Assessing The Extent Of Habitat Overlap And Resource Partitioning Between Ibex And Livestock In Khyber valley Pakistan

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Abstract
Ibex and livestock distribution and habitat preferences were assessed using ecological niche factor analysis (ENFA). The study area was divided into 45 grid cells of 500 x 500 m pixels. Ibex and livestock were documented to occupy 30.61% and 26.5% of the study area, respectively, from June to November. Male and female ibex showed significant sexual segregation during this period. From November to May, male ibex occupied 32.6% of the study area and female ibex 34%. Livestock occupied 19% of the study area from June to September and 14.2% from September to May. The ENFA results indicated that both ibex and livestock show selective habitat preferences but are selecting for the same resources. The first two principal components (PCs) explained 49.3% and 17.88% of the variation in the data, respectively. The first PC was related to distance to settlements, distance to rivers, distance to roads, and rangelands. The second PC was related to rangelands and snow covers. The biplot of ENFA differentiated available habitats from habitat used (by ibex/livestock) through shades of grey, where light grey areas correspond to all the available habitat and dark grey area represented the used area (ecological niche of the animal). The ENFA plot indicated that though ibex and livestock have selective approach towards habitat usage, but selecting for the same resources.

Keywords: Ibex, livestock, distribution, habitat preferences, ecological niche factor analysis (ENFA), sexual segregation

Introduction

Wild ungulates play a crucial role in maintaining the ecological balance of ecosystems due to their significant impact on the environment. By consuming plants, these animals can influence vegetation structures and species composition, thereby shaping the overall ecosystem dynamics. Additionally, they contribute to essential processes such as nutrient recycling and act as a crucial prey base for large carnivores (Ahmad et al., 2022; Bagchi & Ritchie, 2010; Karanth, Nichols, Kumar, Link, & Hines, 2004; Suryawanshi et al., 2017). Pakistan's Himalayan, Hindu Kush, and Karakoram mountain range harbour a rich diversity of wild ungulates that hold immense significance for conservation efforts. These mountainous regions provide a unique habitat for various species of wild ungulates, which contribute to the ecological balance and biodiversity of the area (Zafar et al., 2014). These ungulate species require more research, and data on their distribution and population are patchy, undermining the need for conservation efforts in this region.

The Himalayan Ibex (hereafter ibex) is the most common member of the Caprinae family (Hess 1990) and the largest species of ibex in the genus “Capra” (Jabin et al. 2023) mostly found in relatively dry mountains between 2000-5000 m in elevation (Zafar et al. 2014). Ibex tend to avoid forests, but they may take refuge in them during hot weather. They prefer living in areas such as canyons, rocky outcroppings, and steep terrain because it allows them to quickly escape if necessary (Fedosenko and Blank 2001). They primarily feed on alpine plants and sage and have crepuscular feeding habits, preferring to forage in the evenings and early mornings (Fedosenko and Blank 2001). Ibex usually live in small groups of 6 to 30 animals. However, group size varies greatly, and finding them in herds larger than 100 animals is rare (Reading et al. 1999; Fedosenko and Blank 2001; Mansoor et al. 2022). The species has recently been globally declared "Near Threatened" in the IUCN red data book (Reading et al., 2020). Unfortunately, due to limited attention, there is a general lack of awareness about the species distribution and population trends throughout its range (Roberts 2005; IUCN 2017).

The ibex can be found in various countries across the globe, including India (Namgail, 2006; Mansoor et al., 2022), Afghanistan (Moheb et al. 2023a; Moheb et al. 2023b), China (Reading and Shank 2008; Xu et al. 2012), Russia, Mongolia, Tajikistan, Kazakhstan, Kyrgyzstan and Uzbekistan (Reading and Shank 2008; Li et al. 2015; Reading et al., 2020). In the Karakoram–Himalayan–Hindukush (KHH) region it lives in relatively dry mountains between 2000-5000 m asl (Zafar et al. 2014). In northern Pakistan, Ibex are the most common species of wild ungulates, but their population has decreased, restricting them to the far northern regions of the country. They can be found from Khunjerab to Swat in the north, Azad Jammu, and Kashmir (AJK) in the south, and Chitral district in the west (Ali et al. 2007; Ahmad et al. 2015; Khan et al. 2016b; Ahmad et al. 2020).

Accurately estimating the population of ungulate species is crucial for their conservation. Unfortunately, in Pakistan, this issue has received little attention. The native population trends throughout their distribution range have not been defined accurately, making it difficult to determine their conservation status (Sheikh and Molur 2005). Currently, the population status of ibex in Pakistan remains to be discovered. While studies have been conducted on the subject (Khan et al. 2016a; Ahmad et al. 2020; Khan et al. 2020b), they are restricted to only certain areas of the species' habitat. To effectively manage wide-ranging species, it is important to have accurate information regarding their distribution and population trends (Marques et al. 2001).

Aims and Objectives:

- Understand factors that influence habitat selection by ibex in Khyber valley.
- Understand degree of overlap between livestock and ibex habitat

Materials and Methods

Study Area:

The Khyber Valley is located in the northeast of Hunza district. It is situated at an elevation of 2500 to 5708 meters and has an area of 116 km2. The valley is home to three villages: Shahee Khyber, Imamabad and Khyber. It has a total of 130 households. The valley was declared as Controlled Hunting Areas (CCHA) in 1996. The Shahee Khyber, Imamabad and Khyber Development Organization (SKIDO) is jointly managing wildlife and other natural resources in the valley with Gilgit-Baltistan Parks and wildlife department (GBPWD) and different Non-governmental organizations (NGOs) (Brambilla, Von Hardenberg, Nelli, & Bassano, 2020).

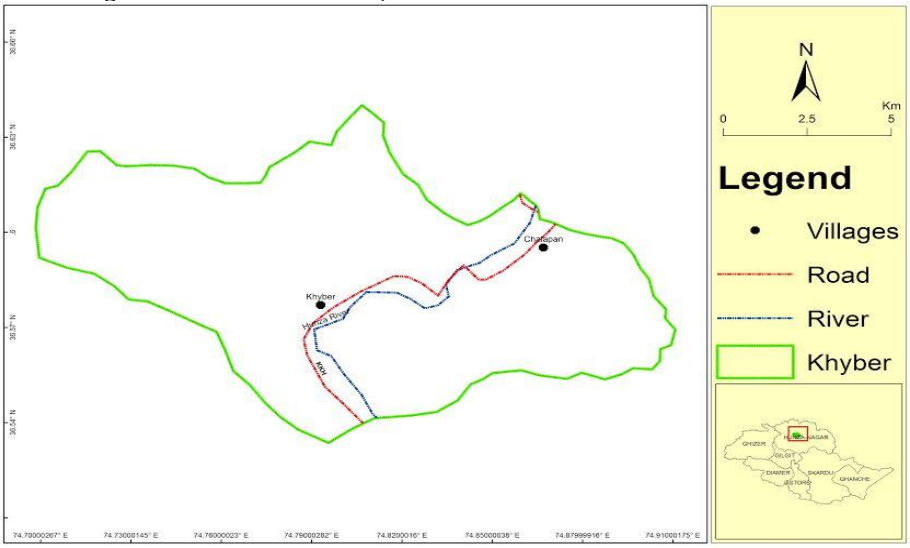


Figure 1: Map of Khyber Valley, District Hunza (Gilgit Baltistan) Pakistan

Table 1: Key Characteristics of the Khyber Valley

Variables	Description
Climate	Very dry
Rainfall	High in pastures, snow in Dec-Feb
Temperature	Summer: 30-35°C, Winter: -10°C
Flora	Ailanthus, Robinia, Seabuckthorn, Poplars, Willows, Mulberry
Fauna	Himalayan ibex, snow leopard, golden marmot, red fox, Himalayan snow cock, Kashmir flying squirrel, chukar partridge
Livestock	Cattle (330), sheep (600), goats (200)

Data Collection

The Double Observer method, originally by Forsyth (1997) and modified by Suryawanshi, Bhatnagar, and Mishra (2012), was used to estimate the Himalayan ibex population in the study area. The valley was divided into three watersheds, and two observer teams, A and B, were assigned to scan ibex at 15-minute intervals. Observations occurred from 7:00 am to 10:00 am and 3:00 pm to 6:00 pm using Pentax binoculars (10×50) and a Nikon Coolpix L110. Herds were demographically categorized (young, yearlings, female, male) and further classified based on horn characteristics (Male class I-IV) according to Schaller (1977). GPS recorded herd locations, mapped later (Namgail, 2004). In the evenings, both observer team's cross-verified data to eliminate double counting based on herd demography.

Study Map

Data for Ibex was separated on basis of their sex and seasonal locations. And separate distribution maps were prepared in ARC GIS 10.3 to know the seasonal distribution of female and male ibex in 1x1 km grids in the valley. Livestock maps were prepared using the same strategy.

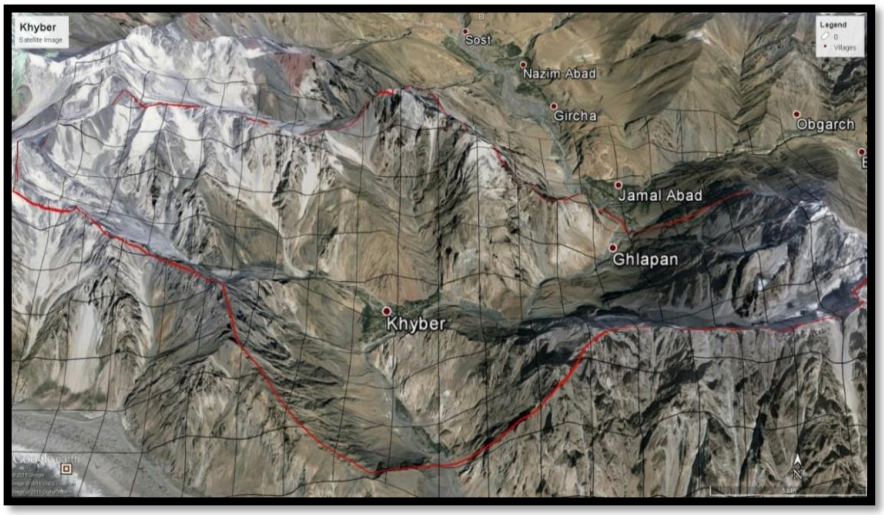


Figure 2: Map of Khyber Valley with 1x1 Kilometers Grids Cells

Model Data:

Table 1: Eco-Geographical Variables Used in ENFA

Environmental Gradient Variables (EGVs)	Code	Description
DEM	Elevation	Digital elevation map downloaded from(USGS)
Slope	Slope	Slope in degrees calculated by Spatial analyst extension in GIS
Distance to roads	Roads	Distance to road layer developed by using Euclidean distance tool in GIS.
Distance to settlements	Settlements	Same as above
Distance to river	River	Same as above
Distance to bare rocks	Bare Rocks	Same as above

Data Analysis & Interpretation

R was used to analyze kasc images of ASC layers, focusing on Ibex and cattle locations. PCA was used to understand Environmental Gradient Variables' spatial structure and relationships. The ratio of expected nearest-neighbor distance to observed mean revealed clustering tendencies in PCA. Environmental Niche Factor Analysis (ENFA) used unbiased presence data instead of absence data, which proved beneficial. Absence data was often unreliable, causing problems. ENFA and Mahalanobis distances examined slope, height, vegetation type, and human disturbance to reveal habitat preference. Using presence-only data, ENFA identified favorable species locations to estimate distribution. Mahalanobis distance was used to map habitat appropriateness, with smaller distances indicating better conditions. Under the multivariate normality assumption, squared Mahalanobis distances assumed a Chi-square distribution with n degrees of freedom (EGVs). R's Adehabitat package assisted in the creation of continuous gradient suitability maps (p-values 0–1).

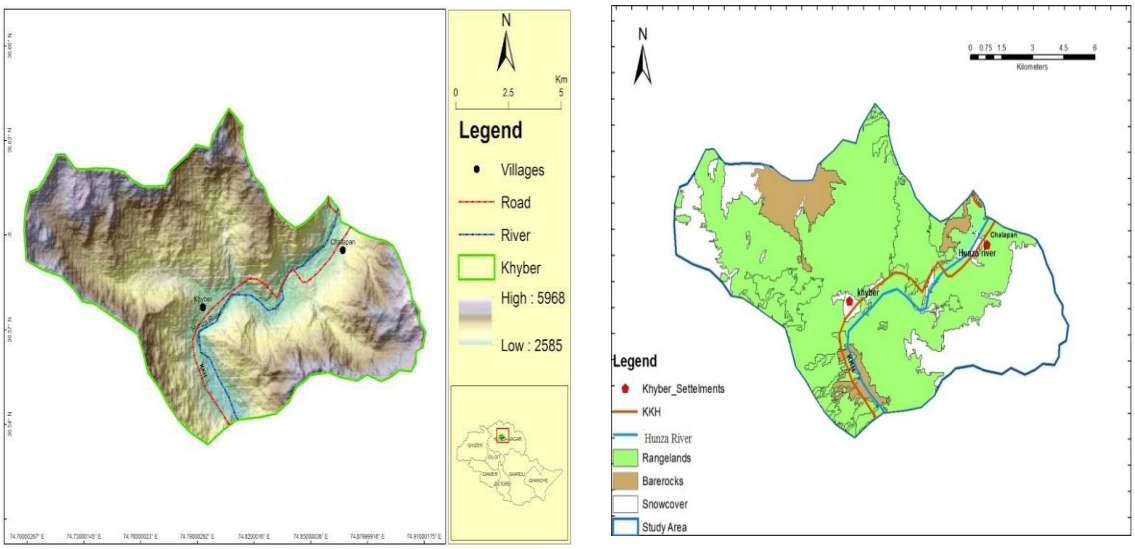


Figure 3: (a) Digital Elevation Map Showing Elevation Range in Khyber Valley (b) Land Cover Types in Khyber Valley (FAO, 2016)

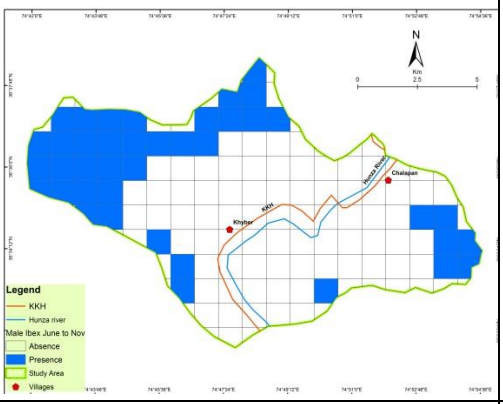
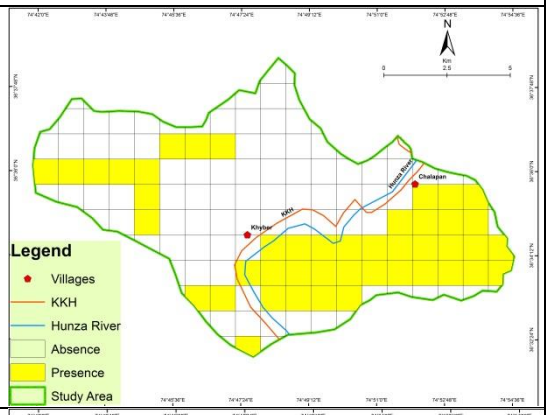
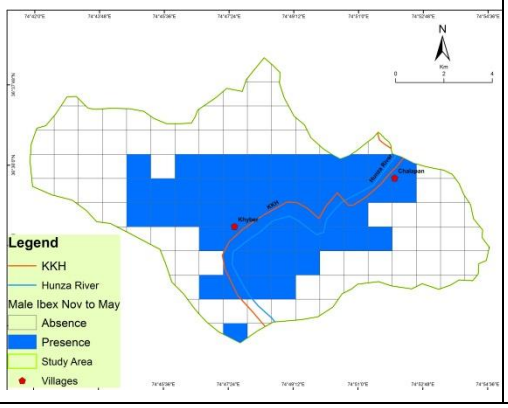
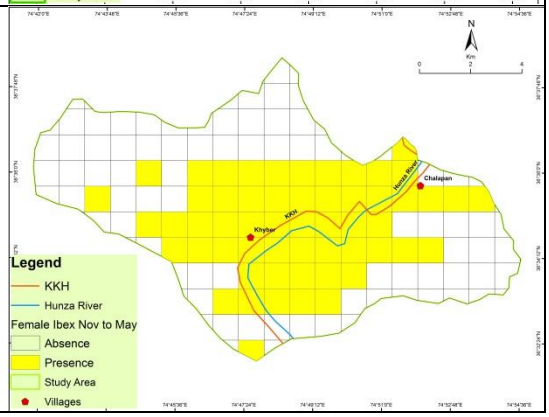
Results

3.1 Species Distributions

3.1.1 Ibex

In June–November, female ibex occupied 30.61% of the research area (45 grid cells) and male ibex 26.5 % (39 grid cells).Male and female ibex were sexually divided during this time, according to local knowledge maps. The study area included a large overlap between male and female ibex habitat from November to May. In November to May, male ibex occupied 32.6% of study area (48 grid cells) and female ibex 34% (50 grid cells) (Figure 5).

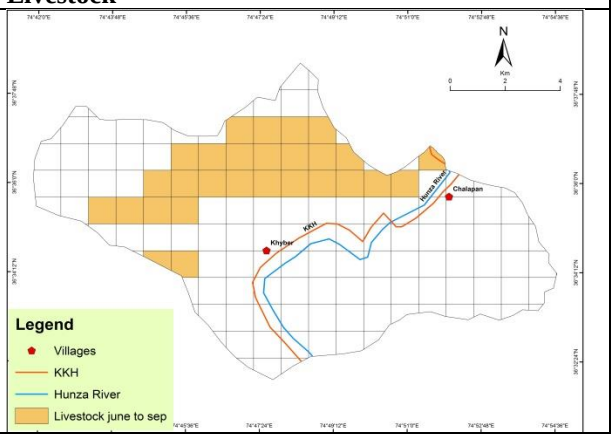
Figure 5: Seasonal Distribution of Ibex in the Study Area

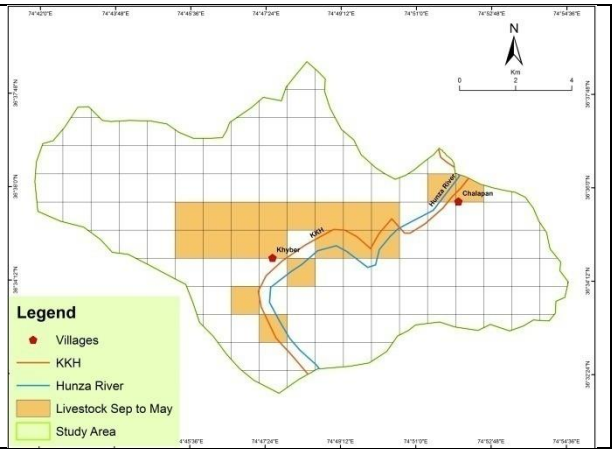
Time	Male Ibex	Female Ibex
June to November		
November to May		

Distribution of Livestock in Khyber Valley:

From June to September livestock presence was documented in 19% of the study area (28 grids occupied). Similarly, fro m September to May the livestock occupied 14.2% of the study area (21 grids)(Figure 6).

Figure 6: Distribution of Livestock

Time	Livestock
June to September	

September to May	

Habitat Analysis

Analysis is based on 153 occurrence points for Ibex, 74 points for livestock and 8 eco-geographical variables (Table 1). Each variable was represented by a raster cell of 500 x 500 m pixels, called resource unit (RU).

Principal Component Analysis (PCA)

Table 2: Coefficients of First and Second Principal Component Analysis of 8 Eco-Geographical Variables Depicting Their Relationship in Khyber Valley (Hunza), Pakistan

Variables	Component 1	Component 2
Slope	0.09716616	-0.275600889
Distance to River	-0.92744460	0.290883863
Distance to Settlements	-0.84226203	0.325469168
Distance to Roads	-0.92447722	0.320325094
Rangelands	0.58282227	0.755835557
Snow-covers	-0.61916938	-0.687175302
Bare rocks	-0.02257593	-0.138841731
Elevation	-0.89068782	0.002592219

The PCA showed that first two eigen values are considerably large than the rest so two axes are enough to explain the variability of the data set, though the first one is much larger than the second (Figure 7). First component explained 49.3% of the variation in the data while second one explained 17.88% of variation in data.

First Principal Components (PC) showed that distance to settlements, distance to rivers and distance to roads are positively correlated. Rangelands appear to be in vicinity of settlements, roads, and rivers as they are positively correlated. Second component stressed on two important factors: Rangelands and Snowcovers. Thus this component can be looked upon as measure of terrain. Rangelands and Snowcovers are negatively correlated.

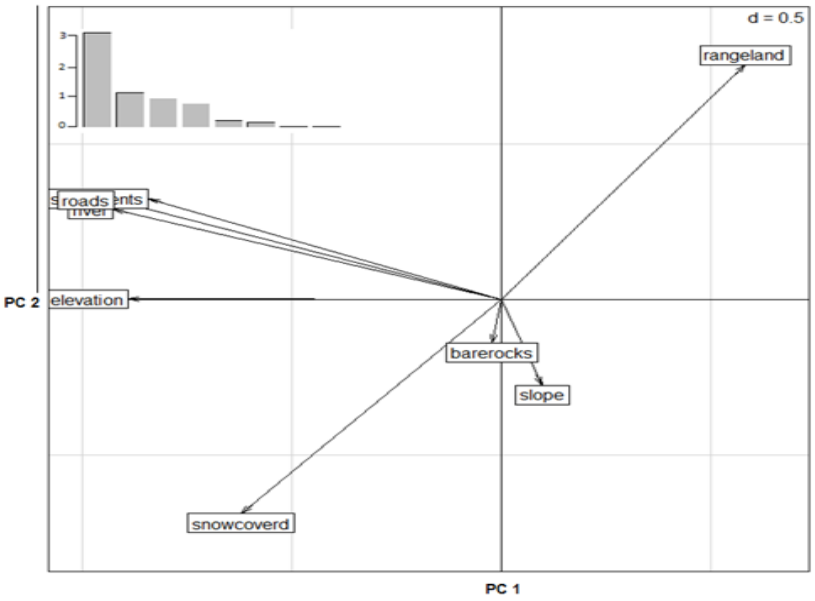


Figure: 7First two principal components showing relationship among 8 Ecogeographic variables in Khyber valley. A bar plot of the Eigen values as a small inset shown on top left corner.

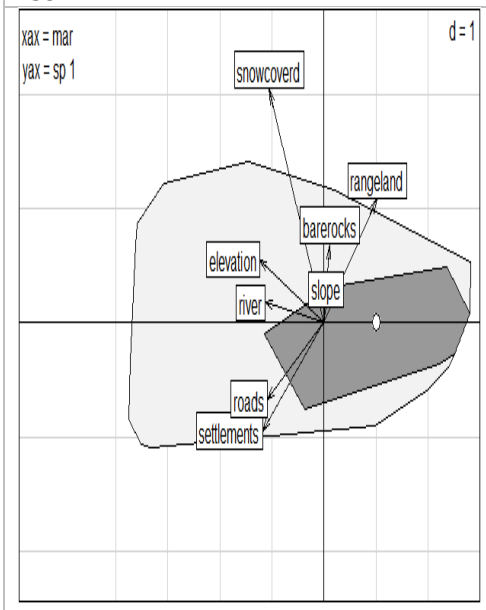
Habitat Suitability for Ibex and Livestock:

Habitat analysis is based on 153 occurrence points for Ibex, 74 points for livestock and 8 eco-geographical variables (Table 1). Each variable was represented by a raster cell of 500 x 500 m pixels, called resource unit (RU).

Biplot of ENFA (Figure 8) differentiated available habitats from habitat used (by ibex/livestock) through shades of grey, where light grey areas correspond to all 2the available habitat and dark grey area represented the used area (ecological niche of the animal). The ENFA plot indicated that though Ibex and livestock have selective approach towards habitat usage, but selecting for the same resources.

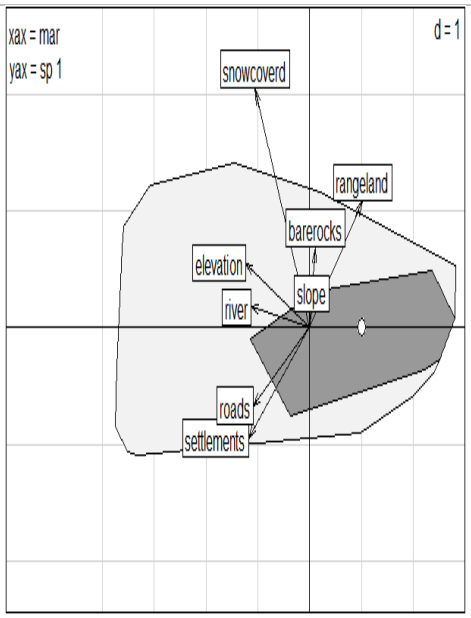
Figure 8 Biplot of the Ecological Niche Factor Analysis

Ibex



The plane comprises of marginality on the X axis and the prime specialization on the Y axis. Eco-geographical variables are planned through arrows. The white dot corresponds to the barycenter of the niche. The space between this point and the barycenter of available conditions specifies the marginality of the niche present in the available habitat

Livestock



Biplot is formed by the *marginality* axis (*X*axis) and the first *specialization* axis (*Y*axis). Arrows showing projections of environmental variables. The white dot corresponds to the centroid of livestock niche in each region

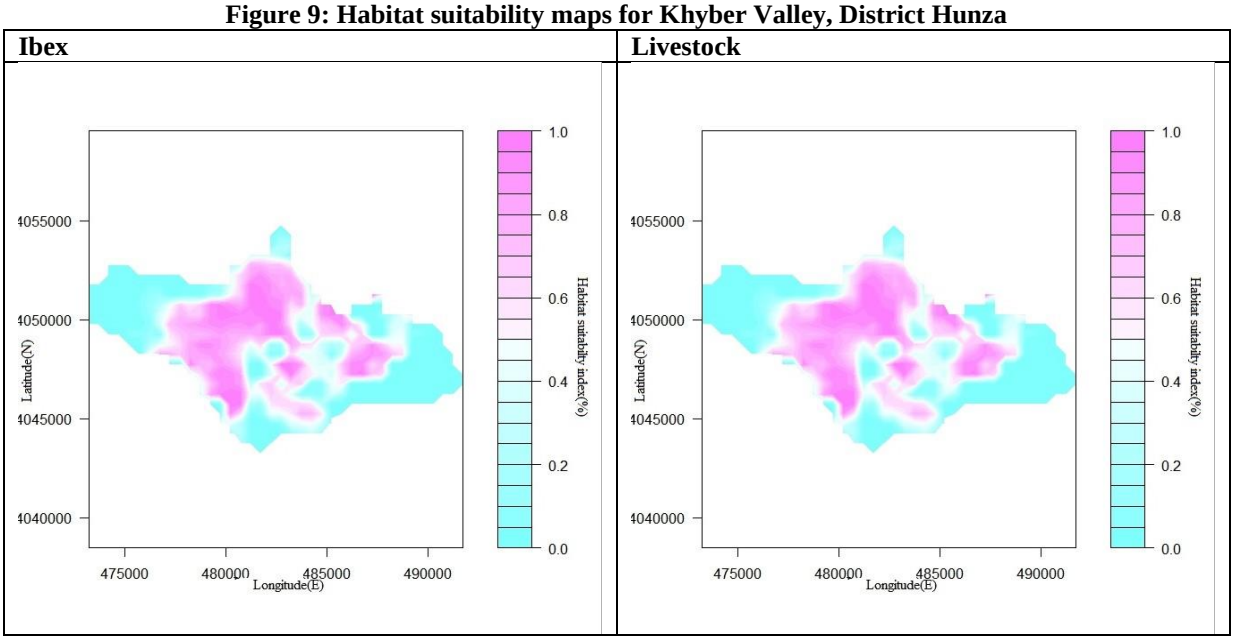
Table 3 Marginality values of environmental variables and their correlations with the specialization axes of the ENFA (Spe1, Spe2) for Ibex and Livestock

Variables	Ibex Marginality	Livestock Marginality	Ibex Spe 1	Ibex Spe 2	Livestock Spe 1	Livestock Spe 2
Slope	0.0118455	0.0118455	0.0475317	-0.004347	0.0475317	-0.004347
Distance to settlements	-0.428932	-0.428932	-0.345330	0.0378428	-0.345330	0.0378428
Distance to River	-0.410134	-0.410134	0.0636854	-0.073196	0.0636854	-0.073196
Distance to Roads	-0.397604	-0.397604	-0.244522	-0.107125	-0.244522	-0.107125
Elevation	-0.449291	-0.449291	0.2006292	0.1177255	0.2006292	0.1177255
Bare rocks	0.0407330	0.0407330	0.2522022	-0.331231	0.2522022	-0.331231
Snow covers	-0.384039	-0.384039	0.7456655	-0.658108	0.7456655	-0.658108
Rangeland	0.372247	0.372247	0.393402	-0.651946	0.3934021	-0.651946

Habitat Suitability Mapping:

Habitat suitability map for ibex and livestock (Figure 9) followed the productivity pattern of the valley; snow covers received the lowest suitability value while rangelands received the highest suitability value. The central part of the valley is mapped as the most suitable for both species, with the peripheral parts as least suitable. Vegetation map (Figure 4) justified this suitability map as rangelands are in central part of valley while on the peripheral parts snow covers are present which are avoided by ibex and livestock.

Figure 9: Habitat suitability maps for Khyber Valley, District Hunza



Discussion

In any natural setup it is apparently believed that species may compete for resources (Geist & Petocz, 1977), but evolutionary history of species shows that they have adopted to a resource use pattern that allows living with other species (Boyd, Blench, Bourn, Drake, & Stevenson, 1999). The climate change is influencing number of faunal and floral species globally (Inouye, Barr, Armitage, & Inouye, 2000) this change may affect those behavioral changes that species acquired in their evolutionary history. This change in behavior of species may be attributed with severe changes in temperature, precipitation, human encouragement and resulting pressure on alpine regions (Goudie, 2000), therefore, knowledge of species resource selection in change climatic changes is important for proper management of species.

The current study indicated that livestock and ibex make seasonal migration against the altitudinal gradient (Fox, Sinha, & Chundawat, 1992; Schaller, 1977). However females did not participate in altitudinal migration, rather prefer to stay at low altitude throughout the year, this phenomenon is more pronounced in pregnant and lactating ibex (Schaller, 1977). This could be attributed to the early availability of green sprouting, and avoidance of predators to visit low altitudes that may be close to human settlements (Schaller, 1977). Strong mother-young bond exists, for male yearlings it's for about a year while for female yearlings it exists temporarily (Schaller 1977).

During mating season male and female ibex use overlapping range while spatial segregation occurs between both sexes after the rut (Villaret & Bon, 1995). The current study agrees with the results of (Villaret & Bon, 1995) as (Figure 5) showed that both sexes inhabited different places in the study area but from November to May female and male ibex inhabited same place. (Tettamanti & Viblanc, 2014)observed that Ibex mate during winter season. (Schaller, 1977) also proposed that ibex mate in December-January so this overlap in both sexes suggests that mating between male and female member happened during these months (Figure 5).

Our results suggested that rangelands were positively selected by the ibex while they avoided snow covered areas. This is because they get better food in dense vegetation, and rangelands are vegetation rich areas as compared with the snow covered areas. Accordingly, (Stefano Grignolio, Parrini, Bassano, Luccarini, & Apollonio, 2003)found ibex preferring alpine meadows over rocks and stony ravines, as alpine meadows were offering more trophic resources.(Lovari et al., 2009) stated that herds of ungulates can coexist for browsing of finer biomass on same habitat. This behavior is adapted to minimize chances of getting preyed upon by predators.

In our study ibex showed no preference for bare rocks, but (S Grignolio, Rossi, Bassano, Parrini, & Apollonio, 2004) reported that bare rocks were used by Ibex in winter as they were the only snow free patches. Principal Component Analysis indicated that rangelands were positively correlated with settlements, river and road, (Li, Yu, & Shi, 2015)observed that Ibex tolerates human settlements and roads to maximize its foraging. The overpopulation of livestock in Himalaya cause degradation of pastures (Mishra, 1997; Rawat & Satyakumar, 2002), which could also force ibex to stay near the human settlements to forage on human cultivated alfa.

The outputs of ENFA model showed that, there is a strong overlap between ibex and livestock, which is agreement with past studies in the region suggesting that ibex and livestock (goats, sheep and horses) do compete for resources(Bagchi, Mishra, & Bhatnagar, 2004; Schoener, 1974).

The alpine region supports relatively low ungulate/herbivore biomass due to high seasonality and low biomass productivity (Sathyakumar and Bashir 2010). To meet the food requirements wild ungulates move to places where there would be better chances of getting good quality food, this intrinsic behavior of ibex contradicts with the human will to forage their livestock in areas with better forage, thus pose a serious threat to ibex survival (Bhatnagar 1997). Similarly, (Virk, 1999) noticed that due to increase in human population in Khyber valley, people take livestock to pastures where ibex usually forage during winters. A high gradation of spatial overlap between ibex and livestock existed in spring but

in summer ibex moved to higher elevations whereas most livestock remained beside the valley extremity which results in spatial segregation.

This study showed that rangelands and river are positively correlated; this means that both ibex and livestock were present close to river.(Hochman & P Kotler, 2006)while studying Nubian ibex observed that ibex was used to forage areas closer to water sources. Snow covers were negatively correlated to rangelands and were strongly avoided by ibex and livestock, this avoidance may be attributed with lack of camouflage on snow covered patches, ibex becomes more conspicuous on snow than any other habitat type, the second reason for avoidance may be lack of forage in that patches (Hochman and Kotler, 2006). In norther Pakistan, winters are prolonged and severe making it difficult to walk through on snow (Schaller 1977). On the other hand, low quality forage on snow covered habitats, forces ibex to confined to steep slopes which have less or no snow cover (McCorquodale, 1993).

Resource partitioning refers to the differential use of available resources by the organisms for example food and shelter (Schoener, 1974) . This differential use explains the coexistence of species in areas of high overlap in ecological resources (MacArthur, 1972). An extensive overlap can be indicative of competition but only in case of limited resources. When resources are in excess, this overlap may infer lack of competition as well (Putman & Putman, 1996; Schoener, 1983).Though the model suggest, strong overlap between ibex and livestock, but despite this overlap the ibex population is on the increase. Since the area has been declared a CCHA, the increasing demand for crops and stone fruits have changed people's reliance on livestock for livelihood has decreased pressure on the pastures especially from the summer grazing areas of ibex (Virk 1999). Many NGOs had provided funds to Khyber to construct water channels that resulted to irrigation of barren land in close vicinity of villages, hence better fodder production practice near village caused fewer people to take their livestock to high pastures. This developed range condition and lessen competition between wild ungulates and domestic stock at upper elevations (Virk, 1999).

The villagers of khyber follow a strict grazing pattern according to which high pastures are used throughout summer while meadows close to the villages and along the river are used in winter. Ibex and livestock used the same resource but local community did not showed any offence regarding this habitat and resource overlap. Only (11%) residents complained that competition for food with intrinsic ungulates was drawback for their livestock (Virk, 1999).

Conclusion and Recommendations

The current study documented a strong habitat overlap between livestock and ibex population in Khyber. Ibex selects area near dense vegetation and water sources. Due to sparse vegetation snow covered areas are side stepped by both ibex and livestock. But, the study concludes that despite strong overlap, there is no immediate threat to ibex due livestock in the Khyber valley. However, since ibex and livestock have similar food preference, this may result in eradication of some nutritious species from the habitat, therefore, livestock grazing should be monitor properly. Based on results of the study following recommendations are suggested:

- To reduce the unwanted influence of livestock on ibex population, management of the herding practices and feasible livestock grazing is important. Sustainable stocking rates, close monitoring of number and distribution of livestock population need to be determined in area. Conduction of detailed inventory of the rangeland is necessary to maintain sustainable stocking rates in future.
- To minimize impact of habitat overlap between ibex and livestock, activities like collecting livestock fodder should be restricted in the valley.
- Studies focused on biomass production of pastures and consumption by livestock must be conducted in order to maintain carrying capacity of the pastures.
- The current research encourages comparative investigations regarding habitat use of ibex with other ungulate specie in sympatry.

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