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HABITAT USE AND FOOD SELECTION BY WILD AND DOMESTIC UNGULATES IN THE SIKKIM TRANSHIMALAYA

Dissertation Submitted to
University of Saurashtra, Rajkot

In partial fulfilment of
Master's Degree in Wildlife Science

By

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CERTIFICATE

This is to certify that *Mr. Pranav Chanchani* of the Wildlife Institute of India, Dehradun has carried out original research work titled **'Habitat Use and Food Selection by Wild and Domestic Ungulates in the Sikkim Trans-Himalaya'** towards the partial fulfillment of the M. Sc (Wildlife Science) degree from Saurashtra University, Rajkot, India. The study was conducted under our supervision from November, 2006 to June, 2007. We also certify that this research work has not been submitted for the award of any other degree to any University.

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SUMMARY

By defining a resource, determining the resources available to animals and sampling the array of resources actually used by an animal (Krebs 1999), it becomes possible to gauge the nature of interactions between species. This study explored aspects of resource use by diverse assemblage of wild and domestic herbivores including The Tibetan argali (*Ovis ammon hodgsoni),* Tibetan Gazelle *(Procapra picticaudata),* kiang *(Equus kiang),* blue sheep (*Pseudois nayaur),* domestic yak and sheep in a Trans-Himalayan environment during the lean winter period. Sampling was carried out in a systematic manner using trails, as well as by sampling opportunistically. To quantify vegetation, a 3.5^2 km grid was overlaid on an image of the study area, and grids were randomly picked from these for random sampling. A number of habitat and vegetation variables were measured or noted for all ungulate sightings or within vegetation sampling stations and these were used in analysis to ascertain patterns of habitat use and food selection. Using a hierarchy of spatial scales, the study modeled animal distributions, and investigated the use of habitats and food habits of ungulates in relation to the availability of these resources in their environment. The study's major findings were that all ungulates were found to occur in the true Trans-Himalaya except for the blue sheep which selected more mountainous terrain in the transition zone between the greater and Trans-Himalaya.. Statistical tests of significance revealed that ungulates differed from one another or from random in their use of resources. Further, terrain features appeared to influence habitat selection to a greater extent than vegetation. Finally, the findings of this research indicate that although the wild and domestic ungulates of this region all exist in relatively large numbers, they tend to vary in their use of habitats and food either by differences in their distribution, or in the selection of finer environmental (habitat and food) variables. The study therefore concludes that competitive inter-specific interactions are not very apparent in this region.

1. INTRODUCTION

The survival of individual animals and populations depends on the availability of adequate life requisites or critical resources of the habitat (Manly et al. 1993). Differential resource selection is one of the principal strategies that permit species to co-exist (Rosenzweig 1981). Studies on the resource selection and patterns of habitat use by sympatric species in highly seasonal environments are of academic and conservation significance as they help in understanding the ecology of the species and in gauging the nature and dynamics of interactions of a species with biotic and abiotic factors and variables in its environment. Although some recent studies have addressed aspects of resource selection by ungulates in the Trans-Himalayan landscape, virtually none have been carried out in the resource –scarce winter months, and the present study aims to explore aspects of resource use in the winter in a an area with a large and varied assemblage of ungulates.

1.1. Resource selection and the niche theory

It has long been established that closely related species that meet in the same region can persist together only if they are separated ecologically by habitat or food preference or by both. When two species similar in size and morphology occupy the same habitat, then competition can be expected unless the habitat is partitioned. If species are of different size, it is often inferred that they differ in food selection (Schaller 1977). Where spatial use and selection of food resources overlap, temporal separation is likely to occur. Species interactions may be viewed within the paradigm of the classical 'niche' theory (Scheoner 1974), which emphasizes the role of inter-specific competition and resource partitioning facilitating species co-existence. Even within the same spatial confines, the strategies of resource utilization by herbivores are likely to be vastly different. The fundamental separation often occurs at the levels of physiology and behavior, so that organisms are evolutionarily selected to optimize survival and success. Strategies, however, have to be modified when an assemblage of species with similar requirements for space and food requirements are proximately located.

Theoretically, herbivores can utilize resources most efficiently when use is directly proportional to plant abundance (McArthur and Levins 1967). Deviations in such utilization are possible when confronted by competing species, and the resource loss can be both temporary and permanent impinging on the survival probability of species. However, interactions between herbivores need not be competitive, and 'stability' is achieved in a system when equilibrium exists between animals and vegetation; such equilibrium is defined by 'its 'characteristic density of animals' (Caughley 1979) or 'constancy of herbivore biomass' (Prins and Hamilton 1990).

Resource selection is generally expected to occur in a hierarchical fashion, ranging from the geographic range of species, to habitats within home ranges, and the selection of specific food elements within a general feeding site. The criteria of selection may be different at each level (Johnson 1980). Resource selection studies have long tried to ascertain the selection of resources by animals and underlying causes that influence selection. Selection by itself reveals little without knowledge of available resources. In practice, studies on resource selection suffer from a number of lacunae; many deal with establishing use (or an absence of it), and quantifying availability (Porter and Church 1987, Manly et al. 1993). Other problems in such studies deal with the selection of inappropriate spatial and temporal scales that are revealing of patterns of resource utilization. Studies on habitat and resource use have however yielded important information the interactions and dependence of organisms their environment. Such information, if incorporated into management strategies can contribute significantly to conservation.

1.2. Resource selection in the Trans-Himalaya

Resource selection by sympatric species is particularly interesting in varying environment conditions in space and time, and more so, in harsh climatic conditions. The Trans-Himalaya is one such environment, characterized by severe winters and low primary productivity. The Tibetan plateau is home to a large number of wild ungulates, many of which are listed as endangered (Fox et al. 1990, Schaller 1998). This plateau has also been used for livestock grazing by pastoral communities since centuries. Mishra et al. (2001) demonstrate that the Trans-Himalaya has the lowest mean graminoid biomass when compared with other comparable global grassland eco-systems such as the polar tundra, temperate steppes and tropical grasslands. Given that wildlife has been on a decline in many areas of the Trans-Himalaya, one obvious hypothesis for decline stems from resource competition between wild and domestic ungulates, and this has been the subject for research for several studies in the region recently, e.g., Bhatnagar (1997), Mishra et al (2004) and Bagchi et al. (2004).

Several studies in the Trans-Himalayan rangelands have revealed overlaps in resource utilization by domestic and wild ungulates. High livestock densities in rangelands in the Trans-Himalaya have yielded evidence for resource competition (Mishra et al. 2001). Mishra et al. (2002) contend that rangelands of the Trans-Himalaya may be over-stocked. Further, they hypothesize that the millennia of grazing by domestic livestock in these areas may have led to the exclusion of wild herbivores in many rangelands (Mishra, Heitkonig et al, 2002). These findings corroborate to different extents by a number of studies.

The study by Mishra (2001) in the rangelands of Spiti suggests that competition is the dominant interaction among herbivores of relatively low productivity systems like the Trans-Himalaya. Further evidence of this is found in other recently conducted studies. Research by Bhatnagar (1997) and Bagchi et al. (2004) reveal that Asiatic ibex (*Capra ibex sibirica*) are limited in their use of habitat and resources by livestock. Mishra et al. (2004) show evidence of competition between blue sheep or bharal (*Pseudois nayaur*) and domestic livestock, and Raghavan (2003) demonstrates that an overlap in the diet and habitat requirements of Ladakh urial (*Ovis orientalis vignei*) and livestock may have resulted in the former occupying sub-optimal habitats. Namgail et al. (2006) suggests that livestock have a clear disturbance effect on the argali and that competition is a distinct possibility. Recent research by Bhatnagar et al (2006) implicates competition with livestock as a major factor that has led to the drastic decline of Tibetan gazelles in Ladakh. While the above studies indicate that livestock impose resource limitation on wild ungulates in many areas, other research suggests that this is not always so. Schaller (1998) reports that competition in the Chang Tang is low; particularly where densities of both livestock and wildlife are low. Studies on summer diets (Shreshtha et al, 2005), and habitat segregation (Namgail et al. 2004) between sympatric wild ungulates indicate that in some areas within their ranges, argali and bharal co-exist without apparent competition. Negative interactions are usually avoided where animals differ in their selection of habitats, vary in selection of forage species, or differ in behavioral adaptations such as anti-predator strategies. It is often problematic to demonstrate overstocking or competition by livestock and Shrestha et al. (2005) suggest that these anthropogenic factors may actually contribute significantly to declining trends observed in many populations of wild ungulates.

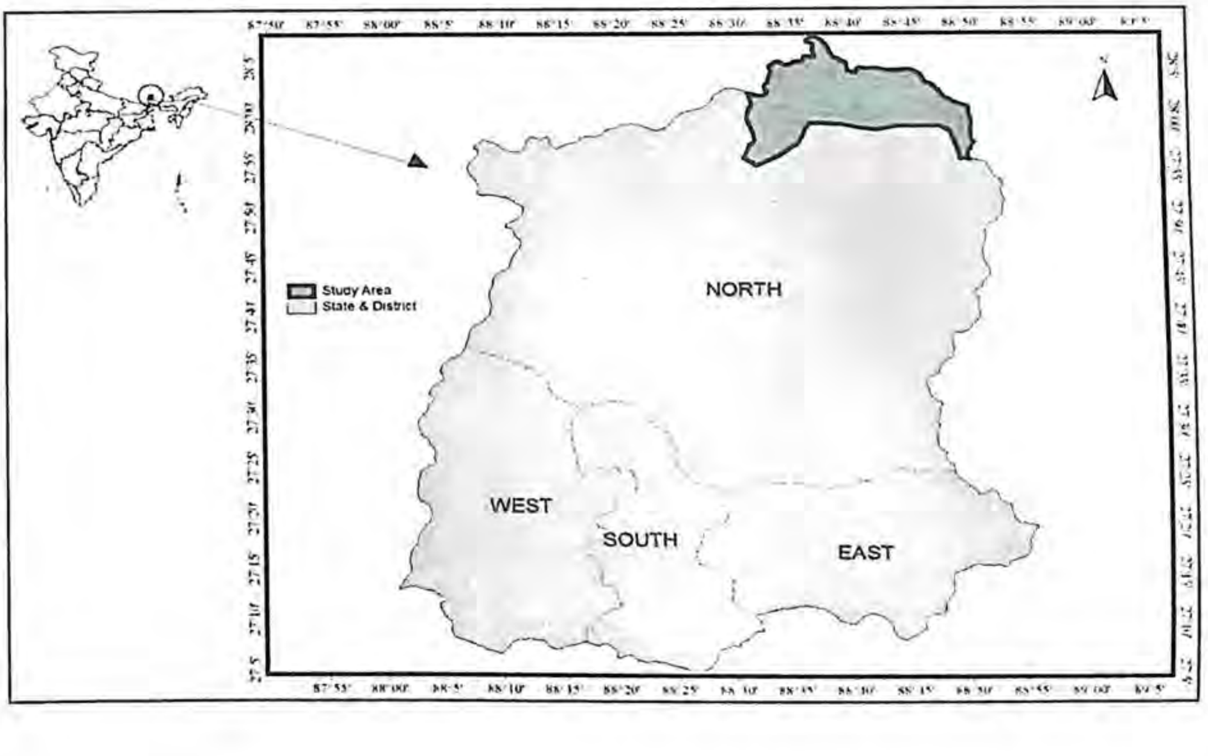
1.3. Issues in the Sikkim Trans-Himalaya

Although rich in wildlife, and home to some of the large and rare ungulate species of the high central Asian rangelands, the Sikkim Trans-Himalaya largely remains unstudied. This region supports an assemblage of wild herbivores that include *Ovis ammon hodgsonii* (Nayan), *Procapra picticaudata* (Tibetan gazelle) and *Equus kiang* (Tibetan wild ass). However, Schaller (1998) reports that a number of species which are found patchily distributed across the Chang Tang plateau and China, have populations in Sikkim. However, there is little information on this region apart from a status survey on the Kiang by Shah (1994), and a report on Tibetan gazelles by Ganguly-Lachungpa (1997). These do not go beyond listing the assemblage of wildlife on the plateau, and providing survey-based population estimates for some species.

Bhatnagar et al. (2006) extensively surveyed large areas in Ladakh for the Tibetan gazelle, and estimated the population size to be no more than 50 (over an area of 20,000 square kilometers), and they highlight that this species is under severe threat in Ladakh. The only other population of this species in India is found within the 200 sq km. area of Sikkim Trans-Himalaya, where it reportedly exists in fairly high densities. Similarly, large aggregations of Nayan numbering over two hundred animals have been recorded in Sikkim. The presence of sizable populations of globally threatened wild ungulates, with little information on their population and status, highlights the pressing need for a study. Like other rangelands of the Trans-Himalaya, the Sikkim plateau is also grazed by livestock, viz., yaks, goats and sheep. Several studies have been conducted on the interface between domestic and wild herbivores in the Trans-Himalaya, and have either predicted competition, or the absence of it on account of niche separation or low densities of domestic or wild ungulates. This suggests that patterns of resource partitioning may vary over a range of spatial scales and at different localities. This study in the Sikkim Trans-

2.1. Location and topography: The Sikkim Trans-Himalaya forms the eastern-most extent of the Trans-Himalaya in India. Although a major portion of the study area lies within a region that can be categorized as 'Trans-Himalayan', its southern portions occupy an area that can best be described as being a Transition zone between the Greater Himalaya and the Trans-Himalaya. The village of Thangu close to the southernmost point of the study area is quite distinctly alpine in appearance, and with respect to its flora and physiognomy of vegetation. The international boundary between India and China along the northern rim of Tso Lhamu region roughly follows a discrete natural watershed boundary. The water flowing south from the catchment area joins the Teesta as its principal tributary, the Lachen (*chu*) river. This study was focused in north-eastern part of Sikkim (Figure 2.1). The area is variously referred to as Tso Lhamu by its local inhabitants and as the 'Sikkim Plateau' by the Indian Army. The Tibetan plateau was formed as a result of the collision of many crustal blocks into Asia over a long period of time, starting 300 million years ago. However, it acquired its present elevation only after the Indian plate, moving from the south, collided with the Asian landmass in the mid-

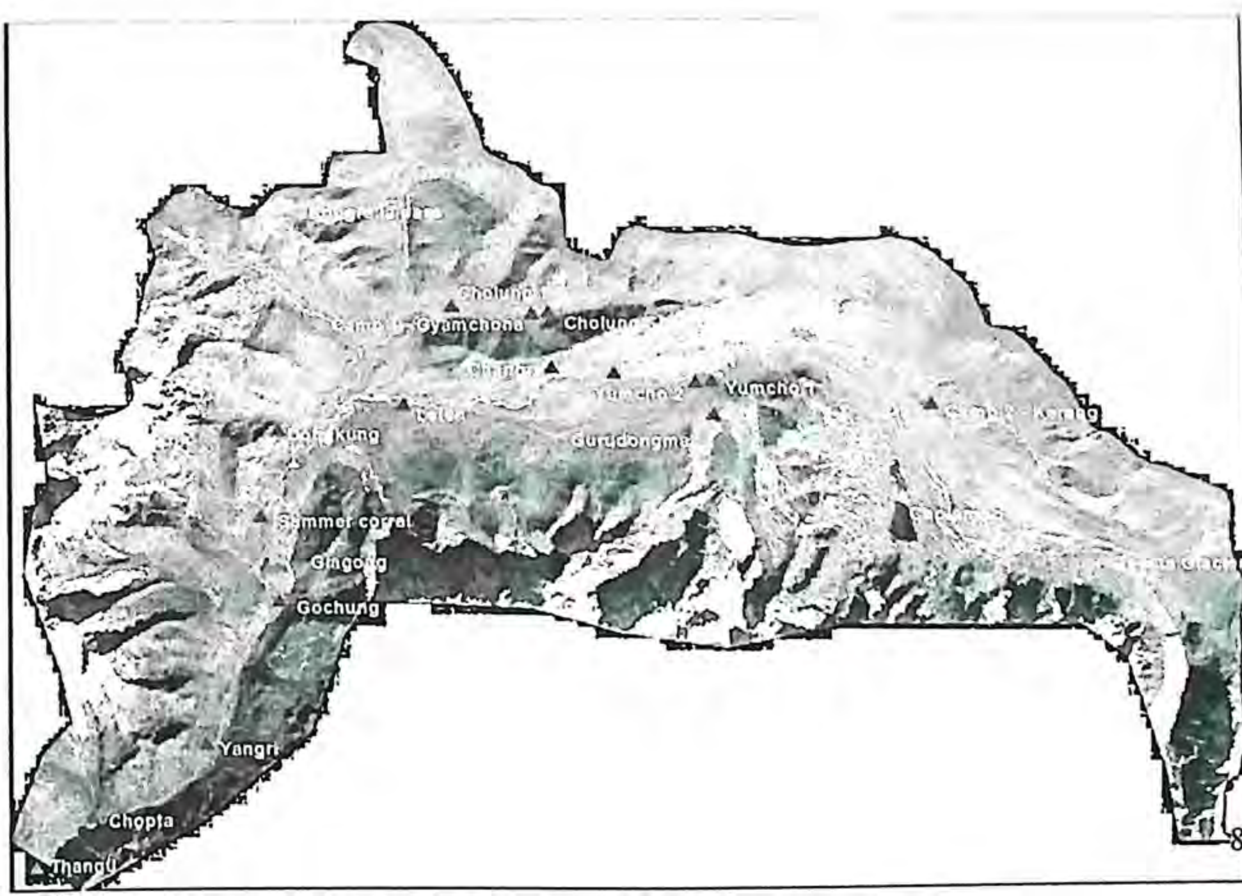
Figure 2.1. Map of study area map



Cretaceous era. Today, about half of the Tibetan plateau has of its landmass lying above 4500m (Schaller 1998). The climate in this large region has changed dramatically over eons. It became predominantly cold following the Pleistocene glaciation and it is presently of the continental type. The Tibetan plateau plays a pivotal role the operation of the monsoon climate in South Asia. The region is a catchment for several major river systems in Pakistan, China,and Indo-China most notably the Indus and the Brahmaputra. The plateau is marked by extremely low temperatures which remain below 0°C in many areas even in the summer months, particularly after sun-down. Precipitation is scant and few places receive over 500 mm annually. Overall, the precipitation gradient declines from east to west. Precipitation, temperature, altitude and latitude all affect the distribution and species of plants and animals in the region. Plants in the region have adapted to extreme cold and aridity and animals, particularly several ungulate species, have adapted to optimize their survival in this harsh desert environment.

The study area has a fairly vast altitudinal range between 4020 m and 5980m. The

Figure 2.2. False Color Composite of Landsat image, with prominent locations marked



most conspicuous features on the plateau are the Kanchangao (6889m) and the Chommoyummo (6829m) massifs. The broad Teesta basin (Chombo Chu) has an east-west orientation. Several valleys branch off from the Cholung funnel towards the north, and these areas support large populations of the Tibetan gazelle and Tibetan argali. To the west, Chommoyummo, Lungma la and the jagged peaks that lie south of it form a formidable barrier. Immediately north of Kerang and the Chomo chu basin, the area rises and then flattens out into a fairly extensive 'elevated plateau', which marks the international border with China. There are several sizeable glacial lakes in the Tso Lhamu region of which the Gurudongmar and Khangchung lakes, at the foot of the Teesta Khangse glascier, are the largest (CISMHE 2004).

Although Tso Lhamu is the only true Trans-Himalayan region in Sikkim, the region of Muguthang which lies west of the Chommoyummo massif in the North and Thangu in the south is also broadly classified as a cold-desert. This region has large broad valleys, but it resembles the Transition zone between Thangu more closely than the 'plateau'. The region of Yumesamdong lies south of the Kanchangao massif and the Donkyala pass near lake Cholamoo. Yumesamdong lies in a rain-shadow region too, but differs from the plateau in its general topography. Although they lack the diversity of wild ungulates found in the Tso Lhamu region, the Muguthang and Yumesamdong regions have floral and faunal elements akin to those found in TsoLhamu.

2.2. Climate

Because the Trans-Himalaya and the Tibetan plateau are shielded from rain laden clouds by the Himalayan ranges, this region lies in an area of rain shadow, and receives little precipitation. Most of this is received as snow. While regions south of the Tso Lhamu plateau have an oceanic climate and receive much rain in the monsoon, the climate on the plateau is largely continental, making the area arid. The area receives about 1000mm of rain annually. Temperatures are consistently low on the plateau owing to its great altitude, and probably remain below freezing at night through the year. Winter temperatures occasionally plummet down to -30°C at Gyamchona (~16,400 feet). The lowest diurnal temperatures are often recorded very early in the morning. Temperatures during the day vary depending on cloud cover. The region is swept by cold winds and wind velocities of 50 km ph are not uncommon. The wind velocity is generally higher post noon.

2.3. Vegetation types and flora

The vegetation of the study area is greatly influenced by topography, altitude, aspect and soil moisture. Broadly, the vegetation of the study area can be grouped into following principal types: (i) Moist Alpine Scrub, (ii) Dry Alpine Scrub, (iii) Riverine scrub, (iv) Desert steppe and (v) Sedge meadows. Vegetation of the Transition zone is characterized by a number of perennial shrubs e.g., Juniperus *indica, Rhododendron setosum* and *Rhododendron campanulatum*. A large number of herbs, grasses and sedges also occur on gentle south facing slopes. The riverain patches have luxuriant growth of *Salix calyculata, Myricaria prostrata* and *Hippophae tibetiana.* The upper reaches of the Transition zone have a fairly high proportion of species common to both the Greater and Trans-Himalaya namely *Rhodiola heterodonta, R. tibetica, Arenaria densissima, Kobresia spp.,* and animal species. The Transition belt also supports a large number of herbs and forbs including species of *Primula, Androsace, Pedicularis, Aster flaccidus, Lamium rhomboideum, Delphinium caeruleum, Leontopodium* sp and *Anaphalis royleana.* Species diversity and abundance are greater in the Transition zone.

Generally there is low vegetation cover and species are sparsely distributed. Furthermore, most of them are short and grow close to the ground. Shrubs are sparse although *Caragana versicolor* is seen on some South and East facing slopes. Forbs such as *Potentlla biflora* and *Anaphalis xylorhiza* are fairly abundant as are a number of grasses. Sedges (*Kobresia pygmea, Kobresia schoenoides* and *Kobresia royleana*) form 'carpets' along water courses and lakes banks, whereas *Carex moorcroftii* grows in extensive patches on well drained sandy soil. A number of grasses also occur in the region. *Stipa orientalis* is widespread though it grows sparsely in most areas. In the winter, the vegetation is largely in a dormant or senescent stage and above ground parts are sparse, fibrous and often leafless. Large area of this region, particularly certain slopes and plateaus are under fell-field vegetation characterized by prostrate, sparse and spiny vegetation dominated by *Arenaria sp* and *Androsace sp* interspersed with *Saussurea sericea* and *Festuca valesiaca.* Large patches or rock and scree are generally devoid of vegetation though *Potentila biflora, Urtica hyperborea, Elymus nutans* and *Caragana versicolor* may occur in patches. At altitudes above 5300m, the vegetation is very sparse and dominated by *Rhodiola sp, Festuca valesiaca* and *Kobresia pygmea* in moister areas.

2.4. Major fauna

Various wild bovids found in this region are *Ovis ammon hodgsoni,* Pseudois *nayaur,* and *Procapra picticaudaya.* The Southern kinag (*Equus kiang polygdon)* belongs to Equidae. Hooker (1854) sighted and made detailed sketches of the Tibetan antelope *(Pantholops hodgsonii)* in this region, but this species has become locally extinct for several decades at least. Local herders speak of the wild yak in the area in the times of their grandparents. Interestingly, the Southern kiang was believed to be extinct in Sikkim until 1992 (Duncan 1992) but reports by Shah (1994) established its presence there and reported a population between 74-120. Shah (1994.) also mentions that the frequent movement of the Kiang across the border into Tibet makes its true status indeterminate. Predators include the snow leopard (*Uncia uncia*), the Tibetan wolf (*Canis lupus chanko)* (Shah, 1994), and the Tibetan Sand fox (*Vulpes vulpes ferrilatus).* Though there was no sighting of snow leopard during the study period, their scats and pugmarks were recorded on a few occasions. Pikas *(Ochotonia sp),* woolly hares *(Lepus oiostolus)* and the Himalayan marmot *(Marmota himalayana)* are the small herbivores of this system.

Several large birds of prey sighted regularly included the golden eagle (*Aquila chrysaetos*), the lammergeyer (*Gypaetus barbatus*) and griffons (*Gyps himalayensis*). Large flocks of Tibetan snow finches (*Montifringilla adamsii*) aggregated in many areas. Red-billed choughs and ravens were regular visitors at camps, and groups of Tibetan snow cocks (*Tetraogallus tibetanus*) were frequently spotted on rocky, broken or vegetated slopes.

2.5. Human Populations and Land use

The Tso Lhamu region has long been home to the nomadic Dokpa herders. This region historically formed an important trade route into Tibet in general and Lhasa in particular (Hooker 1854). Prior to the Chinese occupation of Tibet in 1965, this region, though recognized as a part of Sikkim, was open to herders from both the Tibetan and Sikkim sides – the Dokpas were then one homogenous community. With the sealing of the border in 1965, the movement of humans and livestock across the regionally important Kongra La into, and out of Tibet ceased. This significantly changed the dynamics of livestock grazing and animal husbandry in the region and also impacted socio-economic and cultural aspects of the Dokpas' lives. Local Dokpa herders say that the number of livestock in the region has decreased significantly in recent decades and in indication of this is seen by comparing current livestock numbers with those reported by Palzor (2001) . At present there are fourteen Dokpa families in the Tso Lhamu region. Of these four families are primarily sheep herders though they may own a few yaks as well. In total there are about one thousand yaks and about an equal number of sheep/ goats in the study area. Sheep greatly outnumber goats of which there may be a total of about hundred animals in the region. The people of Lachen have historically owned yaks and sheep which are grazed in this region by the Dokpa herders, and the Lachenpas exercise considerable control over the region and its herders. At present about fifty percent of the livestock on the plateau is owned by the Lachenpas. The herders spend their winters (November-Mid April) on the Tso Lhamu plateau (the region North of Giagong), whereas the summers are spent in the regions between Thangu and Giagong, and primarily in the Lasher valley which runs parallel to and east of the Teesta valley (South of Giagong). The Dokpas have a number of temporary settlements all over the plateau. A settlement typically consists of a small hut for the herder made of stone and mud, and a number of low rock corrals to pen livestock. Such habitations are usually clustered in areas near the river where vegetation is relatively abundant.

Unlike similar communities in other regions of the Indian Trans-Himalaya such as Spiti where herders are agro-pastoralists (Mishra et al, 2001), the *Dokpas* of Sikkim are herders alone and do not practice any significant agriculture. Their primary source of income is from the sale of yak meat, and is supplemented by money earned from contracting pack animals to the army. The Dokpas are a community in Transition, cut off from their former associates in Tibet, there is a great dichotomy in their lives as they continue to live the Spartan nomadic lives of their ancestors while their children all study in schools in Gangtok. Many of the younger generation may have aspirations that are incompatible with their current nomadic mode of existence.

Forces of the Indian Army and para-military forces have been stationed in this region for several decades now. Roads and other essential services are all maintained by the army particularly in the regions north of Lachen. Because of its strategic location, much of the Tso Lhamu region is restricted and only a small area within the actual plateau (the region around lake Gurudongmar) is open to tourists and casual visitors.

3. MATERIALS AND METHODS

3.1. Terms and target species

In this thesis, the terms 'observation' and 'sighting' have been used interchangeably, and both refer to an independent sighting of an animal. The terms 'Transect' and 'trail' have been used interchangeably in the case of foot trails. The term 'ad-lib' refers to opportunistic animal sightings. The terms relevé, sampling station and plot have been used interchangeably. The definition of a relevé follows Mueller-Dombois and Ellenberg (1974) who describe a relevé as a record of vegetation composition that requires a comprehensive list of plants in a relatively small and environmentally uniform habitat.

This study follows the type I design of Thomas and Taylor (1990) wherein resource selection is studied at the population level, and not at the level of individual animals. Further, the study follows a 'use-availability' framework (Manly et al., 1993). The terms availability and use have been variously described in habitat ecology literature by Johnson (1980) Garshelis (2000), Manly et al (1993) and Fuller et al (2005). For the purpose of this study I followed Johnson's (1980) definition wherein the availability of a resource component is its accessibility to the consumer. Some of the other definitions of availability necessitate the estimation of area or quantity of each resource unit; Johnson's definition is simple and can be uniformly applied for habitat and food resources by spatially demarcating available areas for each species. I define use at two levels: for habitat analysis use was defined as the presence of an animal at a given location within a given terrain or habitat type. To assess the selection of forage, used sites were only those in which an animal was seen feeding, here, mere presence did not amount to use.

Table 3.1 provides the list of study species and additional information about distribution and population status.

Table 3.1. List of study species.

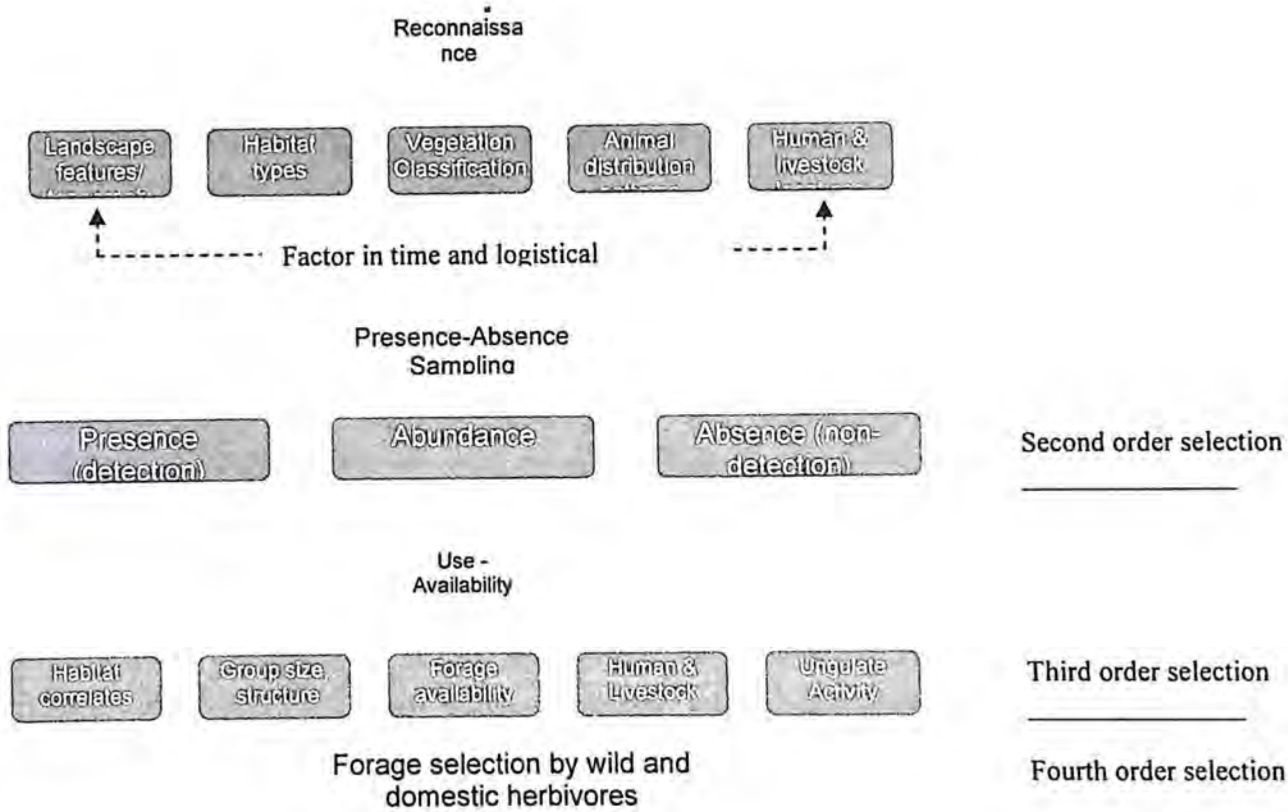
S. No.	Species	Geographical Distribution	Habitat	Approximate population in Sikkim*	Conservation Status (IUCN, IWPA)
1.	Tibetan argali *(Ovis Ammon hodgsonii)*	Ladakh to eastern China	Rolling Scree/& gentle Slopes	180-230	Vulnerable, Schedule I
2.	Tibetan gazelle (*Procapra picticaudata)*	Ladakh, Sikkim & Tibet	Gentle slopes, valleys	90-120	Lower Risk, Schedule I
3.	Kiang (*Equus kiang)*	Tibet, Ladakh & China	Rolling plains, gentle slopes	< 25	Data Deficient, Schedule I
4.	Blue sheep or bharal (*Pseudois nayaur)*	Across Central Asia and Himalayas	Meadows, cliffs and rocky slopes	~ 350	Lower Risk
5.	Domestic Yak		Valley bottom, slopes	>1000	-
6.	Domestic Sheep and goats		Valley bottoms, slopes	~1000	-

* *Personal observation*

3.2. Sampling strategy

It is well established that resource selection by animals occurs in a hierarchical manner and at different spatial scales (Johnson 1980) and that inferences of selection may differ with sampling at different tiers in this hierarchy (Manly et al 1993). In line with this hypothesis, the following overall sampling strategy was envisaged while designing the methods for this study. First order selection refers to the selection of a broad geographic range by a species. In this case, the range of the ungulates studied may extend into Tibet. Although animal distributions within the Sikkim plateau have been plotted, these may not portray the ecological ranges of the species.

Figure 3.1: Hierarchical sampling framework



An initial reconnaissance was carried out between 19th December 2006 – 7th Jan 2007 to refine and further develop a sampling strategy, while factoring in logistical constraints likely to be encountered in the field from mid December.

The assessment of resource use and selection was broadly carried out within a use-availability framework. In order to estimate population size and density of wild ungulates Transects and trails were carried out using repeats, and species occupancy data was collected using pellets. To assess habitat selection, animal locations were meticulously recorded with a number of habitat variables. Observations on group size and composition were also made where possible. Food selection was based on vegetation sampling; both in areas where animals were seen foraging and in randomly selected grids to compare if use differed from availability. We closely observed animals feeding whenever possible, primarily to corroborate data from plots; and detect obvious food preferences where possible. Further, ungulate pellets were collected for laboratory analysis to compare diets, and reference samples of important plant species were collected to aid in species identification in fecal analysis (Neff 1968).

Sampling was carried out over the winter (mid-December – end April). Although temperatures were relatively higher towards the end of the study period, most vegetation still remained senescent until about the third week of April, after which new shoots began to appear in a few species of graminoids and forbs in some areas, soon after the winter snow melted completely. The onset of spring was a little earlier at lower altitudes in the Transition zone. Observations were made within daylight hours between 0600 am and 1800 hours. Most observations were however made between 0800 am and 1700 hours.

3.3. Stratification method

Based on the initial reconnaissance the study area was divided into five blocks. This division was broadly made on the presence of wild and domestic ungulates in the region and on physiognomy and broad vegetation types. This preliminary stratification was carried out to facilitate efficacious sampling; to rationalize 'effort' across the larger study area, and ensure a greater degree of representative-ness in sampling. Dividing the area into blocks based on initial observations of animal distribution patterns also helped in the establishment of 'control' areas – those with less observed animal use. The study was carried out from three locations; a base camp at Thangu and from army camps at Gyamchona and Kerang respectively – having three widely separated base camps permitted wider coverage of the study area on a regular basis.

A grid (1 minute x 1 minute, grid size = 3.4 km) was overlaid on a satellite (Google Earth) image of the area (grid size = 3.4 km^2) and each grid served as a sampling unit; these grids were primarily used to randomize while sampling for forage availability. It was felt that this relatively small grid size would probably help in detecting heterogeneity in distribution and abundance of types and map habitat selection at a finer scale. Larger grid sizes may have resulted in a lack of resolution when analyzing selection, whereas under the study's time constraints, it may have been inappropriate to attempt to sample the entire area effectively using a smaller grid size.

Camp	**Altitude**	**Days spent**	**Species in proximity**
Gyamchona	5000	61	Argali, gazelle, yak, sheep
Kerang	5200	21	Gazelle, kiang, yak, blue sheep
Thangu	3920	28	Blue sheep
Giaong	4700	7	Blue sheep, yak

Table 3.2 Study area and species of ungulate found

GPS locations of animals were recorded by visiting the exact location (after the animals moved out of the area) when possible, or by projecting GPS locations – although this may have resulted in slightly imprecise locations, when distances and angles were measured

correctly, the location recorded was usually within about 40m of the actual animal location. Where animals were seen at the junction of vegetation or terrain types an attempt was made to record the precise location. All locations were later plotted on a 30m satellite (LANDSAT) image.

3.4 Data collection protocol

Since the study area is fairly large, combination of vehicle count, trail walk, point count and opportunistic records were employed. A total of 5 vehicle routes were selected for Transects varying in length between 6 km and 16 km. Two foot trails (Transects) of around 3 km were selected initially, with one addition at a later stage (Table 3.3). Two vantage points were selected for point counts. Following a spell of heavy snowfall (February and March), when vehicle Transects and other systematic were not feasible, opportunistic records were also made, largely restricted to a small area in the proximity of camps.

In vehicle Transects, the vehicle would move at a constant speed of 12-15 km/h and the vehicle would be stopped to count and observe wild and domestic ungulates when sighted. On foot trails, the observers would walk at a uniform pace, each scanning either to the left or right. Both on vehicle and foot trails, the observers carried binoculars (8x40). For finer observations to ascertain age classes and sex, and activities, a 15x45 X (Bushnell Spacemaster II) spotting scope was used. Any animal sighted comprised an observation. If an animal or group of animals was separated from another by approximately 150 meters, it was identified as a separate group. There was little overlap in the areas visible from different Transect routes. Where overlaps in visibility did occur, distances were often too great to spot animals from the further Transect. Point counts from vantage points were also used to sample for animal densities and the area visible in each was roughly estimated by counting the number of grids visible from the point. Two observers would scan a vast area from a high vantage point using binoculars and a spotting scope for a duration of one hour, and all animal locations were recorded.

ID	Type	Location	Length (km)	Repeats	Zone	Ungulates spotted	Months
VT1	Vehicle	Chopta bridge (above Thangu)-Lukrep	16	10	Transition zone	Blue sheep, yaks, sheep	Jan, Apr
VT2	Vehicle	Giagong-Gyamchona	12	9	Transition zone , Trans-Himalaya,	Yaks, sheep, Tibetan gazelle	Jan, Apr
VT3	Vehicle	Leten – Kerang	13	9	Trans-Himalaya	Tibetan gazelle, Tibetan Argali, yak, sheep	Jan, Apr
VT4	Vehicle	Gyamchona – Cholung funnel end	6	10	Trans-Himalaya	Tibetan gazelle, Tibetan Argali, yak, sheep	Jan, Apr
VT5	Vehicle	Cholung end – upper Kerang	16	2	Trans-Himalaya	Tibetan gazelle, kiang, yak , sheep, Tibetan argali	Jan, April
FT1	Foot	Gyamchona – Kongra la	3	16	Trans-Himalaya	Tibetan gazelle, Tibetan argali, yak, sheep	Jan, Feb, Mar, Apr
FT2	Foot	Kerang – Moraine of Teesta Khangse glacier	3.	5	Trans-Himalaya	Yak, sheep	Jan, Mar, Apr
FT3	Foot	Below Sese la pass – 5 fingers (Upper Kerang)	3.	3	Trans-Himalaya	Tibetan gazelle, kiang, yak , sheep, Tibetan argali	Mar, Apr

Table3.3: Transect length, and number of repeats; both foot and vehicles.

Occupancy sampling (presence absence) was carried out within a double sampling framework wherein *n* sites were to be sampled once and *x* sites, a subset of the *n* sites are sampled repeatedly (Mackenzie and Royle 2005). While this sampling was initiated at the beginning of the study, it was later dropped on account of a number of problems which have been highlighted in the discussion section of this thesis. Pellets or droppings were recorded in each of the 1470 1x1m quadrats (3-5 sampling stations per grid) in which vegetation was sampled. Although plots sampled were not repeated, the presence or absence of pellets in each plot can be used as a measure of occupancy.

3.5 Animal – Habitat relationships

In order to quantify and detect patterns in habitat use and selection by ungulates, data collection was carried following focal species plot sampling, wherein, habitat variables were recorded around the location of an individual. Among others, the dominant variables recorded were group size characteristics, elevation, topography, vegetation cover and snow condition.

3.6 Vegetation classification

Vegetation sampling in relevès was the primary method use to collect data for vegetation classification. A total of 294 relevès were sampled across the study area. Of these, 163 were 'availability' relevès in randomly selected grids across the study area, whereas the rest were 'use' relevès, at sites where ungulates were seen feeding. The GPS location for each vegetation relevè was later plotted on a satellite image of the area. For every vegetation relevè, the altitude, slope and aspect were recorded. The 'availability' relevès within randomly selected grids were later used to assess whether resource selection deviated from random. The vegetation plots in combination with unsupervised classification process on Landsat satellite image were done to map broad vegetation types of the study area.

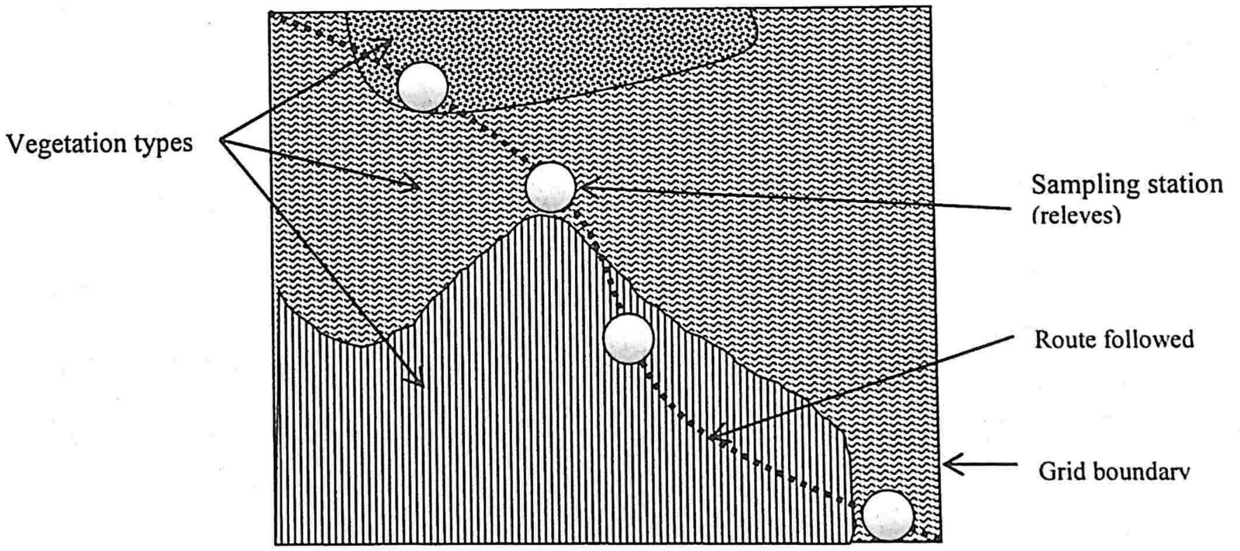
3.7. Forage availability and selection

Like habitat selection, food selection was also assessed within a use-availability framework wherein forage availability was sampled for in randomly selected grids. Simultaneously, the heights of major species within a quadrate or sampling station were recorded, as were major environmental variables such as aspect, slope and elevation. 3-5 relevès were laid within each of these grids, and each relevè was sampled on one occasion.

Within each relevè, I laid 5 1 x1 m quadrats. 1 x 1 m quadrats have been used elsewhere in the Trans-Himalaya to classify and quantify the forage (Rawat and Adhikari 2004). The quadrat size was 1x1m. The five plots were usually laid within a radius of 12-15 m of a central point at which variables for the relevè were first recorded. Within a relevè, the selection of sites for quadrats was randomized using a dial watch and a stone was tossed in the direction of the seconds hand to select a site to be sampled.

While grids were selected randomly, there was a degree of subjectivity while selecting sites for relevès within each grid. Where possible, I would walk diagonally across the grid in order to traverse the entire grid. Plots would be laid at intervals of about 200-500m. An attempt was made to sample in each visibly different vegetation community within each grid.

Figure 3.2: Method used in sampling vegetation, habitat variables and pellets in randomly selected 'available' grids.



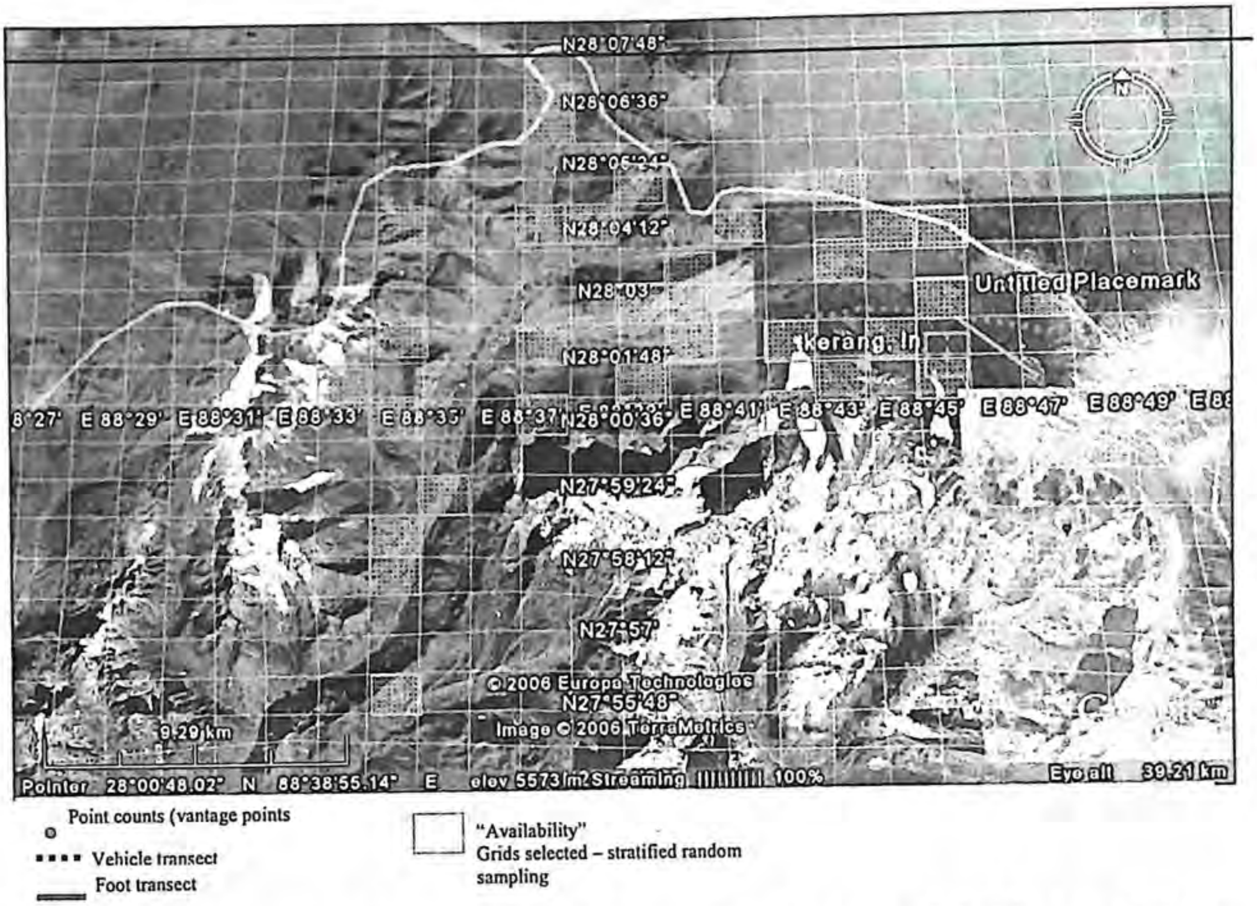


Figure 3.3: Randomly selected grids for sampling forage and habitat availability. Various Transects, trails and point count locations/ routes are also marked.

For 'use', a number of sites where animals were seen feeding were sampled similarly once the animals movie out of the area (usually the same day or within the next 40 hours). While sampling at sites where ungulates were seen feeding, an attempt was made to place quadrats exactly where ungulates were seen feeding; however this was only possible when we could sample an area immediately after the animals vacated it. When sampling was carried out at a later time, quadrats would be selected randomly within relevès like they were when sampling for forage availability.

Pellets and dung of all ungulate species in the area were collected for fecal analysis to determine major species in an herbivore's diet. An attempt was made to collect fresh pellets (over the winter months). Pellets were collected from as wide an area as possible within a species range, and the site of collection was noted. At least 15 samples were collected for all species between January and April 2007.

3.8. Logistical constraints and limitations

The study could not achieve intended targets for some of the proposed objectives due to unpredictable and challenging conditions on the Tibetan plateau. Three weeks (mid November – 10th December) had to be spent in anticipation of permits from the Ministry of Defense, Government of India, to carry out this study. Another fourteen days were spent in acclimatizing at lower altitudes (following an Army regime). Vehicle based sampling was initially planned in order to effectively cover the fairly large study area, and model species-habitat association and map distribution surfaces for the entire study area. However, running a vehicle at 5000 meters and above in sub-zero temperatures turned out to be an arduous task: breakdowns were the norm and service facilities were very rudimentary. Despite changing three vehicles over sixty days, a vehicle could only be used for about thirty five days and often in a very limited manner. Thereafter an effort was made to cover as much of the area on foot as possible while adhering to the overall use-availability sampling framework. However, systematic sampling was severely affected by these problems. Although bad weather was factored into original plans a particularly, severe winter (with more snowfall than there has been in about a decade) hampered the original systematic sampling strategy. These constraints largely made it very difficult to rationalize effort over the entire study area. Availability sampling could however be carried out effectively in the pre and post snow seasons.

3.9 Analytical Methods

Cluster analysis, and measures of diversity and richness were performed on releve plots using PC/ORD and TWINSPAN software. To determine resource selection by animals, at a broad spatial scale (landscape level habitat features), abundances were related to habitat types and ANOVA, T-test and appropriate non-parametric tests were done to detect statistical significance. Logistic regression was used to predict variables contributing to the presence or absence of an animal at a given location. This was done primarily to determine if selection could be explained at a finer spatial scale i.e. within specific plots within which a number of habitat and vegetation variables had been recorded.

To uncover patterns of food selection at a broad scale, the proportions of ungulates seen feeding in various prominent vegetation types was calculated for each species. Based on field observations, a checklist of favored plant species was made for ungulates and the proportions of major species were calculated from use plots where animals were seen feeding. Further, micro-histological analysis of fecal samples was carried out in the lab to determine the percentage of monocotyledonous and dicotyledonous plants consumed by various species.

4. RESULTS

4.1. Vegetation communities

Cluster analysis, using average abundance (percent cover) values for each species in every releve, and Eucleadian distance measure and Ward's linkage methods, revealed nine clusters of vegetation communities (Figure 4.1, Table 4.1). Clusters were analyzed at approximately 53% similarity. At the first branch point, two major clusters were formed, the *Kobresia* sedge releves being separated from all other releves. This division probably occurred because the *Kobresia* meadows on the plateau comprise a homogenous community comprised of a few species.

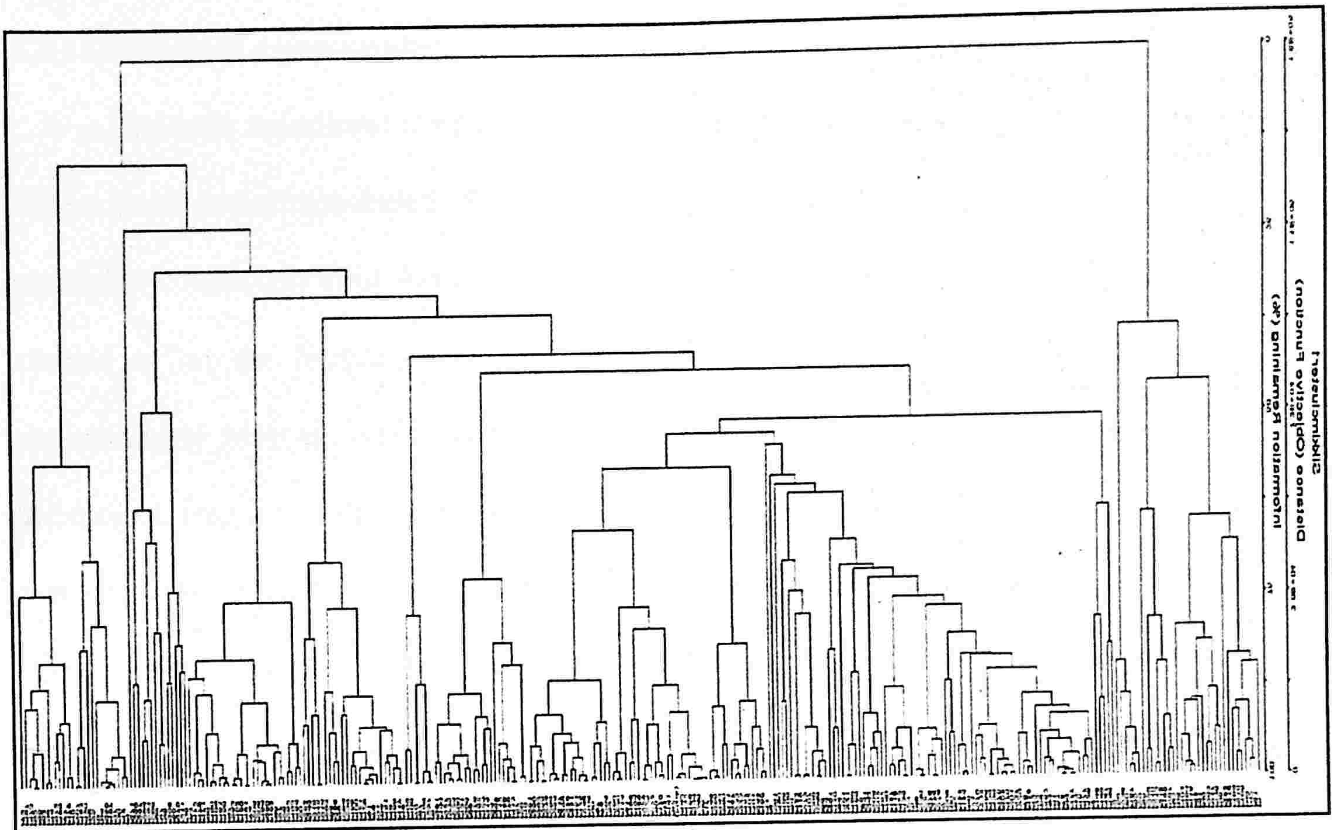


Figure 4.1. Dendrogram of vegetation communities

Table 4.1. List of major vegetation communities from cluster analysis.

Community 1	Sedges *Kobresia sp.* (mostly along water courses)
Community 2	*Ephedra, Anaphalis, Artemisia, Androsace*
Community 3	*Caragana sp – on scree slopes..*
Community 4	*Androsace, Arenaria* (fell-field vegetation).
Community 5	*Juniperus indica, Rhododendron setosum scrub.*
Community 6	*Rhododendron campananulatum*
Community 7	*Stipa* and Associates
Community 8	*Carex moorcroftii*
Community 9	*Potentilla biflora*

4.2. Description of the vegetation communities

Major vegetation communities have been described here in terms of dominant species, associated species and their relation to landform features Vegetation communities described in table 4.1 have been described below. . For this description, graminoid, herb, shrub and mixed communities are dealt with separately.

4.2.1 Graminoid communities

***Kobresia* meadows**: Sedges are largely water dependant species, and 'carpets' of sedges were found distributed along stream and river course; areas that remain moist perennially. Although most dense growth of *Kobresia sp* occurred in the basin along water courses or on the fringes of lakes, they were often seen at higher altitudes up to approximately 5450 m. Such patches were characterized by *Kobresia pygmea* along with the tussock forming *Kobresia schoenoides* and *K. royleana. Carex parva* often occurred sparsely in these patches, as did other associated non-sedge species including *Juncus sp, Pedicularis, Poa, Triseitum spicatum* and *Gentianella* with these, but found sparsely interspersed with *Kobresia sp.* In some areas, *Potentilla biflora* and *Rhodiola tibetica* were also found to be associated with the sedge meadows. In the southern most extent of the plateau at its boundary with the Transition zone, sedge meadows were often a mosaic of *Kobresia sp, Rhododendron nivale* and *Potentilla biflora.* Such patches varied greatly in size and extent. Along the Teesta course in the Chombo chu, they were restricted to about 75 m on either bank of the river. Elsewhere in basins or along, meandering stream courses, their extent was slightly larger. In all, there were 7 sizable sedge patches (2-6 ha) the lowest being at Giagong, and the highest at Khongyakma, east of Kerang. Smaller patches occurred in several places, usually along stream courses or at the foot of gullies.

Carex moorcroftii meadows: *Carex moorcroftii* is the only species that grows in very homogenous patches – where no other species grow. Pure patches of *C. moorcroftii* , are usually found in very sandy soils or fine gravely soils. This sedge seldom grows on slopes and is usually seen in basins or depressions. In some areas, patches are dense and the biomass of this species is fairly high (weigh biomass of 83g from 1 sq m plot.). Pure patches of *Carex moorcroftii* may grow in discreet patches in an area otherwise dominated by *Stipa orientalis.* Schaller (1998) terms this vegetation zone as Stipa steppe. *Carex* *moorcroftii* patches are also found along the outer fringes of *Kobresia* meadows, particularly in the Chombo chu basin.

Stipa meadows: *Stipa orientalis* is probably the most widely distributed grass in this desert steppe. Although patches are often not very large, this grass seems to be fairly ubiquitous in its distribution being found on gentle rolling slopes and plateaus. *Stipa orientalis* forms pure patches in a few places, but is generally associated with forbs; *Anphalis sp, Oxytropis sp,* and with *Carex moorcroftii*. In some areas, *S. orientalis* co-occurs with other *Stipa sp,* particularly *Stipa jaquemontii*. *Stipa* also occurs on slower scree slopes in small sparse patches.

4.2.2 Shrub & herb communities

Ephedra gerardiana – Anaphalis – Artemesia – Oxytropis: These species are often found to be associated with each other forming a mixed community. Associated species include *Oxytropis lapponica, Stipa orientalis and Elymus nutans, Androsace sp* and *Arenaria sp*. Generally, this community occupies rockier, drier regions with gravely soils and a large portion of the study area falls under this type between 5000 and 5200m. Prominent localities under this community include lower and middle slopes of the Cholung funnel, and lower northern flanks of the Kanchangao massif that sweep down to the Chombo chu basin. This community is often found on undulating terrain or slopes.

Caragana – Elymus type: *Caragana versicolor,* a stunted shrub with long axillary and terminal spines is fairly limited in its distribution in the Sikkim Trans-Himalaya. Usually found at altitudes between 5000 and 5250 m, and confined to steep slopes and edges between valleys and slopes. This species is sparse in distribution, and found primarily on south and west facing scree slopes. Associated species include *Potentilla biflora Artemesia sp Urtica hyperborea Arennaria serpylliifolia, Meconopsis species,* *Astragalus sp, Elymus schrenkianus* and *Stipa sp.* Interestingly, *Caragana* versicolr is seldom seen in the eastern regions of the plateau around Kerang, whereas the south facing slopes of the Cholung funnel and those in the proximity of lake Gyamchona support this species.

Androsace - Arenaria - Saussurea serecia - Fell field vegetation: Fellfield vegetation is characterized by prostrate herbs, with very reduced above ground parts, which may often be spiny. Three species dominate in this association – *Androsace sp, Arenaria sp* and *Saussurea sericia (cf).* This vegetation type is usually found on wind swept plateaus and slopes. *Festuca valesiaca,* a small graminoid frequently occurs in fellfields. In terms of biomass, fellfields are lkely to rank the lowest, and most species in such areas probably remain unavailable to grazing ungulates during winter because of their highly reduced above ground parts (Schaller 1998). The upper slopes in some areas are also characterized by fellfield vegetation *Arenaria densissima* and *A. festucoides* are the typical species of higher fellfields which can be seen growing around 5580m in some areas, the only other vegetative life forms in the region were lichens.

Potentilla biflora: It seems to have adapted to a fairly diverse range of microhabitats. It grows on scree slopes with *Caragana*, on rocky slopes with *Ephedra*, and in basins often in clumps within sedge meadows. It often lines gullies and water courses. Other species associated with *P. biflora* vary with the site at which it grows, and all the associations detailed about earlier may be found in areas dominated by *P. biflora.*

Hedenia-Elsholzia- Dracocephalum - Microgonacum tibeticum. This community typically occupies dry, gravely valley bottoms away from water. Cover is very sparse (usually not in excess of 15%). A fairly small region of the study area is under this type of vegetation. Associated species include *Oxytropis lapponica, Carex moorcroftii and Artemesia sp.*

Rhodiola-Festuca-Potentila-Arenaria type – This vegetation association typically occupies the highest vegetation zones. At altitudes of about 5340 m, *Rhodiola sp* may first appear in association with *Potentila microhylla, Elymus sp, Arenaria sp and Saussurea sp.* At about 5500 m, only *Rhodiola sp* and *Festuca* sp were found growing.

4.2.3. Shrub-herb-graminoid Transition belt communities

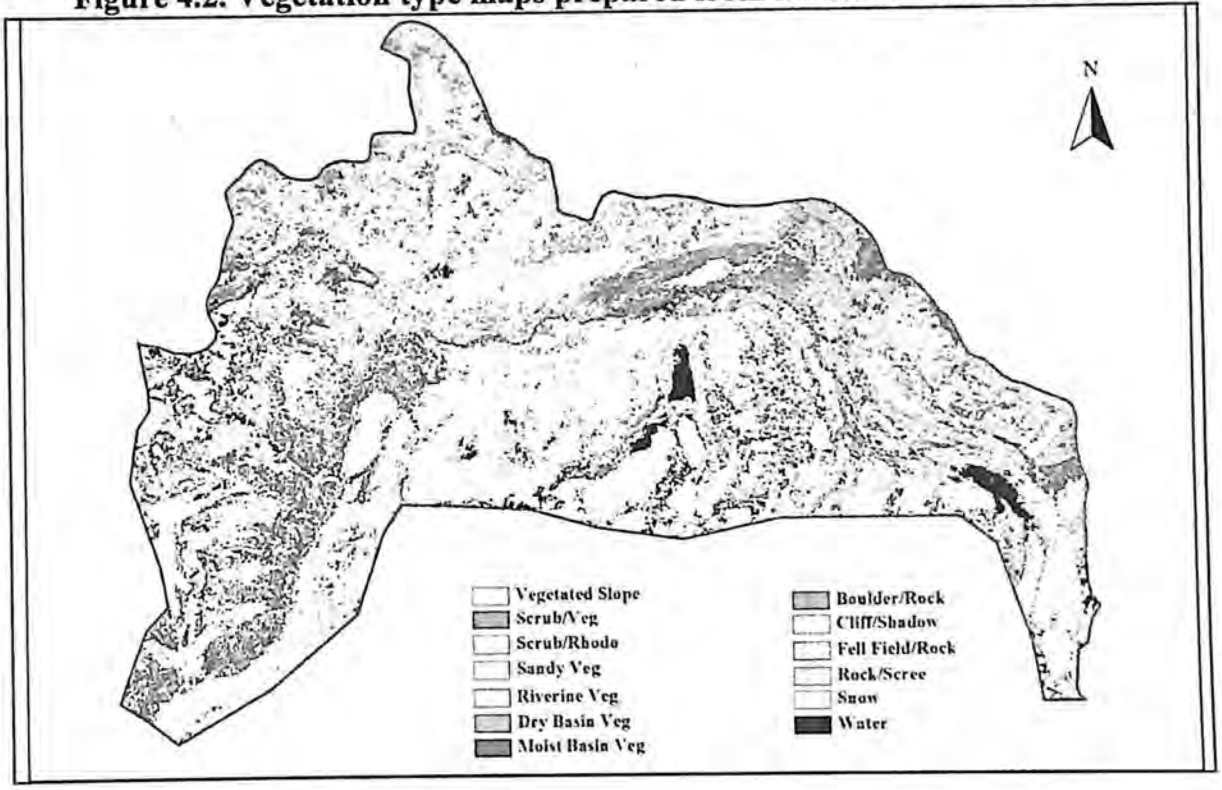
***Juniperus- Rhododendron-Anaphalis*:** Transition zone vegetation. The vegetation of the Transition zone (between Thangu and Giagong), and in the Lasher valley are quite distinct from the vegetation of the true cold desert. In the Transition zone, east facing slopes between 4300 – 4600m are dominated by *Juniperus, Rhododendron setosum* and R. l*epidotum* in the shrub layer. *Berberis sp* may occur in places as may *Cotoneaster* and *Gaultheria spp. Salix species* often grows in dense tangles along stream course and gullies. A large number of herbs and forbs grow in such areas – prominent among these are *Anaphalis royleana, A. nepalensis, Leontopodium alpinum, Cyananthus incanus. Thermopsis barbata* is rare. Much of this vegetation grows on fairly steep slopes 50-75^{o} on the true right back on the Teesta. A large number of graminoids are also present e.g., *Kobresia royleana, K. nepalensis, K. cappilifolia,* species of *Agrostis* and *Calamagrostis* Overall, the vegetation cover in this region is about 75%.

***Rhododendron campanulatum*:** *Rhododendron campanalatum* forms an extensive homogenous cover on the left bank (west facinfgg slopes) of the Teesta between Yangdi and Gochung (just short of Giagong). From here on, *R campanulatim* is replaced by a graminoid-shrub community comprised of *Kobresia sp*, *Rhododendron nivale* become the dominant shrub here and *Cassiope fastigiata* and *Anaphalis royleana* are fairly common. Gullies and moister areas have sedges and *Salix*

4.3. Vegetation type map

A 30 m resolution LANDSAT image of the study area (26TH December 2000) was classified using unsupervised classification methods with 50 classes being created initially. Meaningful classes of 15 were identified, of which, nine were vegetation classes and six were non-vegetation classes (Figure 4.2). While a resolution of 30m did not permit classification down to precise communities identified previously, broad vegetation units such as sparse scrub on scree slopes, wet basin vegetation and fell-fields were identifiable.

Figure 4.2. Vegetation type maps prepared from landsat satellite data



4.3. Plant species richness and diversity

Species diversity measures can serve as in index of habitat quality and may influence resource selection. Species richness simply refers to the number of species in a community. Evenness measures control for species heterogeneity caused by varying abundances of species in a community where a few are dominant and others rare.

Shannon-Wiener Index is a popular index to measure order or disorder in a community (Krebs 1999).

Richness was lowest in shrub habitats ($S=1, H=0$), more specifically by *Rhododendron campanalatum* in the Transition zone. The highest ($S>10$, $H>1.82$) is shown by dwarf shrub habitats in Transition zone. Vegetation communities of the plateau have moderate richness values ($6<S<9$, $1.08<H<1.66$). The lowest evenness ($E=0$) is shown by shrub habitat of *Rhododendron camapanulatum*. The sedge meadows, *Caragana scrub* and *Carex moorcroftii* patches all have moderate evenness values ($0.55<E>0.65$). Other communities of the plateau all have higher evenness ($0.70<E<0.85$). Simpson's index 'D' is a measure of richness + evenness and the trends shown are similar to those shown by richness, S.

4.4. Distribution, population and group size composition of ungulates

Tibetan gazelle was the most commonly sighted species, followed by Tibetan argali, however, in terms of abundance; Argali was high constituted by large group sizes. Kiang was seen on only 17 occasions, while Blue sheep were seen on 23 occasions (Table 4.2). Argali, gazelle and kiang were limited in their distribution, restricted to the Trans-Himalaya. Blue sheep was largely found within the Transition zone. In terms of spatial pattern, argali were confined to smaller area. Though gazelles were concentrated in the same areas as the argali, the former had much wider distribution range (Figure 4.3.). All the sightings of kiang were on the eastern region of the plateau (Kerang), while blue sheep occurred in two distinct regions namely, (1) along the banks of Teesta south of Giagong, and (2) north facing slopes in the southern ranges (Figure 4.4.). The domestic ungulates (yak and sheep) were found across the plateau, but localized in their concentration that are often fluid on account of migration, and were largely centered on the corral sites (Figure 4.5, Figure 2.1).

Table 4.1: Records of ungulates and population size.

Species	Sightings (n)	Number of individuals sighted	Mean group size ± SD	Mean distance sighted at (m) ± SD
Tibetan Argali	188	4410	24.5 ±326.70	501 ± 356.8, (n=166)
Tibetan gazelle	232	1472	6.3 ± 5.94	503.46 ± 274, (n=211)
Kiang	17	77	4.5 ± 3.48	644 ± 289, (n=15)
Blue sheep	23	384	4.5 ± 3.4	629 ± 773.8, (n=19)
Yak	80	4479	107 ± 785.85	549, (n=51)
Sheep	21	4045	192 ± 91.01	726 ± 808.5, (n=16)

Table 4.2. Group size and composition of ungulates

Species	No. of sightings	% classified in each group	Adult male (%)	Adult female (%)	sub-adult male	Sub-adult female	Juvenile
Tibetan Argali	188	32%	48	45	33	20	39
Tibetan Gazelle	232	65%	47	50	4	1	6
Kiang	17	18%	3	6	1	0	3
Blue Sheep	23	35%	52	39	22	0	22
Yak	80	-	-	-	-	-	-
Sheep	21	-	-	-	-	-	-

Classification was carried out on the basis of distinctive characteristics from literature as well as those developed from preliminary observations Tibetan argali and kiang proved to be particularly difficult to classify. In many cases, identification was difficult on account of large distance between observers and animal. Broad classification into age and sex groups for all is reported in table 4.2. For yak and sheep no attempt was made to classify animals into age or sex classes – groups were often very large and misidentification was a serious issue.

Figure 4.3. Records of Tibetan argali, kiang and blue sheep

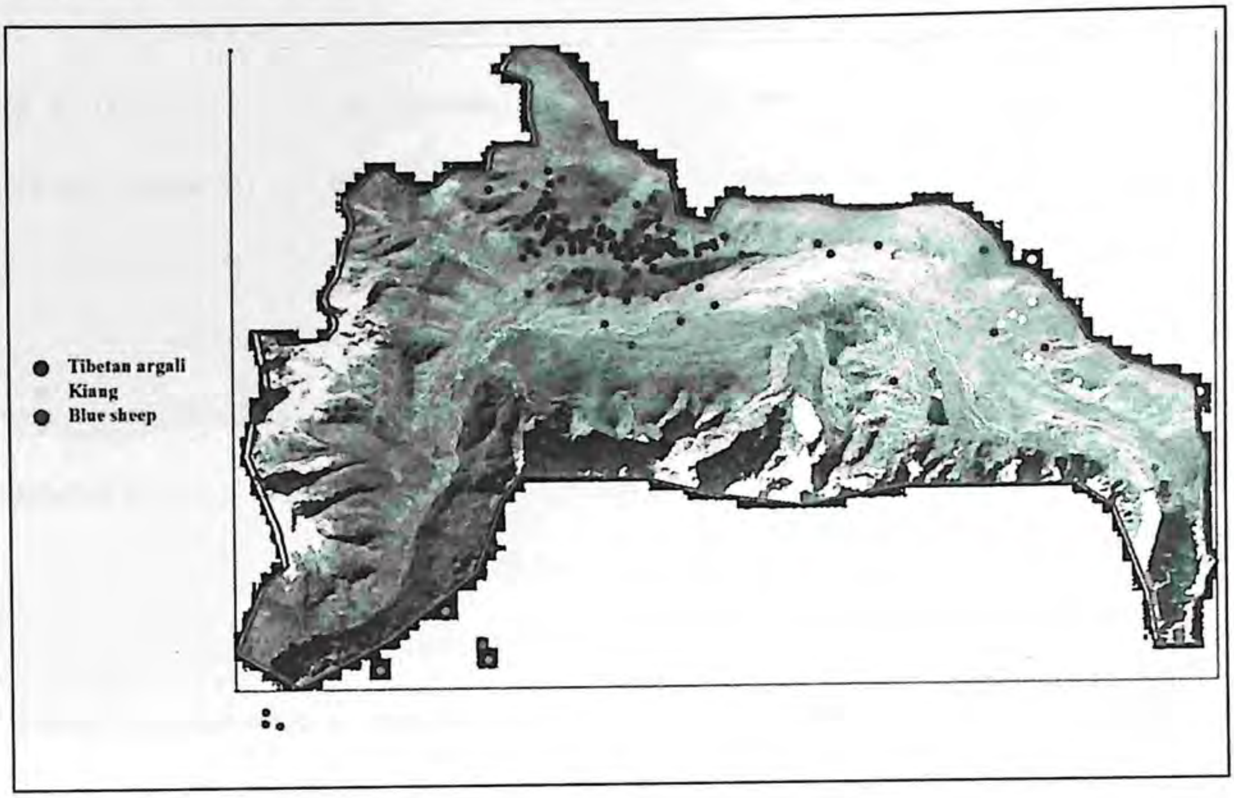
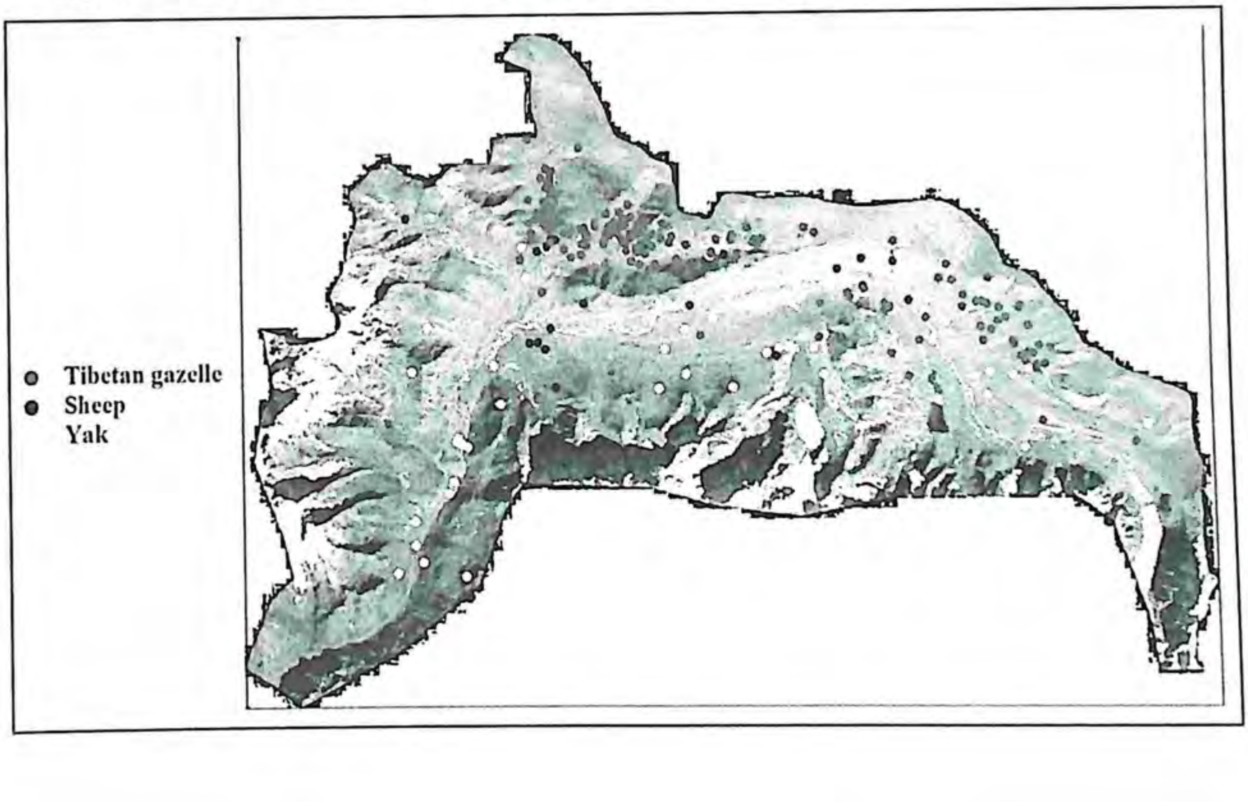


Figure 4.4. Records of Tibetan gazelle, yak and sheep



4.5. Animal - habitat relationships

All data collected on animal sightings which includes systematically sampled data (from Transects) as well as ad-libitum data have been combined for analysis here. In this section, habitat use has been assessed at two scales: larger scale considering broad habitat features and categories and a finer scale of a sampling station (specific sites within which vegetation sampling was carried out). Analysis was carried out in two stages (a) by comparing the habitat variables between areas where an animal was sighted and randomly selected (available) sites across the study area and (b) analysis to compare use of habitat across species. An effort was made to include only ecologically meaningful sites in analysis. Using the broad study area boundaries to define availability for all ungulate species may have led to erroneous conclusions on habitat use (Krebs 1999) primarily because there are two very distinct zones that exist within it – a cold desert and a Himalayan (continental) Transition zone. Argali, gazelle and kiang are adapted to the cold desert do not venture into the steeper, moister Transition zone. Such divisions are however not applicable to yaks, sheep, and to some extent, blue sheep.

4.6. Use of elevation and topography

Argali were confined in their distribution to the Trans-Himalayan region. They were largely seen on or in close proximity of rolling slopes and there were far fewer sightings in other terrain types. In general, middle slopes appear to be used in a fairly high proportion whereas there may not be significant trends for lower and upper slopes. Basins, valleys and plateaus appear to be used less frequently. Mean elevation for the argali based on 163 sightings was 5050m (SD =20.56) whereas the lowest elevation recorded for this species was 4910m the highest being close to 5500m. Argali appear to select slightly lower elevations (mean5050m) than available sites (mean 5184m), (t=8.96, df=322,

$P_{0.05}$=0.00). Argali also differ from random in their selection of slopes - the mean slope of areas where they were sighted is 27° compared to the overall mean slope in available sites 20^0 (t=-3.14, df=323, P=0.02).

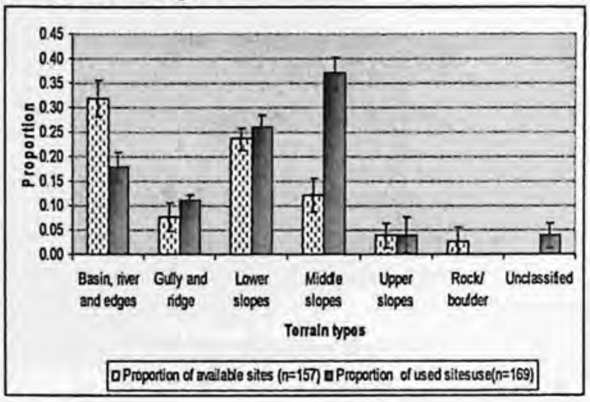
A fairly high proportion of gazelle sightings were in flat terrain i.e. valleys, basins and plateaus. Lower and middle slopes were also used in fairly high proportions relative to their availability. Use of other terrain categories was minimal. Mean elevation of sites (n=204) where gazelles were sighted (5095m) differed from the mean elevation of randomly selected sites (n=156) defined as being available for the gazelle (t=2.348, df=335, $P_{0.05}$=0.019). Mean slope angle did not vary between random sites (20°) and those where gazelles were spotted (21°)(t=-,0276, df=325, $P_{0.05}$=0.783).

Mean elevation of sites (n=16) where kiang were sighted (5287m) differed from the mean elevation (5170m) of randomly selected sites (n=156) considered as being available to the kiang (t=-02.12, df=170, $P_{0.05}$=0.036). Mean slope angle did not vary between random sites (20) and those where gazelles were spotted (19)(t= 0.229, df=170, $P_{0.05}$=0.819).

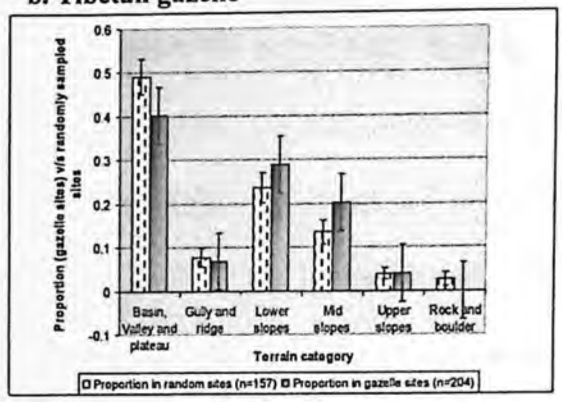
The use of lower and middle scree slopes is relatively greater by the Tibetan argali and gazelle. Upper slopes are not used much by most species; this is partly explained by a deficit of forage on steep slopes. While both the argali and gazelle use scree slopes, the argali uses middle scree slopes to a greater extent. Kiang select lower vegetated slopes in a fairly high proportion. While the argali clearly seems to avoid level areas- namely basins, valleys and plateaus, yak, sheep, kiang and the gazelle all use such plain habitats in fairly high proportions. Cliffs and rocky slopes are used by blue sheep alone.

Figure 4.5 Use of terrain by ungulates

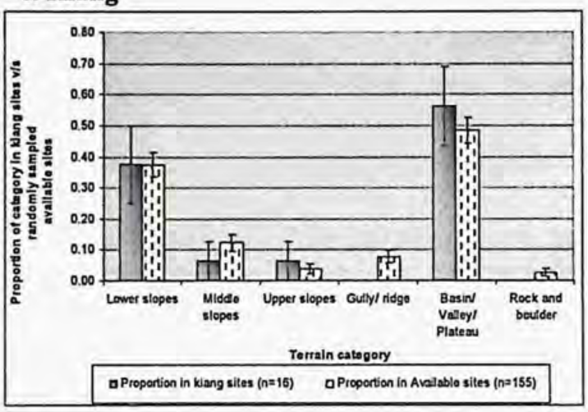
a. Tibetan argali



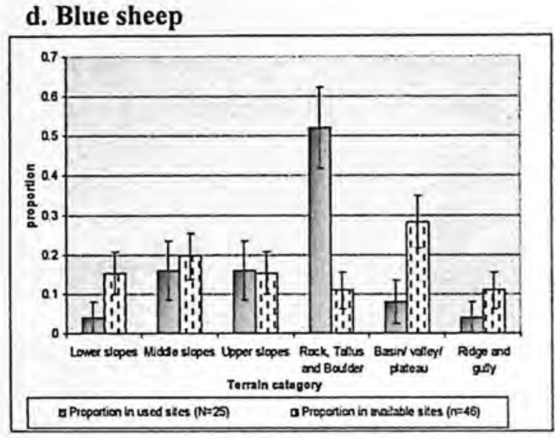
b. Tibetan gazelle



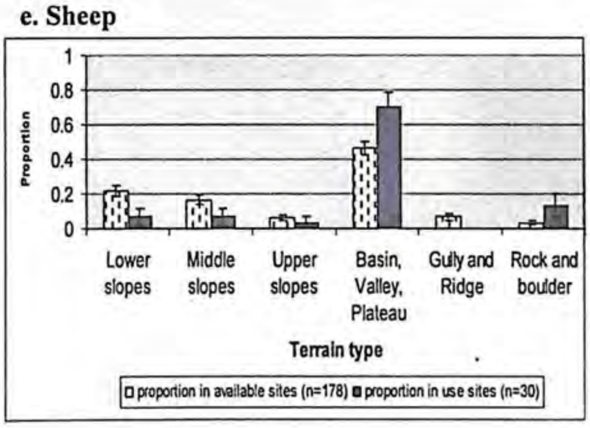
c. Kiang



d. Blue sheep



e. Sheep



f. yak

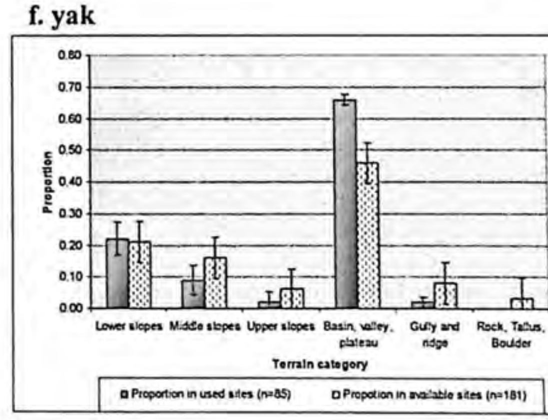
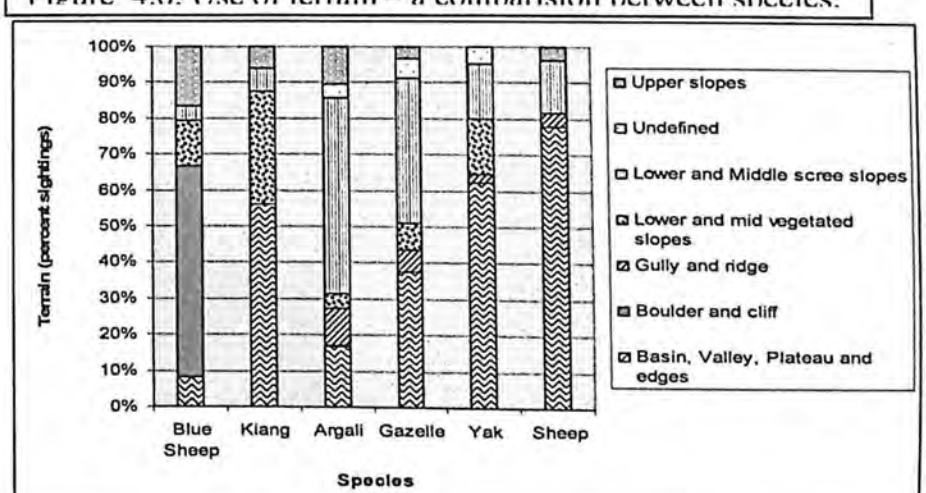


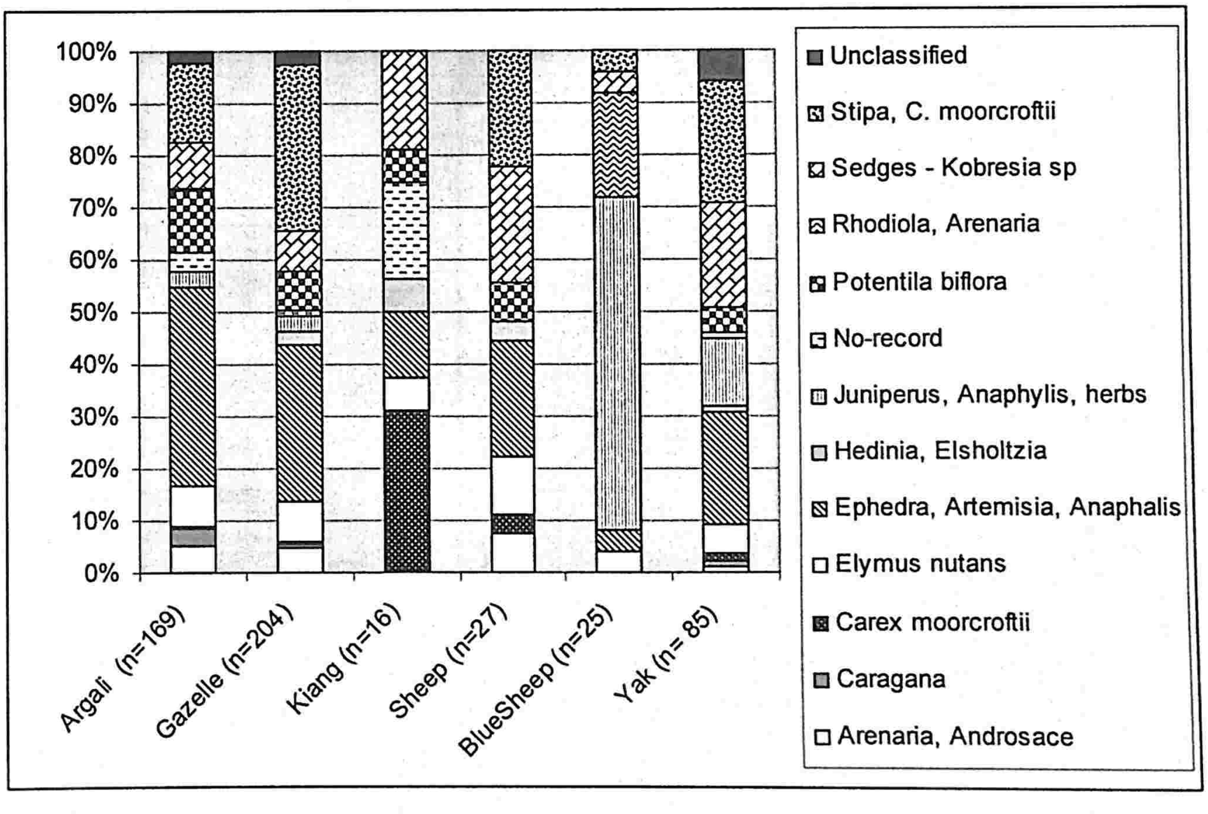
Figure 4.6: Use of terrain – a comparision between species.



4.7. Use of vegetation communities

A few patterns emerge this figure that illustrates the percentage sightings of each species in broad vegetation types. Blue sheep differ in their usage of vegetation type from other species. This is most clearly bore out by the high percentage of *Juniperus* as a vegetation category – this species association is found in the lower altitude Transition zone. Most species on the plateau are found in areas characterized by *Carex moorcroftii - Stipa orientalis, Ephedra,* and the *Kobresia* meadows. Disproportionately hiogh numbers of argali and gazelle are found in the vegetation zones dominated by *Epheddra gerardiana, Artemesia sp, and Anaphalis sp.* Yak and kiang are found more in communities dominated by graminoids.

Figure 4.7 Use of different vegetation types by ungulates



4.8. Availability of resources

Logistic regressions:

Logistic regressions have frequently been used in studies of resource selection and they are particularly useful in modeling the use of resources or resource categories by a species, particularly where models can be selected using a combination of statistical and biological criteria (Franco et al 2000). Here, binary logistic regression was used by selecting a few relevant variables for analysis using SPSS 14

Logistic regression was used to asses the effect of habitat variables. Overall prediction and classification of these models were generally high and varied between species with high R^2 values being obtained for blue sheep and kiang (Table 4.3).

Table 4.3 : Predictions for use and available sites using logistic regression

Species	**Observed**	**Predicted**			**HL test**			**R^2**
		0	1	% Correct	Chisq	df	sig	
Blue sheep	0 1 Overall %	41 1	1 13	97.8 92.9 96.7	2.39	8	0.996	0.885
Sheep	0 1 Overall %	115 6	25	86.1 76.9 85.0	4.782	8	.429	.429
Kiang	0 1 Overall %	152 2	5 12	96.8 85.7 95.9	1.085	8	.998	.736
Tibetan Argali	0 1 Overall %	108 15	49 150	68.8 90.9 80.1	10.570	8	.227	.559
Tibetan gazelle	0 1 Overall %	115 36	42 163	73.25 81.91 78.09	10.567	8	.227	.560
Yak	00 1.00 Overall %	140 15	25 20	77.8 81.5 78.9	11.450	8	.153	.516

Table 4.4 : Variables predicting resourses selection from logistic regression

BLUE SHEEP		B	Sig.
	Altitude	-3.348	0.151
	Slope	-0.011	0.771
	Terrain		1
Sheep			
	Altitude	-1.803	0.114
	Aspect		0.232
	Terrain type		0.196
	Vegetation type		0.728
Kiang			
	Altitude	6.366	0.148
	Aspect		0.78
	Terrain		0.265
	Vegetation type		0.948
	Slope	0.061	0.193
Argali			
	Altitude	-1.122	0.031
	Aspect		0
	Terrain		0.001
	Vegetation type		0.01
Gazelle			
	Altitude	0.022	0.953
	Aspect		0
	Slope	0	0.977
	Vegetation type		0
Yak			
	Altitude	-0.038	0.96
	Aspect		0.022
	Terrain		0.089
	Vegetation type		0.02
	Slope	-0.003	0.764

4.9 Animal habitat relationships based on pellet presence – absence data.

Pellets are reliable indicators of ungulate presence in a given area and these have been frequently used for analyzing habitat use and resource selection e.g., Schaefer et al (1996) and Borkowski (2004). In high altitude areas such as Tso Lhamu, low temperatures and humidity cause pellet result in very slow rates of pellet decomposition. Pellet detection is also high on account of sparse vegetation cover in such regions.

In this study pellet groups were searched within 5 1x1 m quadrats within sampling stations of 10 m radius area across major habitat types. Qualitative and quantitative data on vegetation were collected within each sampling station. By analyzing pellet presence data for all species at 'small, specific' sites within wider habitat features across the landscape, this component of the study hopes to address selection at a finer spatial scale. Pellets were sampled for in 292 sampling stations across the study area. Of these, 161 were randomly selected, whereas the others were areas in which animals, primarily wild ungulates had been seen feeding. Within each sampling station, 5 1x1 m quadrats were randomly placed, and the detection of pellets or dung was recorded for argali, gazelle, yak, sheep, kiang and blue sheep. Several habitat parameters and vegetation parameters for each site were also recorded or extracted using GIS tools.

Table 4.5: presence and absence of ungulate pellets

Species/ pellet presence or absence (n=292 sampling stations)	Pellets present	Pellets absent
Argali	86	206
Gazelle	64	228
Kiang	17	275
Blue Sheep	22	270
Yak	169	123
Sheep	102	190

Data from the 5 quadrats that constituted a sampling station were pooled for analysis as a 1x1 m quadrat sampling was considered too fine for ungulates using the data collected in this study.

4.10 Comparisons of use and availability between species

Using pellet presence data, an attempt was also made to assess selection by each species by comparing habitat variables at use sites versus available sites.

Using pellet data and sampling station level the results largely match the results on habitat selection from animal sighting data, particularly those indicating that Kiang differ in their use of elevation when compared with available sites. Some vegetation variables also give significant values (independent samples t-test). Most notable among these are the standard deviation of cover (which explains how heterogeneous cover values for plants species are in a sampling station. Argali, yak and sheep appear to select plots with more homogenous cover, i.e. areas dominated by a few plant species. Using a non-parametric Kruskal Wallis test, animals are seen to differ in their selection of different terrain types (from what is available) whereas this is not only blue sheep differ in their selection of vegetation type for available.

Quite apparently, it reveals that based on the parameters presented here, ungulates in the study area do no appear to differ greatly in the use of most features

One way ANOVA or Kruskal-Wallis non-parametric tests were carried out to test for differences in numbers of sites with pellets between species for each habitat or terrain category (Zar 1999 Based on pellet presence within plots, species did not differ in their selection of areas based on percentage cover of shrubs, herbs, graminoids or forbs cover and for overall cover and species richness. However, ANOVA revealed differences between species with respect to mean elevation and the standard deviation of the number of species in each plot. Based on pellet presence using Tukey's post-hoc tests, the kiang differed from other ungulate species in its mean use of elevation, this being higher than the other species ($F=2.771$, $df=436$, $P0.0_5=0.018$). Although a few blue sheep pellets were recorded at the highest altitudes their mean elevation was lower than that of the kiang. In terms of the standard deviation of vegetation cover species differed form each other.(F=2.65, df=236, P(0.05) = 0.22).

Amongst the categorical variables, terrain type (0.00, chi-square 33.437, 5 df), and aspect (0.027, Chi 12.613, 5df) were found to differ significantly with respect to pellet presence of ungulates (Kruskal Wallis test), whereas vegetation types did not differ.

Table 4.6 Summary of means and standard deviations for various habitat and vegetation variables recorded within sampling stations. n = number of sample sites within which pellets of species 'x' were found.

	shrub % cover	herb % cover	Graminoid % cover	Forb % cover	Overall % cover	richness	slope (degrees)	Elevation (meters)
Argali (N=86)	3.41 (+) 1.06	18.44(+)1.23	20.70(+)2.02	1.21(+) 0.467	42.54(+)2.37	8.43(+)0.273	20(+)1.94	5136(+)13.11
Gazelle (n=64)	3.77(+)0.95	17.09(+)1.55	21.53(+)2.47	1.48(+)0.6	42.38(+)3.26	7.86(+)0.32	22(+)2.29	5139 (+)16.17
Yak (n=169)	4.27(+)0.82	16.69(+)0.87	21.40(+)1.38	.91(+)0.30	42.36(+)1.71	8.34(+)0,06	21(+)0.24	5108(+)1.40
Sheep (n=102)	3.75(+)0.87	14.93(+)1.01	18.92(+)1,79	1.22(+)0.47	37.61(+)1.86	8.17(+)0.33	22(+)1.91	5108(+)24.76
Blue sheep (n=22)	1.86(+)0.98	15.68(+)2.35	22.45(+)4.67	2.27(+)1.26	40.00(+)3.51	8.64(+)0.75	16(+)3.31	5117(+)108.33
Kiang (n=17)	3.82(+)2.96	**10.47(+)1.86**	**28.00(+)5.67**	.88(+)0.64	42.29(+)5.12	8.41(+)0.67	18(+)4.43	**5302(+)17.569**

4\. 11 **Food selection by wild and domestic ungulates.**

Food selection and forage preferences are studied at multiple levels too. At the broadest level, species preferences for given vegetation types in terms of proportion of use v/s the proportion available are compared using graphs.

The following series of tables summarize food selection by ungulates. Major species that contribute to an ungulate's diet (based on direct observations, discussions with herders and literature) were included for analysis. The species included in these lists have been drawn from 'use' plots – those where ungulates were seen feeding and subsequent vegetation sampling was carried out. Although feeding signs were quantified on plots based on direct sightings, these figures are relative and may be erroneous as other ungulates may have fed on the same species at a prior time. Blue sheep are spatially segregated and have not been included in this analysis.

Figure 4.8 Comparison between used and available vegetation types for Argali

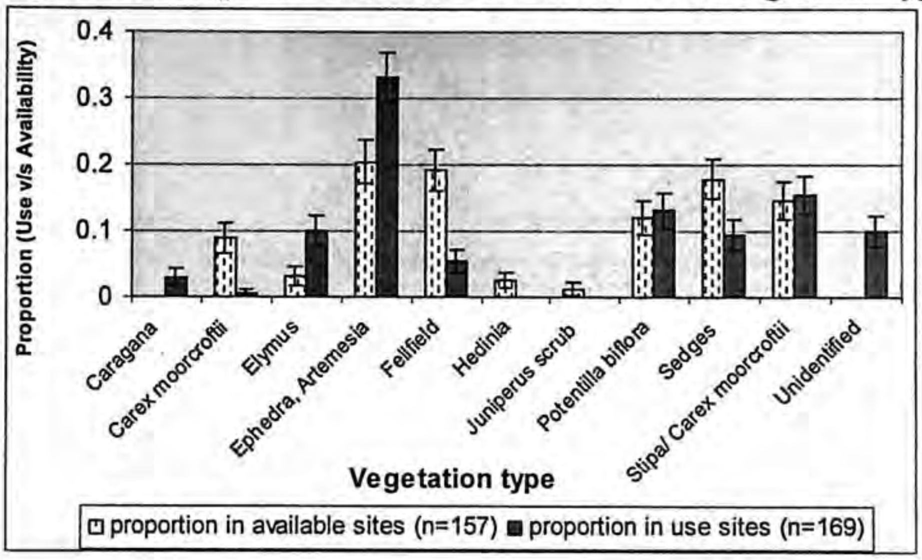


Table 4.7 Use of forage species by argali

Argali – feeding (n=40) (Dicot = 37, monocot = 25)

Species	Number of plots found in	number fed on	Percent of plots seen in	Average cover	sd cover
Anaphylis sp	23	8.0	57.5	4.9	2.2
Artemesia sp	26	10.0	65.0	4.4	1.2
Astragalus sp	5	3.0	12.5	0.1	0.8
Caragana sp	7	3.0	17.5	15.3	15.9
Elymus sp	22	7.0	55.0	1.4	1.7
Ephedra sp	19	11.0	47.5	7.0	6.4
Festuca sp	8	2.0	20.0	1.6	1.2
Kobresia sp	17	9.0	42.5	9.7	13.6
Oxytropis sp	19	11.0	47.5	2.7	2.8
Potentila biflora	16	9.0	40.0	6.8	7.5
Stipa sp	25	12.0	62.5	3.9	3.5

Number definitely fed on: 12, possibly fed on = 10 (winter) = 35% of total

Argali appears to select *Ephedra sp, Oxytropis sp, Potentilla biflora and Stipa sp. Kobresia* and *Artemisia,* species also occur in fairly high proportions in plots where argali were seen feeding. Argali frequently observed digging out *Artemisia* roots (on slopes) with their hooves and feeding on these. This was observed more frequently in females.

4.9 Comparison between used and available vegetation types for Gazelle

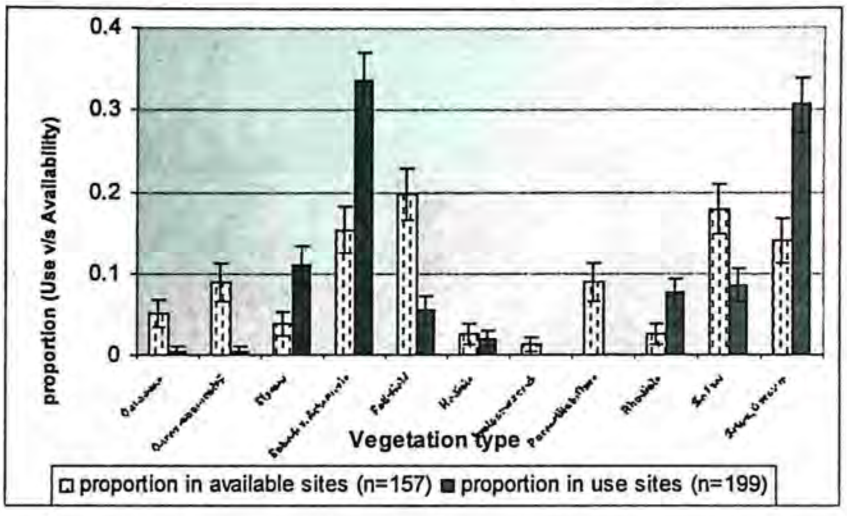


Table 4.8 Use of forage species by gazelle

Gazelle – (n=34 plots), total species = 53, fed on ~ 10. (monocot =17, dicot = 33)

Species	number seen in	Percent of plots seen in	number fed on	Average cover	sd cover
Anaphalis sp	24	70.6	7.0	4.9	4.2
Artemisia sp	21	61.8	5.0	5.8	5.8
Astragalus sp	6	17.6	3.0	1.4	0.5
Caragana sp	–	–	–	–	–
Elymus sp	22	64.7	14.0	5.4	7.1
Ephedra sp	7	20.6	2.0	8.1	10.0
Festuca sp	7	20.6	4.0	4.2	6.7
Kobresia sp	5	14.7	2.0	12.4	16.2
Oxytropis sp	16	47.1	12.0	3.1	2.6
Potentilla biflora	18	52.9	3.0	3.9	4.3
Stipa sp	21	61.8	13.0	6.7	4.0

Gazelle appear to select areas with greater amounts of *Elymus sp, Oxytropis sp, Astragalus sp* and *Stipa sp. Ephedra sp, Potentilla biflora, Artemisia sp and Kobresia sp* do not appear to be major constituents of their diets.

4.10 Comparison between used and available vegetation types for Yak

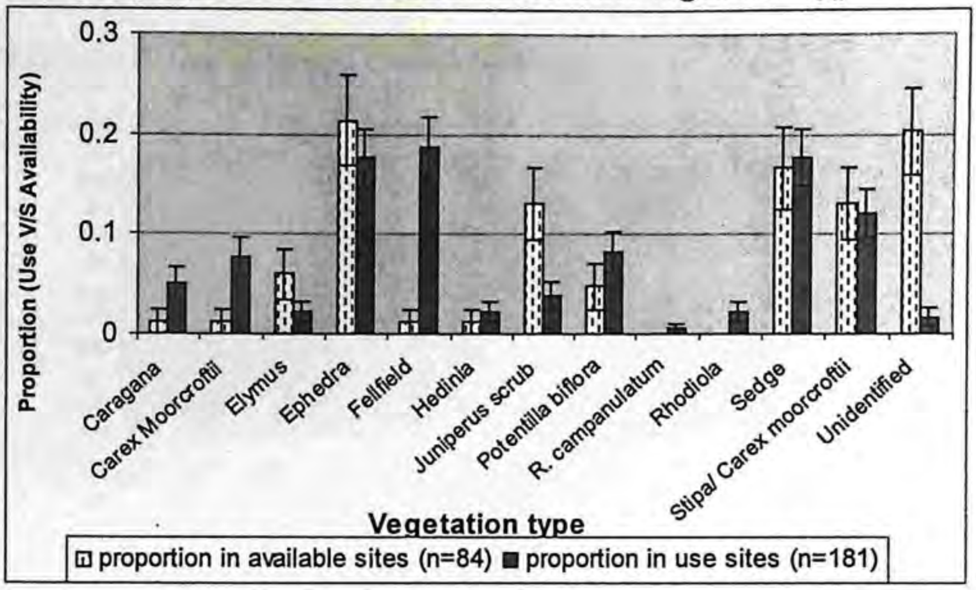


Table 4.9 Use of forage species by domestic yaks

YAK

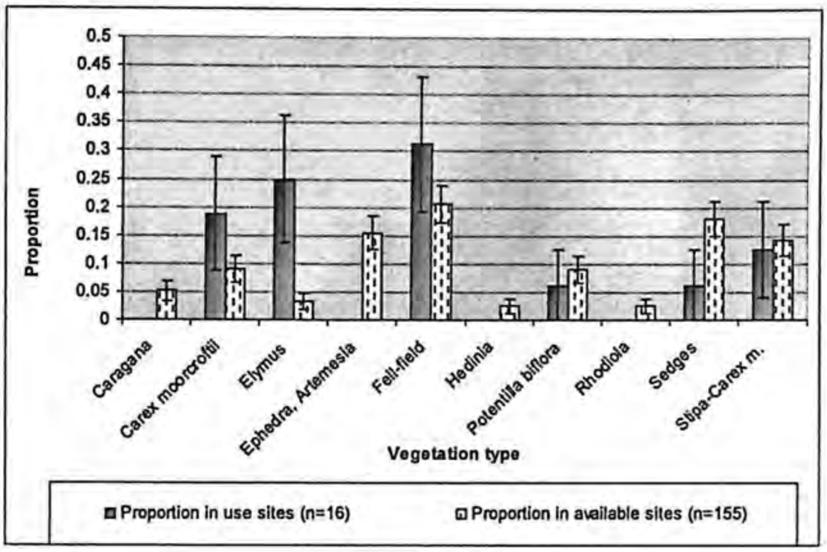
n=28, species = 63

Species	number seen in	Percent of plots seen in	number fed on	Average avg cover	sd cover
Anaphalis sp	17	60.7	8	3.5	3.5
Artemisia sp	14	50.0	34	3.7	2.5
Astragalus sp	–	–	–	–	–
Caragana sp	3	10.7	0	10.8	6.1
Elymus sp	11	39.3	7	6.4	4.5
Ephedra sp	7	25.0	3	4.4	3.9
Festuca sp	9	32.1	5	2.9	3.0
Kobresia sp	13	46.4	12	14.2	19.3
Oxytropis sp	7	25.0	3	1.9	2.4
Potentila biflora	10	35.7	3	6.1	4.9
Stipa sp	19	67.9	12	6.1	6.7
Saussurea serecea	15	53.6	9	4.7	4.9
	monocot = 20	dicot=43			

Yaks select areas with graminoids. *Kobresia sp, Stipa sp* and *Elymus* all appear to be contributing to their diet. *Sussurea serecia* also contyributes to the diet of yaks in considerable amounts. *Potentilla biflora* and *Caragana sp* do not appear to contribute much to their diet.

4. 11 Comparison between used and available vegetation types for Kiang

Table 4.10 Use of forage species by kiang



Kiang

Total plant species=32, n plots = 11

Species	number seen in	Percent of plots seen in	number fed on	Average cover	sd cover
Anaphalis sp	8	73	2	4	2.9
Artemisia sp	4	36	2	4	2.9
Carex moorcroftii	6	55	2	17	11.9
Astragalus sp		0			
Caragana sp		0			
Elymus sp	7	64	4	2	2.0
Ephedra sp		0			
Festuca sp	7	64	4	1	0.4
Kobresia sp	2	18		12	4.8
Oxytropis sp	3	27	1	3	0.4
Potentilla biflora	3	27	0	2	1.5
Stipa sp	8	73	4	12	8.0
Saussurea serecea	6	55	4	7.58	8
Monocot=13	Dicot=21				

Like yaks, the kiang to appears to select areas with higher graminoid cover. *Stipa orientalis, Festuca sp, Elymus sp, Saussurea serecia and Carex moorcroftii,* all appear to be selected. *Kobresia sp* and *Potentilla biflora* do not rank high in the diet of kiang.

Fig 4.12 Comparison between used and available vegetation types for Sheep

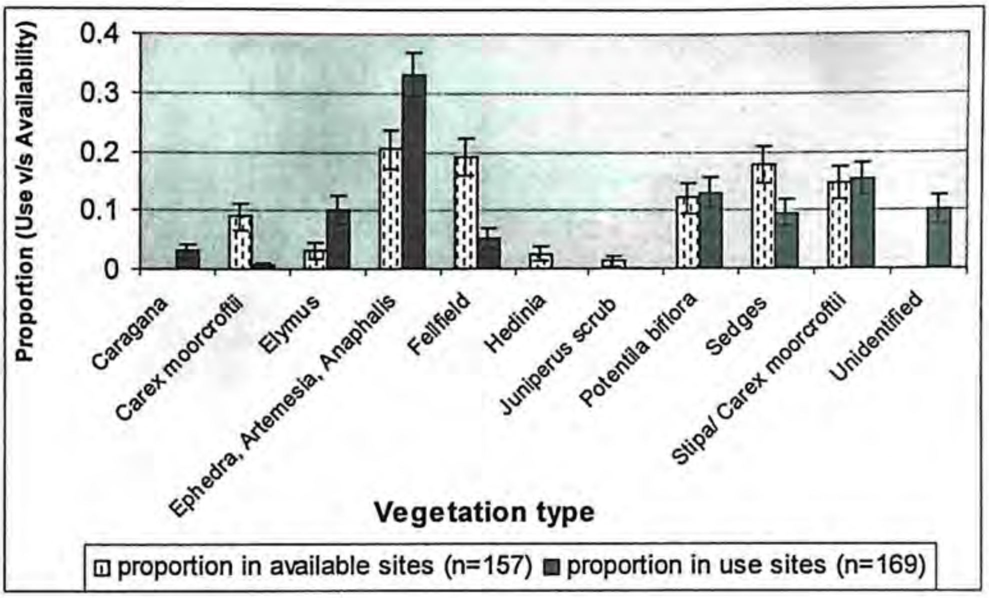
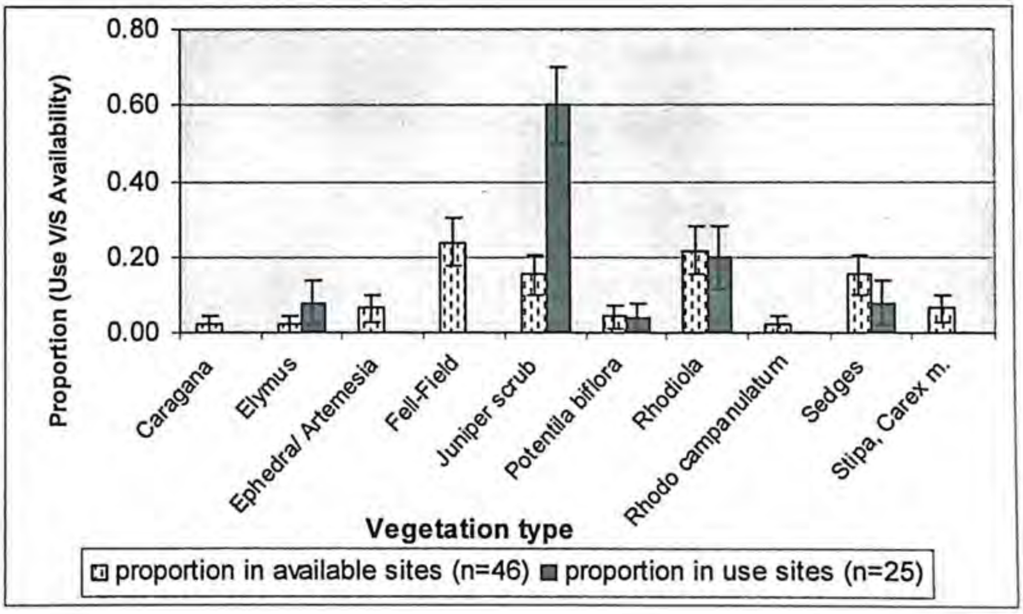


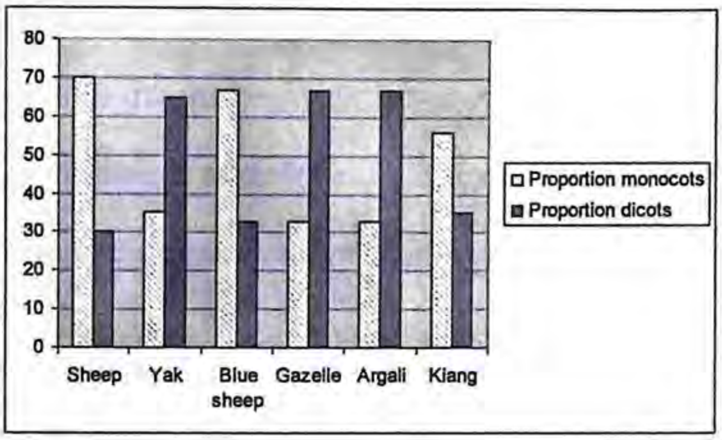
Fig 4.13 Comparison between used and available vegetation types for blue sheep



4.12 Food selection for fecal samples

Standard methods were used to estimate food selection by wild and domestic ungulates by comparing the percentage of monocots and dicots in their diets. Sheep, blue sheep and kiang had higher proportions of monocots in their diets whereas yak, gazelle and argali had higher dicots in higher proportions.

Fig 4.14 Percentage of monocots and dicots in the feacal samples



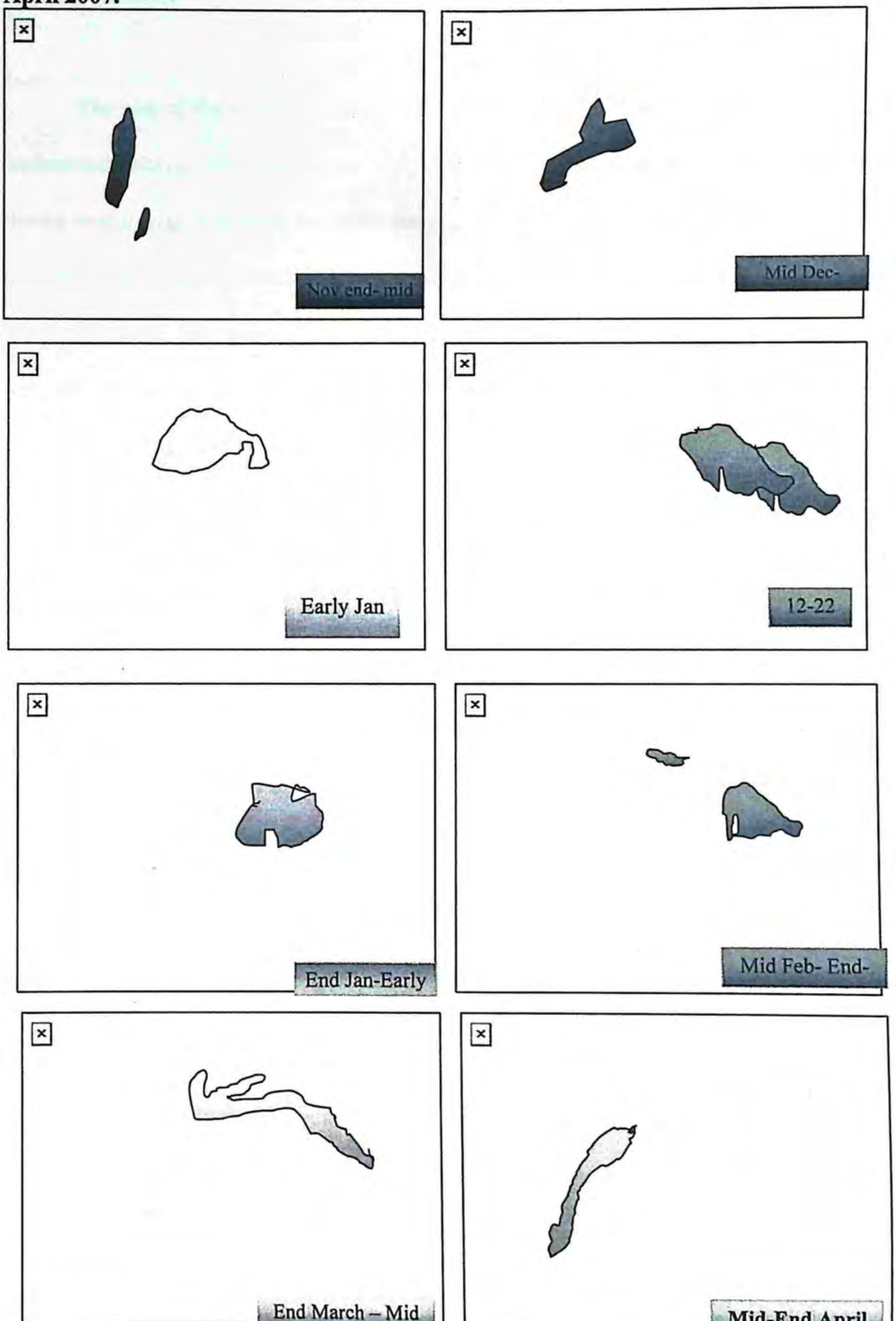
4..1.2 Grazing patterns of domestic yaks

Yaks advanced northwards on the plateau and in Mid-December they were largely at Giagong having descended from their summer pastures in the Lasher valley. Between January and mid-April they roamed the plateau covering much of area that could be accessed by them. By the end of April most yaks had descended off the plateau and were stationed at Giagong, Gochung and Yangdi. A few had reached Thangu at the head of the Lasher valley (Figure 4.15). In the early winter most of the 14 *Dokpa* families usually stayed in the same locality. Later inn the season herds were more dispersed with 2-3 families each at various sites across the plateau.

Although the corrals are clustered in most places, typically each family takes its yaks out in a different direction each day to graze. When they migrate from one site to another several families and their livestock usually move together. Typically yaks were herded out of their corrals at around 07:15 hours and herded back by 17:30 hours. Once they reached an area selected for grazing for a given day, animals would disperse about the area – dispersion was dependant on vegetation with animals being more clustered where forage was available in larger quantities, typically in sedge meadows.

Sheep and goats are herded together (goats are usually about 5-10% of the total herd size. Usually yak and sheep are not grazed in the same areas simultaneously although overall they both forage in the same areas. Sheep cover greater distances and tend to forage as they move. They too are usually taken to a site and allowed to graze there, and sites are frequently changed. Sheep are often seen on steep scree slopes .

Figure 4.15 The movement of yaks in the study area between December 2006 and April 2007.



5. DISCUSSION

The aim of the study was to record the spatial distribution of ungulates and also to understand patterns of resource use and species interaction. The study was undertaken during winter season in order to understand the habitat-use patterns and survival success of ungulate species during the harsh the winter months. In order to do this, chosen field-parameters were first standardized into discrete categories or units so as to compare the use pattern between and across species. This was important because the various species studied inherently differed in their ecology.

This study both reinforces and deviates from the findings of previous studies in similar areas and on similar taxa. Notably the study largely corroborates existing knowledge on the ecology and feeding habits of Trans-Himalayan ungulates and on the ecological separation of sympatric species in the wild (Mishra 2001). However, it throws up a few questions that are seemingly contrary to existing notions and paradigms, particularly those on the impact of domestic ungulates on wild ones. In Sikkim, the two seemingly appear to co-exist without any negative effects being apparent. However, competition is hard to unearth and while an overlap in resource use may be indicative of competition, it must further be established that competition over shared resources has negative effects (Weins 1989) but beyond the scope of this study. Broad spatial patterns explain habitat selection at a broad scale, one that encompasses the entire study area in this case. Broad spatial patterns of distribution of these species with respect to each other that emerge from this study are interesting, particularly in the cases of the argali, kiang and blue sheep.

This significance of the study is that it makes available baseline data on Tso Lhamu's endangered wildlife and also investigates the use of habitat and food resources by ungulates in the region. The important findings of this study are discussed in terms of their distribution, habitat-use, habitat-selection and food selection. Based on these findings, I discuss whether any two ungulate species (both ungulate and domestic) are competing. In the light of existing socio-economic pressures, what is the emerging situation Sikkim Trans-Himalaya. Since, this study was conducted in harsh winter conditions some problems related to data collection are also discussed.

5.1 Distribution

Studies on ungulates and herbivory in environments with patchily distributed forage have found strong associations between the selection of aggregated food patches of preferred vegetation over dispersed patterns (Dumont et al 2002). In the light of this statement, one would expect that ungulates on the Sikkim plateau congregate in areas where resources are concentrated. If they select areas with dispersed resources it might be inferred that species forage preferences vary, or that they avoid certain areas on account of deeper ecological differences or due to negative competitive interactions.

Approximately, 180 – 230 Tibetan argali and 90-120 Tibetan gazelles occupy this region. The Kiang population doesn't appear to be resident in this area in the winter, only a few individuals (<20) sporadically use the area. Blue sheep occur in large numbers but occupy spatially distinct zones so that there is little overlap between them and other ungulates. About 1000 domestic yak and an equal number of sheep and goats are herded on the plateau over the winter season.

The concept of abundance occupancy relationships draws a link between the abundance of a species and its distribution wherein species that is more abundant show an increase in the number of sites they occupy, and vice-versa (Gaston et al, 2000). By generally remaining restricted to one small area the argali population here exploit only a small subset of resources potentially available to it. Big-horn sheep have been reported to have seasonal home ranges and exhibit great fidelity to their ranges (Giest 1971). My observations on the argali appear to be similar with animals remaining restricted to a small area. Following heavy snowfall in mid-February, the argali population shifted off the slopes of the Mirdo valley to the slopes of the adjacent Cholung funnel. My obsercations concuse with those of Schaller (1998) wherein argali prefer rolling, unbroken hills avoiding low hills and plains .These observations differ slightly from those of Fox et al (1991) and Namgail (2006) who write that the argali in Ladakh prefer "open and rolling terrain...". One distinct feature of the argali is its scarce use of vast flatlands (Fedosenko and Blank 2005) . Argali are well adapted to foraging on stable scree slopes. Shallow gullies appear to be the choice terrain in harsh weather conditions. Ideal terrain appears to be constituted by scree slopes, often lower slopes in close proximity of relatively narrow and level valleys, to be an area with a fairly narrow Trans-Himalayan valley with scree slopes on either side. In the harsh winter months, high densities and very localized populations of argali on slopes with scant vegetation seem somewhat counter-intuitive. The images with GPS locations of animals plotted out clearly bring this out. Interestingly the area occupied by the argali and the bulk of the gazelle population is one that is least used by yaks, their use of the area being limited by Army restrictions.

Blue sheep are spatially separated from the other species, and they largely seem to avoid the vast rolling Trans-Himalayan landscape. Blue sheep are spatially segregated from the other ungulates by occupying a region that does not comprise habitat for the other wild ungulates. The selection of steeper, rockier and more 'Himalayan' regions by blue sheep is likely to be an out-come of their preference for cliffs as escape terrain (Namgail et al 2004), and possibly to greater forage availability and higher diversity in the Transition zone. However, at least three populations are confined to the southern boundaries of the plateau, up on rocky slopes where vegetation is scant. This suggests that blue sheep have wider niche breadths than the other ungulates in the region.

The results of the present study on the ecology of the Tibetan gazelle fit well with previous studies. A recent study by Bhatnagar et al (2006) revealed the Gazelle's preferences for relatively flat areas and south facing slopes. The Sikkim population too uses level areas disproportionately, but does not appear to avoid steep (40-60^{o}) slopes in the winters. Gazelles appear to be distributed over a considerably larger area. Their densities however vary greatly and the factors affecting these could pertain to disturbance or other extraneous factors rather than fundamental selection.

The kiang is extremely limited in its distribution and certainly appears to avoid habitats that seem appropriate, particularly the vast basin areas of the Chombo chu. Hence, kiang distribution appears to be linked to avoidance strategies. Although kiang are reported to favour broad open habitats, in the Sikkim Trans-Himalaya, they completely avoided the river basin and were restricted to the edge or lower slopes. The kiang's use of a slightly higher elevation (>5000 m) may to be an artifact of deliberate avoidance of certain (lower) areas more prone to human disturbance rather than an ecological preference for higher altitudes.

Yak and sheep uniformly distributed, with local concentrations around corral sites. Broadly, the distribution of livestock is an index of areas with highest forage biomass (and possibly the most nutritive too) as livestock are herded with much judgment. That these animals too forage on steep and sparsely vegetated slopes on occasion is clearly indicative of the fact that the *Kobresia* meadows and deserts steppe dominated by *Carex* and *Stipa* do not suffice as 'forage reservoirs' for a large livestock population.

5.2 Habitat selection

Habitat use by a species was largely explained by broad topographical and environmental variables – this may be an artifact of scales at which selection was studied or may indicate that species select broad habitat features over finer ones in the winter. Only by looking at these factors in combination does a picture of habitat selection appear. An often repeated theme in literature is that habitat selection by ungulates may occur at multiple spatial scales (Boyce et al 2003), and studies of this nature are often best achieved by including the 'spatially explicit distribution of environmental variables' (Dettki et al 2003). Interpretations of resource selection are known to vary at different spatial scales (Boyce 2006). While studies can be made at one scale or multiple scales, it is essential that 'control plots' be employed to characterize available habitat features, in the absence of these no conclusions on preference can be made. (Zhang et al 2006).

In the study area, species differed in their use of terrain features, altitude and slope may show greater preference for some features disproportionate to their availability in the area. Some clear trends that emerge are that argali use slopes to a greater extent, gazelles use both slopes and basins or valleys. Kiang appear to positively select basins and blue-sheep select vegetated, rocky slopes over other terrain categories.

Analysis on pellet presence data reveals similar results, only a few finer scale variables now appear to explain habitat selection with species differing from random in their selection of such areas. The homogeneity of cover for different species across plots and the percentage cover of shrubs, herbs, forbs and graminoids explains the finer scales of selection for some ungulates. Logistic regression models also predict terrain type, vegetation type, slope, aspect and altitude as being major factors influencing an animals use of an area, and some finer scale variables emerge in analysis based on pellet presence.

At a finer scale vegetation variables such as richness and percent cover vegetation do not appear to explain selection as emphatically as broad scale geographic features seem to

5.3 Food selection

Food selection by ungulates occurs at various scales sometimes referred to as a foraging hierarchy (Bailey et al 1996). Sheeny and Varva (1996) emphasize that ungulates do not select plant communities, but select for specific plants according to an intrinsic value system relating to palatability and availability of plants within the composite of vegetation and terrain forming plant communities. Hence vegetation communities may only be indicative of broad food preferences and interpretations at such scales should be made with caution and knowledge of the plant community. A hierarchical framework similar to the one followed for habitat selection was followed when looking at food selection. At a broad scale, data were first analyzed to ascertain if species differ in their selection of vegetation types from random.

Species appear to select terrain features more strongly than vegetation types but the two are likely to be auto-correlated. Selective foragers like the argali and gazelle use slopes where biomass may not be high but favoured species may be present. Bulk feeders like yaks seem to use valleys more – that may be partly explained by the presence of areas such as sedge meadows which offer relatively large proportions of forage. Yaks seem to desist form using upper slopes which are likely to fall in the range of 5250m – 5500m) – such areas are likely to have little forage. Sheep appear to use valleys disproportionately, this may be because of greater forage abundance – herders probably choose to graze their flocks in areas where forage resources are more concentrated in larger amounts. However, for sheep, a small sample size and lack of observations in the snow-covered months may have affected the data and its interpretation.

Field observation showed that blue sheep largely depended on a different resource base for their food by occupying spatially distinct areas. A few species appeared to be selected by the other ungulates, most notably *Stipa orientalis, Oxytropis lapponica* and *Elymus nutans.* For instance, both the argali and gazelle appear to select the *Ephedra-Artemisia* communities over other types. Although these are the dominant species within this community, ungulates may actually be selecting less abundant but more preferred forage species. In the above example, Argali feed on *Ephedra* and *Artemisia* apart from feeding selectively on *Stipa* and other plant species that co-occur in such areas. In the case of gazelles, *Ephedra* and *Artemisia* may occasionally be nibbled but they primarily feed on *Stipa orientalis, Elymus nutans* and *Oxytropis lapponica,* all of which are sparsely distributed within the broad vegetation type. Similar interpretations exist for the use of categories such as 'juniper scrub' by blue sheep. All animals appear to primarily feed on graminoids and a few species of forbs in the winter. Although gazelles have been reported to primarily feed on forbs (Schaller 1998), they appear to be eating graminoids like *Elymus nutans, Stipa orientalis and Festuca sp.* in the study area.

At a finer scale, when the samples of the food plant species were analyzed in the laboratory interesting patterns emerged. The proportions of graze to browse in the diet varied for the ungulate species. Domestic sheep, blue sheep and kiang were largely grazers while yak, Tibetan argali and gazelle predominantly fed on herbs, forbs and shrubs.

5.4 Inter-specific interactions

A well established theory in ecology establishes that in order to co-exist without competition, sympatric species must vary in their use of habitats or food resources (Schaller 1977). However the role of inter-specific competition in structuring species assemblages remains contentious Conell (1983), Prins and Olff (1998). Based on evidence of high dietary overlap and density-dependant forage limitation, Mishra et al (2004) demonstrate that competition occurs between blue sheep and livestock. Sheep and goats are fairly similar in body size to the argali, although smaller. Sheep are most likely to compete with the argali. Research in Mongolia has shown significant dietary overlap between Mongolian gazelles and domestic sheep and goats and that they may be potential competitors (Campos-Arceiz et al 2004). My observations on sheep were too few to make any conclusions, Argali were seen tolerating their presence at short distances on several occasions.

Are ungulates in the region competing for resources?

Amongst the wild ungulates only the argali and gazelle have completely overlapping distributions, and the two species feed in the same areas – different body sizes, likely to differ in their use of food. Argali select larger shrubs and herbs such as *Artemesia* roots, *Ephedra gerardiana,* and *Potentilla biflora.* Gazelles select smaller forbs such as *Oxytropis* . Both feed on *Stipa orientalis* and *Elymus*, while avoiding *Carex moorcroftii* in the winter.

By virtue of having similar body sizes, the argali and blue sheep are potential competitors. However, a complete spatial separation between the two species even in the resource-scarce winter months rules out potential competition, and the mechanisms for this have been explored by Namgail et al (2004). In another study, the competition between the Tibetan argali, Tibetan gazelle and kiang was not significant (Harris and Miller 1995).

While wild and domestic ungulates certainly use the same areas, the extent of use within different terrain types varies and there were few observations of animals directly competing for a given site. Although yak and sheep forage on scree slopes that are home to the Argali, livestock clearly use valley and basin areas to a greater extent for foraging. Although such interactions may be more frequent than I report here, a negative interaction was only observed on one occasion when yaks displaced a herd of 40 argali from a snow-free site on scree slopes soon after a heavy spell of snow in February.

Gazelles and yaks tend to co-occur in some areas, and this has been reported by Bhatnagar et al (2007) from Ladakh as well. However, where they overlap, yaks are generally seen in sedge meadows which do not appear to rank high in the Gazelle's preference list. Gazelles are clearly more abundant in areas not frequented by livestock.

Competition may be likely between yaks and the kinag. They have similar feeding preferences with both species selecting *Stipa* and *Carex moorcroftii.* The area occupied by kiang is frequently and heavily grazed by yaks, and kiang usually vacate the area during such periods. Further evidence of kiang competing with and avoiding livestock is demonstrated by the fact that the kiang completely avoid sedge meadows in the valley bottoms although these are known to be favoured feeding areas in Ladakh (Bhatnagar et al 2006). Kiang and yaks may therefore be competing for common food resources and low kiang numbers in the region during the winter may be on account of avoidance behavior and food overlap. Kiang appear to prefer foraging in areas with the least conflict, given the locations and social ranks of sympatric species (Rosenberg and McKelvey 1999). Studies have shown that caecal digestors and large ungulates are more limited by time than ruminant digestors and small ungulates (Hanley 1982) and this may explain why the kiang may be out-competed.

Competition between wild and domestic ungulates does not appear to be the predominant or intense (except in the case of the Kiang) on the Tso Lhamu plateau, though it may possibly be exaggerated during winters. Prins and Voeten (1999) suggest that overlap in resource use can occur under food-limited conditions and that this may consequently imply competition. Evidence for a lack of competition is probably best reflected in the health of ungulates. Research has clearly shown that when animal numbers are at the ecological carrying capacity, animals are unlikely to be in good condition (Caughley 1979), in indication of such a scenario is likely to be seen in what Jackson (1985) describes as "undernourished, unproductive (livestock) beyond the carrying capacity of the land".

5.5 Socio-economic aspects

Several recent studies Mishra (2000), (2001), Schaller 1998, Fox et al (1994) write about significant and socio-economic changes across the Tibetan plateau. Most such development is detrimental to wildlife of the plateau. Fortunately no changes of this magnitude seem to be occuring in the Sikkim Trans-Himalaya. To the contrary, the population of humans and livestock appears to have declined in the area in recent years. The *Dokpas* have self regulated systems that ensure that their winter pastures are not overgrazed. The community has to vacate the plateau by April and no individual is permitted to stay on beyond this period until they return in the winter. Tsoar and Meir

(1996) provide an example to show how new restricted borders can cause disruptions in local herding systems which may result in intensified grazing pressures over smaller areas and subsequent ecological damage. Their attitudes towards wildlife are largely of tolerance and co-existence. Wolves and snow leopards are somewhat disliked for the damage they cause by lifting sheep and young yaks.

Methods and approaches in wildlife studies in the Trans Himalaya- Lessons learnt:

1) **Presence-absence sampling for occupancy models**: I had intended to follow a double sampling strategy (Mackenzie and Royle 2005), while sampling for ungulate occupancy. Such methods however have limited scope especially when undulating terrain makes it impossible to detect presence (or absence) in a grid. Two approaches are suggested: to sample at several points in a grid by walking across, while ensuring that entire area comprising the grid (or much of it) is visible. A still better approach may be to sample for pellets at several locations within a grid (either systematically or randomly).
2) **Sex and age of wild ungulates:** These were particularly problematic to ascertain for argali, gazelles, and kiang. Argali groups tend to be very large and there is much room for erroneous identification, particularly among the sub-adults. Objective criteria for classification of age and sex in argali have to be refined and tested in a more detailed study.
3) **Food selection:** Quantitative data for food selection was difficult to obtain in a short term study that cannot be backed by an experimental design. Bite counts to quantify forage use and selection (Manjrekar 1997, Mishra et al 2004) are hard to standardize when comparing between wild and domestic ungulates. When

observing wild ungulates, even when proximity is achieved, rocks and depressions always obstruct clear viewing and results are not quantifiable unless the plant communities are distinct, comprising only one or two species.

4) **Point count method:** Point counts are not recommended in studies involving the Tibetan gazelle since they are difficult to spot from a distance and unsuitable for calculating density estimates (Schaller 1998).

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