimal.

In terms of the intensive study area as a whole, approximately 81% of it was grazed by migratory livestock during the summer season. Only a limited portion, around 18%, remained ungrazed, while the remaining 1% was covered by summer settlements. The primary challenges and risks faced by the ibex population in the grazed areas were the presence of aggressive Bhotia dogs owned by herders. Each herd group maintained 5-6 dogs specifically for protecting their livestock. Conversely, the herder's livestock faced significant losses due to foot-and-mouth disease (FMD). During survey the herders revealed that in the Tsoham base camp around 90 sheeps lost due to respiratory problem.

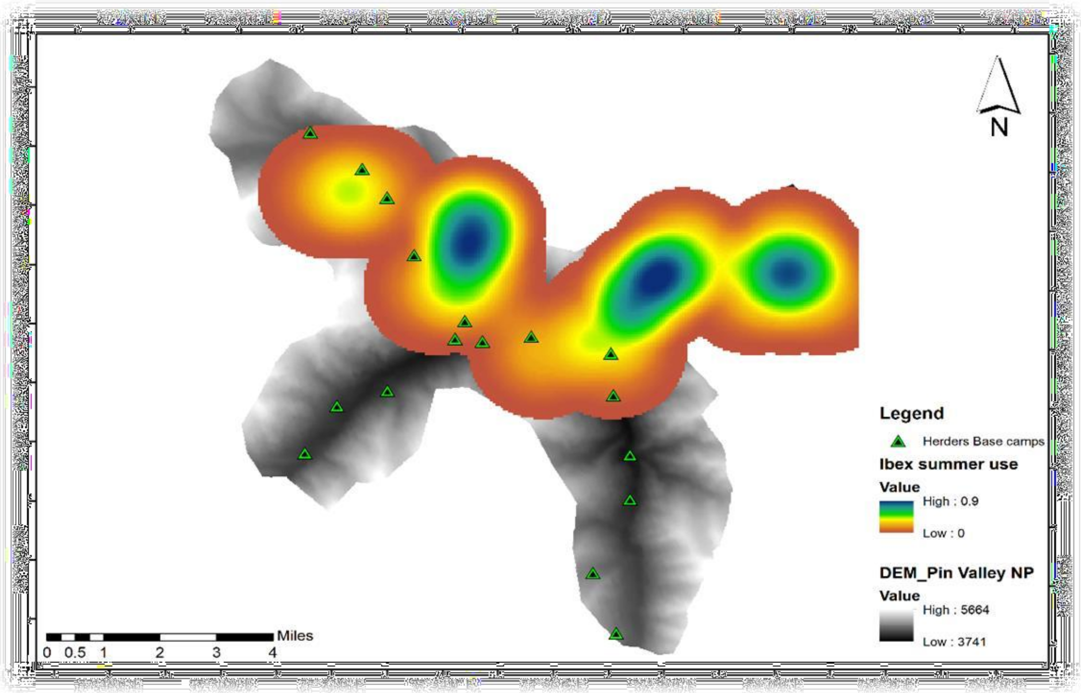


Figure 5.9: Kernel density estimation (KDE) showing Ibex spatial use pattern during summer when migratory livestock present.

5.4.8.2 Winter spatial use:

During the onset of early winter, Ibex tend to migrate towards lower altitudes. In the absence of migratory livestock during winter, their utilization of grazed and ungrazed areas becomes more similar (Figure 5.10). However, after heavy snowfall, Ibex tends to concentrate more in the north-eastern part of ungrazed areas where there is better sun exposure. This is because other parts of the southern areas and shaded regions have higher snow accumulation, making it difficult to find forage. During winter, the spatial niche width of Ibex also becomes narrower compared to summer.

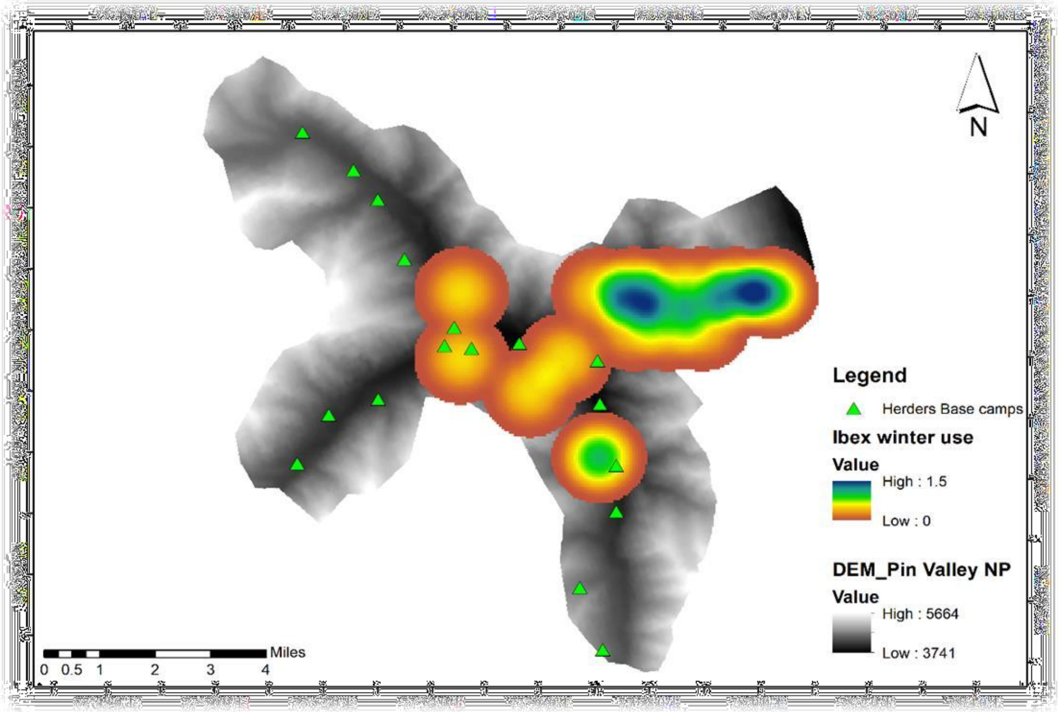


Figure 5.10: Kernel density estimation (KDE) showing Ibex spatial use pattern during winter when migratory livestock absent.

5.5 Discussion

Livestock and Ibex exhibited minimal dietary overlap, with a low Panka's index of 0.19 observed in both migratory livestock grazed and ungrazed areas. The highest diet overlap was found between goat and sheep in the grazed area, suggesting their shared use of pasturelands and similar herd group composition. In contrast, the lowest overlap occurred between Ibex and livestock, potentially due to habitat separation and the Ibex's limited utilization of grazed areas as they herded livestock. Broadly examining the feeding preferences, Ibex showed a strong preference for the *Polygonum-Stipa-Oryzopsis* vegetation community and a lesser preference for the Ephedra community. Analysis of the use availability ratio revealed that while *Cicer-Aconogonum* availability was relatively low, it was highly utilized by Ibex, while other resources were used in proportion. The trophic niche width was wider in the ungrazed Ibex diet compared to grazed ungulates. Additionally, diet quality was higher in the summer season but gradually degraded as winter approached, as indicated by crude protein and ash content.

Spatially, there was minimal overlap between livestock and Ibex in both grazed and ungrazed areas during summer. However, in winter when livestock were absent, the utilization of both grazed and ungrazed areas by Ibex was relatively similar, as indicated by encounter rates (Chapter 3). Statistical analysis revealed significant differences in encounter rates during summer (F=5.671, p=0.04), whereas in winter, the differences were non-significant (F=0.571, p=0.5).

An intriguing question arises regarding whether Ibex, in the absence of migratory livestock grazing during summer, would utilize the areas previously used by herded livestock. This study observed that Ibex descended to lower altitudes due to snow cover in higher reaches during late autumn and winter. Remarkably, Ibex were found to use areas that were grazed by migratory livestock more frequently during autumn and winter compared to summer. This evidence suggests that Ibex are sensitive to disturbance and tend to avoid these areas during the summer and early autumn until the season concludes and migratory livestock are removed.

The literature discussed in this section sheds light on the interactions and potential impacts of livestock on wild ungulates and their habitats. Migratory livestock have the potential to act as carriers of diseases that can affect Ibex populations (Bhatnagar, 1997; Manjrekar, 1997). This highlights the importance of considering disease transmission dynamics and implementing appropriate management strategies to minimize the risk to Ibex populations. Resident livestock, on the other hand, did not significantly interfere with Ibex for resource selection (Bhatnagar *et al*., 2000). This suggests that resident livestock may have a lesser impact on Ibex habitat use and resource availability compared to migratory livestock. Overstocking of livestock has been found to reduce the density of wild herbivores (Mishra *et al*., 2001). Livestock grazing, combined with high diet overlap with Bharal, has been identified as a factor leading to resource limitation and a subsequent reduction in Bharal density (Mishra *et al*., 2004). This suggests that competition for forage resources between livestock and Bharal can have negative consequences for the Bharal population. In the case of Ibex, it has been observed that migratory goats and sheep impose resource limitation and spatial exclusion on Ibex, while local livestock have a lesser impact on Ibex populations (Bagchi *et al*., 2004). This highlights the importance of considering the specific dynamics of different livestock types and their interactions with Ibex when assessing the impact of grazing on Ibex populations. Furthermore, grazing has been found to have an impact on forage biomass (Ghoshal *et al*., 2017). This emphasizes the need to carefully manage livestock grazing to maintain suitable forage availability for both livestock and wild herbivores, including Ibex.

Understanding the influence of grazing intensity on resource allocation, plant production, and vegetation composition is crucial, as it can vary depending on data metrics and local plant species richness (Bagchi & Ritchie, 2010; Bagchi *et al*., 2012). The Himalayan Mountains, renowned for their diverse ecological characteristics, present high grazer species richness attributed to altitudinal migration patterns, biogeography, and the abundance of graminoids and plant nutrients (Mishra *et al*., 2016). However, grazing impacts can differ among plant functional groups, with graminoids and forbs being negatively affected while shrubs thrive under grazing pressure (Lamba, 2015).

Considering the potential effects of grazing on vegetation composition is essential, as it can have subsequent impacts on soil carbon dynamics, particularly in light of projected changes in precipitation (Bagchi *et al*., 2017). Moreover, livestock grazing has been identified as a significant factor reducing the availability of graminoids, which are crucial food resources for grazing species like the bharal (Mishra *et al*., 2001). Predictions based on functional traits consistently indicate negative impacts of grazing on graminoids and forbs, while shrubs tend to benefit (Lamba, 2015). Additionally, livestock grazing influences soil microbial abundance and community composition in the Trans-Himalayan region, emphasizing the importance of understanding these microbial dynamics for broader ecological implications (Bagchi *et al*., 2017).

The competition for forage resources between musk deer and livestock is influenced by dietary consumption and seasonal variations (Khadka *et al*., 2017). Similarly, the interaction between naur and free-ranging yak, including diet overlap and competition, varies with seasons and stocking densities (Shrestha & Wegge, 2008). However, interspecific competition for summer forage between livestock and Ibex is minimal due to spatial separation and limited dietary overlap (Shrestha, Wegge & Koirala, 2005). Diet of bharal in summer overlapped completely with the diet of yak, donkey, and sheep. This overlap was less in winter due to shortage of forage and expanded diet spectrum of bharal (Mishra *et al*., 2001). During spring and summer, an abundance of high-quality food resources is available, but this changes in winter due to snow cover, resulting in a decline in both food quality and quantity. The inaccessibility of herbaceous vegetation and graminoids during winter poses challenges for wild herbivores (Manjrekar, 1997).

Livestock grazing has been identified as a contributing factor to habitat degradation, leading to the decline of wild ungulate populations (Kittur *et al*., 2010). Moderately grazed rangelands had a higher density of bharal, and populations. Presence of livestock caused an average of 33 % reduction in bharal performance in the intensively grazed rangeland (Mishra *et al*., 2001).

Therefore, effective management strategies are necessary to address the negative consequences of livestock grazing on wildlife populations and their habitats in the Himalayas. The establishment of livestock-free zones and control of livestock densities, even within wildlife reserves, are crucial for maintaining the ecological balance (Mishra *et al*., 2001). These measures can promote coexistence between livestock and wild ungulates while safeguarding their habitats and supporting the social, cultural, and economic landscape (Singh *et al*., 2015).

To mitigate the negative impacts of competition and prior habitat destruction, reducing livestock numbers, implementing rotational grazing, and shortening grazing periods have been recommended (Bhattacharya & Sathyakumar, 2011). Such conservation measures aim to foster coexistence between livestock and wild mountain ungulates, thus ensuring the preservation of their habitats and promoting sustainable ecosystem management in the Himalayan region.

In conclusion, this discussion section has explored the interactions and potential impacts of livestock on Ibex feeding behaviour and habitat selection. The dietary overlap between livestock and Ibex was minimal, and their spatial overlap was limited during summer. The Ibex exhibited preferences for certain vegetation communities and showed dietary variations throughout seasons. Additionally, the presence of migratory livestock influenced the Ibex's habitat use patterns. Furthermore, the discussion highlighted the complex relationships between livestock, grazing species, and ecological processes in the Trans-Himalaya region, emphasizing the need for effective management strategies to conserve wild herbivores and their habitats. Long-term monitoring and further research are essential to gain a comprehensive understanding of the dynamics of Ibex and migratory livestock interactions and their impacts on feeding ecology and habitat use. By integrating these findings into conservation and management efforts, it is possible to support the coexistence of livestock and wild ungulates while ensuring the long-term ecological integrity of the Himalayan region.

5.6 Conclusion

The Ibex is an intermediate or mixed feeder, primarily consuming graminoids and herbaceous plants during the summer. It exhibits distinct dietary preferences based on different vegetation communities, favouring the *Polygonum-Stipa-Oryzopsis* community and showing the least preference for the *Ephedra* community. There is a high dietary overlap between Ibex and livestock in grazed areas, with the maximum overlap observed between goats and sheep. Interestingly, the Ibex diet composition in grazed areas shows more similarity to the diet in ungrazed areas. Seasonally, the Ibex prefers specific plant types, with a higher utilization of monocots in winter and dicots in summer. Ibex in ungrazed areas have a higher trophic niche width, indicating greater dietary diversity, while Sheep have the lowest niche width. Approximately half of the available forage is palatable to Ibex, with the rest being unpalatable. The Ibex's diet undergoes seasonal changes, with the highest forage quality in summer and spring, but a decrease in autumn and winter due to limited vegetation growth. Nitrogen and phosphorous levels are highest during the summer season, as observed in Ibex pellet samples. During summer, there is a forage shortage due to migratory herder groups, leading to overstocking, while in winter, the Ibex relies on dried plants from summer to survive. Spatially, the Ibex demonstrates a stronger preference for ungrazed areas during summer and prefers rocky habitats while avoiding riverbeds. The migratory livestock diseases, such as foot and mouth disease, along with their guard dogs and other free ranging dogs could potentially pose a threat to the wildlife in the protected area.

Image 5.1: Cyclotec machine used to grind sample up to 1mm fine powder for the preparation of slides.

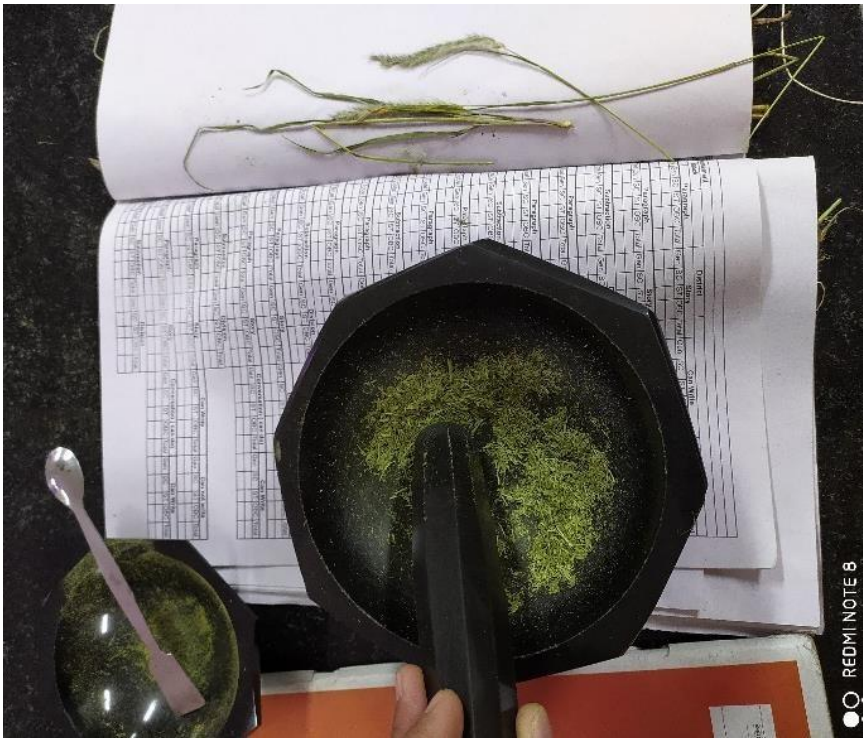


Image 5.2: Mortar and pestle used to grind samples.

Image 5.3: Sample specimen (Ibex faecal pellets) before grinding for the biological and chemical analysis.

Image 5.4: Microhistological slides preparation in the biology laboratory for the food habit study.

Image 5.5: Representation of chemical analysis prosses in the analytical laboratory.

Image 5.6: Estimation of chemical analysis like K and P through Spectrophotoscopy apparatus**.**

Image 5.7: Kjeldahl apparatus used for the estimation of crude protein of a given sample.

Image 5.8: Muffle Furnace is a unique test cabinet designed to detect the percentage of ash content in a particular test specimen like rubber, elastomers.

Image 5.9: Ibex and domestic Yak coexistence when limited food resources are left due to the senescence of vegetation in the Autumn season.

Chapter 6

Conclusion and management implications

This chapter serves as a comprehensive culmination of the previous chapter's findings and discussions. It includes the conclusions drawn from the study results, an evaluation of potential limitations, implications of the research, and suggestions for future directions.

6.1 Conclusion from the chapter uunderstanding pastoralism and its recent trends in pin valley national park

The current situation in agriculture and livestock management raises concerns about the focus on cash crops at the expense of self-sustenance and local food security. Declining local livestock numbers can be attributed to social, cultural, and economic changes impacting traditional livestock rearing practices. Predation by free-ranging dogs has led to significant losses of local livestock especially goats and sheep, necessitating effective management strategies. The decline in livestock numbers may also have an impact on agricultural quality as there is a decreased requirement for manure. Furthermore, the transportation of cattle manure from outside the valley by vendors may introduce exotic weeds onto local farmlands, posing additional risks. Unchecked extension of agricultural land can result in the loss of valuable natural resources. Another concern is the threat posed by free-ranging dogs to both wildlife and local livestock in the area.

It is crucial to adopt a balanced approach to agriculture and livestock management, prioritizing food security, considering social and economic changes, and implementing sustainable practices. To ensure conservation and coexistence, careful management and sustainable practices are necessary for wildlife, livestock, and local communities.

6.1.1 Management implications

The above observed trends underscore the importance of adopting a following:

1. Balanced approach to agriculture and livestock management.
2. This approach should prioritize local food security,
3. Consider the impact of social and economic changes to Ibex and its habitats.
4. Implement sustainable practices that mitigate threats to pasturelands and livestock.

6.2 Conclusion from the chapter understanding natural resource use by the Spiti Bhot Community in Pin Valley National Park

Several significant trends have been observed regarding people's dependency on natural resources and conservation efforts in Pin Valley. Firstly, there has been a decrease in people's reliance on National Park (NP) for vital resources such as dung, fodder, fuelwood, and medicinal plants. This shift suggests a potential diversification of resource acquisition methods or alternative sources for these necessities.

Secondly, over the period from 1995 to 2019, there has been a significant increase in depot wood use within Pin Valley. This rise in wood consumption indicates a growing demand for this resource, likely driven by various factors such as population growth or changes in local industries and practices.

However, the collection and use of medicinal plants have witnessed a decline due to a decrease in the number of Amchies, traditional practitioners of Tibetan medicine. There appears to be a direct impact on the availability and utilization of medicinal plants in the region.

On a positive note, efforts towards medicinal plants conservation have been initiated by identifying three High Conservation Value (HCV) sites in Gangnam, Darbak, and Solokyok. These sites hold significant potential for the future preservation and sustainable management of medicinal plants, ensuring their continued availability for medicinal and ecological purposes.

Overall, these trends highlight the complex interplay between human reliance on natural resources, evolving practices, and conservation efforts in Pin Valley. Continued monitoring and targeted interventions will be crucial to strike a balance between meeting the needs of the local population and protecting the region's biodiversity and ecological integrity.

6.2.1 Management implications

1. Unchecked pasture land fragmentation needs to be checked.
2. Maintaining livestock diversity is crucial for both agropastoral practices and ecological balance. It is important to preserve the previous rearing patterns to ensure the benefits of diverse livestock species.
3. Crop cycle is important for long survival of agriculture and nutrients recycle for better quality soil.

6.3 Conclusion from the chapter understanding resource availability with respect to Ibex (Capra sibirica) and its habitats

The study identified ten major vegetation communities in the area of interest. The dominant community, covering the highest percentage of the total area, was the *Oryzopsis* dominated community. It was observed that ungrazed pastures exhibited higher plant species richness, density, and diversity compared to grazed areas. The resource availability in terms of diet and space for Ibex is higher in the ungrazed areas as compared to the livestock grazed during peak summer. The Bray-Curtis vegetation dissimilarity between grazed and ungrazed areas indicated a significant difference in vegetation composition between the two land management practices. Among the top fifteen dominating species, *Stipa* sp. had the highest density. Additionally, regardless of grazing, the MD landform showed the maximum vegetation cover percentage. These findings shed light on the composition, distribution, and diversity of vegetation in the studied area, emphasizing the impact of grazing on plant communities, density and diversity and highlighting the importance of landform in influencing vegetation cover.

6.3.1 Management implications

1. It is imperative to conserve habitats rich in medicinal plants to safeguard their ecological and medicinal value.
2. The grazing of migratory livestock in identified High Conservation Value (HCV) sites should be prohibited to prevent degradation and promote conservation.
3. The uprooting of certain plants, such as *Arnebia euchroma* for the purpose of using them as manure should be banned to protect their populations and preserve biodiversity.

6.4 Conclusion from the chapter understanding interactions and resource use between wild (Ibex) and domestic ungulates

The Ibex shows a preference for the *Polygonum-Stipa-Oryzopsis* vegetation community and least prefers the *Ephedra* community. This indicates a specific habitat preference for the Ibex.

There is a moderate level of diet overlap between Ibex and livestock, with the highest overlap observed between Ibex in grazed areas and livestock. However, the diet overlap is lower between Ibex in ungrazed areas and livestock.

The Ibex diet in grazed and ungrazed areas shows a relatively high similarity, indicating that their food preferences remain consistent regardless of grazing activity.

During different seasons, the Ibex shows varying preferences for plant types. Monocots are highly utilized during winter, while dicots are preferred during summer. This indicates a seasonal shift in the Ibex's dietary preferences.

In terms of trophic niche width, the Ibex diet in ungrazed areas has the highest width, suggesting a broader range of food resources utilized by Ibex compared to other ungulates like Sheep.

A significant portion of the available forage was categorized as palatable, indicating that the Ibex has a range of options for food selection.

The presence of Nitrogen and Phosphorous in Ibex pellets is highest during summer, which may be related to the increased consumption of dicots during this season.

Spatial use and encounter rate of the Ibex are higher in ungrazed areas during summer. This suggests that ungrazed areas provide more favorable conditions or resources for the Ibex during this season.

The Ibex shows a strong preference for rocky habitats, while riverbed habitats are least preferred. This indicates a specific habitat preference for the Ibex, favoring areas with rocky terrain.

In summary, the Ibex demonstrates preferences for specific vegetation communities, seasonally varied diet compositions, and particular habitat types. Additionally, the Ibex's trophic niche width, spatial use, and encounter rates show variations based on grazing activity and season.

6.4.1 Management implications

1. The population of migratory livestock utilizing the park should be regulated and monitored to ensure appropriate management.
2. Mandatory vaccination of migratory livestock should be enforced prior to their entry into the area to prevent the spread of diseases.
3. The number of dogs used for livestock protection should be controlled to minimize conflicts with wildlife.
4. The population of free-ranging dogs should be monitored and managed across the entire region of the Spiti valley.
5. The presence of trekkers bringing dogs with them and allowing them to roam freely in the Spiti region should be regulated and monitored.

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Publications and conferences

List of peer reviewed papers

1. Targe K., Lyngdoh S., Bussmann R.W., and Adhikari B.S., (2022). Conservation linkages of threatened medicinal plants used in traditional health care system in Pin Valley National Park, Himachal Pradesh, India. *Ethnobotany Research and Applications*. 24:36
2. Targe, K., Negi, H. S., Lyngdoh, S., & Adhikari, B. S. (2023). First Sighting of a Himalayan Serow *Capricornis sumatraensis thar* Hodgson, 1831 in the Cold Desert of Spiti Valley, Himachal Pradesh, India. *Journal of the Bombay Natural History Society (JBNHS)*, *120*(2).
3. Manuscript entitled First Locality Record of Ladakh Cliff Racer, *Platyceps ladacensis* (Anderson 1871) from Spiti Valley, Lahaul and Spiti, India Kalzang Targe, B.S. Adhikari, Tushar Parab, Salvador Lyngdoh MS_ID: 18983 Reptiles and Amphibians (Accepted on 25.05.2023)
4. Manuscript entitled 'Traditional use of medicinal plants for curation of liver cirrhosis, tuberculosis and other associated health issues in Pin Valley National Park, Himachal Pradesh, India'. *Indian Journal of Traditional Knowledge*. (reviewers comments incorporated and resubmitted) manuscript MS_id 164273 Kalzang Targe, Salvador Lyngdoh and Bhupendra Singh Adhikari
5. Manuscript entitled First Locality Record of Indian Scops-Owl *Otus bakkamoena* (Pennant, T 1769) from Pin Valley National Park, Lahaul and Spiti, Himachal Pradesh, India Kalzang Targe, Salvador Lyngdoh, Tushar Parab, Bhupendra Singh Adhikari. MS_ID:16978501. Indian Forester. (Under review)

List of conferences

National

1. Targe K., Lyngdoh S., and Adhikari B.S. (2018). National seminar on researches in environment and biosciences: current scenario and future perspectives organized by: Department of Zoology, D.A.V. (P.G.) college Dehradun, Uttarakhand.
2. Targe K., Lyngdoh S., and Adhikari B.S. (2021). Spatial and trophic interactions between Ibex and livestock in the Alpine pastures of Pin Valley, Himachal Pradesh. 5th Himalayan research Seminar, Wildlife Institute of India, Dehradun.

International

3. Targe K., Lyngdoh S., and Adhikari B.S. (2022). 3rd International Web-Conference on Natural Resource Management for Global Food Security and Sustainable Development Goals. Organized by in collaboration with Academy of Natural Resource Conservation and Management KSN University of Agricultural and Horticultural Sciences Shivamogga.

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NATIONAL SEMINAR
ON
Researches in Environment and Biosciences: Current Scenario and Future Perspectives

Organized by: Department of Zoology, D.A.V. (P.G.) College, Dehradun, Uttarakhand
In Association with: Indian Academy of Environmental Sciences (IAES), Haridwar
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and Uttarakhand Science Education and Research Centre (USERC), Dehradun

22 - 23 June, 2018

Certificate of Participation

This is to certify that Prof./Dr./Mr./Ms. KALZANG TARGE
from Wildlife Institute of India, Chandrabani, Dehradun, 248001
participated in the National Seminar. He/She has chaired/ co-chaired a session/ delivered an invited lecture/ made an oral/ poster presentations entitled Pastoral Practices and their influence on Habitats used by Wild Ungulates in Pin valley National Park

Dr. Ajay Saksena	Dr. R.K. Jauhari	Dr. Pushpendra Kr. Sharma	Dr. Vivek Kumar Tyagi	Prof. B.D. Joshi
Principal	**Chairman**	**Convener**	**Organising Secretary**	**President, IAES**

Academy of Natural Resource Conservation and Management, Lucknow (UP), India
and
Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Iruvakki, Shivamogga, India

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CERTIFICATE OF PRESENTATION

This is to certify that Kalzang Targe participated and presented a paper entitled Conservation linkages of natural resources used by the local agropastoral community in Pin valley National Park, Himachal Pradesh, India. in the oral session of the 3rd International Web-Conference on "Natural Resource Management for Global Food Security and Sustainable Development Goals" Organized by the Academy of Natural Resource Conservation and Management (ANRCM), Lucknow in association with Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Iruvakki, Shivamogga during 2-3 December, 2022 on the occasion of "World Soil Day-2022"

Ajay K Bhardwaj	M S Nagaraja	Sanjay Arora	Atul K Singh
Org. Secretary	Org. Secretary	Secretary ANRCM	President ANRCM

Annexures

Annexure 1: List of common and uncommon forage species observed in the Ibex diet in livestock grazed and ungrazed areas.

Sr. No.	**Common forage species in diet of Ibex ungrazed and Ibex grazed areas**	**Unique forage species in diet of Ibex grazed area**	**Unique forage species in diet of Ibex ungrazed area**
1	*Cicer microphyllum*	*Carex infuscata*	*Poa allenuata*
2	*Oryzopsis sp.*	*Bistorta affinis*	*Rheum webbianum*
3	*Hyssopus officinale*	*Potentilla pamirica*	*Taraxacum officinale*
4	*Astragalus zanskarensis*	*Arabidopsis sp.*	*Linum perenne*
5	*Aconogonum tortuosum*	*Thymus serphyllum*	*Ephedra gerardiana*
6	*Geranium pratense*	*Festuca kashmiriana*	*Tanacetum gracile*
7	*Oryzopsis munroi*	*Astragalus candoleanus*	*Nepeta sp.*
8	*Cousinia thomsonii*	*Astragalus webberi*	*Elymus sp.*
9	*Lindelofia stylosa*	*Lotus corniculatus*	*Linum sp.*
10	*Artemisia maritima*	*Draba altaica*	*Astragalus peduncularis*
11	*Nepeta podostachys*	*Elymus nutans*	*Carex sp.*
12	*Stipa sp.*	*Poa sp.*	*Codonopsis clematidea*
13	*Arnebia euchroma*	*Thalictrum platycarpum*	*Bupleurum falcatum*
14		*Potentilla multifida*	*Erimurus sp.*
15		*Kobresia sp.*	*Chaerophyllum villosum*

Annexure 2: List of most and least palatable plant species collected through people perception survey, direct and indirect documentation from Pin Valley national Park

High palatable forage species	**Least palatable forage species**
Acconogonum tortuosum	*Allium carolinianum*
Arabidopsis sp.	*Anaphalis contorta*
Arnebia euchroma	*Arnebia guttata*
Artemisia maritima	*Artemisia scoparia*
Astragalus candoleanus	*Asperugo procumbens*
Astragalus peduncularis	*Astragalus nivalis*
Astragalus webberi	*Astragalus strobiliferus*
Astragalus zanskarensis	*Astragalus webbianus*
Berginea strachei	*Berberis sp.*
Bistorta affinis	*Bromus arvensis*
Bupleurum falcatum	*Calamagrostis emodensis*
Carex infuscata	*Calamagrostis epigejos*
Carex sp.	*Caparis spinosa*
Carex vulpinaris	*Chenopodium album*
Causenia thomsonii	*Chenopodium foliosum*
Chaerophyllum villosum	*Christolea himalayensis*
Cicer microphyllum	*Cotoneaster gilgitensis*
Codonopsis clematidea	*Cristolea crassifolia*
Crepis sp.	*Cuscuta europaea*
Cystopteris fragilis	*Dianthus orientalis*
Draba altaica	*Ephedra gerardiana*
Elymus nutans	*Epilobium angustifolium*
Elymus sp	*Erigeron acer*
Ephedra gerardiana	*Eritrichium spathulatum*
Epilobium angustifolium	*Euphorbia tibetica*
Erigeron sp	*Glocoma nivalis*
Erimurus sp	*Hyoscyamus niger*

High palatable forage species	**Least palatable forage species**
Eritrichium fruiticulosum	*Krascheninnikovia ceratoides*
Ferula jaeshkeana	*Lamium rhomboideum*
Festuca altaica	*lapidium latifolium*
Festuca kashmiriana	*Leymus secalinus*
Galium aparine	*Lonicera asperifolia*
Geranium pratense	*Melica persica (inflorescence brown*
Hyssopus officinale	*Melica persica (inflorescence golden yellow)*
Kobresia sp.	*Nepeta longibracteata*
Lindelofia stylosa	*Oxytropsis tatarica*
Linum perenne	*Pennisetum flaccidum*
Lotus corniculatus	*Phragmites australis*
Melica persica	*Pleurospermum angelicoides*
Mentha longifolia	*Polygonum cognatum*
Nepeta podostachy	*Potentilla argyrophylla*
Nepeta sp.	*Potentilla salessoviana*
Oryzopsis munroi	*Psychrogeton andryaloides*
Oryzopsis sp (Jampi)	*Rhodiola heterodenta*
Parrya nudicaulis	*Rosularia alpestris*
Poa allenuata	*Rubia tibetica*
Poa sp.	*Rumex dentatus*
Potentilla multifida	*Rumex nepalensis*
Potentilla pamirica	*Rumex patientia*
Potentilla sp.	*Scorzonera virgata*
Rheum webbianum	*Silene rechingeri*
Rosa webbiana	*Stipa capillata*
Rumex sp.	*Stipa mongholica*
Saxifraga sp.	*Thermopsis inflata*
Scaphularia sp	*Tragopogon gracile*

High palatable forage species	Least palatable forage species
Sisymbrium sp.	*Verbuscum thjapsis*
Stipa capillata	
Stipa sp.	
Taraxacum officinale	
Tenacetum gracile	
Thalictrum platycarpum	
Thymus serphyllum	

Annexure 3: List of overall palatable plant species documented in the wild and domestic ungulates diet from Pin Valley national Park.

Plant species	**Ibex**	**Goat**	**Sheep**
Acconogonum tortuosum	+	+	+
Arabidopsis sp.	-	-	-
Arnebia euchroma	+	+	+
Artemisia salsoloides	+	+	+
Artemisia maritima	+	+	+
Astragalus peduncularis	+	-	-
Astragalus candoleanus	-	+	-
Astragalus webbianus	+	-	-
Astragalus webberi	+	+	+
Astragalus zanskarensis	-	+	+
Berginea strachei	+	-	+
Bistorta affinis	+	+	+
Bupleurum falcatum	+	-	-
Carex infuscata	+		
Carex sp.	-	+	+
Carex vulpinaris	+		
Causenia thomsonii	+	+	-
Chaerophyllum villosum	+	-	-
Cicer microphyllum	+	+	+
Codonopsis clematidea	-	-	-
Crepis flexuosa	-	-	+
Cerastium cerastoides	+	+	+
Cystopteris fragilis	+	-	-
Draba altaica	+	-	-
Elymus nutans	+	-	-
Elymus sp	-	-	-
Ephedra gerardiana	-	+	-

Epilobium angustifolium	+	-	-
Erigeron sp	-	+	-
Erimurus sp	+	-	-
Eritrichium fruiticulosum	-	-	-
Ferula jaeshkeana	+	-	-
Festuca altaica	-	-	-
Festuca kashmiriana	+	+	-
Galium aparine	+	+	
Geranium pratense	+	+	+
Hyssopus officinale	+	+	+
Kobresia sp.	+	+	+
Lindelofia stylosa	+	+	+
Linum perenne	-	-	-
Lotus corniculatus	-	-	-
Melica persica	+	-	-
Mentha longifolia	+	+	-
Nepeta podostachy	+	-	-
Nepeta sp.	+	-	+
Oryzopsis munroi	-	+	-
Oryzopsis sp (Jampi)	+	-	+
Parrya nudicaulis	+	-	-
Poa allenuata	+	+	-
Poa sp.	+	+	+
Potentilla multifida	-	-	+
Potentilla pamirica	+	+	-
Polygonum cognatum	+	+	+
Potentila desertorium	-	+	+
Potentilla argyrophylla	-	+	+
Primula microphylla	-	-	+

Potentilla sp.	-	-	-
Rheum webbianum	-	-	-
Rosa webbiana	+	+	-
Ribes orientale	+	-	-
Rumex sp.	+	-	-
Saxifraga sp.	+	+	-
Scaphularia sp	+	+	
Sisymbrium sp.	-	-	-
Stipa capillata	-	+	-
Stellaria crispata	-	+	-
Stipa sp.	-	-	+
Taraxacum officinale	-	+	-
Tenacetum gracile	-	-	-
Thalictrum platycarpum	-	+	-
Thymus serphyllum	-	-	+
Veronica ciliata	-	-	-
Cotoneaster gilgitensis	-	-	-

Annexure 4: Images used

Chapter 1 images

Image1.1: Study area landscape view during winter season.

Image 1.2: Study area landscape view during summer season.

Chapter 2 images

Image 2.1: The Pin Valley experiences an intense winter characterized by abundant snowfall and a thick snow cover. During this season, the valley transforms into a winter wonderland, presenting awe-inspiring landscapes and challenging conditions for its inhabitants.

Image 2.2: Locals practices a unique tradition of storing ashes from their fires during winter. This traditional practice facilitates the snowmelt process in the onset of spring, especially when they need to catch up on their cultivation activities. They strategically scatter these ashes on selected areas of the heavy snow-covered fields. The ashes' dark colour absorbs sunlight and accelerates the snowmelt in those specific spots. It exemplifies the harmonious relationship between the people and nature in the Pin Valley, where age-old traditions continue to play a crucial role in sustaining their way of life.

Image 2.3: Historical traditional way of ploughing agriculture field using Yak and dzo.

Image 2.4: The modernization of agriculture has introduced advanced machinery like tractors and power trailers, replacing traditional manual labour and greatly improving work efficiency. However, this shift has also led to a decline in the number of livestock, such as yak and dzo, potentially impacting the traditional agropastoral practices. This could result in various imbalances, affecting the ecological, economic, and cultural aspects of the community's livelihoods in the future.

Elderly perspectives suggest modernized agriculture may increase field weeds. Machinery may not eradicate them effectively as traditional methods, leading to chemical reliance.

Image 2.5: During the harsh winter climate, with temperatures plummeting to -35 to -40℃, the practice of water restoration from rivers and streams becomes essential. This is a reliable alternative when conventional water taps freeze. Drawing water from flowing sources ensures a steady supply, supporting the community's water needs and sustenance during the challenging winter months in some villages.

Image 2.6: During the Lavi fair in Rampur district, Himachal Pradesh, the age-old tradition of horse trading is still cherished. The fair, held from 11th to 14th November, now sees locals transporting horses by trucks, whereas in the past, they would journey on horseback through the entire route.

Image 2.7: The entire Spiti valley, faces a significant challenge with free-ranging dogs, posing threats to local livestock and wildlife. The increasing number of dogs is partly attributed to tourists and trekkers who bring and leave them behind during their journeys. This situation calls for attention and responsible practices to address the impact on the valley's delicate ecosystem and ensure the well-being of its inhabitants.

Chapter 3 images

Image 3.1: Group discussion and awareness program with local community.

Image 3.2: The Pin Valley National Park boasts a rich diversity of rare and endangered plant species that hold significant value for medicinal purposes. These invaluable plants have been utilized by traditional healers and local communities for generations due to their unique medicinal properties. Some of the noteworthy species found in the park are shown in this image.

Image 3.3: Traditional way of fodder collection by the local people wearing locally called Hultum for fodder collection.

Image 3.4: Livestock Dung collection inside Pin Valley National Park.

Image 3.5: Medicinal plant collection by local *Amchi* during peak vegetation growth

Image 3.6: Many significant shrub species, including *Salix* spp., *Myricaria* spp., and *Hippophae* spp., which are the main riverine plants, degrade and are washed away with water during the peak summer season when river level reaches to its peak. When the river volume drops in the autumn, people gather such uprooted shrubs for fuel.

Image 3.7: Local woman preparing traditional basket from *Salix* spp. (saplings or young tree) locally known as 'Tsewu'. Tsewu are woven or crafted to hold and carry various items, ranging from dung collection and other necessities. Baskets are often crafted by hand, showcasing the skill and artistry of the individuals or communities that create them.

Chapter 4 images

Image 4.1: Into the wild documenting the beauty of nature's flourishing vegetation.

Image 4.2: Green meadow dominated by the *Landilofia stylosa*

Image 4.3: Overstocked migratory livestock in the historically grazed area.

Image 4.4: Trail of Ibex in the scree landform during summer season.

Image 4.5: Trail of Ibex in the search of food during winter season when landscape is covered with full of snow.

Image 4.6: Ibex feeding on *Rosa webbiana* during winter when all other vegetation is covered by the snow.

Chapter 5 images

Image 5.1: Cyclotec machine used to grind sample up to 1mm fine powder for the preparation of slides.

Image 5.2: Mortar and pestle used to grind samples.

Image 5.3: Sample specimen (Ibex faecal pellets) before grinding for the biological and chemical analysis.

Image 5.4: Microhistological slides preparation in the biology laboratory for the food habit study.

Image 5.5: Representation of chemical analysis prosses in the analytical laboratory.

Image 5.6: Estimation of chemical analysis like K and P through Spectrophotoscopy apparatus**.**

Image 5.7: Kjeldahl apparatus used for the estimation of crude protein of a given sample.

Image 5.8: Muffle Furnace is a unique test cabinet designed to detect the percentage of ash content in a particular test specimen like rubber, elastomers.

Image 5.9: Ibex and domestic Yak coexistence when limited food resources are left due to the senescence of vegetation in the Autumn season.

Abbreviations:

H.H	Household
PVNP	Pin Valley National Park
Poly-Stipa-Ory	*Polygonum-Stipa-Oryzopsis*
Aco-Pot.Argy	*Aconogonum-Potentilla argyrophylla*
Carex-Artemi	*Carex-Artemisia, Oryzopsis*
Ory	*Oryzopsis*
Stipa-Oryz	*Stipa -Oryzopsis*
Mix. herb (HM)	Mixed herbaceous (higher meadow)
Mix. Herb (LM)	Mixed herbaceous (lower meadow)
Ephedra domi	*Ephedra* dominated
NP	National Park
MPs	Medicinal Plants