HABITAT USE
BY GORAL (Nemorhaedus goral bedfordi)
IN MAJHATAL HARSANG WILDLIFE SANCTUARY, HIMACHAL PRADESH, INDIA

DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT, IN PARTIAL FULFILMENT OF MASTER'S DEGREE IN WILDLIFE SCIENCE (1993)

BY

CHARUDUTT MISHRA

SUPERVISOR

Dr. A.J.T. JOHNSINGH

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Total 54 pages

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that Mr. Charudutt Mishra of the Wildlife Institute of India has carried out an original piece of research work entitled "Habitat use by goral (*Nemorhaedus goral bedfordi*) in Majhatal Harsang Wildlife Sanctuary, Himachal Pradesh, India" in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University. These investigations were carried out under my supervision at the Wildlife Institute of India from November 1992 to June 1993. I also certify that this work has not been submitted for any other degree of any university.

DATE: 5/7/93.
PLACE: DEHRADUN

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CONTENTS

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LIST OF TABLES AND FIGURES

TABLES

FIGURES

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SUMMARY

I studied the habitat use pattern of goral (*Nemorhaedus goral bedfordi*) in Majhatal Harsang Wildlife Sanctuary in the Himalaya to determine its habitat requirements. Of special interest were the roles of forage availability and quality and the antipredator strategy of goral in determining its habitat selection. These factors are of paramount importance in influencing the habitat selection by mountain ungulates.

Diet composition of goral in terms of the proportions of graminoids versus browse was determined through pellet analysis. Its escape strategy was determined by direct observation. These results were then related to the actual habitat use patterns, which were determined by obtaining and quantifying locations of goral (n=334) over two seasons, along five monitoring trails. Use of each habitat category was interpreted with respect to its availability. A non-mapping technique was used for determining the availability of each habitat component.

I identified nine vegetation types based on physiognomy and floristics. These were: Open Pine Community (OPC), Dense Pine Forest (DPF), Open Oak-Pine Community (OOPC), Dense Oak-Pine Forest (DOPF), Nullah Oak Forest with Low undergrowth (NOFL), Nullah Oak Forest with High undergrowth (NOFH), *Euphorbia-Woodfordia-Dodoenia* Scrub (EWDS), Open *Euphorbia* Scrub (OES) and Low Altitude Nullah Forest (LANF).

Both forage quality and the antipredator strategy had a profound influence on habitat selection by goral. Goral was a grazer. It was partial to the younger, more nutrititive grass

phenophases - a prediction that can be made on the basis of its small body size. It preferred open areas with extensive grass cover. Forest cover, along with cliffs, was an important escape area for goral. But it avoided areas with extensive shrub cover. Such areas have little grass. Besides, the shrub cover obstructs visibility and quick movement, and makes the animal vulnerable to predation.

Although goral seems to have followed the general pattern of caprid evolution in having stepped out of the forest, it is still bound to the vicinity of forest cover.

CHAPTER I: INTRODUCTION

Specific habitat requirements of species need to be determined for their effective management and conservation (Eisenberg and Seidensticker 1976, Ben-Shahar 1990). Many recent studies have concentrated on the associations between ungulates and their habitat components (eg. Van Dyke *et al.* 1983; Pratt *et al.* 1986; Fox et al. 1989; Ben-Shahar 1990). Inspite of the subjectivity in selection of habitat categories, it is possible to identify the important factors that affect the extent of use of an area by an animal (Ben-Shahar 1990). For example, forage, water, thermal cover, escape terrain, and areas for rutting and lambing have been identified as factors which influence habitat use by bighorn sheep (Van dyke *et al.* 1983). Such knowledge has been applied for reclamation of devastated bighorn sheep habitats (MacCullum 1992).

Three species of goral inhabit the hill ranges of Asia ; the goral (*Nemorhaedus goral*) in the Himalaya, red goral (*N. baileyi*) restricted to the extreme northeastern part of India and the adjoining regions of Burma and China, and Chinese goral (*N. caudatus*) in Burma, Thailand, through China into the Soviet Far East (Groves and Grubb 1985). While the Ussuri region of Russia harbours goral at sea level, it is found upto 4500m asl in China (Zhang 1987). Himalayan goral, the study animal, is found from 200m asl in the Shivalik Hills to 4000m asl in the main Himalayan range (Schaller 1977, Johnsingh 1992).

Inspite of its wide distributional range, habitat requirements of goral are not well understood. This study, conducted from November,1992 to May,1993, was aimed at determining the habitat use

pattern of goral in the Himalaya, and to identify the factors that affect the distribution and abundance of goral in the area.

1.1 REVIEW OF LITERATURE

1.1.1 HABITAT USE

Herbivores rarely have a uniform distribution (Pratt *et al.* 1986). Instead, they use habitats disproportionately more or less (prefer or avoid respectively) in relation to their availability. The basis for habitat selection studies is to relate the abundance of an animal to the features of its habitat (Partridge 1978). The extent to which a habitat can fulfil the animal's requirements determines habitat selection. In general, the habitat use by a herbivore is affected by factors such as abundance and quality of food, availability of water, suitability of weather and shelter against extremes of weather, availability of areas for escape from predators, and human influence (Wilson 1981, Pratt *et al.*1986, Fiesta-Bianchet 1988, Fox *et al.*1989, 1992, Rautenstrauch and Krausman 1989).

The importance of availability while determining habitat selection has long been recognised (Glading *et al.* 1940, Bellrose and Anderson 1943, both in Neu et al.1974). A study on bighorn sheep found that the animals did not use >20% of the available range (Krausman and Leopold 1986). Neu *et al.*(1974) analysed the habitats used by moose (*Alces alces*) in northeastern Minnesota in relation to their availability and found that the animals preferred peripheral burnt habitats and avoided the centerburn and unburned habitats. Irwin (1975) reported results similar to Neu *et al.*(1974) in the same study area (northeastern Minnesota) for moose as well as white tailed deer (*Odocoileus virginianus*) and explained that

habitat preference was related to the presence of preferred forage.

Forage seems to be an important determinant of habitat use by herbivores. Seasonal changes in forage quality cause shifts in habitat use (eg. Klein 1970 in Schaller 1977; Kutilek 1979, Elsner-Schack 1985, Pratt *et al.* 1986, Dinerstein 1987, Gordon 1989a, 1989b). Plant species distribution and phenology in hilly areas are affected by features such as aspect, altitude and degree of slope (Schaller 1977). These habitat components have an influence on forage quality, and consequently on habitat use (Schaller 1977, Elsner-Schack 1985).

Antipredator strategies may have an overriding importance in determining herbivore habitat use. Fiesta-Bianchet (1988) concluded that antipredator strategy of pregnant bighorn ewes (*Ovis canadensis*) prevented them at certain times from using the habitats with best forage. The pregnant ewes migrated to more secure areas at higher elevations before new plant growth had started there. The non-pregnant yearling ewes which had followed the pregnant ones returned to lower elevations soon after discovering the lack of quality forage. Goat (*Capra* spp.) and sheep (*Ovis* spp.) inhabit open areas and show gregariousness as an antipredator strategy (eg. Geist 1985, 1987, Fiesta-Bianchet 1988) which enhances early detection of predators. As a consequence, bighorn sheep avoid habitats where vegetation obstructs visibility (Risenhoover and Bailey 1980, 1985). Chamois (*Rupicapra rupicapra*) use open areas. Their habitat use is determined by the presence of broken or rugged terrain which is used for escape (Elsner-Schack 1985). On the contrary, hog deer (*Axis porcinus*) require a habitat that provides ample escape cover. When threatened, they take refuge in thick vegetation (Dhungel and O'Gara 1991).

Thus, presence of quality forage and a[illegible] escape seem to be of a paramount importance in determining [illegible]ate habitat use patterns.

1.1.2 GORAL

A general description of goral, a cliff-dwelling mountain ungulate, can be found in Prater (1980) and Mead (1989). Its classification has been a subject of much debate, and has recently been summarized by Groves and Grubb (1985) who have classified goral into three species.

While other genera of goral's tribe (Rupicaprini), namely chamois, serow (*Capricornis* spp.) and Rocky Mountain goat (*Oreamnos americanus*) have been studied extensively (eg. Saunders 1965, Fox 1983, Elsner-Shack 1985, Hamr 1985, Lovari and Cosentino 1986, Masui 1987, Fox *et al.*1989), there is a dearth of published scientific literature on goral. Most of the literature published on goral is anecdotal or pertains to natural history accounts (eg. Blanford 1888-91, Stebbins 1912, Lydekker 1924 all in Schaller 1977; Dang 1968, Roberts 1977, Prater 1980, Green 1981).

Distribution and Habitat use: Himalayan goral has two subspecies: (i) Grey goral (*N. goral bedfordi*) is distributed from Eastern to Western Himalaya. The Swat Province in northern Pakistan is the western limit of goral distribution. I studied this subspecies. (ii) Brown goral (*N. goral hogdsoni*) is distributed from Eastern Himalaya to Assam (Roberts 1977; Prater 1980; Groves and Grubb 1985).

There is no quantitative study on habitat use by goral. Accounts are largely descriptive. According to Stebbins (1912) (in Schaller 1977), all forest types in Indian Himalaya above 900m asl

are inhabited by goral but it is not abundant above 2500m asl Powdery snow 40-50cm deep affects goral distribution adversely (Schaller 1977). He summarised that,'the goral's choice of habitat is liberal as long as the terrain is steep, rocky, and provides some cover'. Observations on the steepness of slopes used by goral differ. While goral in Thailand uses very steep slopes ($>60^0$) (Lovari 1986), reports from Western Himalaya are conflicting. Green (1987) reported the use of 30^0-40^0 slopes in Kedarnath Sanctuary in the state of Uttar Pradesh. Lovari and Apollonio (in press) reported similar results in Himachal Pradesh, while another report from the same state claims that goral uses $>60^0$ slopes (Cavallini 1992).

Diet: Reports on food habits indicate that while goral in the Himalaya is predominantly a grazer, it may be a mixed feeder in other areas showing seasonal changes in the proportions of graze and browse in the diet (Roberts 1977, Nasimovich 1955 in Schaller 1977; Bromeli 1956, Valova 1978, Zhang 1987, all in Mead 1989; Green 1987).

Social organization: Goral in general, and the adult males outside the rut in particular, are solitary (Roberts 1977, Schaller 1977, Green 1987, Zhang 1987 in Mead 1989). But group size is reported to vary from 1 to 12 (Stebbins 1912 in Schaller 1977; Prater 1980, Mead 1989). Males may become territorial during the rut (Mead 1989). Apollonio and Lovari (1991) found the sex ratio to be even.

1.2 OBJECTIVES

My main objectives were :

1. To determine the habitat requirements of goral.

2. To determine how the availability and quality of forage, and the antipredatory strategy, affected the habitat selection by goral.

A common null hypothesis was tested for most of the habitat components; that goral used the habitat categories in proportion to their availability.

To meet my objectives, I also had to determine :

1. The diet composition of goral in terms of the proportions of graminoids versus browse.

2. The antipredator strategy of goral in terms of the areas used for escape.

CHAPTER II: STUDY AREA

2.1 ADMINISTRATIVE

The thirty nine square kilometer Majhatal Harsang Wildlife Sanctuary (76^0 55'to 77^0 5'E and 31^0 15'to 31^0 18'N) in Himachal Pradesh lies to the northwest of Simla in the catchment of the River Sutlej (Fig. 1). Situated in the districts of Simla and Solan, the Sanctuary is administered under Piplughat Range, Simla Wildlife Division. The area was declared a Sanctuary in 1962.

2.2 PHYSICAL

Situated in the Middle Himalaya, the Sanctuary has a hilly terrain with altitude ranging from about 575m to 1985m asl. The area is marked with limestone deposits belonging to the Basantpur formation of the Shali-Simla groups. Other rocks of this succession are shale, siltstone, dolomite, and purple and white quartzite (Kumar 1985). Soils in the area are immature, of variable depth, and deficient in organic matter (Shagotar 1977).

The north-eastern boundary of the Sanctuary is formed by the Sutlej river, while Senj 'khad' (a perennial stream) forms the eastern boundary. There are two other perennial and several ephemeral streams, as well as four springs. The sanctuary comprises of parts of two linked hills; Majhatal and Harsang. The former was my intensive study area.

2.3 CLIMATE

The study area has a sub-tropical monsoon climate with three distinct seasons :

Winter : November to February (March)

Summer : (March) April to June, and

Rainy (monsoon) : July to September (October)

(months in parentheses indicate the period of transition).

The average annual rainfall is 1200-1500mm. Besides the monsoon, spring rains are also experienced. During the study period, slight drizzle to moderate rain was recorded on 31 days. Frost in winter and hail in winter and summer are common. Snowfall, which is rare, was experienced once on 7th January, 1993. Temperatures recorded over two seasons are :

	Maximum		Minimum	
	Range	Average	Range	Average
Winter :	0^0C to 34^0C	16.5^0C	-4^0C to 9^0C	3.8^0C
Summer :	17^0C to 37^0C	25.1^0C	11.9^0C to 22^0	13.9^0C

2.4 VEGETATION

Himalayan chir pine (9/CIb) and ban oak forests (12/CIa) (Champion & Seth 1968) form the major vegetation types. Chir pine (*Pinus roxburghii*) community is usually open with thin canopy cover, whereas ban oak (*Quercus leucotrichophora*) forms a closed canopy. While chir grows on all aspects, ban is restricted to moist pockets. It usually grows as narrow vertical strips along nullahs and gullies. At altitudes below 1600m asl, composition of these nullah forests becomes mixed in nature with little oak. Below 1600m asl on the drier aspects (E,S,SE), chir pine is replaced by Subtropical *Euphorbia* scrub (9/CI/DS2) (Champion & Seth 1968) which

is dominated by *Euphorbia royleana - Woodfordia fruticosa- Dodoenea viscosa* association. Above 1600m esl on the S, SE and SW aspects, open rocky *Euphorbia* scrub occurs along with chir pine. In the intensive study area, I could identify nine vegetation categories which are discussed in Chapter IV.

2.5 FAUNA

Besides goral, Majhatal supports a fauna which includes three species of ungulates; barking deer (*Muntiacus muntjac*), sambar (*Cervus unicolor*), and wild pig (*Sus scrofa*). The latter two are rare. The primates in the study area are rhesus macaque (*Macaca mullatta*) and common langur (*Presbytis entellus*). Amongst the predators, leopard (*Panthera pardus*) frequent the area. Other potential predators of goral are Himalayan black bear (*Selenarctos thibetanus*), Himalayan yellow throated marten (*Martes flavigula*), and lammergeier (*Gypaetus barbatus*), all of which are common. There is a report of a lammergeier having carried off a young goral (Baldwin 1876 in Schaller, 1977).

Viverrids are represented by common palm civet (*Paradoxurus hermaphroditus*) and Himalayan palm civet (*Paguma larvata*). Other carnivores include jackal (*Canis aureus*) and jungle cat (*Felis chaus*). Porcupine (*Hystrix indica*) and rufous-tailed hare (*Lepus nigricollis ruficaudatus*) are fairly common. During the study period, I identified 106 species of birds. The Sanctuary is a very important locality for the chir pheasant (*Catreus wallichi*)(Garson 1983).

2.6 HUMAN PRESENCE

Seventeen villages populated by about 650 inhabitants are located inside the Sanctuary. Cultivation and livestock rearing are

the main occupation of the villagers who have rights to graze, collect fodder, timber, fuelwood and minor forest produce in the Sanctuary (Shagotar 1977). Wheat and maize are the main crops in winter and monsoon seasons respectively. Human-wild animal conflicts are common. There are reports of leopard and black bear attacking people. Leopards frequently kill livestock. Black bear, barking deer, goral, porcupine and hare cause considerable crop damage.

During winter, pastoralist Gujjars come to the area from the higher reaches of Mandi district, and move back with their buffaloes as summer approaches. Herdsmen from the districts of Kinnaur and Kullu also winter in the area along with their goat and sheep.

There is a temple in the intensive study area which is frequented by pilgrims.

A project aimed at providing drinking water to 100 villages is in progress in the western part of the Sanctuary. Just outside the Sanctuary area, work has already been initiated on a private sector cement manufacturing plant with a projected annual capacity of one million tonnes.

Poaching is common in the area. Inside and around the Sanctuary, there are 39 gun licence holders, and I found evidences of unlicenced guns also. Rifle shooting also takes place, with poachers coming from distant areas. The Sanctuary is understaffed with only three unarmed beat guards.

Inspite of human presence and interference, Majhatal supports a high density of goral.

CHAPTER III: METHODS

3.1 FIELD METHODS

3.1.1 SELECTION OF MONITORING TRAILS

Before quantifying the habitat components, I selected five different grass-cutters' paths for use as my monitoring trails to quantify habitat use by goral. The choice was made after an initial survey of the Majhatal Hill covering about 16 km of such paths. Since aspect seemed to affect the vegetation communities, I selected four trails which together represented all aspects, although none of the trails was restricted to any one aspect. Nor were the aspects represented in equal proportions. The final choice of these four trails was based on their proximity to my basecamp. Except for one trail which was 1.5 km long, the remaining three were of 2.0 km length. These trails were restricted to altitudes above 1500m asl. To determine the extent of use of lower slopes by goral, I selected a 1.0 km long trail, which headed down from an altitude of 1530m asl. to about 1270m asl.

3.1.2 QUANTIFICATION OF HABITAT AVAILABILITY

Many workers have used vegetation and terrain maps, or aerial photographs to determine availability (eg. Neu *et al.*1974, Hirst 1975, Irwin 1975, Peek *et al.*1976 in Marcum and Loftsgaarden 1980; Risenhoover and Bailey 1985). Marcum and Loftsgaarden (1980) suggested a non-mapping technique which involves random sampling of the habitat based on a dot grid. This technique has been applied to determine the habitat availability for bighorn sheep (Gionfriddo and Krausman 1986, Dodd and Smith 1988). Other workers divided their study area into grids and quantified each grid for habitat

availability (Nievergelt 1981, Ben-Shahar 1990).

My objective for quantifying the habitat was to obtain a quantitative description and availability of the different vegetation types, and to determine the availability of other habitat components. I followed a modified version of the Marcum and Loftsgaarden (1980) technique. They recommend the use of this technique especially in rugged mountainous areas because it circumvents the problems involved in mapping such areas for vegetation and allows the simultaneous determination of availability of other habitat components.

Due to the non-availability of a relatively small scaled topographical map (<=1:25000), I could not sample the habitat based on randomly distributed points on the map as suggested by Marcum and Loftsgaarden (1980). Therefore I sampled the habitat along my monitoring trails. Riney (1982) has suggested a similar technique of habitat sampling along transects which are used for monitoring. The steep terrain of my study area, however, precluded the use of line transects.

At every 50m along my monitoring trails, I noted the aspect using a compass, and the vegetation type based on physiognomy and floristics. To quantify the vegetation type, I counted all trees in an estimated 10m radius plot using a nylon rope (10m) for guidance. All shrubs within an estimated 5m radius plot were enumerated species-wise. I estimated the shrub cover (in %) and the average shrub height within this plot.

Other habitat components were quantified every 100m as follows:

Altitude: It was recorded in m asl using an altimeter

Slope angle : General slope angle within a 5m radius was measured

... a Spiegel Relaskop and later translated into degr... s

... ss : Grass availability was quantified every month. ... agers cut grass from the forest in winter and summer months. Within a 10m radius, I used to record whether the grass was uncut/ cut/ partly cut. Grass phenology was recorded as flowering/ young/ dormant / dormant-young. Young grass referred to new sprout. Dormant phenophase represented grass that had been cut but the new sprout was yet to come. The grass in this phenophase was represented by dry stalks. Dormant-young phenophase consisted of 40-60% dry stalks and 40-60% new sprout. Two quadrats (0.50m X 0.50m) were placed in permanently marked points each month and the proportions of green and brown grass quantified.

For determining the average grass cover in the different vegetation types, I laid two quadrats at every 5m along a 20m straight line in each vegetation type. Grass cover within each quadrat was estimated in percentage.

3.1.3 QUANTIFICATION OF HABITAT USE

Data on habitat use by ungulates have been gathered by obtaining periodic locations of radiocollared or marked animals (eg.Fiesta-Bianchet 1988, Risenhoover and Bailey 1985, Gionfriddo and Krausman 1986, Krausman and Leopold 1986, Fox *et al*.1989). Some studies involved regular monitoring of fixed routes or transects in order to obtain animal locations (eg.Tilton and Willard 1982, Pratt *et al*.1986, Gordon 1989a, Ben-Shahar 1990). Nievergelt (1981) used fixed observation points to determine habitat use by Walia ibex (*Capra ibex walie*).

To obtain locations of goral, I walked each of the 5 monitoring trails 7 times in each season. Trails were started approximately 30 minutes after sunrise. I noted the location of

each individual/group sighted based on any available landmark and on its position with respect to my trail. Due to frequent poaching in the area, goral view man as a potential predator. On detecting me, the animals would run away. I noted the kind of escape terrain the animals ran to, which were classified as cliff/ rocky area/ cover/ open nullah or gully/ nullah forest.

After finishing the trail, I went to the exact site where each group was first sighted. Of the total 334 sightings, I could quantify the exact locations of 332. I could not reach 2 of the locations because of their inaccessibility due to extreme steepness of the terrain. At each location, I noted the vegetation type, grass phenophase, and, whether the grass was cut/ uncut/ partly cut. Aspect, altitude and slope angle were measured, for which the procedures were the same as followed for the quantification of habitat availability. In addition, I estimated the nearest distances of each location from water and the different kinds of escape terrain.

Since the monitoring was restricted to mornings, the data is likely to reflect an incomplete picture of diurnal habitat use. This problem to some extent is accounted for by the approximately 150 hours of observations that I could obtain on the diurnal activity pattern of goral. I have not been able to use that data here because of time constraint. But the observations indicate that goral are rather sedentary animals, rarely moving more than 300-350m in a day. The observations also indicate that the highest proportion of animals are active during mornings as compared to any other time of the day. Since resting animals would have been difficult to locate, morning time was the best in the present case.

3.4. WEATHER

Temperature : I recorded the maximum temperatures during the hottest part of the day in direct sunlight 1.5m above the ground level. Minimum temperature was recorded at 3:00a.m. in the open. A stem thermometer was used.

Rainfall : I made a note of the total number of days on which slight drizzle to moderate rain occurred during the study period.

3.2 LABORATORY TECHNIQUES

In order to explain the trends in habitat use of goral, I had anticipated the need to determine the proportions of graminoids and browse in its diet. I did this through pellet analysis which was conducted on a weekly basis. Every morning, 2 pellets each from every fresh pellet group encountered were collected. A composite of 30 such pellets (from 15 different pellet groups) was made and oven-dried (60^0C) for 24 hours. The composite was ground using a mortar and pestle into a fine powder. 1.0g (estimated) of this powder was mixed with 10ml of 10% NaOH solution. This suspension was boiled for 2 minutes over a spirit lamp and then transferred onto a mesh sieve. The filtrate was washed under running water and then used as the sample for analysis. Five slides mounted in glycerine were prepared from the filtrate. The slides were analysed under a compound microscope (10X10). I identified the fragments as grass or browse based on the linear or reticulated arrangement of cells respectively, as suggested by Johnson *et al.*(1983). The first 20 identifiable fragments were classified in this way from each of the 5 slides to get the percentages of graminoids and browse in the diet.

3.3 ANALYTICAL TECHNIQUES

For analysis of habitat use data, techniques vary from simple habitat use indices (eg.Pratt *et al.*1986, Gordon 1989a, Escos and Alados 1992) to multivariate techniques (eg.Krausman and Leopold 1986, Dodd and Smith 1988). Multiple regression, regression analysis and correspondence analysis have also been used (eg.Nievergelt 1981, Irby 1982, Ben-Shahar 1990). Neu *et al.*(1974) describe a technique to determine habitat use by evaluating preference or avoidance in relation to availability. Their technique has been widely used to determine ungulate habitat selection (eg.Irwin 1975, Tilton and Willard 1982, Risenhoover and Bailey 1985, Gionfriddo and Krausman 1986, Dodd and Smith 1988).

I used the technique suggested by Neu *et al.*(1974). It involves the use of a Bonferroni *z* statistic in conjunction with chi-square. Chi-square tests the hypothesis that the animal uses habitat categories in proportion to their availability. Bonferroni *z* statistic determines the observations in the data that contribute most to the calculated chi-square value, and thereby evaluates whether a habitat category is preferred, avoided or used in proportion to availability. The significance level was set at $p<=0.05$.

CHAPTER IV: RESULTS

4.1 VEGETATION STUDIES

Based on physiognomy and floristics, along the monitoring trails I identified nine vegetation types (Table 1) :

1. Open Pine Community (OPC)

Represented by 47% of the vegetation sampling points, OPC forms the most extensive vegetation type along my monitoring trails. It occurs on all aspects and has a relatively low average tree density (53 trees/ha). This community is characterized by open grassy slopes with an average grass cover of 67%. Chir (*Pinus roxburghii*) accounts for 87% of all the trees. The average shrub cover (9%) is the lowest as compared to any other vegetation type. The shrub height varies from 0.5m to 1.5m, with the average at 1.0m. *Aechmanthera pedata* represents the most abundant shrub species. *A. pedata* is the most abundant shrub in all vegetation types and on all aspects except in the two oak forest types discussed later in this section. The other common shrubs in OPC are *Hypericium oblongifolium*, *Salvia plebeja* and *Inula cappa*. *Nepeta leucophylla* is common on most open slopes of the drier aspects, especially on the S and SE.

2. Dense Pine Forest (DPF)

DPF consists of pure stands of young, unthinned chir plantations with an average density of 239 trees/ha. It accounts for 10% of the sampling points and is found on all aspects. Most of the ground remains covered with pine needles and the average grass cover is only 10%. Besides *A.pedata*, the other common shrubs are *H. oblongifolium* and *I. cappa*, and together they form a shrub cover of

21%. The average shrub height is 0.90m (range 0.5m to 1.5m).

3. Open Oak-Pine Community (OOPC)

This community covers 8% of the sampling points and is similar to the OPC in having a low average tree density (34 trees/ha) and open grassy slopes with a good average grass cover (69%). However, unlike the OPC which is present on all aspects, OOP is largely restricted to the N and NE aspects. Of the total trees, ban and chir form 38% each, *Lyonia ovalifolia* forms 13%, and the remaining is formed by *Glochidion velutinum* and *Prunus puddum*. *A. pedata and H. oblongifolium* are among the most abundant shrubs which contribute to the overall 21% shrub cover. The average shrub height is 1.1m (range 0.5 to 1.5m).

4. Dense Oak-Pine Forest (DOPF)

This forest covers 5% of the sampling points and is found on the W, N, and NE aspects. Ban (39%) and chir (59%) contribute most to the 145 trees/ha average tree density. The grass cover is 41%. *Rubus ellipticus* is the second most common shrub after *A. pedata*. The understorey shrub cover is extensive (36%) as well as high at 1.3m (range 1.0m to 2.0m).

5. Nullah Oak Forest with Low undergrowth (NOFL)

Occurring in narrow vertical strips along nullahs and gullies, this forest type accounts for 6% of the sampling points. It is found mainly on the relatively moist N and NE aspects. The average tree density is 191/ha with ban alone accounting for 53% of the total trees. *L. ovalifolia*, which is an associate of ban in the study area, forms 15%. *Cornus oblonga* and *C. macrophylla* contribute 7% each. Less common trees found in this forest type are *G. velutinum*, *Rhamnus triqueter* and *Rhus wallichii*. Average grass cover is very less (6%), that too formed mainly by a sedge *Carex*

are less common. The average tree density is 100 trees/ha. Although *A. pedata* is the most abundant shrub, *Woodfordia fruticosa* (8535 plants/ha), *Dodoenea viscosa* (8153 plants/ha), and *Euphorbia royleana* (6752 plants/ha) are most conspicuous owing to their larger volume. Average shrub cover is 31% and the shrub height is 1.9m (range 0.75 to 3.0m). The average grass cover is 30%.

8. Open *Euphorbia* scrub (OES)

Restricted again to the drier aspects (S,SE,SW) above 1600m asl, this treeless community is the least represented one along my monitoring trails, covering only 3% of the sampling points. OES is characterized by a largely rocky terrain, and has a good average grass cover (69%). Shrub cover is relatively less (13%) with an average height of 0.8m (range 0.5m to 1.5m). After *A. pedata*, *N. leucophylla* is the most abundant shrub species. This is followed by *Hamyltonia svaviolens*, which, like *N. leucophylla*, is characteristic of dry, open slopes.

9. Low Altitude Nullah Forest (LANF)

Along nullahs and gullies below 1600m asl, the tree species composition changes from an oak-dominated one into one of mixed nature with the highest tree species richness among all the vegetation types. LANF has an average tree density of 191/ha, and comprises of at least 21 tree species, none of which attains any remarkable dominance. *Bauhinia purpurea*, which is the most abundant tree, accounts for just 15% of the total trees. Ban, *S. villosa*, *F. auriculata* and *R. punjabensis* are common. Shrub cover is extensive (35%) as well as high at 1.5m (range 0.5m to 2.5m). *A. pedata* is the most abundant shrub, followed by equal proportions of *Indigofera hetromella*, *R. ellipticus* and *Myrcine africana*. Understorey is dense and similar in appearance to that of NOFH. The

average grass cover is 18%.

4.2 HABITAT USE

Following are the results obtained when null hypotheses were tested for the various categories of each habitat component:

4.2.1 VEGETATION

Vegetation type : Null hypothesis is rejected. Goral preferred OPC and OOPC, and avoided DPF, DOPF, NOFH and LANF. The remaining vegetation types were used in proportion to their availability ($p<0.001$) (Table 2). Seasonal use showed that in winter, there was no preference for any vegetation type. DPF, NOFH and LANF were avoided while all the remaining vegetation types were used in proportion to availability ($p<0.001$)(Table 3). In summer, there was a preference for OPC while DPF, NOFH, DOPF, EWDS, and LANF were avoided. The rest were used in proportion to availability ($p<0.001$) (Table 4).

Percent shrub cover : Null hypothesis is rejected. Goral preferred areas with shrub cover<=20% and avoided all other areas with a higher shrub cover ($p<0.001$) (Table 5).

Average shrub height : Null hypothesis is rejected. Goral preferred areas with low shrub height (<=0.50m). Areas with shrub height category 0.51m-0.75m were used in proportion to availability. All areas with shrub height >0.75m were avoided. ($p<0.001$)(Table 6).

Grass

Cut/uncut grass : Null hypothesis is rejected. In December-January, goral preferred areas where grass had not been cut, and avoided cut grass areas ($p<0.05$). In February, March and April, both categories were used in proportion to availability ($p>0.05$) (Table 7).

Grass phenology : Null hypothesis is rejected. In December-January,

goral preferred areas where grass was flowering. Areas with dormant grass were avoided, and areas with dormant-young used in proportion to availability ($p<0.001$)(Table 8). Areas with young grass formed only 2.5% of the total sampling points during this time. When subjected to Chi-square analysis, the expected usage for this phenophase was less than 5 (2.088). Since each category represented 25% (>20%) of the total, young grass had to be deleted from the analysis. For February also, the expected usage for areas with young grass was <5 (4.680) and therefore this phenophase is not considered. All other phenophases are used in proportion to availability (Table 9). In March, goral preferred areas with young grass and avoided those with dormant grass ($p<0.001$). Areas with flowering as well as dormant-young phenophases were used in proportion to availability (Table 10). In April, there was no area with dormant grass, and therefore this phenophase is not used in the analysis. Young grass areas were preferred, while areas with flowering and dormant-young phenophases were used in proportion to availability ($p<0.05$)(Table 11).

4.2.2 ASPECT : Null hypothesis is rejected. Goral avoided the SW aspect in winter as well as summer. The remaining aspects were used in proportion to availability ($p<0.01$)(Tables 12-14).

4.2.3 SLOPE ANGLE : Null hypothesis is rejected. Goral avoided all slopes with an angle $<=30^0$. Slope categories $31-40^0$ and above 50^0 were preferred while $41-50^0$ was used in proportion ($p<0.001$) (Table 15).

For the following habitat components, strict null hypotheses could not be tested because I lacked accurate data on their availability.

4.2.4 ESCAPE TERRAIN

With increasing distance from escape areas, the number of observations of goral showed a rapid decline.

Cliff : 67.4% of the total observations of goral (n=334) were within 50m from cliffs, and 84.8% within 100m (Fig.2).

Of the total times I could see where goral ran to after getting flushed (n=200), 31% of the times they took refuge in cliffs (Fig.8).

Rocky/broken terrain : 85.6% of the total observations of goral lie within 50m from broken terrain and 95.2% within 100m (Fig.3). While fleeing away from me, goral ran into broken terrain 13% of the times (Fig.8).

Open Nullah/gully : 92.5% of the times, goral were seen within 50m from an open nullah or gully, and 98.2% of the times within 100m (Fig.4). Goral ran up or down a nullah or gully 15.5% of the times (Fig.8).

Cover : 63.9% of the total observations are within 50m from cover (including nullah forest) and 77.2% within 100m (Fig.5). Upon getting flushed, 14.5% of the times goral took refuge in some kind of cover (excluding nullah forest). 15.5% of the times they took refuge in nullah forests (Fig.8).

4.2.5 ALTITUDE

Goral showed high use of areas above 1600m asl, and the use decreased progressively with decreasing altitude (Fig.6).

4.2.6 WATER

Goral showed high use of areas within 1000m of water. The trend shows a general decline in the use of areas away from water (Fig.7). However, no distinct pattern emerged when the two seasons are compared.

2.7 DIET

Goral was a grazer in both seasons. Grass formed 92.2% of the total diet in winter and 98.3% in summer.

In the analysis for habitat use pattern, all habitat components were treated independently. But it is the combined effect of many of these components that determines habitat selection.

CHAPTER V: DISCUSSION

5.1 VEGETATION

On analysing the structure of vegetation types avoided by goral, namely Dense Pine Forest (DPF), Dense Oak-Pine Forest (DOPF), Nullah Oak Forest with High Undergrowth (NOFH) and Low Altitude Nullah Forest (LANF), I found that all of them had less grass cover and/or extensive understorey (Section 4.1). Although grass cover in DOPF 41%, the shrub understorey is extensive (Section 4.1). NOFH has a low grass cover (3%) and the most extensive shrub cover which also attains the maximum height. LANF has a similar vegetation structure (Table 1).

The fact that goral is a grazer (Section 4.2.7) makes it important that it selects vegetation types with good grass cover. Goral's avoidance of areas with excessive shrub understory seems to be related to obstruction to visibility and/or to quick movement, rather than to the lack of grass. Usually, grass and shrub cover are mutually exclusive. Areas with extensive shrub cover are bound to have less grass. But as already mentioned, one of the vegetation types in my study area, namely DOPF, is unique in having good shrub as well as grass cover. Avoidance of this vegetation type in both the seasons implies that the structure of the understorey by itself is important in determining goral habitat selection. Goral, which at the shoulder stands only 0.65-0.70m (Prater 1980), avoids areas where the average shrub height is >0.75m (Section 4.2.1). Avoidance of most forested areas is therefore in response to hampered visibility/movement. DPF has little grass cover and although the shrub cover is not very extensive, the low branches of closely

spaced young pine trees (239trees/ha) would hamper movement/ visibility for goral.

Studies on bighorn sheep have shown a similar pattern of habitat selection where the animals even avoid extensive forage rich areas if high shrub cover obstructs visibility (eg.Van Dyke *et al.* 1983, Risenhoover and Bailey 1980, 1985, Dodd and Smith 1988). For bighorn sheep which dwells in open areas, vision has an important role in predator avoidance, as opposed to smell, which is important for a dense forest animal (Schaller 1977). As will be discussed later, goral is neither an exclusive inhabitant of open terrain, nor is it entirely restricted to the forest. It is therefore difficult to decide which factor, between visibility and movement, is the important one in deciding goral's avoidance of these dense vegetation types.

There is an overall preference for Open Pine Community (OPC) and Open Oak-Pine Community (OOPC) because these vegetation categories have open areas with little shrub cover and extensive grass cover. Although both these categories have an average shrub height which is higher than the shoulder height of goral, the percent shrub cover in OPC is very less. In the case of OOPC, the average shrub cover is comparable to that in DPF which is avoided. However OOPC lacks a vegetation structure which would obstruct quick movement or visibility, and together with a high grass cover provides a more suitable habitat.

Goral's selection of open communities as opposed to those rich in cover fits well with the general pattern that ungulate evolution has followed. The earliest ungulate forms were forest-dwelling browsers (Eisenberg 1987). Ungulate evolution shows a trend where animals acquire the ability to exploit grass as a food source and

become less dependent on forested habitats (Eisenberg and Lockhart 1972, Clutton-Brock *et al.*1982). This is true for caprids which have evolved from rupicaprids, and their evolution has partly been a consequence of progressive exploitation of open habitats (Schaller 1977, Geist 1987). While the ancestral rupicaprid of the Miocene was a rain forest inhabitant, its descendants, the modern goat and sheep, inhabit open areas (Schaller 1977, 1980). The importance of grass in goral's diet, together with its preference for open areas and avoidance of dense forested ones, suggests that goral as a species has followed the general pattern of caprid evolution.

Open *Euphorbia* Scrub (OES) is similar to OPC and OOPC (which are preferred) in having open grassy slopes. Aspect seems to be the reason why this vegetation type is not preferred. Sixty-seven of the sampling points representing this vegetation type fall in the SW aspect which is avoided by goral. Also, the presence of OES only on drier aspects implies that would lack interspersion with Nullah Oak Forest with Low undergrowth (NOFL) which serve as important escape cover for goral.

Euphorbia - Woodfordia - Dodoenia Scrub (EWDS) on the whole is used in proportion to availability inspite of being characterized by a high shrub cover. Besides, it is the only vegetation type which despite being restricted to altitudes below 1600m asl is not avoided by goral. The likely reason behind this is human influence. Grass-cutters remove shrubs on most open slopes to allow good grass growth. The effect is marked in EWDS which has extensive as well as high shrub cover. Gaps created in the shrub cover have allowed the growth of a grass cover of 30% (Section 4.1). It is usually such gaps which are used by goral. However, the surrounding cover does

have the potential to obstruct visibility and quick movement. The number of observations in EWDS is the same in both seasons (n=12). However, owing to the a relatively high increase in the number of observations in other vegetation types in summer, especially OPC, results show a relative avoidance for EWDS.

The only forested vegetation type used in proportion to availability and not avoided is NOFL. This vegetation type forms an important escape area for goral (Section 4.2.4), and also provides thermal cover during daytime (pers.obs.). It is probable that most of my observations in NOFL were of those animals which had sensed my approach before I could see them and taken refuge here.

The digestibility of a forage plant (and therefore its nutrient value) is a function of its protein and fibre contents (Blaxter *et al.* 1961, Elliot and Topps 1963 both in Geist 1974; Jarman 1974). Protein content is highest and fibre content lowest in newly emerged plant tissue which is therefore the most nutritious phenophase (Jarman 1974). In this regard, plant parts and phenological states are given importance when optimal foraging theory is applied to ungulates (eg. Westoby 1974 in Fiesta-Bianchet 1988, Owen-Smith and Novellie 1982). New grass sprout has a high nutritive value which decreases as the grass matures.

The energy and protein requirements of mammals are a function of their weight raised to the power of 0.75 (Geist 1974, Demment and Van Soest 1985 in Gordon 1989b). Therefore, smaller mammals have a relatively higher metabolic energy requirement per unit body weight. Goral can be considered as a small to medium sized ungulate, with weight ranging from 25-30kg (Prater 1980). Whatever information is available in Schaller (1977) and Prater (1980) suggests that goral is among the smallest members of the Caprinae,

possibly larger only to the chamois. Therefore, goral is expected to have a relatively high metabolic energy requirement. Green (1987) found that in his study area, goral had a higher crude protein content in its diet than the other larger sympatric ungulates; sambar and serow. Only musk deer (*Moschus chrysogaster*) which is smaller than goral had a higher value.

Since graminoids have a relatively higher fibre content, browse species in general are more nutritious (Dinerstein 1987). In this context, goral is expected to be a browser. I have no explanation why, goral, inspite of its small size, was still a grazer in Majhatal. Taking the example of hog deer, Dinerstein (1987) hypothesized that a high rumen size to body size ratio was a probable factor behind this medium sized ungulate (45kg) to be a grazer. A high rumen volume allows a slower turnover time which is necessary for the digestion of grasses. This could possibly apply to goral also. Grass being the major component of goral's diet in Majhatal, I expected that goral would be partial to areas with relatively younger phenophases of grass. The pattern of microhabitat selection by goral in terms of grass phenology validates these predictions to a certain extent.

Preference for uncut grass areas and avoidance of cut grass areas in December-January was related to grass phenology. Very few cut grass areas during this time had the dormant-young phenophase (which was used in proportion to availability at all times it was available). Since new sprout had not appeared in most grass cut areas, such areas represented the dormant phenophase which consists of dormant grass stalks. The dormant phenophase is likely to have the least food value among all phenophases, and was therefore avoided. Goral preferred uncut grass areas where though the grass

was mature and flowering, grass blades were available as forage.

Grass cutting by the local villagers continued as the months progressed. As a result, availability of uncut grass areas (and therefore of the flowering phenophase) reduced progressively while that of cut grass areas increased. As spring and later summer approached, areas with new flush of grass (young phenophase) increased. Availability of the dormant phenophase declined. Dormant-young phenophase did not show any increase, but in fact, disappeared in April by which time all such areas were replaced by the young phenophase.

In February, flowering, dormant and dormant-young grass phenophases were used in proportion to availability. Young grass was still too less to be used in the analysis. Dormant-young phenophase has around 50% new sprout, which, as discussed earlier, has a high protein and low fibre content. In terms of food value, I had predicted a hierarchial use in which goral in February would prefer the dormant-young phenophase and avoid the dormant one, with the flowering phenophase somewhere in between. But the observed trend did not fit the expected pattern. In the presence of flowering and dormant-young phenophases, why the dormant phenophase was used in proportion to availability (and not avoided) is difficult to explain.

However, in March and April, as expected, areas with dormant grass were avoided. During these months, young phenophase became available and was preferred. Flowering grass was used in proportion to availability. The dormant-young phenophase was used in proportion to availability in March while the phenophase was not available in April. It is interesting to see that the dormant-young phenophase was used throughout in proportion to availability,

whereas the young phenophase, once it became available, was preferred. Although the new sprout in dormant-young phenophase is expected to have a food value which is comparable to that of the young phenophase, an animal feeding in such an area would have to make relatively more effort to select and pick out the young blades which lie interspersed among the dormant stalks.

5.2 ASPECT

The exact reason for avoidance of SW aspect is not clear. Vegetation type did not seem to be the cause since 56% of the sampling points on this aspect are represented by OPC which is a preferred category. Steepness of slope seems to be one of the causes as 81.8% of the sampling points on this aspect fell in the $21\text{-}30^{0}$ slope category which was avoided by goral. However, effects of other habitat components such as water and escape terrain for which I lack accurate data on availability, cannot be ruled out. On the whole, there was no striking difference in the use of aspects within and between seasons. However, the southern side of the Majhatal Hill has more villages, which are also larger than the few small ones on the northern side. Besides, the potential habitat for goral in the northern side extends right upto the Sutlej gorge (Fig. 1). As a result, the available habitat is far greater on the northern side of Majhatal.

5.3 ALTITUDE

The best habitat in terms of goral abundance was above 1600m asl. Use of areas below 1600m asl, decreased progressively in the intensive study area. However, the pattern in Fig.5 indicates that goral do not use areas below 1400m asl, which actually is a

reflection of the situation only in my intensive study area I found evidences of goral as low as 600m asl outside my intensive study area, just above the Sutlej gorge (Fig. 1).

5.4 SLOPE ANGLE

Avoidance of lesser slope angle categories and a preference for categories with slope $>30^0$ show that goral prefer steeper areas. I have no explanation why goral used the $41-50^0$ category in proportion to availability rather than showing a preference for it as the trend would indicate. Slopes between $31-50^0$ angle seem to be the most important for goral. Although the $>50^0$ category is preferred, such areas form only 1.1% of the sampling points and are rarely available.

Fox *et al.* (1989) reported that mountain goat in Alaska used steep southerly slopes in winter because the shallow snow on these slopes increased forage availability. In Majhatal, the snow cover lasted only 2-3 days and therefore did not affect the availability of grass in any way. Grass phenology on all slopes seemed to be uniform and was largely determined by its condition, i.e., whether the grass was cut or not. Preference for higher slope categories, therefore, did not seem to be in response to availability of forage but could be a function of the antipredator strategy. Light *et al.* (1967)(in Van Dyke *et al.* 1983) found that bighorn sheep travelled through and even bedded in cover-rich areas (which were otherwise avoided) if these happened to be on steep slopes, which highlights the use of steep slopes as an antipredator strategy.

5.5 ESCAPE TERRAIN

Distribution of goral with respect to escape terrain suggests that nullah/gully followed by broken/rocky terrain are the most important escape areas. However, this is likely to be an artefact of differential availability of the different kinds of escape terrain which is difficult to quantify. It is clear from the data on actual use of escape terrain that cliffs are one of the most important escape areas. Cover seems to be the next highly used escape terrain. Since nullah forest presents a combination of two kinds of escape areas; steep terrain and cover; it is treated separately. Inspite of this, cover accounts for 14.5% of the overall use of escape terrain. Although nullah forests as well as open nullah/gullies are used in equal proportions (15.1%), the fact that nullah forests are restricted to moist pockets while open nullah/gullies are found on all aspects irrespective of moisture suggests that the former have a far lower availability. Therefore, nullah forests are more important escape areas compared to open nullah/gullies. Broken/rocky terrain was the least used escape area. Thus, cliff and cover are the most important escape areas for goral.

Vegetation cover of the habitat is an important determinant of the antipredator strategies of ungulates (Geist 1974, 1987). Inhabitants of dense cover assume a hiding strategy, whereas most mountain ungulates flee into steep, broken terrain to escape from predators (Geist 1974, Schaller 1977, 1980). Availability of escape terrain has been identified as an important component determining the habitat use by bighorn sheep (Tilton and Willard 1982, Risenhoover and Bailey 1985, Dodd and Smith 1988, MacCullum 1992). Foraging efficiency of bighorn sheep is reported to go down with

increasing distance from escape terrain (Risenhoover and Bailey 1985). Old World sheep are an exception in that they depend on cursorialism for escape (Geist 1987). Goral has been called a 'typical cliff-dweller' by some workers (eg.Heptner *et al.*1989, Mead 1989, Lovari and Apollonio, in press), while Geist (1987) refers to goral and serow as 'tropical hiders'. The fact, that along with cliffs, cover is an important escape area for goral, suggests an intermediate nature of its escape strategy. Affinity for proximity to cover and its use for escape show that goral, unlike the modern goat and sheep, is still bound to the forest to a certain extent. Serow shows a similar escape strategy of combining retreat into cliffs with hiding in dense vegetation (Englemann 1938 in Hutchins and Geist 1987). I want to specify here that goral only use forested areas with low shrub cover. In any case, the escape strategy of goral and serow and the overall habitat use patterns of goral seem to reflect their actual position in the evolution of caprinae. Both are among the most primitive extant caprine bovids (Schaller 1977, Geist 1985, 1987, Groves and Grubb 1985) which should be partial to cover and cliff.

5.6 CONCLUSIONS

1. Availability and quality of food and the antipredator strategy of goral are important determinants of its habitat selection.
2. Goral selected habitats with extensive grass cover as opposed to the forested ones with little grass, suggesting that it has followed the general pattern of caprid evolution. But unlike most other extant members of the caprinae, goral is still bound to the forest to some extent.
3. Goral avoided areas with extensive shrub cover. This was related

to forage availab...ty as well as its antipredator strategy.

4. Goral was a grazer. As can be predicted from its small body size, it was partial to relatively younger grass phenophases which are higher in nutritive value. In this regard, the existing practice of grass-cutting in Majhatal seems to benefit goral.

5. Goral preferred steep slopes as opposed to the gentle ones. This seemed to be related to its antipredator strategy rather than to forage availability.

6. Cliffs and forest cover are important escape areas for goral. But it uses only those forested areas which have little understorey. Canopy openings due to human activities promotes shrub growth in the oak forests, which can prevent goral from using such areas.

7. On the whole, availability of steep, open grassy slopes interspersed with oak forests and cliffs for escape, and the presence of water within 1.0 km radius are the important habitat requirements of goral in Majhatal.

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APPENDIX

TABLE 1. FEATURES OF EACH VEGETATION TYPE

VEGETATION TYPE	OPEN/CLOSED CANOPY	AVERAGE TREE DENSITY (/ha)	AVERAGE SHRUB COVER (%)	AVERAGE SHRUB HEIGHT (m)	AVERAGE GRASS COVER (%)
1. OPC	OPEN	53	9	1.00	67
2. DPF	CLOSED	239	21	0.90	10
3. OOPC	OPEN	34	21	1.10	69
4. DOPF	CLOSED	145	36	1.30	41
5. NOFL	CLOSED	191	20	1.10	6
6. NOFH	CLOSED	346	46	2.00	3
7. EWDS	OPEN	100	31	1.90	30
8. OES	OPEN	0	13	0.80	69
9. LANF	CLOSED	191	35	1.50	18

TABLE 2. CHI-SQUARE VALUE AND OVERALL INTENSITY OF USE OF THE DIFFERENT VEGETATION TYPES (Neu *et al.*1974)

VEGETATION TYPE	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1. OPC	0.455	0.486	0.637	PREFERRED
2. DPF	0.089	0.000	0.029	AVOIDED
3. OOPC	0.100	0.109	0.222	PREFERRED
4. DOPF	0.056	0.000	0.043	AVOIDED
5. NOFL	0.056	0.049	0.137	USE IN PROP.
6. NOFH	0.056	0.000	0.023	AVOIDED
7. EWDS	0.111	0.033	0.111	USE IN PROP.
8. OES	0.033	0.018	0.084	USE IN PROP.
9. LANF	0.044	0.000	0.033	AVOIDED
Chi-square value =		87.408691	*z* value =	2.769999

TABLE 3. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF THE DIFFERENT VEGETATION TYPES IN WINTER (Neu *et al.*1974)

VEGETATION TYPE	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1. OPC	0.455	0.396	0.633	USE IN PROP.
2. DPF	0.089	0.000	0.028	AVOIDED
3. OOPC	0.100	0.092	0.276	USE IN PROP.
4. DOPF	0.056	0.000	0.104	USE IN PROP.
5. NOFL	0.056	0.021	0.156	USE IN PROP.
6. NOFH	0.056	0.000	0.028	AVOIDED
7. EWDS	0.111	0.021	0.156	USE IN PROP.
8. OES	0.033	0.000	0.070	USE IN PROP.
9. LANF	0.044	0.000	0.070	USE IN PROP.
Chi-square value =		30.474551	*z* value =	2.769999

TABLE 4. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF THE DIFFERENT VEGETATION TYPES IN SUMMER (Neu *et al.*1974)

VEGETATION TYPE	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1. OPC	0.455	0.497	0.691	PREFERRED
2. DPF	0.089	0.000	0.039	AVOIDED
3. OOPC	0.100	0.081	0.223	USE IN PROP.
4. DOPF	0.056	0.000	0.000	AVOIDED
5. NOFL	0.056	0.038	0.155	USE IN PROP.
6. NOFH	0.056	0.000	0.030	AVOIDED
7. EWDS	0.111	0.014	0.108	AVOIDED
8. OES	0.033	0.017	0.115	USE IN PROP.
9. LANF	0.044	0.000	0.019	AVOIDED
Chi-square value =		67.700157	*z* value =	2.769999

TABLE 5. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF THE DIFFERENT SHRUB COVER CATEGORIES (Neu *t al*.1974)

SHRUB COVER CATEGORY	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1. 0-20%	0.510	0.704	0.820	PREFERRED
2. 21-40%	0.356	0.128	0.234	AVOIDED
3. 41-60%	0.078	0.017	0.074	AVOIDED
4. 61-80%	0.056	0.000	0.027	AVOIDED
Chi-square =		86.043785	*z* =	2.499999

TABLE 6. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF THE DIFFERENT SHRUB HEIGHT CATEGORIES (Neu *et al*.1974)

SHRUB HEIGHT CATEGORY	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1. 0-0.50m	0.144	0.333	0.468	PREFERRED
2.0.51-.75m	0.078	0.061	0.144	USE IN PROP
3.0.76-1.0m	0.434	0.210	0.332	AVOIDED
4. >1.00m	0.344	0.169	0.283	AVOIDED
Chi-square =		188.108840	*z* value	2.499999

TABLE 7. CHI-SQUARE VALUES AND THE INTENSITY OF USE OF THE GRASS CUT AND THE GRASS UNCUT AREAS (Neu *et al.*1974)

GRASS CONDITION	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
		DECEMBER-JANUARY		
1. UNCUT	0.551	0.553	0.780	PREFERRED
2. CUT	0.449	0.220	0.447	AVOIDED
Chi-square =		4.704762	z =	2.239999
		FEBRUARY		
1. UNCUT	0.532	0.222	0.573	USE IN PROP.
2. CUT	0.468	0.427	0.778	USE IN PROP.
Chi-square =		2.799306	z =	2.2399999
		MARCH		
1. UNCUT	0.430	0.217	0.442	USE IN PROP
2. CUT	0.570	0.558	0.783	USE IN PROP.
Chi-square =		3.623085	z =	2.239999
		APRIL		
1. UNCUT	0.354	0.158	0.372	USE IN PROP.
2. CUT	0.646	0.628	0.842	USE IN PROP.
Chi-square =		2.817593	z =	2.239999

TABLE 8. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF AREAS WITH DIFFERENT GRASS PHENOLOGIES IN DECEMBER-JANUARY (Neu *et al.*1974)

GRASS PHENOLOGY	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1.FLOWERING	0.569	0.596	0.836	PREFERRED
2.DORMANT	0.356	0.063	0.258	AVOIDED
3.DOR-YOUNG	0.075	0.036	0.211	USE PROP.
Chi-square =		14.31085	z =	2.389999

TABLE 9. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF AREAS WITH DIFFERENT GRASS PHENOLOGIES IN FEBRUARY (Neu *et al.*1974)

PHENOLOGY	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1.FLOWERING	0.560	0.219	0.630	USE PROP.
2.DORMANT	0.170	0.042	0.382	USE PROP.
3.DOR-YOUNG	0.270	0.163	0.564	USE PROP.
Chi-square =		2.502078	*z* =	2.389999

TABLE 10. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF AREAS WITH DIFFERENT GRASS PHENOLOGIES IN MARCH (Neu *et al.*1974)

PHENOLOGY	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1.FLOWERING	0.444	0.204	0.455	USED PROP.
2.YOUNG	0.247	0.413	0.678	PREFERRED
3.DORMANT	0.099	0.000	0.000	AVOIDED
4.DOR-YOUNG	0.210	0.037	0.213	USE PROP.
Chi-square =		46.071243	*z* =	2.499999

TABLE 11. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF AREAS WITH DIFFERENT GRASS PHENOLOGIES IN APRIL (Neu *et al.*1974)

PHENOLOGY	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1.FLOWERING	0.304	0.116	0.332	USE PROP.
2.YOUNG	0.480	0.511	0.760	PREFERRED
3.DOR-YOUNG	0.216	0.051	0.231	USED PROP.
Chi-square =		8.284314	*z* value =	2.389999

TABLE 12. CHI-SQUARE VALUE AND THE OVERALL INTENSITY OF USE OF THE DIFFERENT ASPECTS (Neu *et al.*1974)

ASPECT	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1. E	0.145	0.112	0.223	USE IN PROP.
2. W	0.024	0.004	0.055	USE IN PROP.
3. N	0.179	0.120	0.234	USE IN PROP.
4. S	0.123	0.091	0.196	USE IN PROP.
5. NE	0.235	0.162	0.287	USE IN PROP.
6. NW	0.068	0.047	0.133	USE IN PROP.
7. SE	0.113	0.086	0.189	USE IN PROP.
8. SW	0.123	0.004	0.055	AVOIDED
Chi-square =		30.666416	*z* value =	2.729999

TABLE 13. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF THE DIFFERENT ASPECTS IN WINTER (Neu *et al.*1974)

ASPECT	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1. E	0.145	0.048	0.202	USE IN PROP.
2. W	0.024	0.000	0.103	USE IN PROP.
3. N	0.179	0.081	0.257	USE IN PROP.
4. S	0.123	0.042	0.193	USE IN PROP.
5. NE	0.235	0.117	0.309	USE IN PROP.
6. NW	0.068	0.053	0.212	USE IN PROP.
7. SE	0.113	0.081	0.257	USE IN PROP.
8. SW	0.123	0.000	0.056	AVOIDED
Chi-square =		28.370250	*z* value =	2.729999

TABLE 14. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF THE DIFFERENT ASPECTS IN SUMMER (Neu *et al.*1974)

ASPECT	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1. E	0.145	0.120	0.274	USE IN PROP.
2. W	0.024	0.000	0.039	USE IN PROP.
3. N	0.179	0.107	0.257	USE IN PROP.
4. S	0.123	0.090	0.233	USE IN PROP.
5. NE	0.235	0.150	0.314	USE IN PROP.
6. NW	0.068	0.014	0.107	USE IN PROP.
7. SE	0.113	0.054	0.178	USE IN PROP.
8. SW	0.123	0.000	0.071	AVOIDED
Chi-square =		19.291992	*Z* value =	2.729999

TABLE 15. CHI-SQUARE VALUE AND THE INTENSITY OF USE OF THE DIFFERENT SLOPE CATEGORIES (Neu *et al.*1974)

SLOPE CATEGORY	EXPECTED PROPORTIONATE USE	LOWER CONFIDENCE LIMIT	UPPER CONFIDENCE LIMIT	INTENSITY OF USE
1. $<21^0$	0.167	0.038	0.113	AVOIDED
2. $21-30^0$	0.522	0.319	0.457	AVOIDED
3. $31-40^0$	0.200	0.304	0.441	PREFERRED
4. $41-50^0$	0.100	0.072	0.164	USE IN PROP.
5. $>50^0$	0.011	0.016	0.075	PREFERRED
Chi-square =		113.754653	*z* value =	2.579999

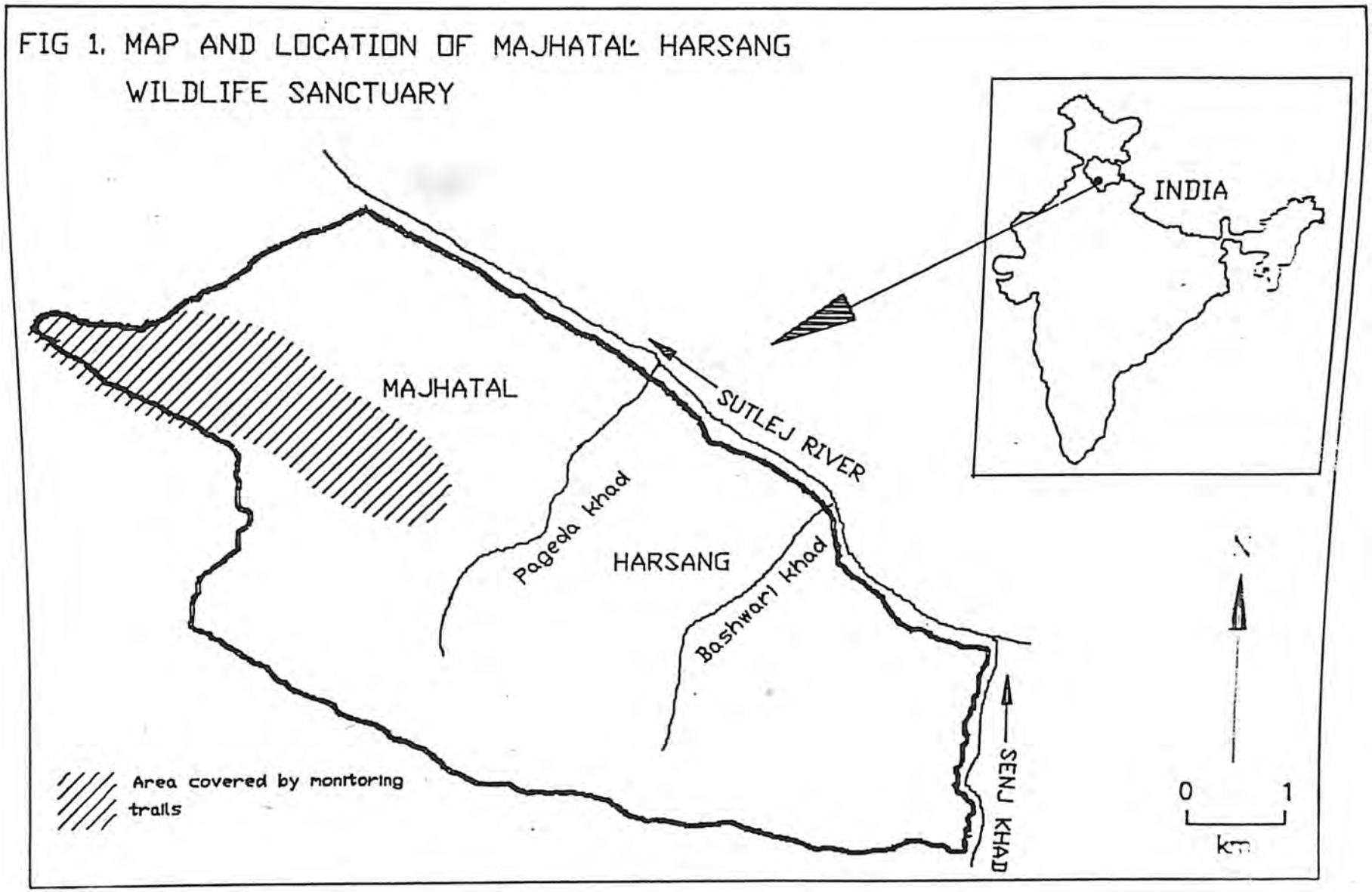
FIG 1. MAP AND LOCATION OF MAJHATAL HARSANG WILDLIFE SANCTUARY
INDIA
MAJHATAL
SUTLEJ RIVER
Pageda khad
HARSANG
Bashwari khad
SENJ KHAD
Area covered by monitoring trails
0
1
km

FIG. 2 DISTRIBUTION OF GORAL SIGHTINGS WITH RESPECT TO CLIFFS

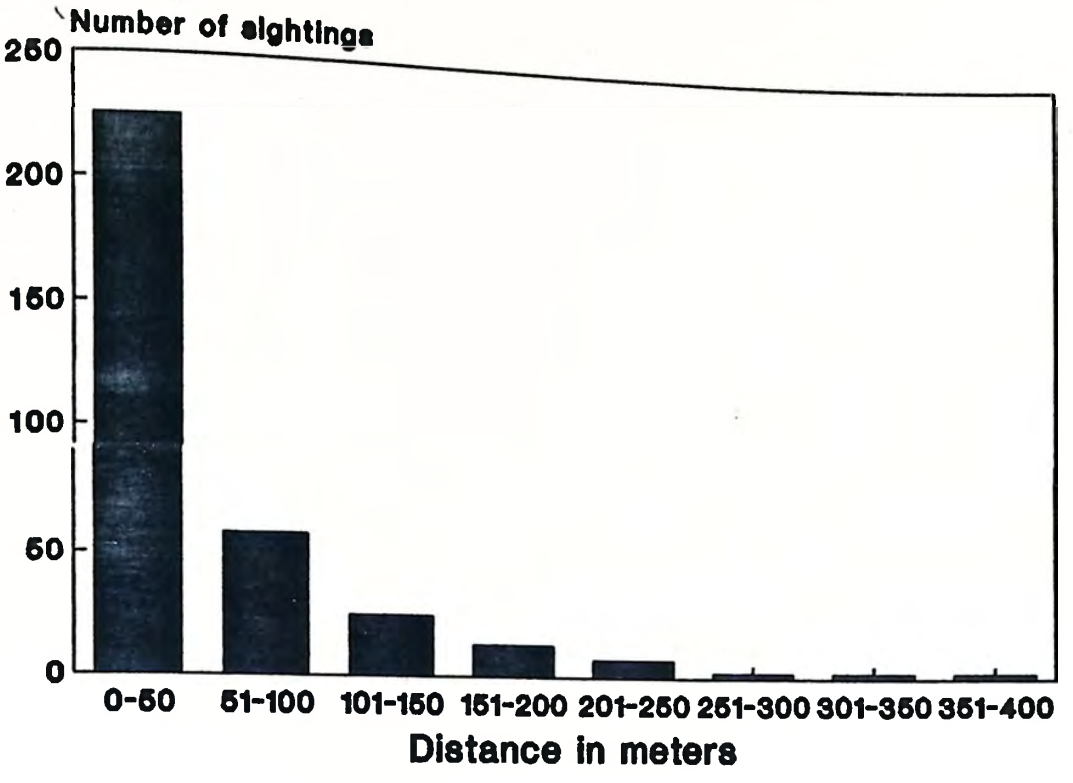

FIG. 3 DISTRIBUTION OF GORAL SIGHTINGS WITH RESPECT TO ROCKY/BROKEN TERRAIN

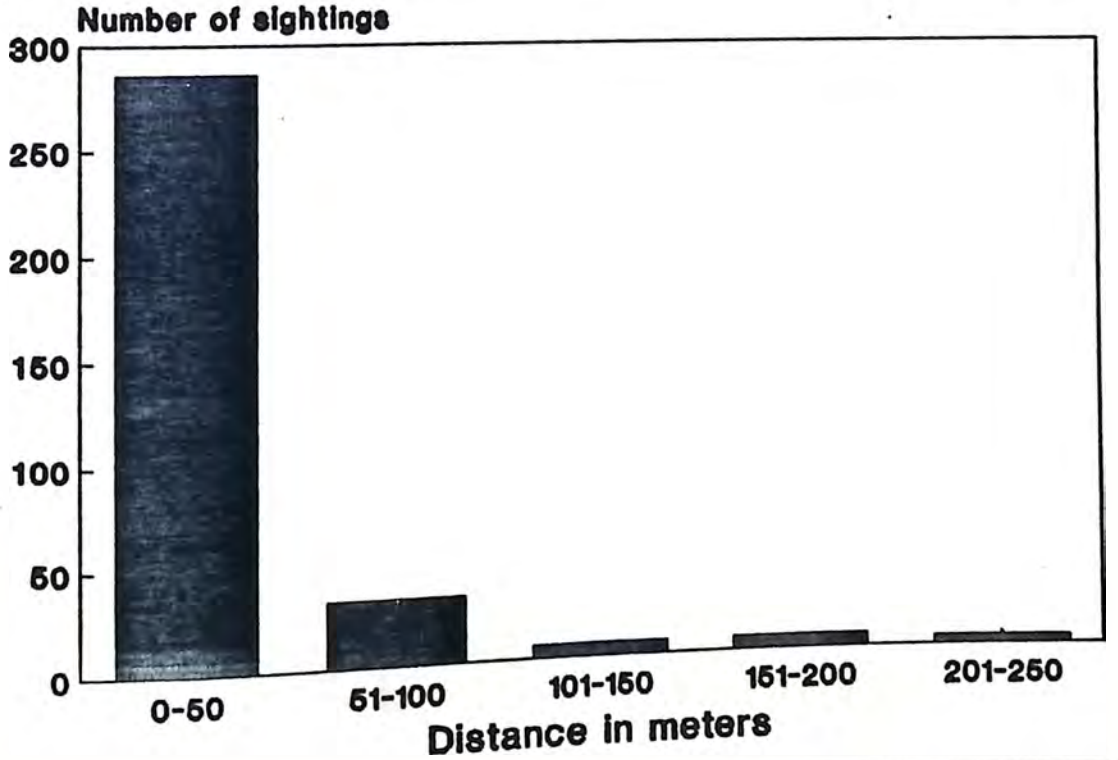

FIG. 4 DISTRIBUTION OF GORAL SIGHTINGS WITH RESPECT TO OPEN NULLAH/GULLY

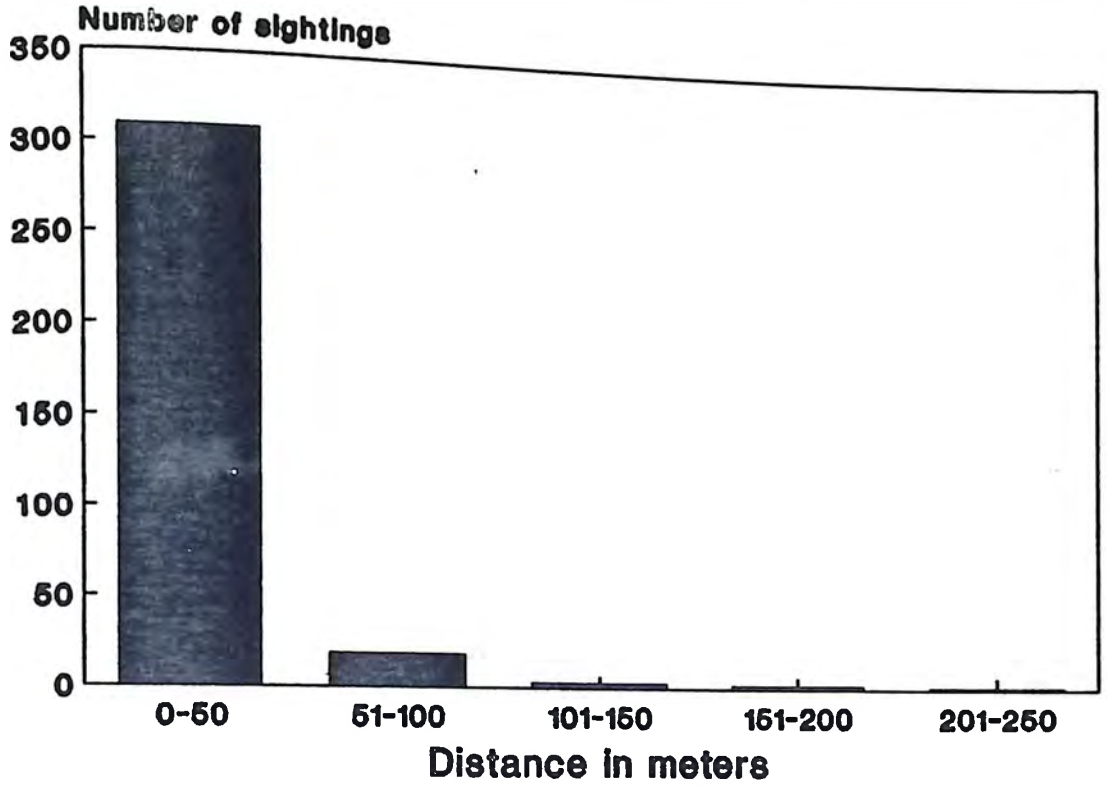

FIG. 5 DISTRIBUTION OF GORAL SIGHTINGS WITH RESPECT TO FOREST COVER

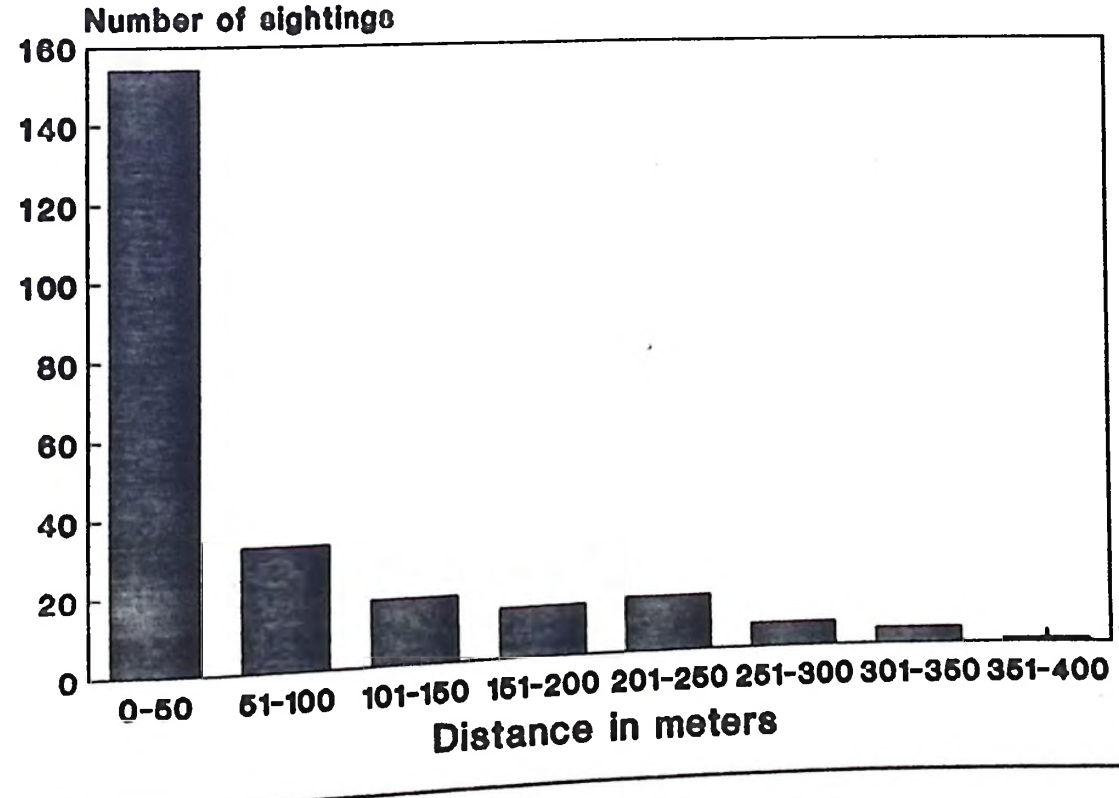

FIG. 8 ALTITUDINAL DISTRIBUTION OF GORAL SIGHTINGS IN THE TWO SEASONS

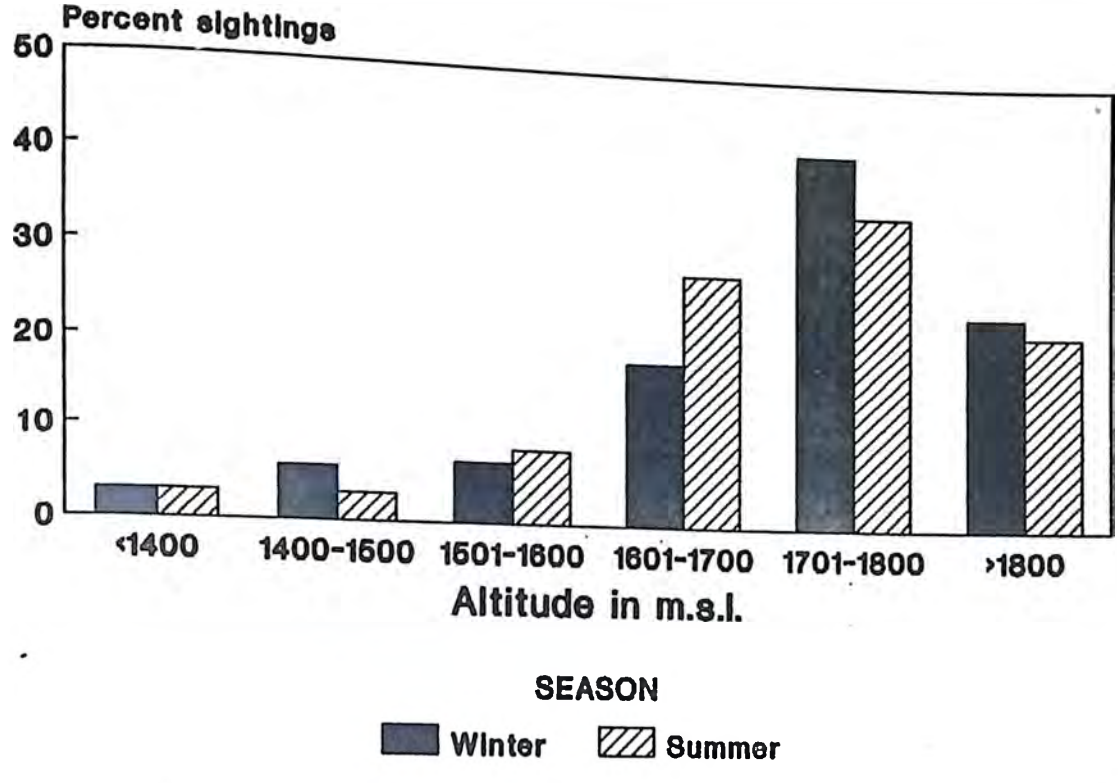

FIG. 9 SEASONAL DISTRIBUTION OF GORAL SIGHTINGS WITH RESPECT TO WATER

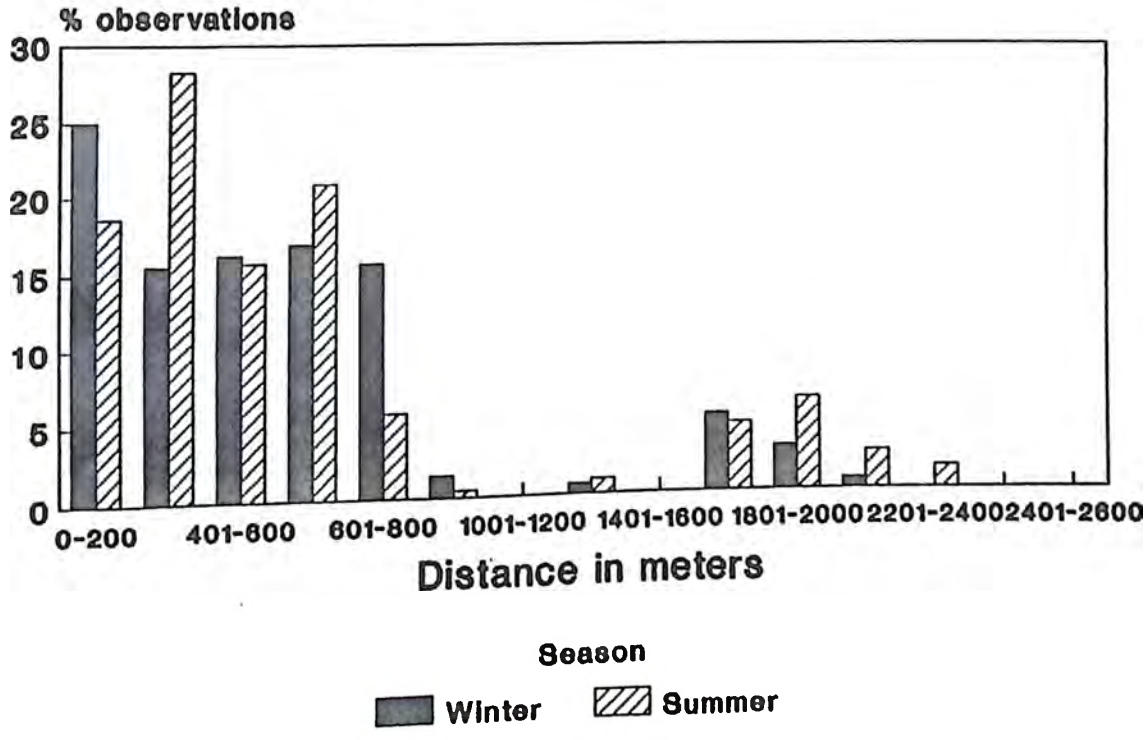

FIG. 8 USE OF DIFFERENT KINDS OF ESCAPE AREAS IN PERCENT