HABITAT USE BY CHITAL (Cervus axis)

IN DHAULKHAND,

RAJAJI NATIONAL PARK, INDIA

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BY

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CERTIFICATE

This is to certify that Mr. Shridhar D. Bhat of the Wildlife Institute of India has carried out an original piece of research work entitled "Habitat use by chital (*Cervus axis*) in Dhaulkhand, Rajaji National Park, 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.

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SUMMARY

A study on the habitat use by chital or spotted deer (*Cervus axis*) was conducted in Dhaulkhand, Rajaji National Park, from November 1992 to May 1993. The study covered winter and spring-summer. The objectives of the study were to understand the spatio-temporal use of habitats by chital and to identify the factors that govern the patterns of habitat use.

Foot transects were used to estimate the densities of chital and quantify the availability and utilisation of resources. Ten marked transects, 5 in hills and 5 in plains, were used. *Ad libitum* records of chital were made. Monitoring along a road and a search path to quantify chital use of habitat was also done. Eight habitat types were identified based on topography and vegetation. They were Hill Forest, Hill Woodland, Hill Scrubland, Scrubland, Mix Forest, Sal Forest, Woodland, and Mix Forest Plantation. Circular plots and quadrats were used to quantify the density and relative abundance of tree, liana, shrub, grass, herb, and climber species. The availability of habitat features such as slope, aspect and terrain in hills and cover types both in hills and plains was estimated.

In both the seasons, there was no significant difference in the density of chital between the hills and the plains. In the hills, Hill Forests were used more than Hill Woodland. Seasonal shift in habitat use was marked in plains. Sal forest was used less in winter and more in spring-summer. Mix forest plantation was used more in winter, but less in spring-summer. Overall, forests and higher canopy cover categories were used more. Denser shrub and ground cover were used less than sparser shrub and ground cover.

In hills, 11-30^0 slopes were used more than 0-10^0 and >31^0 slopes. Valleys and ridge lines were used more than hill slopes. S, SE and E aspects were used more than NE, N, NW and W aspects.

Wind seemed to affect chital habitat use in hills. Food, water, cover, terrain, weather, association with langurs and rhesus macaques and human influence in the form of fire, lopping, creation of water and grass cutting were identified as the factors governing the pattern of chital use of habitat.

CHAPTER 1. INTRODUCTION

Habitat is the place where an animal can live and reproduce. Food, water, cover and space are the basic requirements of an animal (Dasmann 1981). The extent of use of a habitat by an animal is determined largely by the extent to which the habitat can supply these requirements. Besides the basic requirements, there are other factors that influence the use of a habitat, e.g. terrain, weather, human influences, and other animals (Schaller 1967, Eisenberg & Lockhart 1972, Sharatchandra & Gadgil 1975, Seidensticker 1976, Mishra 1982 cited in Putman 1988, Newton 1984, Bhatnagar 1991). All these factors ultimately determine the pattern (extent, purpose, time of day, duration, season and strategy) of use of a habitat (Graf & Nichols 1966, Schaller 1967, Eisenberg & Lockhart 1972, Sharatchandra & Gadgil 1975, Mishra 1982, Newton 1984). The present study, conducted in a part of the Shivaliks and the Bhabar tract, aimed at understanding the pattern of habitat use by chital and at identifying the factors that govern such a pattern. The study was conducted from 16 November 1992 to 9 May 1993.

Chital or spotted deer (*Cervus axis*), in its wild state, is confined to the Indian subcontinent. West to east, it ranges from Gujarat and eastern Rajasthan to Sundarbans and western Assam. North to south, it is distributed from the foothills of the Himalayas to Sri Lanka (Schaller 1967, Prater 1980). Chital are found generally in moist deciduous and dry deciduous forests and have only a peripheral occurrence in evergreen and thorn forests (Schaller 1967). Introduced populations are found outside the subcontinent also e.g., in Hawaii and Texas (Graf & Nichols 1966, Ables 1977).

1.1 Review of literature :

Deer (Family Cervidae) evolved primarily as species of the woodland or woodland edge. However, they show wide adaptation to different habitats (Putman 1988). The general habitats of 8 species of Indian deer have been discussed by Prater (1980). The same for the 36-39 of the world's deer species has been done by Cockerill (1984) and Putman (1988). Putman (1988) reviewed the studies done on habitat use of different species of deer in various parts of the world.

There have been studies on habitat use by chital, e.g., in Corbett National Park [NP] (De & Spillett 1966, Schaller 1967), Kanha NP (Schaller 1967), Wilpattu NP, Sri Lanka (Eisenberg & Lockhart 1972), Royal Chitwan NP, Nepal (Seidensticker 1976, Mishra 1982) and Karnali-Bardia Wildlife Reserve, Nepal (Dinerstein 1979). These and other studies (Graf & Nichols 1966, Ables 1977) indicate that chital use a wide variety of habitats ranging from grassland to moist deciduous forest. In Hawaii, chital avoided extensive open areas as well as extensive closed forests (Graf & Nichols 1966). In Bandipur NP they used the forest-grassland ecotone more than the thicker forests of closed canopy (Sharatchandra & Gadgil 1975). In Nagarhole NP, they were more abundant in Teak Dominated Forests and Moist Deciduous Forests than in Dry Deciduous Forests (Karanth 1988).,In Parambikulum Wildlife Sanctuary (WLS), they were more in grassland compared to evergreen/semi-evergreen/deciduous forests and plantations (Balakrishnan & Easa 1986).

During dry season, their use of forests increased (Schaller 1967, Balasubramaniam et al. 1980 cited in Putman 1988, Mishra 1982). The time and duration of such use of grasslands and forests varied with the weather. During rains and cloudy weather, chital

spent more time in open areas and grasslands (Graf & Nichols 1966, De & Spillett 1966, Schaller 1967, Eisenberg & Lockhart 1972, Mckay & Eisenberg 1974) a pattern they repeated in the rainy season (Balasubramaniam et al. 1980, Mishra 1982).

Rodgers (1987) classifies chital as a generalist in its feeding habits. Much of the literature suggests that chital obtain the bulk of their diet from grasses and sedges, but they do supplement their diet with considerable browse, especially when grasses are not available or are not palatable (Schaller 1967, Graf & Nichols 1966, De & Spillet 1966, Dinerstein 1979, Prasad & Sharatchandra 1984, Johnsingh & Sankar 1991). Studies of various intensities and duration conducted in different areas have produced information on food plants of chital. Schaller (1967) listed 51 species of plants eaten by chital, Ables (1977) listed 48, Dinerstein (1979) listed 79, Prasad & Sharatchandra (1984) listed 38, Nair & Jayson (1988) listed 24, and Johnsingh & Sankar (1991) listed 162 species of food plants of chital.

Chital are very much dependent on surface water for drinking, especially in the hot-dry period. Water is a very important determinant of their habitat use (Graf & Nichols 1966, Schaller 1967, Ables 1977).

Chital tend to avoid the close confinement of dense and continuous vegetation cover. But, they have a great affinity for partial cover. The nearness of cover is very essential for them for escape and fawning (Graf & Nichols 1966, Schaller 1967, Johnsingh 1983) and for shade during the hot hours of the day (Graf & Nichols 1966, De & Spillet 1966, Schaller 1967, Ables 1977).

Schaller (1967), Sharatchandra & Gadgil (1975), and McDougal (1977) noted that chital avoided rugged or hilly terrain. In

Sariska Tiger Reserve, they preferred flat terrain (Chakraborty 1991) as also in Gir (Berwick 1974). However, in Hawaii and in Texas (USA), chital did use slopes and ridges (Graf & Nichols 1966, Ables 1977). Schaller (1967) mentioned their occurence in the Shivalik hills.

1.2 Objectives of the study :

While the literature suggests that chital avoid hilly terrain, the frequent occurence of chital in the hills of the study area led to a question - do chital use hills more here ? Such a question initiated this study.

The objectives were :

1. To compare the spatio-temporal use of habitat by chital in hills and plains.
2. To determine the factors that govern such a use of habitats.

To fulfil the objectives, I sought answers for the following questions-

1. Between hills and plains, which one is used more by chital ? How does such use compare between winter and spring-summer ?
2. Within hills and plains, to what extent do chital use each secondary habitat type and each of the different categories of habitat components such as canopy cover, shrub cover, ground cover, terrain and aspect ? How does such use compare between seasons and between morning and evening ?
3. What are the causes responsible and how are they responsible for the patterns of habitat use mentioned above ?

CHAPTER 2. STUDY AREA

2.1 Administrative and general :

The intensive study area (approximately 30 km^2) was Dhaulkhand region (78° E and 30° N) in the south-western portion of the proposed Rajaji NP (824 km^2), Uttar Pradesh (Fig.1). Rajaji is about 250 km north of Delhi. It includes parts of 5 districts - Dehradun, Saharanpur, Haridwar, Pauri and Tehri-Garhwal (Rodgers et al. **1990**). In 1983, the Government had declared its intention to create this park by merging Chilla WLS, Motichur WLS and Rajaji WLS. However, the legal procedures necessary for the creation of the park are not yet complete. Rajaji has 2 main conservation objectives (Rodgers et al 1990) ;

1. It includes a large area of the fragile Shivalik system.
2. It is the home of the most northwestern population of the Asiatic elephant (*Elephas maximus*).

Most of the intensive study area lies in Dhaulkhand Range and a smaller part in the adjacent Chillawali Range. However, for convenience, I call the intensive study area as Dhaulkhand.

2.2 Physical :

Rajaji is bisected into its northern and southern parts by the Shivalik hill system. The Shivalik hills are a recently uplifted ridge system, 2 to 10 million years old (Rao et al. 1979 cited in Rodgers et al. 1990). They are basically composed of the material eroded from the Himalayas and deposited in the alluvial pans and basins at the foot of the mountain. These have now been uplifted to form unconsolidated boulder deposits of sandstone and conglomerate (Rodgers et al. 1990). Being the sedimentary traps formed in front

of a rising chain of mountains, Shivaliks are a foredeep folded belt (Kumar 1985). Hereafter, the word 'hills' refers to the Shivalik hills unless mentioned otherwise.

The middle Shivaliks are largely sandstones, alternating with gravels and clays. The upper Shivaliks are largely composed of conglomerates with alternate layers of sandstone and grits. More recent deposits of gravels were made in the Pleistocene (less than 1.8 million years old), largely in the "Dun" (the valley in between the Shivaliks and the Himalayas). South of the Shivaliks, there is 'Bhabar' tract. Bhabar landscape is a series of pans consisting of boulders, gravels and sand deposits from the streams of the Shivaliks. These deposits are of Holocene (recent) and Pleistocene epochs (Rodgers et al. 1990, Kumar 1985). Hereafter, the word 'plains' refers to the Bhabar tract unless mentioned otherwise.

The Shivaliks are highly dissected, the degree of dissection increasing towards the central ridge and being highest on the very steep and scarp southern slopes of the central ridge. The north facing slopes are more gentle with less degree of dissection than the south facing ones (Rodgers et al.1990).

Soils in general are poorly developed due to the young landscape and extreme erosion. On stable sites of gentle slopes, soils are deeper and better formed. On higher slopes, soils are poorer. Within a local mosaic, depending on the site history of erosion and accumulation, soils are very variable. Generally, soils are slightly acidic with pH 5.2 to 6.5 (Rodgers et. al. 1990).

The area is traversed by numerous wide beds of seasonal rivers, locally called 'rau(s)'. During winter and summer most of the water dries up in the raus and is available only in pools and puddles.

Dhaulkhand consists of a part of the Bhabar tract (overall slope 2-5^0) in the south and southwest and a part of the Shivalik hills in the north and northeast. The highest point in Dhaulkhand is 741 m (SOI 1969). There are 4 raus. Along the banks of the raus, at certain places, natural salt licks are present. There are numerous gullies and nalas, especially in the hills.

2.3 Climate :

The study area experiences 3 seasons (Rodgers et. al. 1990), viz:

- Monsoon - July to September (October),

  Winter - (October) November to February (March),

  Summer - (March) April to June. (Months in brackets are transitional). Mean annual rainfall at Dhaulkhand is 1531 mm (Rodgers et al.1990). As a result of Western Depressions (Ramdas 1974), it receives winter rains also. During the study period, out of 130 days observed, 43 days were cloudy, 6 days rainy and 6 days foggy while it drizzled on 6 days and hailed on 2 days. Snow fall in the Himalayas would lead to a drop in the temperature at Dhaulkhand. Temperature figures for the study period are given in Fig.2.

2.4 Vegetation :

The vegetation types in Dhaulkhand correspond to the Champion and Seth (1968) categories of Tropical Moist Deciduous Forests (3C/C2a), (3C/C2bi), Tropical Dry Deciduous Forests (5B/C1a, 5B/C2 and 5B/1S2) and Subtropical Shivalik Chir Pine Forests (9/C1a).

Vegetation in the hills has a different appearance compared to that in the plains. There are no extensive grasslands.

Vegetation in the plains : Certain parts are covered by Moist Bhabar dun Sal forest [3C/C2b(i)] (Plates 2 and 3), where sal (*Shorea robusta*) trees dominate to form the top canopy. The other common trees are *Mallotus philippinensis*, *Ehretia laevis*, and *Miliusa velutina*. The common shrubs are *Mallotus philippinensis*, *Colebrookia oppositifolia*, *Milletia extensa*, and *Lagerstroemia parviflora*. *Desmostachya bipinnata* and *Chloris dolichostachya* are the common grasses.

Some areas have been converted to forest plantations of *Tectona grandis*, *Acacia catechu*, *Dalbergia sissoo*, *Ailanthus excelsa*, *Kydia calycina*, *Bombax ceiba* etc.

In and around the raus there are mixed dry deciduous forests (5B/C2) (Plate 1) which occur as a seral stage due to edaphic conditions (Champion & Seth 1968). These have sparsely spaced trees of *Adina cordifolia*, *Mitragyna parviflora*, *Terminalia bellirica*, *Bombax ceiba*, *Terminalia tomentosa*, *Mallotus philippinensis*, *Zizyphus mauritiana*, *Cassia fistula*, *Holarrhena antidysenterica*, *Cordia obliqua* and many other species. Canopy openings of various extents are common, thus giving an appearance of woodland. Grassy patches are frequent. Shrubs such as *Adhatoda vasica*, *Lantana camara*, *Vitex negundo*, *Zizyphus oenoplia* and *Mallotus philippinensis* often form dense scrubland. Sometimes, *Dalbergia sissoo* along with *Saccharum spontaneum* forms another stage of succession (5B/1S2) along the rau banks. All these successional communities gradually give place to sal forest with increasing distance from the raus.

Vegetation in the hills : Dry Shivalik Sal forest (5B/C1a) and Moist Shivalik Sal Forest occur in the hills. The upper slopes are grassy, dotted with trees such as *Anogeissus latifolia*, Sal, *Acacia catechu*, *Buchanania lanzan*, *Zizyphus xylopyra*, *Ougeinia ougeinensis* and *Nyctanthes arbor-tristis* and lianas such as *Bauhinia vahlii* and *Pueraria tuberosa*. The common shrubs are *Colebrookia oppositifolia*, *Helicteres isora*, *Carissa opaca*, *Holarrhena antidysenterica*. The common grasses are *Chrysopogon fulvus*, *Eulaliopsis binata*, *Desmostachya bipinnata* and *Neyraudia arundinacea*. Towards the valleys, the frequency of trees, shrubs and lianas increases. Valleys generally are forested. The gentler northern slopes have more canopy cover than the steeper southern slopes.

Subtropical Shivalik Chir Pine Forests (9/C1a) occur on the higher slopes. There, apart from the above mentioned trees, Chir pine (*Pinus roxburghii*) grows and the shrub growth is less. Along the raus and in certain moist valleys there are forests where *Syzygium cumini*, *Terminalia tomentosa* and sal trees dominate.

General appearance : Continuous and uniform canopy is present only in sal forests and forest plantations of the plains. All other vegetation types described before (both in the hills as well as in the plains) have a broken and discontinuous canopy. They seem to be a result of edaphic conditions and biotic influences (fire, lopping, cutting, grazing), which keep them at various levels of succession. Canopy openings, irregular height of the canopy, grassy openings interspersed with growth of trees and/or lianas and/or shrubs, and frequent occurence of dense and continuous shrub growth - these are the features of vegetation over a larger part of

Dhaulkhand. Further details are in Section 4.1.1. The plant species are listed in Appendix II.

2.5 Fauna :

Besides chital, the other common mammals seen in the area are the Asian elephant (*Elephas maximus*), sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjac*), nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*), ghooral (*Nemorhaedus goral*), rhesus macaque (*Macaca mulatta*), common langur (*Presbytis entellus*), tiger (*Panthera tigris*), leopard (*P. pardus*), jackal (*Canis aureus*) and Himalayan yellow throated marten (*Martes flavigula*). 316 species of birds have been listed for Rajaji (J. Joshua, WII, pers. com.). Rai (1991) listed 189 species in winter-summer (6 months) in Dhaulkhand. The khaleej pheasant (*Lophura leucomelana*), goral and the Himalayan yellow throated marten represent the Himalayan elements in the fauna of the region (Bhatnagar 1991).

2.6 Human influence :

There were 8-10 families of Gujjars in Dhaulkhand region during the study period. Gujjars are herdsmen herding mostly buffaloes and cattle. Earlier, along with their livestock, they used to migrate to the Himalayas by the beginning of summer, stay there till September, and return to the Shivaliks by the beginning of winter, to leave for the Himalayas again in the next summer. This was a regular feature. But now, many of them have ceased their migration. During recent years, there have been attempts to translocate the Gujjars to an area outside the Park. But, the attempts have been unsuccessful. By lopping, grass-cutting and creation of surface water for their livestock, and by fuelwood

collection and other activities, they exercise a strong influence over the area. They had at least 220 buffaloes / cattle and at least 20 horses which were dependent on the fodder resources of Dhaulkhand.

Other sources of influence are the villages in the plains along the southern boundary of Rajaji NP. The villages are located about 5 km south of the line where the Shivaliks meet the Bhabar tract. Many villagers come into Dhaulkhand region to cut bhabar grass (*Eulaliopsis binata*). This grass, among other purposes, is used for making ropes, cot, and paper pulp. Bhabar-cutting has been a practice for many years. It starts in September-October (M. Yasin, WII, pers com.). This year, extending through winter, it was on as late as the end of April. By mid-November, bhabar on the hills nearer to the villages had been cut. By the beginning of February, to obtain bhabar, bhabar-cutters were already traversing to or across the Shivalik ridge more than 12 km away from their villages. Since their activity is considered illegal, an accurate estimate of their number is not available. However, by their movement and bhabar cutting, they influence almost the entire region.

Some villagers bring their cattle, goat and sheep into the southern fringes. The zone of such use is upto about 3 km from the village.

Some villagers cut and carry away *Desmodium pulchellum* used supposedly for medicinal purposes. There were evidences of honey collection in April and May. During April end and early May, forest fires spread in the plains from the fringe areas and burnt large chunks of forest, especially of sal.

CHAPTER 3. MATERIALS AND METHODS

3.1 Background:

Studies on habitat use can be carried out at 2 depths. One of them does not consider the sampling intensity or the proportion of each habitat type, but, focusses just on the general trend of the animals' presence and usage of that habitat type (e.g. De & Spillett 1966,, Graf & Nichols 1966, Schaller 1967). In contrast, the other considers the sampling intensity or the proportion of each habitat type and then weighs the extent of use (e.g. Nievergelt 1981, Bhatnagar 1991). Because the former requires more time to draw conclusions, I chose the latter which is quicker and can be done by determining availability - utilisation or estimating densities.

Availability can be determined by gridding the area and sampling each grid (e.g., Nievergelt 1981) or by the non-mapping technique suggested by Marcum & Loftsgaarden (1980) where a certain proportion of points are sampled. Constrained by time, funds and personnel, I could not use these techniques.

Instead, I used a technique suggested by Riney (1982). It involves sampling along transects and the principle is similar to that in the non-mapping technique. Sampling along transects is simple, quick and makes less demands on funds and personnel. Another advantage is that the information on utilisation of the habitat can be obtained from the same transects (Riney 1982). Bhatnagar (1991) had followed this method in his study on habitat preference of sambar in Dhaulkhand region. Riney (1982) appreciated that transects efficiently describe the habitat features available to the animals. Though he cautioned that transects may

underestimate the proportion of bare ground due to non-sampling of cliffs and rocky exposures, he asserted that in terms of grassy habitat available to deer, transects reflect a good perspective.

Further, animal density in a habitat reflects the abundance of animals in that habitat. It is expected to be a measure of habitat use. Higher density in a habitat indicates higher use of that habitat and vice versa. Besides using availability-utilisation approach, to compare the use of some broader habitat types, I wanted to estimate the densities of chital. Transects were ideal for this purpose.

3.2 Field Methods :

3.2.1 Stratification :

I stratified the intensive study area into primary strata and secondary strata.

a. Primary strata were based only on terrain. They were :

1. Plains
2. Hills

b. Secondary strata were based on vegetation type.

In the plains, they were :

a. Sal Forest (SF),
b. Mix Forest (MF),
c. Mix Forest Plantation (MFP),
d. Scrubland (SL),
e. Woodland (WL).

In the hills, the secondary strata were :

a. Hill Woodland (HWL),
b. Hill Forest (HF),
c. Hill Scrubland (HSL).

Criteria for defining secondary strata were as follows :

Tree canopy cover and shrub cover influence the ground cover. These and the plant species composition make a habitat type appear what it is. Together, they are expected to affect chital. Therefore, these were the features to define the secondary strata. A habitat was considered as a 'forest' if the canopy cover was 51% or more. Anchoring to this definition, I defined the secondary strata as follows.

SF : Sal trees contribute 51% or more to the canopy cover.

MFP : Planted trees contribute 51% or more to the canopy cover.

MF : Forest which cannot be identified either as SF or as MFP.

SL : Canopy cover of 50% or less but shrub cover of 51% or more.

WL : Canopy cover as well as shrub cover is 50% or less. Includes rau beds also.

The habitat types in the hills now become self explanatory.

3.2.3 Laying of transects :

Using topomaps of the region (SOI 1969), the compass bearings for the transects were chosen. For the study, 2 km length of transects was considered optimum. To account for the heterogeneity between the localities within the study area, 10 transects were laid, 5 in the hills and 5 in the plains (Fig.3). One plain transect (PT 1) passed through hills for 0.3km. The location of the transects was a compromise between the need for representativeness and logistics. Two logistic factors mattered here.

1. Frequent occurrence of cliffs and steep slopes which are either impossible or very difficult to traverse.

2. The time taken to reach the transect from the base camp and to return after the transect walk. This was important as elephants were encountered frequently.

To facilitate traversing, narrow trails were cut and cleaned in certain sections of dense vegetation along the transects. Transects went across ridges, valleys and various habitat types but were not absolutely straight. Different localities of the study area were represented, excepting the cliffs, very steep slopes, and upper reaches of 3-4 high hills.

3.2.4 Laying of search path on the highest hill :

An 800 m long search path was laid from base to the top of the highest hill. It followed a ridge line, offering a very wide view of the surrounding slopes. Using topomap and altimeter, the elevation of each 100m point of the path was noted. Monitoring along this search path was to indicate upto what height in these hills chital frequent.

3.2.5 A road chosen to monitor :

One particular locality of the region was heavily used by chital due to presence of water and saltlick. It consisted of MF, WL, and SL. A mud road of about 2.2km (measured by my pacing ; one pace = 70cm) passed through it. I chose this road to traverse and monitor the locality for seasonal and diurnal variations in use.

3.2.6 Seasons in the study : Based on earlier literature (Rodgers et. al. 1990, Bhatnagar 1991), temperature, appearance of new growth and presence/absence of dew, I divided the study period into 2 seasons as -

1. Winter : November to February end. Cold conditions. Dew present.
2. Spring-Summer : Spring - 1st March to 13th April. Cool conditions. Dew present. Summer - 14th April to 30th April. Warm/hot conditions. Dew absent. Since summer was of short duration, during analysis I considered it with spring when needed and separated it when possible.

3.2.7 Quantification of habitat variables :

The 2 purposes of quantifying habitat variables were to determine the availability of habitat parameters (food, water, cover etc.) and to describe the habitat. The methods were broadly designed according to Mueller-Dombois and Ellenberg (1974) and those followed by Bhatnagar (1991). Modifications or additions were done where required. Bulk of the quantification was done in December-January. For this, guided by a stretched tape of 20m, an estimated 10m radius (r) plot was laid at every 100m on each transect. At each plot, habitat variables were quantified as described below.

1. Vegetation type as mentioned in the secondary strata.
2. Aspect (N, NE, E, SE, S, SW, W, and NW) using a compass.
3. Slope in degrees within the plot using a hand made equipment (Fig.4).
4. Position of the plot on the terrain (ridge top, ridge line, hill slope, valley, rau bed, nala bed, and flat ground).
5. Approximate distance to the nearest water source and human settlement - based on personal observation and enquiry with M. Yasin.
6. Canopy cover was assessed visually in classes of 25% based on the cover projected onto the ground of 10m r plot.

7. Ground cover in 10m r plot was assessed visually in classes of 25%.

8. Five 50cm x 50cm quadrats were laid, one of them in the centre and the rest systematically in each quarter of the 10m r plot. After 14 such attempts, this technique was found to be failing and therefore was abandoned. For the rest of quantification, I adopted another technique using four 50cm (estimated) radius plots. Each one of them was randomly placed in one of the quarters of the 10m r plot. In each of these plots, the percent ground cover was visually estimated. For each grass species in the plot, the number of clumps / dominance (whichever of them was possible depending on the growing habit of the species) and the estimated average height (cm) was noted. The number and estimated average height (cm) of each species of herb was noted. Feeding signs on them were noted. Seedlings and thin climbers were grouped under herbs.

While sampling ground vegetation, on 7 (3.3%) occasions, the 10m r plots had been displaced. I call this as placement error. I could not correct the errors later. As they occurred within homogeneous patches, I assume that they were not of serious consequence.

9. Specieswise, the number of trees [>20cm gbh (estimated)], their estimated average height (m), the number of trees with foliage within 2m (estimated) from the ground (assumed to be available to chital) and the number of lopped trees were noted within the 10m r plot.

10. The species and number of lianas in 10m r plot were noted.

11. Concentric to each 10m r plot, guided by the tape, an estimated 5m r plot was laid. The percent shrub cover in it was estimated based on the principle followed for canopy cover.

12. In the 5m r plot, speciswise, the number and estimated height (m) of shrubs was noted. Feeding signs on them were noted.

I quantified parameters 1-8 and 11, while M.Yasin quantified 9, 10 and 12.

Some parameters changed with season. Therefore, in spring-summer, I requantified canopy cover, shrub cover and ground cover. M. Yasin requantified lopping during the final month of the study.

Phenology : Phenology was expected to affect the availability of food and cover. I noted the general phenological stages of common species during the period of each set of transect walks (explained later in the text), and noted it once the set was completed. The stages for trees were noted as leafless / partially leafless / new flush / green / flowering / fruiting, for grasses as new flush / green / flowering / mature / seeding / dry and for herbs as new growth / green / flowering / fruiting / seeding / mature / dry.

Following Riney (1982), habitat heterogeneity on the transect was quantified as number of habitat changes per km.

3.2.6 Quantification of habitat use :

Transect walks were the major means of habitat use quantification. Other means were -

- Traversing the hill search path
- Monitoring one area by road
- *Ad libitum* records.

Transect walks : As done by earlier workers (Johnsingh 1983, Karanth 1988) and as suggested by Rodgers (1991), morning and

evening walks were chosen. Evening transect walks were to compare the habitat use trends of evenings with those of mornings. Each one of the 10 transects was a morning transect. It was not feasible to walk all the transects in the evenings. So, for evening walks, I chose 3 transects (HT1, HT4 and HT5) in the hills and 3 (PT1, PT3 and PT5) in the plains. The starting time of transect walks was anchored to the time of sunrise and sunset (noted and set once every 10-20 days). Generally, morning walks would start about 20-30 minutes after sunrise and be completed in about 3 hours. Evening walks would start about 3.15 hours before sunset and be completed about 15 minutes before sunset. But, there have been exceptions due to weather conditions, elephants or inexperience.

On transect walks, I tried to detect the animals in their activity. To avoid making noise, at places I have used the cattle/animal trails if they lay very near the transect line, but I did so only if walking on these trails did not cause a change in the surroundings seen. This was indispensable in the hilly terrain. However, always in touch with the transect line, I treated all the sightings with respect to the transect line.

Walking zigzag in the hilly terrain entailed pacing a greater distance than the 2 km length indicated by the transect line. Poor visibility in places of dense vegetation and presence of dry leaf-litter necessitated a slow pace of walk so as to reduce the chances of missing the sightings. Slow pace would increase the chances of active detection discussed by Eberhardt (1978) and Burnham et al. (1980). Due to such reasons, I walked the transects usually at a speed of 1km/hour. There have been exceptions due to elephants or weather or inexperience.

In habitat use studies, points of sightings need to be sampled for information on utilisation. This has been followed by earlier workers, e.g. Nievergelt (1981) and Bhatnagar(1991). This requirement led to one deviation in the mode of my transect walks, i.e., I sampled some of the sightings while walking the transects. Those cases involved leaving the transect line, going to the point of sighting, sampling there (for about 15-25 minutes in the 1st 2 sets of transect walks and 7-15 minutes in the latter sets), rejoining the transect line and continuing the walk. I did so because I was constrained by time and had no other time for sampling the sightings of evening transects. This deviation occurred both in hills and in plains. I kept it flexible. If the frequency of sightings was low or medium or if no complications were foreseen, I sampled all or some of the sightings on the transects. But, if the frequency was higher or if complications were foreseen, I did not sample while walking the transects, but sampled later. The implications of such a deviation are discussed in Section 3.3.2.

Binoculars (8x30) were used to confirm the identity of the animals but not to detect them. Sightings resulted from active as well as passive detections discussed by Eberhardt (1978) and Burnham et al (1980). Upon encountering chital, I noted the group size, age-sex composition (number of fawns, does, and bucks in shed-antler, velvet-antler and hard-antler), activity (disturbed, watching, moving, running, feeding/ foraging, sitting, drinking, salt licking), habitat type and remarks if any. Using a compass, the sighting angle was taken to the initial estimated centre of the group ; and in case of flushed animals in dense vegetation, to the initial position of the animals indicated by the movement of

vegetation, as done by Karanth (1988). Usually the sighting distances were visually estimated, but occasionally in the plains, they were estimated by pacing. In the hills, as the transect length was along the ground surface (when represented scalewise on a map, it reduces) and it is the surface that is available to the animals, I estimated the distances along the surface of the ground.

The location of the centre of the group was sampled for most of the habitat variables mentioned before, for some of them in lesser detail. In the hills, some far off points were sampled not by going there, but by using the binoculars.

A set of transect walks (relevant for phenology) was said to be completed when each one of the morning and evening transects was covered once. It would take 10-15 days to complete. However, one set in spring extended for 27 days. There were 4 sets in winter, 2 in spring and 1 in summer.

In the study I had 112 transect walks totalling 224 km. On 38 walks M. Yasin and on 3 walks 2-4 people accompanied me from behind. The remaining 71 times I walked alone. But, on all the walks, I accepted only those sightings which I got or would have got so as to eliminate observer bias.

Traversing the hill search path :

I walked the search path in mornings and evenings 4 and 3 times respectively in winter and spring-summer. Points of sightings were not sampled. The pace of walk was same as on transects. If I saw chital on any of the slopes, I noted relevant information as done on transects and the position of chital with respect to the known elevation of the points of the search path.

Monitoring one area by road :

Analogous to the search path walk, I monitored the road on 7 mornings and 7 evenings. Usual speed was 3km/hr. Points of sightings were not sampled. Relevant information were noted as on transects.

***Ad libitum* records :**

Most of the times when I encountered chital, I kept *ad libitum* records (Altmann 1974) on aspects such as group size, age-sex composition, interspecific association, activity, food items, temperature and presence in sun/shade/partial shade. In winter, on several days, I observed chital for various lengths of time totalling to about 38 hours for activity and about 16 hours (1 1/2 days) at water-points / saltlicks.

3.2.7 Measuring wind strength : I noted wind strength in the field in 2 ways. One was by using a 30cm x 30cm cotton cloth. I suspended the cloth from one of its corners, holding it about 1.3m above the ground in such a way that no part of my body affected the wind blow on to it. The estimated angle of cloth-deflection from the vertical line indicated the wind strength. The other way was to observe the general movement of tree parts (Table 1).

3.2.8 Temperature records : These were obtained from max-min thermometer (Fig.2) and stem thermometer. The former was kept 1.3m high on a wall, inside a room till 22nd December and outside in shade thereafter. In April and May, the maximum figures were excessive due instrumental defect. These figures were approximated

ly comparing them with those of another max-min therm meter near the basecamp. I used the stem thermometer in the field.

3.3. Methods of analysis :

3.3.1. Vegetation : To determine food abundance and to describe the habitat, information on relative abundance of each species of tree, shrub and grass was needed. I did not express this in terms of density or frequency of individuals, owing to the interspecific differences in size. Cover abundance would not indicate the cover of each species. Other established methods such as forage volume, biomass etc. demanded more time. In the absence of such data, I felt that the height of tree and shrub species and cover abundance of grass species would be the best alternative to indicate relative abundance. Hence I used Dominance Index (DI) (modified from Greig-Smith 1983) for trees, shrubs and grasses. This dominance should not be interpreted as an indicator of the ecological phenomenon of suppression. This term simply indicates the prominence of a species in a habitat by virtue of its size, and frequency.

DI for trees and Shrubs : For a given tree species A in a habitat, the DI was calculated as.

DI(A) = av. ht. of all individuals
of A in that habitat x total no. of individuals of
A from all sample plots of
that habitat.

Similarly, for other species of trees and shrubs, the DI was calculated.

DI for grasses and sedges : To determine the grass dominance in a particular habitat , the first step involved evaluating the ranks of the grass cover in each 10m r plot in that habitat. 0-25% grass cover got a value of 1, 26-50% 2, 51-75% 3 and 76-100% a value of 4. This gave cover dominance which was to account for a disparity. The disparity was that a species dominant in a higher cover class e.g., 51-75%, had more volume than another species dominant in a lower cover class e.g.,0-25%. At the second step, I valued the ranks of the first four dominant species by volume. The most dominant species got a value of 4. The second, the third and the forth dominant ones got values of 3, 2 and 1 respectively. This is species dominance. For each species in a plot, an initial Dominance Index (DI) was calculated as follows.

Initial DI= cover dominance of that plot x species dominance for that species.

For example, in a plot of 26-50% grass cover, if *D. bipinnata* was most dominant, its initial DI was 2 x 4 = 8. Values were obtained similarly for other species in each 10m r plot. Adding the initial DI of a particular species from all the 10m r plots of a particular habitat, the final DI for that species in that habitat was obtained. The species with the highest final DI was the most dominant in a particular habitat. Using final DI value, the species were arranged in the order of their dominance in each habitat/vegetation type.

3.3.2. Habitat Use : Recall that some points of sightings were sampled (for information on habitat use) while walking the transects and that such deviations had given rise to some

complications (Chapter 3.2.6). Out of 385 sightings in the study, 201 sightings were sampled while walking the transects and 184, after completing the transects. This was done both in hills and plains. The aforesaid 201 attempts of sampling led to complications 26 times. The complications were in the form of - doubt of double count and hence rejection of a sighting that might have been genuine, seeing more animals upon approaching to sample and another group of chital approaching the transect when I rejoined the transect. Of the 26 cases of complications, I accepted 8 for density estimation and 5 for availability-utilisation analyses.

Estimation of densities from transect data : For each season, I estimated the densities for the primary strata i.e., hills and plains. I could not do the same for the secondary strata (vegetation types) because of their patchy distribution and lack of knowledge of their absolute length.

As only some transects were run in the evening, the evening data were not used for density estimation. Only the morning data were used. Backsightings were not used. In total, 224 sightings were accepted. To estimate densities, FOURIER series estimator (Laake et al 1979) was used because it is a robust estimator compared to other methods (Burnham et.al. 1980).

The differences in densities between seasons and between hills and plains was tested for significance using Chi-square test (Siegel 1956).

Density estimation in the area monitored by road : To compare morning and evening trends in each season, I used King's method of density estimation (Mosby [illegible] 1963 cited in Riney 1982). This

method was used because the dataset had less than 40 group sightings which is insufficient for analysis by FOURIER series. King's method can work with a smaller dataset also.

Availability-Utilisation Analysis : This was done for determining the pattern of use of secondary strata and habitat features.

Some habitat types and features were available and used in very little proportion ($\leq$5%). These were HSL and SL, rau bed, nala bed, ridge top and some of the higher categories of ground and shrub cover. The trends in them were inconclusive due to small sample size. Merging a resource of small proportion with another resource most similar to it would be the best alternative (modified from Siegel 1956). Therefore, HSL was merged with HF, SL with MF, ridge top with ridge line and nala bed and rau bed with valley. The higher categories of ground cover were merged together if they were in small proportions. Same was done for shrub cover.

There was a great deal of variation in visibility both within and between secondary strata. HWL and WL had more visibility ; forests and scrublands had the least. Cover categories and other habitat features also had such variation due to differential vegetation cover. Differential visibility had to be accounted for.

For this, I plotted the frequencies of sightings against perpendicular distances (in 10m interval classes) for each habitat. Rejecting sightings beyond the point where sightings began to fall off (cut off point) would have been ideal (the principle of Kelker's belt mentioned in Rodgers 1991). But, apart from visibility, some other factors also caused such a fall off. For instance, in HWL which had high visibility, this point occurred just after 10m perpendicular distance whereas it occurred even at

30-40m in HF-HSL. This could have been caused by the intensity of use of a habitat or some other unidentified factor. Therefore, I accepted a cut off point within which bulk of the sightings occurred continuously in the densest habitat. That point decided a strip width. A strip width of 100m was found appropriate in the hills. It was applied to all the habitats in the hills. Similarly, a strip width of 60m was applied to all the habitats in the plains. The use of a fixed strip width removed the visibility bias to a great extent. Of the 385 sightings during the study, 252 sightings (827 animals) occurred in these strips and those sightings were used for analyses.

Various techniques are available for utilisation-availability analysis. Such techniques have been proposed by Neu et. al. (1974), Johnson (1980), Friedman (1937), Quade (1979) [the last 3 cited in Alldredge and Ratti (1992)]. Alldredge and Ratti (1992) reviewed a comparison of these methods. Each of the above methods assumes one observation to be independent of another. Therefore they consider each group sighting as one occurrence, irrespective of the number of animals in that group.

In the sightings I used for availability-utilisation analyses, chital group size varied from 1 to 20. Giving same weightage to each group, and not weighing the number of individuals seemed to make less biological sense. I needed a method that weighs each individual. Pratt et al. (1986) used one such method based on Preference Index. But the values of this index vary from -1 to +1, making it difficult to comprehend.

Hence I used Habitat Use Index (HUI) which is based on a similar principle. It is easy to comprehend. HUI was used by Hobaugh (1984).

CHAPTER 4. RESULTS

4.1 AVAILABILITY OF HABITAT FEATURES :

4.1.1 Vegetation types (secondary strata / habitat types) :

Along the total length of 20km of transects, 211 plots were sampled. 109 (52%) were in the hills and 102 (48%) in the plains. The key features of transects are summarised in Table 2. For each habitat type, the details on trees, shrubs and herbs/seedlings/ climbers (densities, total number of species, and number of species of probable forage value with their densities) are given in Tables 3, 4 and 5 respectively. Table 6 has information on lianas. Distribution of cover types in hills and plains is presented in Table 15.

Vegetation in the hills :

Hill Forest (HF) : This type occurred in 45 sample plots (40.29% of the hilly area and 20.75% of the study area). Dominant tree and shrub species with their average height and dominance index are listed in Table 7. 14 species of grasses were recorded. Dominant grasses were *C. fulvus*, *D. bipinnata*, *E. gigantea*, *N. arundinacea* and *Imperata cylindrica*. Common herbs were *Justicia simplex*, *Desmodium sp.*, *Abutilon sp.* and *Urena lobata*. Ferns occurred in 27 (60%) of the plots and moss in 6 (13%) plots.

Hill Woodland (HWL) : Represented in 59 sample plots, this vegetation type covered 54.85% of the hills and 28.25% of the study area. Relevant information on dominant tree and shrub species are in Table 8. Fourteen species of grasses were recorded. Dominant grasses were *C. fulvus*, *E. gigantea*, *D. bipinnata*, *N. arundinacea*

and *I. cylindrica*. Prominent herbs were *J. simplex*, *Sida sp.*, *S. cordifolia*, *Abutilon sp.*, *Crotalaria sp.* and *Desmodium microphyllum*. Ferns occurred in 28 (47%) plots.

Hill Scrubland (HSL) : Recorded in 5 sample plots, this vegetation type occupied 4.85% of the hilly area and 2.5% of the study area. Dominant trees and shrubs are listed in Table 9 along with relevant information. 6 species of grasses were recorded. Grasses in the order of dominance were *C. fulvus*, *N. arundinacea*, *E. gigantea*, *D. bipinnata* and *Heteropogon contortus*. Dominant herbs were *Ageratum conyzoides* and *J. simplex*. Ferns occurred in 4 plots.

Vegetation in the plains :

Scrubland (SL) : 5.15% of the plains and 2.5% of the study area was occupied by this vegetation type which occurred in 6 sample plots. Dominant tree and shrub species, with relevant information, are listed in Table 10. 11 species of grasses were recorded. The grasses in the order of dominance were *D. bipinnata*, *C. dolichostachya*, *Eragrostis tremula* / *Sporobolus diander* and *Oplismenus burmannii*. Dominant plants at herb level were *A. vasica* seedlings and *J. simplex*. Fern occurred in 2 plots and *Cuscuta reflexa* in one.

Mix Forest (MF) : 14 sample plots, 13.9% of the plains and 6.75% of the study area had this vegetation. Dominant tree and shrub species, with other information, are listed in Table 11. 10 species of grasses were identified. Dominant grass *C. dolichostachya* was followed by *D. bipinnata*, *I. cylindrica*, *C. arcuatus* and *O. burmannii*. Prominent herbs were *J. simplex*, *Cassia tora*, *I.*

frutescens, *Abutilon sp.*, and *A. conyzoides*. *C. tora* was seeding in winter and dry during spring-summer. Ferns occurred in 8 (57%) plots while *C. reflexa* grew on *A. vasica* shrubs in 2 (14%) plots.

Sal Forest (SF) : It occurred in 38 sample plots, 38.14% of the plains and 18.5% of the study area. Dominant tree and shrub species are listed in Table 12. The top canopy was almost uniform and about 23m tall. 10 species of grasses were identified. The dominant ones were *D. bipinnata*, *C. dolichostachya*, *I. cylindrica* and *C. fulvus*. Prominent herbs were *J. simplex*, *A. conyzoides*, *I. frutescens* and *C. tora*. Moss occured in 1 plot and fern in 6 (15%) plots.

Woodland (WL) : This vegetation/habitat type was encountered on 26 sample plots, suggesting that 25.26% of the plains and 12.25% of the study area was covered by it. Information on dominant trees and shrubs are given in Table 13. 13 species of grasses were recorded. *C. dolichostachya* was dominant followed by *D. bipinnata*, *C. arcuatus*, *E. tremula/S. diander* and *Bothrichloa pertusa*. Prominent herb-level plants were *C. tora*, *J. simplex*, *A. vasica* seedlings and *S. cordifolia*. Ferns occurred in 4 (15%) plots.

Mix Forest Plantation (MFP) : 17 plots i.e. 17.52% of the plains and 8.5% of the study area were occupied by this vegetation. Dominant tree and shrub species, with relevant information, are listed in Table 14. 9 species of grasses were recorded. Dominant one was *C. dolichostachya* followed by a sedge, *O. burmannii*, *D. bipinnata* and *C. arcuatus*. At herb level, prominent plants were *J. simplex*, *I. frutescens*, *A. vasica* seedlings, *A. conyzoides*, *C. tora*

and *Parthenium hysterophorus*. The last two were dry and seeding during the study.

4.1.2 Habitat heterogeneity :

The number of habitat changes occurring on each transect are presented in Table 2. In the hills, the highest number of changes in habitat/vegetation in 2km length was in HT5, while in the plains, it was in PT1. Heterogeneity was more (11.8/km) in the hills than in plains (6.28/km).

4.1.3 Other features : The availability of various aspects, slope categories and positions on terrain (all of them only for hills) are presented in Tables 18, 17 and 16 respectively.

4.2 UTILISATION OF HABITAT FEATURES :

4.2.1 Habitat types (Tables 19 and 20) :

In the hills, in winter mornings, HWL was used more compared to HF-HSL. In winter evenings and in spring, HF-HSL was used more compared to HWL. In the plains, MFP was highly used in winter mornings and had low use in spring-summer. SL-MF was highly/very highly used in winter evenings and in spring-summer. SF, which had low use in winter, was increasingly used in spring and showed highest use in spring-summer evenings. Woodlands were used less in the evenings.

Overall, in the hills, both HF-HSL and HWL were used moderately. The former was used more than the latter. In the plains, SL-MF was highly used, MFP had low use while SF and WL were used moderately. WL was used less compared to SF.

4.2.2 **Aspects in hills (Table 21)** : W, NW, N and NE aspects had low or moderate use throughout. S, SE and E aspects were moderately or highly used almost throughout. SW aspect had moderate use for most of the study.

4.2.3 **Slope in hills (Table 22)** : Overall, 0-10^0 slopes and slopes beyond 40^0 were used less. Slopes from 11 to 40^0 were used more. 11-20^0 and 21-30^0 slopes were highly used.

4.2.4 **Positions on terrain in hills (Table 23)** : Valleys/ rau bed/nala bed were used less in winter mornings and more in winter evenings and spring-summer. Ridge line/ridge tops were used more in winter. Overall, valley/ rau bed/nala bed was used highly. Flat ground had low use. Though hill slope and ridge line/ridge top were used moderately the latter was used more.

4.2.5 **Tree canopy cover (Tables 24, 25 and 26)** : In the hills, 26-75% canopy cover was used more in winter mornings. 76-100% cover was used highly in spring-summer evenings. 51-75% canopy cover was used more almost throughout. In the plains, in winter evenings, 51-75% canopy cover was highly used whereas other categories had low use. In spring-summer, 76-100% category was highly used. Overall, in the entire study, higher categories were used more.

4.2.6 **Shrub cover (Tables 24,25 and 26)** : Both in hills and plains, <51% cover was used more, 26-50% cover being used most. Cover >50% had low use in winter and less use almost throughout.

4.2.7 Ground cover (Tables 24,25 and 26) : In the hills, the higher cover categories (>50%) were used less throughout. In the plains, >25% cover had low use in winter, but was highly used in spring-summer.

Overall, <50% cover was used more, and >50% had low use.

4.2.8 Chital densities in hills and plains (Table 27) : In winter, plains had marginally higher densities compared to hills but the difference was not significant (x^2=0.09, df=1, P>0.05). In spring-summer also the trend was same (x^2=0.078, df=1 P>0.05). The spring-summer density in hills was slightly higher compared to winter density but the difference was again not significant (x^2=0.028, df=1, P>0.05). Similar trend was seen in the plains also (x^2=0.0068, df=1, P>0.05).

4.2.9 Chital densities in the area monitored by road : Densities in the mornings and evenings of winter were lower compared to those in spring-summer. Density obtained by King's method was 165.7 individuals/km^2 in winter mornings increasing to 289.5/km^2 in winter evenings. 380.8/km^2 of spring-summer mornings decreased to 257.6/km^2 in spring-summer evenings.

4.2.10 Use of height in the hills (Fig.5) : There were 19 sightings on the search path. The highest level at which chital occurred was the mid-level, i.e., about 620m. 2 sightings occurred at that level.

CHAPTER 5. DISCUSSION

5.1 Background :

In the hills, there were less sightings in the evenings (Table 28). Reasons were unclear in the first two sets of transect walks. The increase of temperature on open slopes during afternoons, the need to move down to water, the movement of langurs to the valleys followed by that of the associating chital and wind were considered to be the potential causes. The role of these causes was investigated and reasoned. By the time of the third set of transect walks, the former 3 reasons seemed unlikely and the possible reason emerged. It seemed to be wind.

During the study, many days were windy. After 24th January, out of observations on 22 afetrnoons in the hills while on transect/search path, at least 10 afternoons had strong/very strong winds from W. On such a day, usually 2.30 hours after sunrise, a wind would start blowing from the direction of the sun. By afternoon it would be a strong wind. As the sun moved west, it would blow accordingly from that direction. The wind, blowing in strong gusts, would continue till about 10 minutes before sunset. It would end with sunset.

In contrast, on some days, especially on the clear days following heavy rains, a strong/very strong wind from E would start with sunrise and continue to blow from E till sunset. There were at least 7 such days.

The winds seemed to affect chital's habitat use, especially in the hills. Chital would use places which were less affected by wind. These places were windlee aspects, valleys, windward slopes preceded by higher hills on the windward side and cover of canopy.

The former 3 would have no/slight wind even if a strong/ very strong wind blew on the slopes just above or nearby.

41 times I saw chital in the hills while the wind was blowing strong. On no occasion I saw chital exposed to strong/very strong wind except when one chital, flushed from a valley below, flashed across for a few seconds along a ridge line exposed to such wind. On 2 occasions I saw chital exposed to moderate wind. On all other occasions, they were in no/slight/moderate wind. Twice I saw behaviour which seemed to be for avoiding wind. On 6 non-windy afternoons, chital were seen on those slopes which they would not have used on a windy afternoon. Observations of their activity also suggested that wind affected their habitat use.

Graf & Nichols (1966) found that chital took to cover when heavy winds blew. They opined that chital avoided strong wind because such wind dissipates odour, creates sound, puts vegetation in motion and makes it difficult to detect danger. In the present study, combination of such effects with that of the intensely cold gusts of winter cannot be denied. Ables (1977) observed that when wind velocity exceeded 20mph, regardless of temperature, chital tended to spend less time in the open, appeared nervous and preferred to feed within brush. White tailed deer (*Odocoileus virginianus*) also were seen to behave likewise. If strong winds blew, chital took to the canyons while on calm days they fed on open hillsides (Ables 1977).

In this study, the sightings on windy afternoons were more in the forests and valleys. This indicated that chital took to such places which had more cover. The gusts in winter were not only strong but also very cold. In spring-summer, as the afternoons grew hotter, the cover in the cooler valleys could have been used more

compared to the hotter open slopes. Hence the detections could have been less. I suggest these to be the reasons for the reduction of evening sightings in the hills.

By virtue of terrain and higher tree canopy cover (Table 15), plains were less affected by wind. For instance, a strong wind at the tree canopy level in a sal forest would be moderate or even less at the shrub level. Could this be the reason why chital numbers and sightings were more in the plains in the evenings (Table 28) ? Where did they come from ? The results of morning and evening sampling in PT1 and PT5 (the transects adjacent to the hills) do not show any definite trend. They do not indicate whether chital from the nearby hillocks came down to the plains in the evenings. The trends in PT3 also were not definite. Why and how did sightings and number of chital increase in the evenings ? This trend, though definite, is difficult to explain.

5.1.1 Relevance of phenology : The crude protein requirements of chital have been discussed by Rodgers (1990). He reported a reduction in protein content of grasses after post flush period. His study suggests that coarse and mature plant is unsuitable as forage to chital. On the other hand browse and forb retain green growth in winter and protein values in them remain high (Rodgers 1990). These phenomena determine the food availability.

5.2 Use of habitat features :

5.2.1 Use of habitat types (Table 19 and 20) : The greater use of HF-HSL during the winter evenings may be due to chital taking more to the valleys which had more cover. This they did when strong winds blew. I expected chital to use HWL more in spring-summer

mornings, because grasses had sprouted there in spring. But the results do not indicate that trend. One reason for this could be that about 10 days of spring could not be used for transect walks. Thus I might have missed detecting the real trend. Secondly, as spring receded, the grass sprouts in the open hill slopes of HWL matured and turned yellow, while those under the partial cover of HSL-HF remained green and succulent for a longer period. Thirdly, when sal flowered in summer, several sightings were in HF having sal as the major component. The last two reasons and wind seem to be responsible for the trend in spring-summer evenings.

The higher use of MFP in the winter mornings was mostly by virtue of high abundance of chital in a 500m stretch of *A. catechu* dominated MFP in PT3. Several sightings occurred where green leaves of *A. catechu* were strewn on the ground suggesting that chital could have gathered there to feed on the fallen leaves. Langurs, with whom chital very often associated, frequented that stretch. Dinerstein (1979) also noted such association in mid-October to mid-February when *A. catechu* fruits were available. Besides, *J. simplex* was succulent and abundant. There was water in the waterhole created nearby by Gujjars for their livestock. Due to these reasons, MFP was highly used. In fact, the HUI would have been even higher for MFP in winter mornings but for sightings and animals missed there due to poor visibility, owing to the dense growth of *A. vasica* and *C. oppositifolia* shrubs. Only this stretch of MFP was highly used. The parts of MFP dominated by teak were used very less as they had very less forage at tree, shrub and ground layer.

In spring-summer, food availability reduced in MFP. *A. catechu* had become partially leafless. Its leaves had turned brown or

dried. Revisiting the points of winter sightings, and looking for leaves of *A. catechu*, I found no green leaves on the ground. When the dry leaves were lifted by hand, the leaflets got separated and dropped down from the rachis. I do not know whether it happens when chital try to feed on it. If it happens, efforts to feed on such leaves (even if they possessed forage value) might not be cost effective. *J. simplex* had matured. The dominant shrubs *A. vasica* and *C. oppositifolia* probably had little food value to chital. These may be the reasons for the low use of MFP in spring-summer.

In SL-MF, trees such as *M. philippinensis*, *M. velutina*, *Bridelia retusa*, *Casearea tomentosa*, *Z. xylopyra*, shrubs such as *M. philippinensis*, the grass *C. dolichostachya* (which was succulent there) and a higher density of palatable herbs (Table 5) and forage trees (Table 3) seem to have provided ample forage. Lopping occured there and attracted chital. Langurs also used MF more. Chital frequently associated with them. The benefits that accrue to chital by such association has been noted earlier by many workers e.g., Schaller (1967), Dinerstein (1979) and Newton (1984). One stretch of SL in PT1 was used intensively in the evenings by chital probably enroute to water 1km away. The new growth of spring remained green and succulent under the partial cover of canopy for a longer duration compared to any open habitat. These seem to be the reasons for high use of SL-MF.

Sal forest had little forage in winter. Sal probably had little forage value at that time. *M. philippinensis* was the only abundant tree species with forage value. The rarity of langurs in sal forest in winter suggested lack of forage in tree layer. The dominant grass *D. bipinnata* was mature and coarse.

By spring-summer, as most of the fodder trees in MF and MFP got lopped, Gujjars started lopping fodder trees in sal forest. This seemed to attract chital. By the end of spring, sal trees started flowering. In summer, they were in bloom. As sal petals and inflorescence are food items (Appendix I), chital congregated there. Langurs increasingly used sal forests. Rhesus were there as before. Some groups of chital associated with these primates. Dinerstein (1979) noted that these monkeys, during their activity, knock down browse. Chital probably got a similar benefit here. Even otherwise, sal petals strewn on the forest floor and litter seemed to provide abundant food to chital. By that time, the new flush of spring had dried in WL and was maturing in MF. Food was scarce elsewhere, but was abundant in sal forest.

Woodlands had food species mostly in the form of ground flora. But several food species such as *C. dolichostachya* and *J. simplex* were mature possibly because of exposure to sun in the open. Some grasses such as *E. tremula/S. diander* were dry. Although WL responded first and best in the form of new growth of herbs and flush of grasses in spring, these plants also matured and seeded earlier there possibly because of their exposure to sun. Besides, inclusion of rau beds under woodlands reduced the effective availability of food. Virtually nothing grew on the rau beds. These may be the reasons why woodlands were used less compared to other habitat types.

Overall, during the study, forests were used more. Such a trend in winter and spring-summer agrees with the observations of Schaller (1967), Balasubramaniam et. al. (1980) and Mishra (1982) who observed that chital used forests more during the drier season. Due to reduction in the availability of graze at that time, chital

are known to take to browse (Schaller 1967, Dinerstein 1979, Rodgers 1990). The seasonal shifts observed in this study were mostly directed by the spatio-temporal variations in the availability of food and water. These were among the factors responsible for the seasonal shifts observed in many other studies (Graf & Nichols 1966, Schaller 1967, Eisenberg & Lockhart 1972, Dinerstein 1979).

5.2.3 Aspects in hills (Table 21) : The higher use of S, SE and E aspects in winter mornings could be because these were the aspects that got exposed to the morning sun in winter. In the cold mornings of winter and spring, chital exhibited a strong affinity to bask in sunshine. They often fed in areas exposed to sun. On many occasions, they sat or stood in sun (without feeding) for a few minutes or 15-30 minutes to more than 1 hour 40 minutes. In cold weather, on many occasions (n>48), chital were in sun despite the proximity of shade. On at least 10 such occasions, they deliberately sat in sun till temperatures as high as 26.5°C. They were seen in sun (moving between shade and sun) till 34°C. These instances suggest that warmth from the morning sun could be important for chital in winter and spring when morning temperatures were low (Fig.2). Therefore they might have used the E, SE and S aspects more and W, NW, N and NE aspects less.

In the cold afternoons of winter, as the sunshine is from west, one would expect chital to be on the western aspects to benefit from the warmth of sunshine. But this did not happen, probably because of the wind. Thus, in the afternoons also, the western aspects were used less. Despite such a pattern, SW aspect is used moderately. The reasons for it are not clear.

5.2.3 Slope in hills (Table 22) : The reason for the low use of 0-10° slopes by chital may be that about 50% of the plots of this slope category either fell in rau beds/nala beds or had a dense ground cover by mature, coarse plant species.

The high use of 11-30° slopes could be because food was present there and chital were able to negotiate these slopes and exploit the food. The decrease in use of slopes >31° was probably related to the morphological structure of chital. They seem to be partial to gentler terrain (Section 1.1). Schaller (1977) characterises these species with thin long legs as opposed to the animals of precipitous terrain with stocky legs and robust forequarters. The structure of chital seems to be less suitable for negotiating steep slopes. The high use of 41-50° in winter evenings is by weight of a single group of 11 animals (17% of the sample) using such a slope in association with langurs. Of more than 250 times I saw chital in the hills, the steepest slope I saw chital negotiate under normal situation was 45°, but in all such circumstances, slopes beyond 20° were invariably negotiated by zigzagging along paths. But when alarmed they have run right up a rock of 45° slope (n=1) and up a path on 50° slope (n=1).

5.2.4 Position in hills (Table 23) : The higher use of ridge line/ridge tops compared to hill slopes in the mornings can be attributed to the basking behaviour of chital. These positions are gentler and easier to negotiate, are exposed to sunlight in the cold mornings of winter, have forage nearby and seem to be the favoured spots to sit or stand or feed. Besides, because of the wide view these provide, and the ease of running to any desired direction, these may provide safety from predators. The high use of

ridge lines in winter evenings came when afternoons were not windy or when ridge lines happened to be in windlee side. Ridge lines / ridge tops were used very often by chital.

Flat ground had low use throughout for the reasons mentioned while discussing the use of $0-10^0$ slope. The low use of hill slopes and high use of valleys in winter evenings could be due to wind.

5.2.5 Canopy cover (Tables 24, 25 and 26) : The low use of 76-100% canopy cover in the winter mornings can be attributed to the affinity of chital to areas exposed to sunlight at that time. The low use of <50% canopy cover in winter evenings seems to be due to wind as discussed before. As spring receded, the new flush of grass in the open slopes of HWL soon turned yellow and mature probably because of exposure to strong sunlight. But the flush that came up in the valleys remained green and succulent for a longer period due to better tree canopy cover and more moisture there. It was so even in summer. Simultaneously, sal also flowered. Together, these factors seem to have caused a shift in use to >50% in spring-summer.

5.2.6 Shrub cover (Tables 24, 25 and 26) : Moderate or high use of <50% cover, and low use of >50% cover may be because chital avoid dense and continuous cover (Graf & Nichols 1966). Chital rely on speed to escape the predators (Dinerstein 1979). Denser shrub cover may impede their speed. Besides, the dense growth of *A. vasica* and *C. oppositifolia* provided little forage at shrub level. However, in winter, in the 500m stretch of *A. catechu* dominated plantation, chital used very dense cover also. This suggests that if food is

less elsewhere and abundant in dense cover, chital do use dense cover.

5.2.7 Ground cover (Tables 24, 25 and 26) : In the hills, the less use of >50% cover is probably an effect of the species contributing to this category. The dominance of two grasses, i.e., either *D. bipinnata* or *N. arundinacea* formed such high cover.

D. bipinnata was coarse and mature during the study, and hence of low forage value. Where it was dominant in a cover of 51% or more, it dominated to such an extent that other grasses and herbs became inconspicuous. Feeding in such cover might demand more feeding effort and reduce feeding efficiency. Besides, such a cover by this species meant that grass was not cut. It meant that bhabar was uncut and there was no sprout of bhabar (Appendix I) available for feeding.

Wherever *N. arundinacea* was dominant in a cover of >50%, it grew dense to a height of 2m or more. Visibility was extremely poor. Any animal as close as 1m behind a clump of this grass could be invisible. Risk from predators could be enormous. Hence chital might have used them less.

In the plains, the low use of >26% cover in winter also could be due to their domination by mature and coarse *D. bipinnata* and the occasional dominance of the then dry *Eragrostis tremula* and *Sporobolus diander*. On the other hand, where *C. dolichostachya* was succulent and green below the partial cover of tree canopy, ground cover happened to be usually <26%. These may be the reasons for the trends observed.

The high use of >25% cover in the spring seems to be a result of not accounting for the increased ground cover of SL-MF and WL in

spring. While analysing, this increase was not taken into account due to its small sample size (data from just 3 vegetation types from just 2 sets of spring transects).

5.2.8 The area monitored by road : Presence of dew could have met the water requirement of chital in the mornings of winter and early spring. Ables (1977) opined that when dew was present, chital depended less on water. The absence of it in the evenings could have made them seek water and use this area. This may be the reason why their density was lower in winter mornings and higher in winter evenings.

In summer, leaving the forage-poorer SL-MF, MFP and WL, chital had started using the SF more. Their abundance reduced in PT3 and increased in the sal forests of PT1, PT2 and PT5. This brought them nearer to the monitored area. Dew fall stopped by summer. In need of water, animals from sections of PT1 and PT5 might have come to the nearest water source which lay in the monitored area. Therefore, the spring-summer morning densities might have increased. The observations of Graf & Nichols (1966) and Schaller (1967) about chital water dependence in hot-dry season explains the trend.

By summer, the Forest Department staff started supplying water at the artificial waterholes scattered in the area. This was being done during daytime. Water would be present in the artificial waterholes at least till evening. I could not observe whether it stayed on till next morning. Most probably it was not or it was very less. This made a difference in the water availability between morning and evening. In the summer evenings, chital might have used the artificial waterholes more, coming less for water in

the monitored area. Spring-summer evening densities could have been less due to this.

5.2.9 Use of height in the hills (Fig.5): This exercise was not aimed at seeing the effect of altitudinal change of temperature, climate or vegetation on chital. Such a change could hardly be expected in a rise of 251m.

The results reflect how far from the flat area and known water sources chital go while moving up on the hill slopes. The farthest they were seen from a flat area was about 1km. But such an area does not seem to be indispensable. Otherwise they would not have used the hill slopes so frequently and their densities in the hills could not have compared well with those in the plains. There was no evident difference in the availability of food with increase in height. Instead, as chital are much dependent on water (Graf & Nichols 1966, Schaller 1967), the distance from water must have been critical in limiting the height to which they could have gone. Moving large distances up and down the slopes for water might involve great efforts for chital which is not an essential inhabitant of mountainous terrain (section 5.2.3). On the other hand, the sightings of goral(n>10), barking deer (n=2) and sambar (n=1) on the highest section of the hill suggest that either these are less dependent on water or are well adapted to negotiate the mountainous terrain to reach water.

Another reason seems to be the presence of cliffs and inaccessible slopes on the southern face of the hill. This halved the chances of chital moving further up.

A third factor is the reduction in availability of surface area with increase in height. The distribution of sightings along

the height (Fig.5) suggests this. Chital, not being a mountain ungulate (Section 5.2.3), cannot be expected to exhibit greater affinity to higher places. But since they are able to use the hills, there must be occasions of their using the higher sections of the hill also. This is supported by an observation that chital occurred on the top of the same hill in the spring of 1989 (A.J.T. Johnsingh, per's.com.). My search path walks (n=14) and about 10 climbs on this hill for purposes other than sampling might have been too less an effort to encounter such a chance occurrènce. According to the locals and A.J.T. Johnsingh (pers.com.) spring is the time when chital go higher in these hills. I could not make the sampling coincide with the peak of spring to confirm this. But the observation of A.J.T. Johnsingh suggests that chital can use most of the accessible hills in Dhaulkhand.

5.2.10 Densities in hills and plains (Table 27) : Although chital did not use slopes >50%, the densities in hills compare well with those in the plains. They suggest that chital, primarily a plains species, have succeeded in the hills to a great extent. This is an exception to the observations of Sharatchandra and Gadgil (1975), Schaller (1967), Mc Dougal (1977), Berwick (1974) and Chakrabarty (1991) that chital avoided hills. But from Hawaii (Graf & Nichols 1966) and Texas (Ables 1977) the frequent use of hills is reported.

There seem to be 3 possible explanations for the trend observed in this study as opposed to several other studies in Indian subcontinent. One of them is the duration and season of this study. While some of the reports are backed by longer duration of observation (Schaller 1967, Berwick 1974, Sharatchandra and Gadgil 1975, Mc Dougal 1977), and covered more than 3 seasons (thus

accounting for seasons when there could have been low use of hilly terrain), the trend in this study is result of just 2 seasons of observation. The trend here in monsoon is not known.

Chitawan (from where observations of Mc Dougal (1977) come) is located farther east and is affected less by the winter rains of Western Depressions (Ramdas 1974). The hills in Dhaulkhand experience these rains. The sprout of grass subsequent to these rains might attract chital more to the hills.

The vegetation cover and species composition in the hills of this study might be different from those hilly areas which chital avoided.

The reason for a high use of hills in Dhaulkhand seems to be the availability of food, water and cover in the hills which chital have managed to utilise. Sprout from cut bhabar, the spring flush of *C. fulvus*, *H. contortus*, *N. arundinacea*, and other grasses and sedges provide food. Forage from many trees (eg., *A. latifolia*, *Z. xylopyra*, *A. catechu*, *G. turgida*) is made available to chital by lopping, langurs, wind and hailstorm. All these seem to have created feeding opportunities well comparable with those in the plains. The only constraint might be the steep terrain.

5.3 Conclusions : The study could answer some of the questions for which answers were sought, could not answer some, and has given rise to some new questions.

Chital used plains slightly more than hills in both the seasons. But the differences were not significant. Between two seasons also the differences were not significant.

Forests were used more than any other vegetation type. The use of habitat features was affected by food, water, cover, terrain,

weather, langurs, rhesus macaques, and human influence in the form of lopping, grass cutting, fire and creation of water.

Chital use of hills as intensively as the plains is an interesting feature of this study.

Further studies are desirable.

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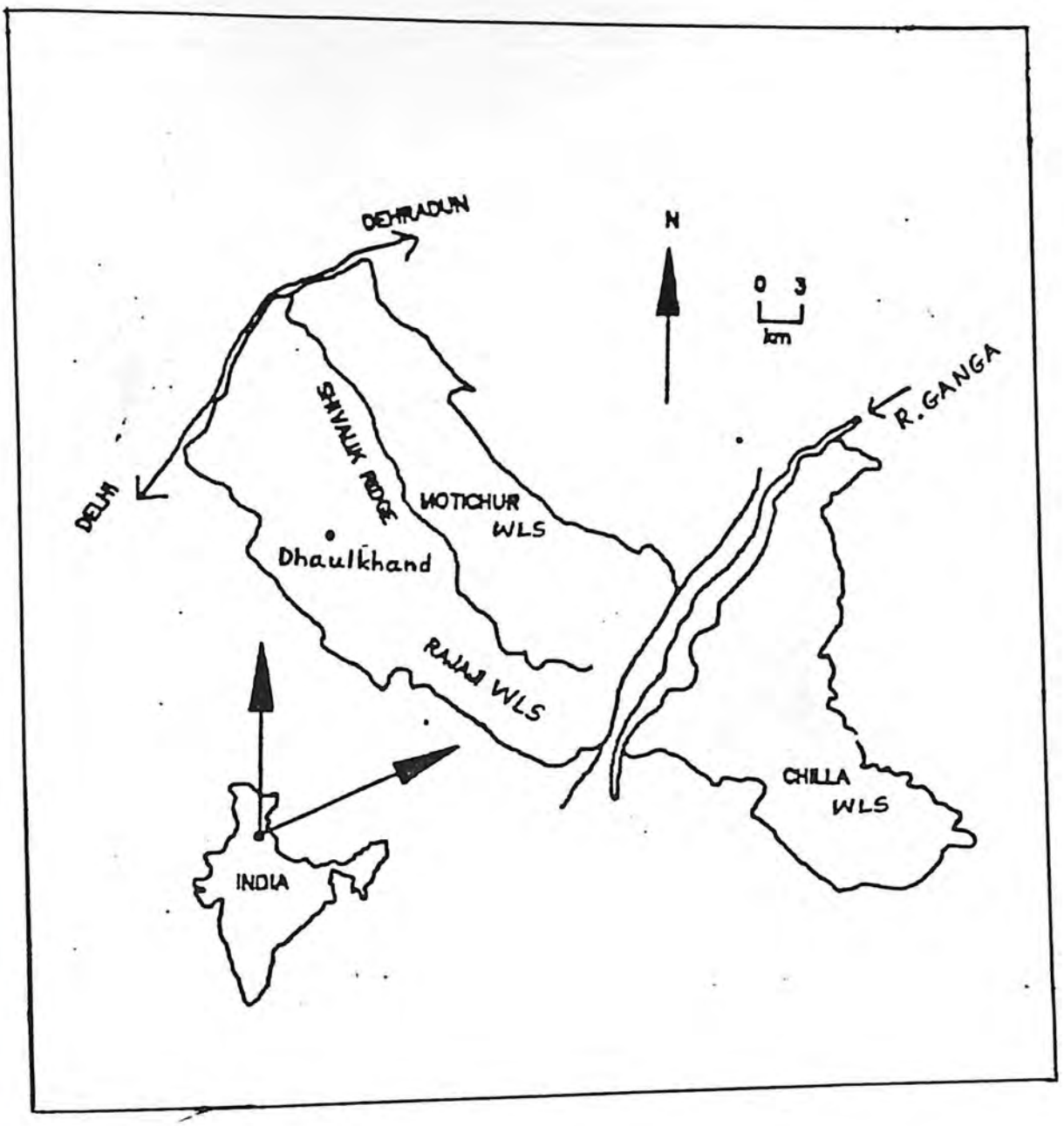
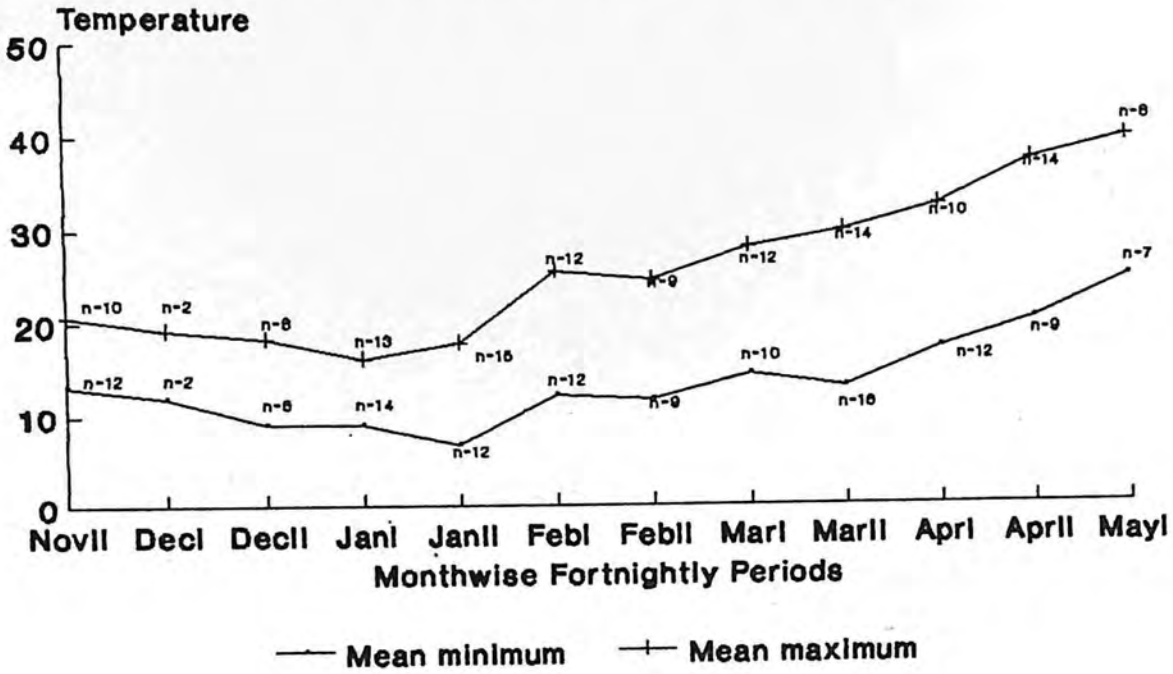


Fig.1 Rajaji National Park

FIG.2 TEMPERATURE AT DHAULKHAND (NOVEMBER 1992 - MAY 1993)



n = sample size = no. of days of obsn.
Maximum temperature figures for April and May are approximations.

Fig.3 The intensive study area (Dhaulkhand) and the locations of the transects.

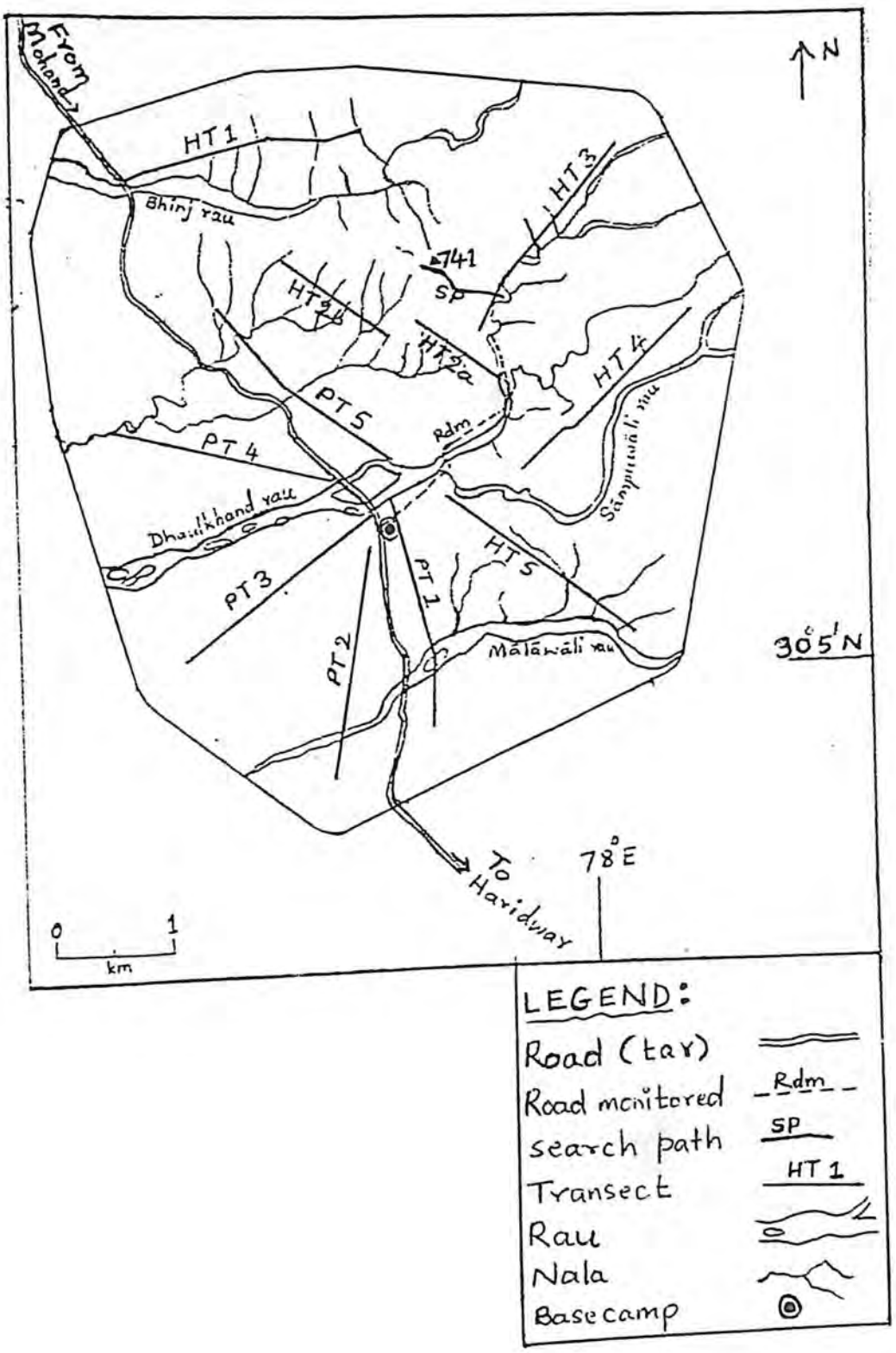
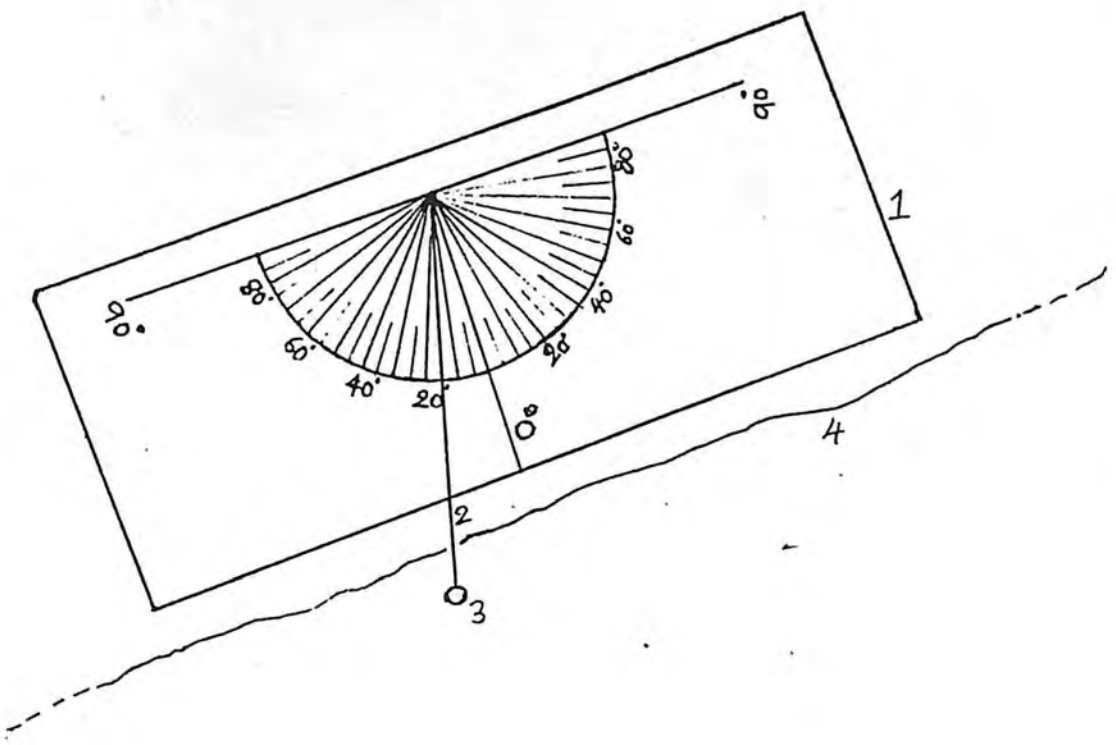
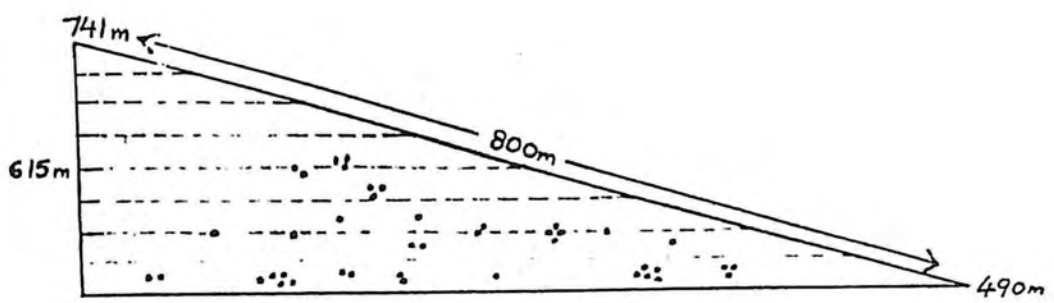


Fig.4 The equipment used for measuring slope.



1. Piece of cardboard (22cm x 10cm)
2. Suspended thread
3. Weight
4. Hill slope that is to be measured

Fig.5 The distribution of chital sightings and number at different heights of the hill monitored by the search path.



Note : Each dot represents one chital.

Plate 1. In the foreground mixed dry deciduous forest is seen interspersed with woodland and scrubland. Note the rau in the left foreground. In the background is the highest hill of the region which was monitored for chital use of height on the hill.

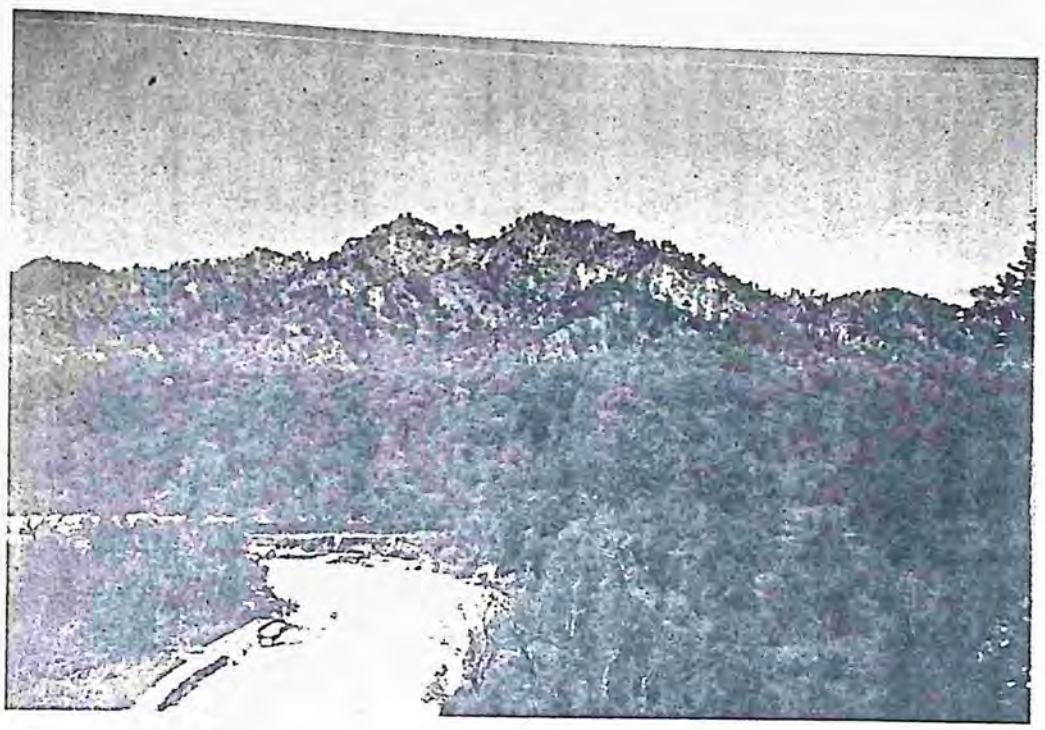


Plate 2. In the foreground, Hill Woodland and Hill Forest are seen. In the background Sal Forest (Moist Bhabar Dun Sal) is seen.

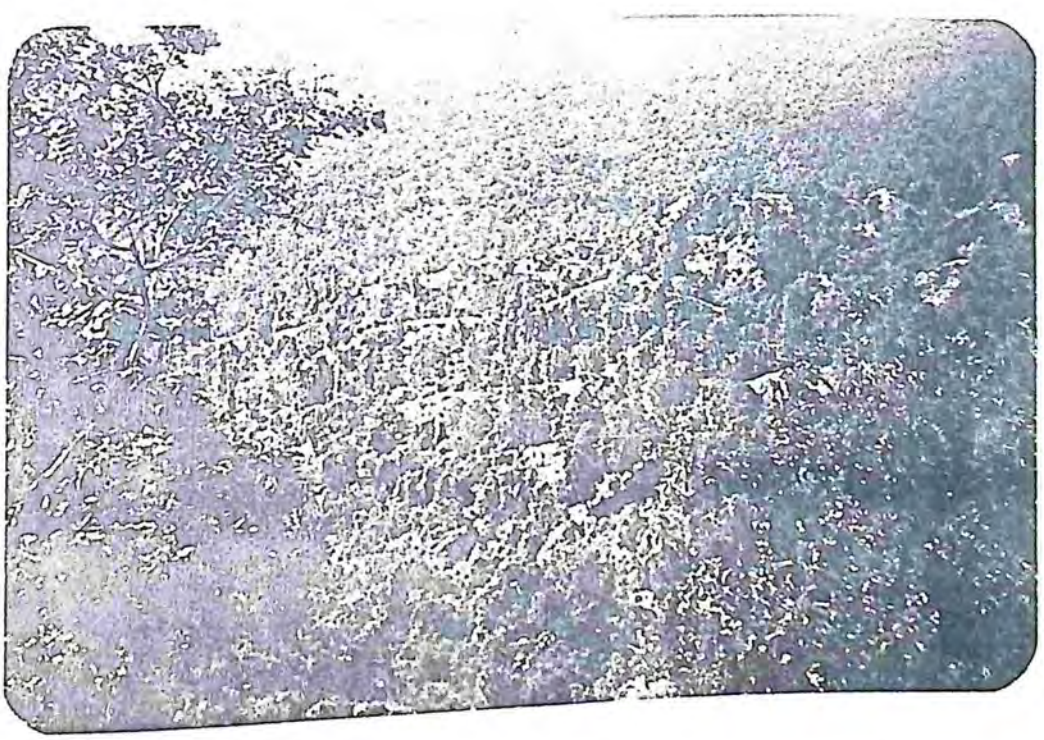


plate 3. Sal Forest (Moist Bhabar Dun Sal) in summer. Note the sal trees in flower.

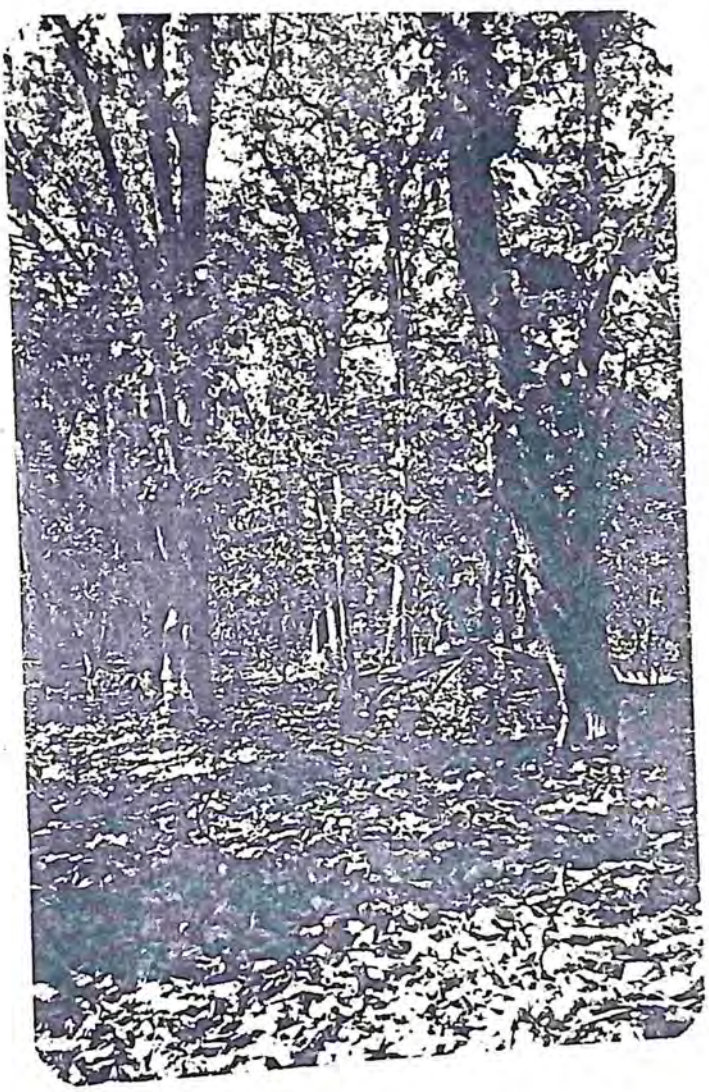


TABLE 1 : Methods for rating wind-strength in the field.

Wind-strength rating	Estimated deflection of cloth from vertical line	General movement of tree parts
No wind	None (vertical suspension)	No movement
Slight wind	Flutters to 10^0	Leaves and raches tremble
Moderate wind	Flutters from 10^0 to 45^0	As above + secondary branches bend/sway
Strong wind	Flutters from 45^0 to horizontal or more	As above + primary branches bend/sway
Very strong-wind	Flutters horizontally for long time	As above + trees bend/sway

TABLE 2 : Main features of the transects. (No. hab. ch. = number of habitat changes on 2km transect.)

Tr. No.	Terrn. type	No. Hab. ch.	Nature of human influence	Hab.types in order of dominance
HT1	Hills	16	Grass cutting, lopping livestock grazing	HF,HWL,HSL
HT2	Hills	14	Grass cutting, lopping livestock grazing	HWL,HF,HSL
HT3	Hills	25	Bhabar cutting.	HF, HWL.
HT4	Hills	24	Bhabar cutting.	HWL, HF, HSL.
HT5	Hills	38	Bhabar cutting,sprg-summer lopping.	HWL, HF.
PT1	Plains, Hills	20	Sprg-summer lopping	MF, SF, WL, SL, HF.
PT2	Plains	15	Sprg-summer lopping	MFP,SF,WL,MF,SL.
PT3	Plains	9	Lopping, Livestock grazing.	MFP,WL,MF.
PT4	Plains	9	Livestock grazing, Sprg-sum lopping.	SF,WL,MF.
PT5	Plains	13	Spring-summer lopping	SF,WL,MF,SL.

TABLE 3 : Trees in different habitat types. (total no. of plots = 211)
[fo<2m = foliage below 2m height.
f. trees = trees of probable forage value.]

Hab type	No.of sample plots	Tree density (No/ha)	Total No. spp.	% f.tree spp.	Density f.trees (No./ha)	% f. trees fo<2m	Winter Lop %	Sp-sum Lop %
Hills:								
HF	45	332	35	77	221	25	-	6
HWL	59	181	30	83	123	20	4	7
HSL	5	127	9	78	57	15	-	-
Plains:								
SL	6	159	11	64	58	17	-	-
MF	14	473	21	76	280	21	-	8
SF	38	404	14	71	129	21	-	1
WL	26	231	24	79	116	34	3	6
MFP	18	363	20	80	113	8	-	8

TABLE 4 : Shrubs and tree saplings in different habitat types.
(total no. of sample plots = 211)
[f. = shrubs of probable forage value.]

Hab.type	No.of sample plots	Density (No/ha)	Total no. spp.	% No. spp.	Density f.shrub (No/ha)
Hills:					
HF	45	2562	29	76	1229
HWL	59	2168	37	68	1332
HSL	5	3312	5	40	790
Plains:					
SL	6	4459	6	50	1486
MF	14	5223	14	50	1064
SF	38	5444	20	50	2477
WL	26	2842	22	45	1161
MFP	18	3022	17	53	750

TABLE 5 : Herbs/climbers/seedlings in different habitats.
(total quadrats / small plots sampled = 859)
[f. herbs = herbs of forage value]

Hab. types	No.Quadrats/ small plots sampled	No. herb/ climber sps.	No.sdlg sps	Total density (No/m2)	Density of f. herbs (No./m2)
Hills:					
HF	185	42	29	7.78	4.56
HWL	242	46	28	8.9	6.7
HSL	22	12	10	9.39	7.38
Plains:					
SL	26	8	8	11.88	6.6
MF	56	21	16	17.5	12.26
SF	152	31	19	11.66	10.6
WL	104	24	15	19.94	10.66
MFP	72	21	15	14.7	8.69

TABLE 6 : Lianas in different vegetation types encountered on transects. (total no. of sample plots = 211)

Vegn.type	No.sample plots	Total no.of spp.	Density (no/ha)	Most dom. species	Proportion of most dom.spp. (%)
Hills:					
HF	45	5	24	*B.vahlii*	62
HWL	59	3	13	*B.vahlii*	66
HSL	5	2	10	Undecided	-
Plains:					
SL	6	0	0	none	0
MF	14	2	27	*M.extensa*	92
SF	38	1	16	*M.extensa*	100
WL	26	2	7	*M.extensa*	83
MFP	18	1	12	*M.extensa*	100

TABLE 7 : Dominant tree and shrub species in Hill Forest (HF).

Sl. No.	Tree sps.	Av.ht. (m)	DI*	Shrub species	Av.ht. (m)	DI*
1.	S.robusta	18	1062	C.oppositifolia	1.5	226
2.	M.philippinensis	8	688	H.antidysenterica	1.2	208
3.	O.ougeinensis	8	343	M.philippinensis	1.0	165
4.	B.lanzan	12	214	H.isora	2.1	104
5.	A.catechu	10	183	E.laevis	1.4	70
6.	E.laevis	7	155	C.opaca	1.3	37
7.	Z.xylopyra	8	144	D.pulchellum	0.5	32
8.	H.antidysenterica	8	141			
9.	C.fistula	9	133			
10.	A.latifolia	13	133			
11.	B.purpurea	8	133			

* DI = Dominance Index = av.ht. x number of individuals.

TABLE 8 : Dominant tree and shrub species in Hill Woodland (HWL)

Sl. No.	Tree sps.	Av.ht. (m)	DI*	Shrub sps.	Av.ht. (m)	DI*
1.	A.latifolia	15	570	D.pulchellum	1.0	261
2.	S.robusta	18	519	H.antidysenterica	1.4	179
3.	B.purpurea	9	285	C.oppositifolia	1.4	132
4.	Z.xylopyra	7	240	M.philippinensis	1.4	115
5.	B.lanzan	9	214	H.isora	2.0	86
6.	A.catechu	11	213	E.laevis	1.4	73
7.	M.philippinensis	6	188	W.fruticosa	1.0	54
8.	H.antidysenterica	7	167			
9.	O.ougeinensis	7	141			
10.	N.arbor-tristis	6	138			

* DI = Dominance Index = Av. ht. x number of individuals.

TABLE 9 : Dominant tree and shrub species in Hill Scrubland (HSL).

Sl. No.	Tree sps.	Av.ht. (m)	DI*	Shrub sps.	Av.ht (m)	DI*
1.	H.antidysenterica	8	77	C.oppositifolia	3.0	225
2.	T.bellirica	24	24	M.philippinensis	3.5	74
3.	A.latifolia	23	23	H.antidysenterica	1.9	31
4.	B.variegata	8	16	H.isora	2.2	22
5.	B.purpurea	13	13	C.fistula	4.0	20
6.	M.philippinensis	5	10			
7.	F.indica	8	8			
8.	C.fistula	8	8			
9.	O.ougeinensis	6	6			

*DI = Dominance Index = Av.ht. x No. of individuals.

TABLE 10 : Dominant tree and shrub species in Scrubland (SL)

Sl. No.	Tree sps.	Av.ht. (m)	DI*	Shrub sps.	Av.ht. (m)	DI*
1.	L.parviflora	14	69	L.camara	2.7	190
2.	H.antidysenterica	8	54	A.vasica	1.6	110
3.	C.fistula	10	40	H.antidysenterica	0.8	34
4.	M.philippinensis	6	36	E.laevis	1.5	25
5.	G.pinnata	23	23	C.oppositifolia	1.5	21
6.	F.benghalensis	23	23			
7.	E.laevis	4	9			
8.	L.acidissima	9	9			
9.	B.monosperma	8	8			
10.	M.koenigii	7	7			

DI* = Dominance Index = Av.ht. x No. of individuals.

TABLE 11 : Dominant tree and shrub species in Mix Forest (MF)

Sl. No.	Tree species	Av.ht. (m)	DI*	Shrub sps.	Av.ht. (m)	DI*
1.	M.philippinensis	8	707	C.infortunatum	1.0	244
2	L.parviflora	13	244	A.vasica	1.5	127
3.	H.antidysenterica	10	214	T.grandis	4.0	75
4.	E.laevis	8	175	M.philippinensis	0.6	56
5.	C.fistula	11	142	H.antidysenterica	0.8	32
6.	M.velutina	8	109	C.oppositifolia	0.8	18
7.	B.retusa	14	58			
8.	C.tomentosa	10	50			
9.	S.villosa	20	41			
10.	S.suaveolens	16	33			

* DI = Dominance Index = Av.ht.x no. of individuals.

TABLE 12 : Dominant tree and shrub species in Sal Forest (SF)

Sl. No.	Tree species	Av.ht. (m)	DI*	Shrub species	Av.ht. (m)	DI*
1.	S.robusta	23	3966	M.philippinensis	0.7	425
2.	M.philippinensis	8	1070	T.grandis	4.2	176
3.	L.parviflora	9	928	C.infortunatum	0.6	128
4.	E.laevis	7	376	A.vasica	1.5	120
5.	M.velutina	10	219	C.oppositifolia	1.3	80
6.	C.fistula	9	46	M.extensa	0.4	67
7.	S.villosa	21	42	H.antidysenterica	0.6	59
8.	L.chinensis	8	25			
9.	T.grandis	8	24			
10.	B.retusa	12	12			

*DI = Dominance Index = Av.ht. x no. of individuals.

TABLE 13 : Dominant tree and shrub species in Woodland (WL)

Sl. no.	Tree species	Av.ht. (m)	DI*	Shrub species	Av.ht. (m)	DI*
1.	S.robusta	23	680	A.vasica	1.4	137
2.	M.philippinensis	7	421	H.antidysenterica	1.0	80
3.	L.parviflora	7	143	M.philippinensis	0.6	76
4.	E.laevis	6	117	E.laevis	1.6	62
5.	H.antidysenterica	7	67	C.oppositifolia	1.6	32
6.	S.suaveolens	9	54	D.pulchellum	0.4	28
7.	C.fistula	7	47	C.fistula	1.1	21
8.	T.grandis ,	10	41			
8.	Grewia spp.	11	33			
9.	W.tomentosa	11	32			

*DI = Dominance Index = Av.ht x no. of individuals.

TABLE 14 : Dominant tree and shrub species in Mix Forest Plantation (MFP)

Sl. no.	Tree species	Av.ht (m)	DI*	Shrub species	Av.ht. (m)	DI*
1.	T.grandis	11	873	A.vasica	2.2	325
2.	E.laevis	8	231	C.oppositifolia	2.4	88
3.	A.catechu	16	214	M.philippinensis	0.6	41
4.	M.philippinensis	8	182	T.grandis	2.5	37
5.	H.antidysenterica	10	150	H.antidysenterica	0.7	27
6.	D.sissoo	14	116	M.extensa	0.4	21
7.	L.parviflora	11	66	M.velutina	0.6	13
8.	B.ceiba	21	64			
9.	M.velutina	8	55			
10.	C.fistula	11	46			

*DI = Dominance Index = Av.ht x no.of individuals.

TABLE 15 : Occurrence of tree canopy cover, shrub cover and ground cover categories on the transects. (no. of sample plots = 211)

Cover type	% occurrence on hill transects	% occurrence on plain transects
% canopy cover:		
0-25	27	14
26-50	32	18
51-75	33	43
76-100	8	25
% shrub cover:		
0-25	81	49
26-50	12	27
51-75	7	19
76-100	0	5
% ground cover:		
0-25	50	87
26-50	35	12
51-75	12	1
76-100	3	0

TABLE 16 : Occurrence of topographic features on hill transects. (no. of sample plots =109)

Category	Hill slope	Valley	Ridge line	Ridge top	Flat ground	Rau bed	Nala bed
%Occurrence	74	9	9	1	5	1	1

TABLE 17 : Occurrence of slope categories on hill transects.
(Number of sample plots =109)

Degree slope	0-10	11-20	21-30	31-40	41-50	51-60	61-70
%Occurrence	22	14	30	25	5	2	2

TABLE 18 : Occurrence of aspect categories on hill transects.
(Number of sample plots = 109)

Aspect	N	NE	E	SE	S	SW	W	NW	undecided
%occurrence	3	21	11	17	12	12	12	12	17

TABLE 19 : Habitat Use Index for Secondary Strata in hills.

Season/time	No. sightings	No. animals	HF-HSL	HWL
Winter morning	48	157	0.82	1.15
Winter evening	24	64	1.51*	0.59 -
Spring-summer morning	49	147	1.46*	0.62 -
Spring-summer evening	20	48	1.31	0.75
Overall study period	140	416	1.02	0.98

* High use; - low use; unmarked indicate moderate use.

TABLE 20 : Habitat Use Index for secondary strata in the plains.

Season/time	No. stgs.	No. animls.	SL-MF	SF	WL	MFP
Winter morning	36	79	0.80	0.66-	1.3	1.52*
Winter evening	23	83	2.53**	0.12-	0.52-	0.82
Spring-summer morning	21	115	1.79*	1.03	1.06	0-
Spring-summer evening	31	134	1.51*	1.55*	0.29-	0.3 -
Overall study period	111	411	1.72 *	0.93	0.75	0.55 -

* High use; ** Very high use; - low use; unmarked indicate moderate use.

TABLE 21 : Habitat Use Index for aspects in the hills.

	Winter morning	Winter evening	Spg-sum morning	Spg-sum evening	Overall study period
No.sighting	45	21	44	18	128
No.animals	152	57	135	46	390
Aspects:					
N	0.58 -	0 -	0.66 -	1.25	0.57 -
NE	0.65 -	0.80 -	0.43 -	0.54 -	0.58 -
E	0.94	1.02	1.49 *	2.95 **	1.39 *
SE	2.16 **	1.02	1.24	2.51 **	1.82 *
S	1.13	4.09 **	1.61 *	0.63 -	1.68 *
SW	1.23	1.31	1.12	0.72 -	1.15
W	0.37 -	0 -	0.56 -	0.18 -	0.36 -
NW	0.11 -	0 -	0.99	0.16 -	0.39 -

* High use; ** Very high use; - low use; unmarked indicate moderate use.

TABLE 22 : Habitat Use Index for slope categories in the hills.

Season/time	No stgs.	No. animals	HUI for degree slope classes				
			0-10	11-20	21-30	31-40	41-50
Winter morning	48	157	0.43-	1.71*	1.49*	0.72	0.69
Winter evening	24	64	1.03	0.77	1.29	0.43-	2.49**
Spring-summer morning	49	147	0.62-	2.32**	1.19	0.74	0-
Spring-summer evening	20	48	0.69	1.03	1.38*	1.01	0-
Overall study period	140	416	0.62-	1.59*	1.34*	0.70	0.75

* High use, ** very high use, - low use.
unmarked indicate moderate use.

TABLE 23 : Habitat use Index for different positions of terrain in the hills (hslp= Hill slope ; val/nbd/rbd = valley / nala bed / rau bed ; rln/rtp = ridge line / ridge top; fg = flat ground).

Season/time	No. Stgs.	No. animals	Positions			
			hslp	val/ nbd/ rbd	rln/ rtp	fg
Winter morning	48	157	1.04	1.04	1.14	0 -
Winter evening	24	64	0.63 -	2.58 **	2.46 **	0 -
Spring-summer morning	49	147	0.99	1.42 *	0.81	0.59 -
Spring-summer evening	20	48	1.03	1.54 *	0 -	0 -
Overall study period	140	416	0.95	1.47 *	1.11	0.29 -

*High use, ** very high use, - low use.
Unmarked indicate moderate use.

TABLE 24 : Habitat Use Index for cover types in the hills.

	Winter morning	Winter evening	Sprg-sum morning	Sprg-sum evening
No.Stags	48	24	49	20
No.animals	157	64	147	48
Cover types:				
% Tree canopy cover				
0-25	0.89	0.55 -	0.71	0.73
26-50	1.23	0.56 -	0.59 -	0.69
51-75	1.06	1.96 *	1.65 *	1.31
76-100	0.23 -	0.74	0.91	1.76 *
% shrub cover				
0-25	0.94	0.95	0.95	1.03
26-50	1.71 *	1.61 *	1.37 *	0.92
51-100	0.52 -	0.41 -	0.93	0.83
% ground cover				
0-25	0.86	1.74 *	0.98	1.55 *
26-50	1.59 *	0.21 -	1.07	0.69
51-100	0.09 -	0.52 -	0.88	0 -

* High use, - low use. Unmarked indicate moderate use.

TABLE 25 : Habitat Use Index for cover types in the plains.

	Winter morning	Winter evening	Spring-sum morning	Spring-sum evening
No. sightings	36	23	21	31
No. animals	79	83	115	134
% canopy cover:				
0 - 25	1.11	0.16 -	0.38 -	0.79
26 - 50	0.93	0.59 -	1.38 *	0.28 -
51 - 75	0.97	1.96 *	0.62 -	0.84
76 -100	1.04	0.19 -	1.71 *	1.90 *
% shrub cover:				
0 - 25	0.98	1.35 *	1.45 *	0.89
26 - 50	1.62 *	0.32 -	0.45 -	2.39 **
51 - 75	0.41 -	0.56 -	0.75	1.15
76 -100	0 -	0.43 -	0.53 -	0.26 -
% ground cover:				
0 - 25	1.13	1.05	0.83	0.74
26 -100	0.10 -	0.81	2.19 **	2.94 **

* High use, ** Very high use, - low use.
Unmarked indicate moderate use.

TABLE 26 : Habitat Use Index for the overall use of cover types during the entire study period.

%canopy cover class	HUI	%cover class and HUI		
			shrub	ground
0-25	0.70	0-25	1.05	0.99
26-50	0.80	26-50	1.13	1.15
51-75	1.21	51-100	0.66 -	0.65 -
76-100	1.19			

- low use; unmarked indicate moderate use.

TABLE 27 : Chital densities in hills and plains during winter and spring-summer.

Parameter	Winter		Spring-summer	
	Hills	Plains	Hills	Plains
No. of sightings	68	45	69	42
GD (Groups/km2)	15.93	16.48	16.86	10.76
SE of GD	2.577	3.324	2.550	2.085
% CV of GD	16.2	20.2	15.1	19.4
95% CI for GD	10.88--20.99	9.965--23.00	11.86--21.86	6.678--14.85
Mean grp.size	3.34	3.42	3.22	5.32
D (individuals/km2)	53.21	56.36	54.29	57.24

TABLE 28 : Reduction in chital sightings and number in hills (HT1, HT 4,HT 5) and increase of these in plains (PT 1, PT3, PT5) from morning to evening (within the a strip width of 100 m in hills and 60 m in plains).

Season/time	Winter		Spring-summer	
	Morning	Evening	Morning	Evening
Hills:				
No. of groups seen	29	24	30	20
No. of chital seen	87	64	96	48
Plains:				
No. of groups seen	24	23	16	31
No.of chital seen	52	83	87	134

APPENDIX I

Food plants of chital (observed or indrect evidences) during the study period [ooo = no direct obsern. of feeding, but very frequent association of chital with the species / probably very instensively used ; + = only one obsern. of feeding / used infrequently ; ++ = fed often, more than one obsern. of feeding ; +++ = fed intensively / repeated obserns. of feeding; * = Item not directly seen fed by the animal but confirmed by the fresh signs at the feeding site ; (?) = species identification doubtful.]

Species	Season			Parts eaten/ remarks
	Winter	Spring	Summer	
Trees:				
A.Catchu	ooo			Leaf
A.latifolia	+++	+++		Leaf
S.robusta			+ooo	Petals and infl.
A.cordifolia	ooo			Leaf
*Z.xylopyra**	ooo			Leaf
	+ooo			Fruit
B. retusa		+ooo		Leaf
M.philippinensis	++	++		Leaf
T.bellirica	ooo	ooo		Leaf
*B.racemosa**	ooo			Fruit
Z.mauritiana	+ooo			Fruit
T.tomentosa	+			Leaf
C.obliqua	+++			Leaf
Shrubs:				
C.opaca	+++	+++		leaf
L.camara		++		
H.isora	+	++		
*M.philippinensis**	+	++		
Herbs:				
*G.leuteo-album**		+++		Came up only in spr.
*A.thaliana**		+		Came up only in spr.
*I.frutescens**	++ ooo	+ ooo		
*A.conyzoides**	+	+		
*M.coromandalicum**(?)		+		
*Crotalaria sp.**	+ooo			
D.roxburghiana		+		
Blumea sp.		+		
J. simplex	+ooo			
Grasses/Sedges:				
N.arundinacea	++	++		
*C.dactylon**	ooo	+ooo		New flush
*H.contortus**	+	++		New flush
*C.fulvus**	++	++		Only the sprout from
*E.binata**	+++	+++		

*C.dolichostachya**	+++	+++	cut stock
*I.cylindrica**	+	+++	New flush
*D.bipinnata**	+	+	New flush
*S.diander**		+ ooo	New flush
*Carex sp.**	+ ooo		
*C.kyllinga**(?)	+ ooo	+ ooo	

Others :

D. falcata	+++

APPENDIX II

plant species encountered in Dhaulkhand, the frequency of their occurence, and thier value as proven or probable food items for wild ungulates (c = common, f = frequent, o = occasional, s = sparse and y = yes).

Trees :	How frequent ?	Of food value ?
Acacia catechu	c	y
Adina cordifolia	f	y
Ailanthus excelsa	f	y
Anogiessus latifolia	c	y
Bauhinia malabarica	f	y
B. variegata	f	y
B. purpurea	f	y
B. racemosa	f	y
Bombax ceiba	f (in plains)	y
Bridelia retusa	f	y
Buchanania lanzan	c (in hills)	
Butea monosperma	o	
Casearea tomentosa	f	y
Cassia fistula	c	
Cordia obliqua	f	y
C. vestita	o	
Dalbergia latifolia	o (in plains)	
D. sissoo	c	
Ehretia laevis	c	
Ficus benghalensis	f	
F. cunea	o	
F. racemosa	o	
Flacourtia indica	f	y
Gardenia turgida	f	y
Garuga pinnata	f	
Grewia spp.	c	
Holarrhena antidysenterica	c	
Holoptelia integrifolia	o	y
Hymenodytction excelsum	f	
Kydia calycina	f (in plains)	y
Lagerstroemia parviflora	c	
Lannea coromandalica	f	
Limonia acidissima	f	y
Litsaea chinensis	f	y
Mallotus philippinensis	c	y
Miliusa velutina	c	y
Mitragyna parviflora	f	y
Murraya koenigii	c	y
Nyctanthes arbor-tristis	c (in hills)	y
Ougeinia ougeinensis	c (in hills)	y
Premna sp.	o	
Phyllanthus emblica	f	y
Randia dumetorum	o	y
Sterculia villosa	f	
Semecarpus anacardium	o (in hills)	
Shorea robusta	c	y
Stereospermum suaveolens	c	y
Syzygium cumini	f	
Terminalia bellirica	c	y
T. chebula	o	
T. tomentosa	c	y

Tectona grandis	*c (in plains)*	
Wrightia tomentosa	*o*	
Zizyphus mauritiana	*c*	*y*
Z. xylopyra	*c*	*y*

Shrubs :

Adhatoda vasica	*c (in plains)*	
Asparagus racemosus	*o*	
Carissa opaca	*f*	
Clerodendron infortumnatum	*f*	
Colebrookia oppositifolia	*c*	
Crotalaria medicaginea	*o*	
Dalbergia sissoo	*c*	
Desmodium latifolium	*c (in hills)*	
D. pulchellum	*c*	*y*
Equisetum sp.	*o*	
Flemingea bracteosa	*c*	*y*
F. congesta	*c*	
F. semialata	*c*	
Grewia sapida	*f*	
Hamiltonia suaveolens	*s*	*y*
Helicteres isora	*f*	*y*
Holarrhena antidysenterica	*c*	
Inula cappa	*c*	
Lagerstroemia parviflora	*c*	
Lantana camara	*c (in plains)*	*y*
Lespedeza gerardiana	*s*	
Mallotus philippinensis	*c*	*y*
Milletia extensa	*c*	
Solanum xanthocarpum	*o*	
Vitex negundo	*f*	
Woodfordia fruticosa	*f (in hills)*	
Zizyphus oenoplia	*f*	*y*

Climbers / Lianas:

Atylosia latibrosa	*o*	
Bauhinia vahlii	*c (in hills)*	*y*
Celastrus paniculata	*o*	
Cissampelos pariera	*c*	
Cryptolepis buchanani	*c*	*y*
Dioscorea belophylla	*f*	
Cuscuta reflexa	*o (in plains)*	
Ichnocarpus frutescens	*c*	*y*
Milletia extensa	*c*	*y*
Pueraria tuberosa	*f*	
Vallaris solanacea	*o*	
Ventilago bicalyculata		

Herbs and ferns :

Abutilon sp.	*c*	*y*
Achyranthes aspera	*c*	*y*
Adianthum edgeworthii (fern)	*c*	
Aerva lanata	*f*	
Ageratum conyzoides	*c*	*y*
Arabidopsis thaliana	*c*	*y*
Arenaria serpyrifelia	*c*	
Artemesia scoparia	*o*	

Asystasia latibracea	u	
Barleria cristata	u	
Biophytum sensitivum	f	
Blumea mollis	u	
Blumea sp.	u	y
Boerhaavia diffusa	u	
Borreria procumbens	f	
Bupleurum tenui	u	y
Cansora diffusa	u	
Cassia tora	o	
Commelina sp.	o	
Conyza stricta	o	
Corchorus aestuans	o	
Crepis japonica	o	
Crotalaria sp.	c	y
Cyanotis vaga	o	
Desmodium microphyllum	c	
Dicliptera roxburghiana	o	y
Elsholtzia sp.	f	
Erigiron canadensis	c	
Evolvulus alsinoides	c	
E. nummularioides	c	
Gynura nepalensis	o	
Gnaphalium leuteo-album	c	y
Hemigraphis latilabris	o	
Ichnocarpus frutescens	c	y
Indigofera sp.	f	
Justicia simplex	c	y
Leucas cephalotes	f	
Malvastrum coromandalicum	f	y
Nepeta graciliflora	c	
Oldenlandia sp.	o	
Parthenium hysterophorus	c	
Peristrophe bicalyculata	o	
Phyllanthus niruri	c	
Polygonum aviculare	o	
Selaginella sp.	o	
Senecio neudicaulis	f	
Sida cordifolia	c	
Sida sp.	f	y
Smithia ciliaris	o	
Stellaria media	c	
Tephrosia purpurea	f	
Thecagonum sp.	c	
Trichodesma indicum	f	
Urena lobata	c	y
Ventilago bicalyculata	o	
Vernonia cinerea	o	

<u>Grasses and sedges:</u>

Apluda mutica	o	
Aristida setacea	o	
Bothrichloa intermedia	f	
B. pertusa	f	
Brachiaria sp.	f	
Brachiaria ramosa	o	
Capillipedium assimile	o	
Carex sp.	f (in hills)	y
Chloris dolichostachya	c	y

Chrysopogon fulvus	c	y
Cynodon arcuatus	f	
C. dactylon	c	y
Cyperus kyllinga	c	y
Desmostachya bipinnata	c	y
Dicanthium annulatum	o	
Digitaria sp.	f	
Digitaria purpurea	o	
Eragrostis coarctata	o	
E. tremula	c	
Eragrostis sp.	f	
Eleucine indica	f	
Eriophorum comosum	f (in hills)	
Eulaliopsis binata	c (in hills)	y
Hackelochloa granularis	o	
Heteropogon contortus	c	y
Imperata cylindrica	c	y
Neyraudia arundinacea	c (in hills)	y
Oplismenus burmannii	c	
O. compositus	o	
Paspalidium sp.	o	
Paspalum flavidum	s	
Pogonatherum paniceum	c	
Saccharum ravennae	f	
S. spontaneum	f	
Setaria glauca	f	
Sorghum helepense	o	
Sporobolus diander	c	y
Thysanolaena maxima	o	
Tripogon filiformis	o	
Vetiveria zizanioides	f	y
Others :		
Dendrocalamus strictus	f (in hills)	y
Dendrophthoe falcata	f	y
Phoenix spp.	f (in hills)	