HABITAT PREFERENCE OF SAMBAR (*Cervus unicolor*) IN RAJAJI NATIONAL PARK

DISSERTATION SUBMITTED TO THE SAURASHTRA UNIVERSITY, RAJKOT IN PARTIAL FULFILLMENT OF MASTER'S DEGREE IN WILDLIFE SCIENCE (1991)

BY

YASH VEER BHATNAGAR

SUPERVISOR

DR. S.N. PRASAD, ASSISTANT PROFESSOR,
WILDLIFE INSTITUTE OF INDIA, DEHRA DUN.

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CERTIFICATE

This is to certify that Mr.Yashveer Bhatnagar of Wildlife Institute of India has carried out an original piece of research work entitled "Habitat preference of sambar (Cervus unicolór) in Rajaji National Park" in partial fulfilment of M.Sc. (Wildlife Science) degree of the Saurashtra University. These investigation were carried out under my supervision at the Wildlife Institute of India from October 1990 to June 1991. I also certify that this work has not been submitted for any degree of any university.

(S.Narendra Prasad)
Scientist-SD

Dated : 24.06.1991

Place : DEHRA DUN

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CONTENTS

SUMMARY

A study on the habitat use by sambar in the Rajaji National Park was carried out from November 1990 to April 1991. Data was collected on the vegetation, habitat use and abundance of sambar. Habitat preferences were studied using the utilization availability technique and animal abundances using the King census method.

The major results regarding vegetation studies were:

1. Nine vegetation types (VT) were recognized in the study area based on their broad association and physiognomy as: the plains sal forests (SF), plains mixed forest plantation (MFP), mixed forests (MF), mixed forest, riverain (MFR), mixed forests slope (MFS), mixed forest shady valley (MFSV), mixed forest grassy slopes (MFSG), mixed forest slope with sal (MFSS) and sal forest slope (SFS).
2. The dominant tree, shrub and grass species and their abundances for each VT are presented.
3. The hills on the whole had a greater proportion of palatable tree species with branches accessible to sambar. They also had a greater diversity of forage and cover providing shrubs.

The major results of the preference analysis were:

1. Sambar shows preference for MFS during both seasons (November to Mid February-winter and Mid February to April-Spring/summer).

2. Low to moderate tree and shrub covers are preferred during both seasons. Higher grass cover categories are preferred by sambar during both seasons.

3. Lopped areas show avoidance mainly during summers.

The major results of the sambar abundance were:

1. Sambar density for the 10 transects, representing hills and plains and varied levels of disturbance are presented.

2. Sambar density during both seasons was higher in the hills.

3. The sambar density does not significantly vary between the hill, disturbed and hill relatively undisturbed transects during both the seasons.

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CHAPTER 1.0. Introduction

Most deer species are considered to be forest animals. It is possible to define a narrow range of conditions under which a deer species may be found (Putman 1988). The evolutionary position and body size govern the feeding strategy of the animal which in turn governs the macro- and microhabitat use of the species (Jarman 1974; Geist 1974).

Such features are known for some of the new world deer species (see a brief review in Putman 1988) and caprids. For example, the major habitat needs of big horn sheep (*Ovis canadensis*) are known to be forage, water, thermal protection, and areas for escape, rutting and lambing. An optimal distribution of these features in its habitat has also been worked out (Van Dyke et. al. 1983). Riney (1983) emphasises the necessity of such studies in effective wildlife management.

Knowledge on the ecology of sambar in India is wanting (Rodgers 1988). Accounts of natural history of the animal are more common (Forsyth 1989, Brander 1923, quoted from Schaller 1967, Prater 1965, Schaller 1967, Johnsingh, 1983). More quantitative literature on sambar habitat use is available from USA (Richardson II 1972, Aynn 1986, Flynn et. al. 1990) and New Zealand (Kelton and Skipworth 1987).

This study is the first such attempt in India.

1.1. Review of Literature

A review on the literature about sambar I could obtain is presented below.

1.11. General Information

Sambar (*Cervus unicolor niger* Blainville) is a generalist feeder and has a wide distribution in south-east Asia (Schaller 1967) with 16 subspecies occurring in this range (Whitehead 1972). However, within an area, certain habitats may be preferred over the others as is suggested by such sources as Schaller (1967) and Johnsingh (1983).

Sambar is believed to have an oriental origin (Rodgers 19 88). It has adapted well to varied habitats such as the Himalayan forests (sub alpine scrub at about 3,300m (Green 1987)), the dry deciduous, moist deciduous and evergreen forests of the peninsular region, the semi-arid western regions and the evergreen forests of the north-east (Prater 1965; Schaller 1907; Eisenberg and Sidensticker 1976). It is interesting to note that introduced sambar has readily taken up such varied habitats as the coastal swamps in New Zealand (Wodzicki 1961,quoted from Aynn 1986), freshwater swamps in Australia and USA (Aynn 1986).

General descriptions of sambar can be found in Prater (1965), Schaller (1967), Kelton (1981). Comments on sambar's behavior can be found in the above mentioned sources as well as Johnsingh (1983). Various aspects of population dynamics have been discussed by Schaller (1967), Johnsingh (1983), Aynn (1986) and Karanth

(1989).

1.12. Habitat Use

Literature giving quantitative information on habitat use by sambar is lacking from India. Some sources are available from sambar introduced in USA (Richardson II 1972, Aynn 1986) and from the Thai sambar population (Ngampongsai 1987,quoted from Karanth 1988).

The habitat use in terms of the habitat requirments of sambar may be summarised as follows:

Food: Sambar is a generalist grazer/browser (Schaller 1967, Rodgers 1988b). Schaller (1967) in Kanha National Park found a variety of grasses, sedges, twigs, leaves, fruits and finely chewed bark in the rumen content of sambar. He recognized 24 species of grasses and 13 species of browse present in sambar diet. Green (1987) in his study in Himalayan forests says that sambar faeces in summer and autumn largely had forbs and grasses, in winter, bamboo, ferns and woody oak. It shifted to more of grass and bamboo during spring. He also analysed sambar dung for the seasonal trends in ash, cell solubles, hemicellulose, cellulose, lignin and crude protein. The crude protein in the faeces showed a high during the wet season between July and October. Sambar in the dry deciduous forests of Rajasthan (Sariska National Park) are known to feed on a few browse species on moderate slopes and narrow gorges (Rodgers 1984). Johnsingh and Shankar (1991) report 139 species which are

known to be eaten by sambar. These include 44 tree, 23 shrub, 28 creeper/climber. Grasses were also frequently eaten.

Green (1987) found distinct use of forage species in different seasons. This may be one of the factors determining the seasonal habitat use and distribution of sambar in an area.

Cover : A dense under cover in forests have been acknowledged to be preferred by sambar (Schaller 1967, Richardson II 1972, Dinerstein 1979, Lo 1985, Johnsingh 1983; Aynn 1986). In Rajaji National Park(Johnsingh & Rawat, unpubl. data) found that sambar prefer areas with >40% shrub cover and >50% grass cover of tall (1-2m) grass.

Water: Apart from requirements for drinking, Sambar stags require water for wallowing during rut. They are believed to have a significant dependency on water (Aynn 1983, Johnsingh 1983).

Interspersion of habitats

Leopold (1961) recognized greater habitat interspersion as being favorable for most ungulates. Karanth (1989) observed that in Nagarhole, sambar preferred teak dominated forests which had higher habitat heterogeneity (in terms of the edge effect created due to tree fall gaps and strips of natural moist deciduous forests in between larger patches of the teak dominated forests). This resulted in a higher species diversity and forage availability in the teak dominated forests.

Effect of human interference:

This effect is not well documented in literature. Panwar (1982) and Saharia (1982) feel that increased interference in the wilderness in terms of cattle grazing, woodcutting, poaching, etc. may have adverse effects on ungulate populations. Verma (1982) suggests that such pressures are high in various parts of the Rajaji and Motichur sanctuaries. Rashid (1982) and observe that stoppage of grazing in some wildlife reserves has resulted in increased ungulate populations.

1.13. Sambar abundance

Studies on ungulate habitat relationships in south-east Asia give density estimates for sambar. These are from Kanha (Schaller 1967), Wilapattu (Eisenberg and Lochart 1972)*, Bardia (Dinerstein 1980), Chitwan (Tamang 1982)*, Bandipur (Johnsingh 1983), Kadarnath Musk Deer Sanctuary (Green 1987) and Nagarhole (Karanth 1989). The sambar density in these areas are 0.9, 1.2, 3.5, 2.7,7, 1.1 and 5.5 per square kilometre, respectively.

On the whole literature suggests that sambar is a generalist feeder and has adapted to varied habitats. It prefers various forests on the hills, with dense undergrowth and close to water.

* quoted from Karanth (1989)

There are indications that it avoids disturbances but the effect of level of disturbance is not available.

1.2. Objectives of the Study

Keeping the above infofmation in view, the study was designed on the following objectives:

1. to determine the categories of preferred habitat component such as terrain, slope (hills and plains), vegetation type, tree canopy, shrub and grass cover.

2. to assess whether disturbance is a significant factor determining the sambar distribution and abundance.

The hypothesis that sambar uses the habitat categories (listed above) in proportion to its availability and it avoids areas under biotic disturbances will be tested.

CHAPTER 2:STUDY AREA

2.1. Administrative and General.

The study area, Dholkhand range (30°E;78°N) is located in the south-west part of the Rajaji National Park (824 sq. km.) (Figure 1). The Government had declared its intention to create this national park in 1983 by merging the Chilla Wildlife Sanctuary (WS), to the east of the Ganges and the Rajaji and Motichur WS, to the west of the Ganges. The legal procedures necessary to complete the National Park (NP) process are however incomplete. Human interference in terms of internal and external populations of pastoralists, grass, fuelwood and other MFP collectors is considerable (Verma 1983). The NP includes parts of Dehradun, Saharanpur, Hardwar and Tehri-Garhwal districts (Osmaston & Sale 1988).

The Park has two main conservation values (Rodgers et. al. in prep). Firstly, it includes a large area of the fragile Siwalik system. The fauna and flora of this region have affinities to the Himalayan and the Gangetic plain biogeographic zones (2 & 7 respectively) (Rodgers & Panwar 1988). This report, however includes the NP in the biogeographic province 7A (northern gangetic plain) of their classification. Secondly, the NP is home to the most north-western population of the Asiatic elephant (*Elephas maximus*). This population is connected to the population at Corbett National Park by a narrow corridor which is under

considrable developmental pressure. Genetic isolation of the two populations is imminent. This may, in due course diminish genetic hetrozygosity due to increased inbreeding within the population, thus threatining the very existance of the elephant populations.

2.2. Physical.

The NP is bisected into the north and south parts by the Siwalik ridge system, which are aligned almost parallel to the Himalayas in this region (Plate 1). The Siwalik ridges consist basically of the material eroded from the Himalayas and deposited at its base. This unconsolidated deposits of sandstone and conglomerates has recently (2-12 million years ago) been uplifted to an altitude of 1,200 meters above msl. in varying degrees from Pakistan (Salt ranges) to West Bengal (Rao et. al. 1979, quoted from Rodgers, et. al. in prep.).

There are significant differences in the geological and vegetational characteristics of the middle and upper Siwaliks and the north and south facing slopes. The upper Siwaliks are largely composed of conglomerates with alternate layers of sandstone and grits whereas the middle Siwaliks are composed primarily of sandstone with alternate layers of gravels and clays.

The north facing slopes are dip-controlled and usually gentle whereas the south facing slopes are usually steep (owing to the bearing of the upliftment) (see Plate 1 & 2).

On the higher slopes the soil has a thinner profile lying over

a strong bouldry sub-soil. The overall texture of the soil is coarse, sandy with high internal drainage and with moisture deficiency. The more stable sites of the deeper and gentle slopes have deeper and better formed soils with satisfactory drainage and water holding capacity. The soils of the region are usually acidic with pH between 5.2 and 6.5 (Yadav 1966, quoted from Rodgers et. al. in prep.).

There are recent and pleistocene deposits of boulders and alluvium to the south of the Siwaliks - the bhabar tract. The bhabar landscape consists of a series of pans consisting of boulder, gravel, sand and alluvium deposits of seasonal streams (`raus') and `nullahs' of the Siwaliks (Rodgers *et.al.*, in prep.).

The above mentioned site characters (soils, geology, terrain features) combined with land use and local climate should significantly influence the vegetation type and the habitat values for the wildlife. Such influences of site characters on the wildlife are however, poorly documented.

2.3. Climate

The Siwaliks have a continental monsoonal climate with three distinct seasons:

Monsoon: July to September (October)

Winter: (October) November to February (March)

Summer: (March) April to June.

(months in brackets are the transitional period.)

There is a significant spatio-temporal variation in the climate and microclimate of the area, primarily due to the relief and proximity to the Himalayas. The average annual rainfall varies spatially from 1,005 mm at Ranipur to 2,464 mm at Thano. The annual average for Dholkhand is 1,531 mm. The northern slopes, i.e. North of the upper Siwalik ridge records a higher annual average rainfall compared to the southern slopes, i.e. south of the upper Siwalik ridge (Rodgers et. al. in prep.). No clear records of temperature exist. Rodgers et. al. (in prep.) say that temperatures vary from a maximum of 45°C in May (with the monthly average of 39°C) to a minimum of 3°C in winter. Frosts occur from December to March and are known to influence the vegetation of the area.

2.4. Vegetation.

Vegetation mapping of this region has been attempted (Van Es 1972, Van Es 1978, Tiwari 1986, quoted from Rodgers, et. al. in prep.). Tiwari mapped the area based on the cover categories and physiognomic characters. This study reveals that the majority of the northern slopes (i.e. north of the upper Siwalik ridge) have forests with canopy cover greater than 50% (46.3% of the area), whereas the southern slopes have a majority of the area under a cover of less than 20% (61.8 % of the area).

Rodgers et. al. (in prep.) describe six different vegetation

communities for the NP area which are given below. The details of community structure and composition are discussed in Chapter 4.

1. The Sal (*Shorea robusta*) Forests. [1]
2. Mixed-Deciduous Forests.
3. Grassy Slopes.
4. Ravines and Cliffs.

The other two categories described in Rodgers et. al. (in prep.) i.e. Swamp Forests and Siwalik Pine Forests do not occur in the study area.

2.5. Fauna.

The Dholkhand area is home to a large variety of large mammals and birds. A few of them are listed below:

The Asiatic Elephant- *Elephas maximus* (Probosoidea , Elephantidae) Among the Artiodactyls are, the cervids - sambar, chital [*Cervus (Axis) axis*] and the barking deer (*Muntjacus muntjak*), the suid, wild boar (*Sus scrofa*), the bovids nilgai (*Boselephas tragocamalus*) and the grey goral (*Naemorhaedus goral*; Rupicaprinii).

The larger carnivores recorded from the area are the tiger (*Panthera tigris*), leopard (*P. pardus*) and jackal (*Canis aureus*).

The primates are represented by Hanuman langur (*Presbitis entellus*) and rehsus macaque (*Macaca mullatta*), which often form feeding associations with the ungulates (Johnsingh,A.J.T. pers. com.). The porcupine, *Hystrix indica* is fairly common and it

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[1]Full scientific names of the dominant plant species is given in Appendix 1.

damages *C. fistula* roots and *A. catechu* bark.

About 189 species of birds have been recorded from the Dholkhand region by Nitin D. Rai in his study on birds during winters and summer.

The kaleej Phesant (*Lophura leucomalana*), the mustalid yellow throated martin (*Martes flavigula*) and the goral suggest an Himalayan influence in the fauna of the region.

2.6. Human Interference

Human interference in the proposed NP is primarily in terms of use by Gujjars, village and 'tongya' dwellers. Gujjars are transhumant pastoralists. They spend summers (April to October) in the Himalayan pastures grazing their buffaloes and descend to the Siwalik forests by November. They stay here all winter till March/April when they start moving back to the Himalayas. During their stay in the Siwaliks they get fodder for their livestock mainly from lopping trees. Legally, a patch of forest is leased out to a 'dera' or a family, within which the are expected to lopp certain prescribed species. The Gujjars usually herd their buffaloes in the afternoon to the lopping site in the forest and let them feed on the lopped leaves all night. They on occasions also collect the lopped leaves and bring it back to the 'dera'.

Currently, the Gujjar population is on the increase. The pressures in certain patches such as Ranipur in Western Rajaji sanctuary are high owing to high grazing and lopping by Gujjars. Since 1985 the Government is making efforts to relocate the Gujjars

outside the park but their efforts are showing a limited response.

The tongyas are villages comprising of the erstwhile forest laborers. They largely depend on the forests for fuel and 'bhabar' grass (*Eulaliopsis binata*). Bhabar grass is extracted from the slopes mostly between November and March. This grass is utilized for making ropes by the villagers and also is used by paper mills. Outside the NP. it is extracted by the forest corporation but within the NP. the extraction is illegal in most parts. On a single evening I counted 75 individuals with headloads of grass on their way back, each with a load of approximately 35 kg.. The total biomass hence extracted would be to the tune of 4,025 kg. on that day from that region. These villagers also possess livestock which they graze in the forests along the fringes. They are also involved in the collection of fuelwood through out the year and minor forest produce such as honey, seasonally.

CHAPTER 3: METHODS

Introduction

Habitat preferences and distributional patterns of animals can be studied from the level of use relative to the availability of the resource (Neu et. al. 1974) or measures of relative abundance of animals in available habitats.

Neu et. al. (1974) suggested a technique for analysis of utilization-availability data. The logic behind this method is that the degree of utilization in itself should not be considered in isolation while interpreting preference or avoidance of a habitat type. The preference/avoidance of a habitat type or category should be interpreted in accordance to the availability of that category.

This method or its modifications have been widely used to determine the forage spp, preferences by ungulates (Krausman 1978, Collins et. al. 1978, both quoted from Marcum & Loftsgaarden 1980; Byers et. al.1983) and habitat preferences (Hirst 1975; Bloom 1978; Collins et. al. 1978, Marcum 1978; all quoted from Marcum and Loftsgaarden 1980 ,Scogings et. al. 1990). Neu et. al. (1974) rely on a 'mapping technique' for obtaining areas under a certain habitat category. This, as suggested by Marcum & Loftsgaarden (1980) is not always possible for areas which lack good vegetation maps, or for such habitat parameters as slope categories, vegetation structural and successional characteristics, distances

from water, ecotones or areas of human disturbance such as roads & logging areas. In addition to this, highly heterogenous habitats are also difficult to map. They, hence, suggest a 'non-mapping technique' for determining the proportions of the occurrence of different habitat categories in the study area. They found the method to be accurate for their study area where the proportions for vegetation types obtained from the above method matched closely with the proportions obtained from an accurate map.

Relative abundance of sambar has also been determined for different strata based on King census to compare different habitat types.

Some studies such as those by Ben-Shahar & Skinner (1988) and Eitchberger (1989) use multivariate analysis and discriminant analysis respectively to determine habitat preferences.

3.1. Sampling Vegetation and Terrain Features

3.11. Stratification

The stratification of the study area has been done based on the terrain features such as hills and plains, vegetation types and presence/absence of disturbance (human interference in terms of lopping, grazing of livestock and grass cutting). As has been discussed above and in the previous chapter, the hills are very heterogenous in terms of habitat features. The plains are relatively more homogeneous with respect to the tree cover. However, the under cover characteristics differ depending on the degree of human interference.

3.12. The Sampling Unit

Line transects (Sale & Berkmuller, 1988) were used to sample for the relative abundance, population structure, and habitat use by sambar. Based on the above mentioned (Section 3.2) features and feasibility, the 10 transects (6 in hills and 4 in plains) were laid as shown in Figure 1. The broad features of each transect are mentioned in Table 1 below:

Because of lack of sufficiently large homogenous patches, it was not possible to get replicate on habitat features finer than hills and plains.

To mark out the transects, a compass bearing was chosen from the survey of India, toposheet Nos: 53 F/16 and 53 J/4 for the study area, keeping in view the identified terrain features and vegetation types. An attempt was made to keep the transect straight but owing to the ruggedness of the terrain, it was not always possible.

3.13. Sampling for vegetation and terrain features:

Data on the vegetation and terrain features were collected at every 50m on the transects using the circular plot method (Sale & Berkmuller, 1988).

The purpose of this exercise was two fold - one for description of the habitat along the transect and two, for getting data on the availability of habitat features. Sampling along

transects gives useful data for determining the availability of habitat variables (Riney 1982).

The following variables were recorded:

1) Distance to water in kilometers.

2) Terrain type: the slope category in degrees varying from Flat to 90° was measured using a clinometer at the center of the 5m plot.

3) Position on slope: i.e. valley, on slope, ridge line, flat,

4) Aspect: (for the hills) the aspect was observed by a magnetic compass as N, NE, E, SE, S, SW, W, NW.

The above factors may affect the vegetation type (VT) of the area.

5) The broad VT was recorded for each plot. Nine vegetation types were identified as sal forest (SF), mixed forest (MF), mixed forest, plantation (MFP), mixed forest, riverain (MFR), mixed forest slope (MFS), mixed forest slope, grassy (MFSG), mixed forest shady valley (MFSV), mixed forest slope with sal (MFSS) and sal forest slope (SFS) (Figure 2). The structure and composition of these VTs would affect the plant species availability and the degree of availability for sambar.

6) The percent tree canopy cover was visually estimated within the plot as a projection of the canopy on the ground. This is mainly expected to affect the sambar for shade and as a variable determining the scrub cover and grass cover in the area that are expected to have direct bearing on the sambar for food and cover availability.

7) The percent shrub cover was assessed for the 5m radius plot in a manner similar to that for trees.

8) The percent grass cover was measured in 3 randomly placed 1m radius plots where the grass height and the broad association (2 dominant species) was also recorded.

9) Other data on trees: Within the plot all the trees (gbh $\geq$ 20cm) were enumerated. Their height, numbers lopped and number of trees with branches below 2.5m (deemed available to the sambar) were counted.

10) Other data on shrubs: within the plot, all the shrub species were enumerated. This included sampling of tree species with gbh < 20cm. The average height of the shrubs, species wise was also recorded.

11) The wild ungulate and cattle dung was counted for each of the 5m radius plots..

The tree and shrub density was calculated for individual plots, VTs and species. Based on the number of trees with branches below 2.5m in each plot, the density of such trees has also been worked out, as an index for forage availability.

Such calculations along with frequencies of different variables have been worked out for all vegetation types. Most calculations have been done using the package, SPSS/PC+. Further details are given in Chapter 4.0, Results.

3.2 Utilization-Availability Analysis

The concept behind this method is mentioned in the introductory part of this chapter. More details are available in Neu et. al. (1974), Byers et. al. (1980) and Marcum & Loftsgaarden (1980).

3.21. Utilization

Data on utilization by sambar was collected along transects. Each of the eight transects was walked 4 times every season (December to February mid - winter and February mid to April - Spring/summer). Transects TH6 and TP4 were walked 3 times each in a season. The data was collected on parameters as detailed in section 3.13. above at each sighting.

Apart from the regular transects, areas were searched for sambar once every season in areas close to the marked transects. These searches were largely confined to the ridges from where the possibility of sighting animals was found to be better. The objective was to mainly collect data on utilization of habitat. Hence, in each season, 6 'wanderings' each measuring approximately 3 km. were walked in the hills and 4 in the plains.

3.22. Estimation procedure for availability of habitat variables

According to Marcum & Loftsgaarden (1980) there are 'n' randomly distributed points in the study area with 'k' areas or habitat categories. The problem is to estimate the proportion of each of the 'k' areas which is statistically similar to estimating

the parameters in a multinomial probability model with 'k' classes. Marcum & Loftsgaarden (1980) suggest a procedure of first gridding the study area and then randomly selecting a sufficiently large number of grids from the map. Plot(s) are laid within these grids where data is collected on the habitat parameters of interest. Proportions for each habitat category is then calculated. The non-mapping technique was used in the present study owing to the lack of an accurate vegetational map of the area, high degree of habitat heterogeneity and inability to find relative areas for the other finer habitat categories identified to be used in the study. Further details on analysis of the data are given in a later section of this Chapter.

In the present study the method has been modified keeping in mind 2 reasons:

1. The data collection for estimation of relative abundance and utilization by sambar was along transects which would be regularly monitored. As only these paths were being monitored for utilization, the availability of the habitat variables have been seen only along these paths.

2. collecting information from randomly distributed grids in the study area is time consuming and so would have not been feasible for this short term study.

3.23. Statistical analysis

The statistical validity of the utilization-availability data may be assessed using Chi-square test with a hypothesis that animals use the habitat or habitat category in proportion to its availability which has a multinomial distribution (Neu et. al. 1974, Byers et. al., 1980 & Marcum & Loftsgaarden, 1980). If the calculated Chi-square is significant at the desired level of significance, the null hypothesis is rejected. This means that the habitats are not used in accordance to their availability. One will now have to examine which habitat categories are causing the significance of the Chi-square statistic. This involves construction of simultaneous confidence intervals for the theoretical proportions of occurrence of the multinomial distribution in order to determine whether the expected values lie within the magnitude of significant effects. An important adjustment required in the calculation is for the Z statistic to be used in constructing the CIs. Neu et. al. (1974) explains this as follows:

"When estimating a single parameter, the probability of obtaining an incorrect interval estimate is controlled at a 'level of significance' α. The resulting interval estimate is termed $(1-\alpha)100$ percent confidence intervals. When estimating 2 or more parameters simultaneously, however, the probability that any one interval estimate is incorrect increases beyond and is partially dependent upon the number of estimates being made. In order to bound the probability error rate at α i.e. the probability that

atmost one interval estimate is incorrect, a scaling down of the significance level of each estimate is required. The resulting interval estimates are termed a (1-α)100 percent 'family' of CIs with a (1-α) confidence coefficient".

The Z statistic used here is $Z_{(1-\alpha/k)}$ instead of $Z_{(1-\alpha/2)}$ where k is the no. of habitat categories). These are the Bonferroni normal statistics (Muller, 1966; quoted from Neu et.al., 1979). Hence at the level of significance the resulting CI will be slightly wider for each multiple estimate than for an estimate of one parameter only. The form of confidence intervals hence is:

$$P_i - Z_{(1-\alpha/2k)} \sqrt{P_i(1-P_i)/n} < P_i < P_i + Z_{(1-\alpha/2k)} \sqrt{P_i(1-P_i)/n}$$

where P_i is the proportion of animal sightings in the i^{th} habitat category and m is the sample size, the number of animal sightings. P_i is the true proportion of sightings in the i^{th} habitat category. The above calculations have been done by using a software developed at WII, Dehradun.

Neu et al 1979) and Marcum & Loftsgaarden (1980) pose two assumptions that should be met in any study using their method. They are:

1) that the animal has an opportunity to select any habitat which is deemed available, and

2) that observations are collected in a random and unbiased manner.

The first assumption is clearly met in this study. As mentioned earlier, the utilization data was collected along 10

transects and/or search paths that were deemed to be random for all practical purposes. Any sighting which was judged to be a repetition of a previous one was excluded from the data. Sambar are secretive, cryptic animals and are often not easy to observe. The transects were walked with caution so as to see the sambar early and record the observations from unflushed animals. Inspite of the caution a certain amount of observational bias could not be avoided. However, this bias would be insignificant as there are a large number of sightings (n=356).

The cover differed in different areas and so did the visibility. Further discussion on this is detailed in the Chapter 4.

3.3 Sambar Abundance

The transect was started an hour after sunrise at 0730 hrs. during winters and 0630 hrs during spring/summer. At each sambar sighting, their age, sex, and numbers for each category were recorded along with the angular sighting distance (r_1) and the location on the transect. As mentioned below the density (D) was then calculated using the King census formula.

Density expressed in terms of either individuals/ unit area or as an index to numbers such as numbers of faecal droppings per 100 stations can give useful information on use (Riney 1982; Rodgers 1988).

The King census (Mosby et. al. 1963; quoted from Riney 1983) is a robust and flexible method of gathering density estimates.

The density D is given by:

$$D=n/2Lr$$

where, n is the no. of animals seen on the transect, r is the mean sighting or flushing distance & L is the length of the transect. This estimator has been acknowledged to be good for getting density estimates for monitoring trends of the population (Rodgers 1988[a]). Each transect except TP4 and TH6 were walked 4 times each during winter and spring/summer respectively.

3.31. Limitations of density estimates

1. The transects in hills were not always a straight line.
2. There was considerable heterogeneity of habitat in hills and also plains, along the transect.

Riney (1983) while taking about the limitations of King census says:

> "The method is <u>not accurate</u> when the cover is sufficiently dense to permit some animals to move away from the observers range of vision without being seen, ... It is probable that the method can be used on most game species where there is <u>not more than 15% cover</u> of shrub or trees exceeding the height of the animals".

Keeping these in mind, the encounter rate (no. of sambars seen per km/transect) as a rough estimate of abundance has also been calculated.

Every 50m along the transect, sambar pellet groups and cattle dung was counted in 5m radius plots. This was done in November/December, at the beginning of the study and in April, at the end of the study. These allow comparison of sambar abundance between transects, between hills and plains, and between habitats. The increase in the number of pellet groups between November and April was also compared for each transect and for hills and plains separately. Z test and the students' t-test were used for these comparisons.

CHAPTER 4: RESULTS AND DISCUSSION

This Chapter is divided into three sections. Section 4.1 gives results of vegetation studies; section 4.2 gives the results of the utilization-availability analysis and discusses the habitat selection based on the vegetation studies; section 4.3 gives the sambar abundance and discusses the trends with the help of vegetation data.

4.1. Vegetation Studies

The primary objective of this study was to enable habitat (VT) description in terms of the species composition, abundance of species and habitat values based on the proportion of palatable species and species with cover values (for shrubs). This section primarily presents the results and the discussion follows in section 4.2 and 4.3 below.

Vegetation types - description

Based on physiognomic features the vegetative types have been classified into nine major categories, viz. a) Sal forest (SF), b) mixed forest, plantation (MFP), in the plains, c) mixed forest (MF), d) mixed forest, riverain (MFR), occurring in both plains and hills and e) mixed forest, slope (MFS), f) mixed forest, shady valley (MFSV), g) mixed forest slope, grassy (MFSG), h) mixed forest slope with sal (MFSS) and i) sal forest slope (SFS). The details of classification with analogies to Champion and Seth (1968) are dealt in Rodgers et. al. (in prep).

4.11. Sal Forests (SF): (Plate 2)

This forest occurs on the plains and covers about 22% of the area sampled. The dominant tree species were *S. robusta (34%), Mallotus (26%), Lagerstroemia (19%) and Ehretia* (7%) (see Table 2 & 11 for more details on density, species richness, percent tree cover, etc.). Twenty of the 31 species present are known to be palatable to ungulates (judged based on Johnsingh, A.J.T. & personal observation) (Table 11). Among the more common ones are *Mallotus (26%), Ehretia (7%), Miliusa (3%) and Z. xylopyrus (3%).*

Mallotus is the primary shrub species (48%) followed by species such as *Millettia (9%), Lagerstroemia (7%), Holarrhena (6%) and Adhatoda (4%)* (see Table 1 & 12 for more details on density, percent shrub cover, species reduces and no. of species with cover and forage values). Of the 23 species of shrubs present, 11 are known to be browse species. The major ones apart from *Mallotus are Flacourtia (3%), Miliusa (2%), Ehretia (2%).*

Chloris predominates in the grass layer which is on the whole sparse. Three out of the 5 species present are known to be palatable.

4.12 Mixed forest plantation (MFP):

This forest covers about 12% of the area sampled.

The plantation mainly consists of species such as *A. catechu (24%), D. sissoo (5%), T. grandis (4%) and Aelanthus (2%).* The dominant tree species apart from *A. catechu* are *Ma lotus* (18%),

Ehretia (17%) and *Holarrhena* (8%) (Table 3 and 12). Twenty five out of the 37 species present are known to have forage values to sambar. Important forage species are *A. catechu, D. sissoo, Mallotus, Ehretia and Aelanthus* (See details are given in Table 3 and 12). About 14% of the trees were found to be lopped to some degree of intensity.

Adhatoda (62%), Colebrookia (13%) and Holarrhena (12%) constitute the bulk of shrubs present. Five out of the 14 species present are known to have forage values. They, however have a sparse occurrence (8.5%). Some of the more important species are *Ehretia (3%) and Mallotus (1%)* (Tables 3 & 11).

The only grass species recorded in this type was *Chloris* which did not show any browsing signs. The proportion of areas devoid of any grass cover was high (44.3%).

4.13. Mixed forest (MF):

This forest constitutes 8% of the total area sampled-38% of this occurred in the plains and 62% in the lower slopes, always within 15° slope category (Table 14).

Mallotus (25%), Lagerstroemia (11%), Holarrhena (10%), C. fistula (9%) of Z. mauritiana (8%) form the dominant tree species in MF. Twenty eight out of 42 species of trees present are known to be palatable. The more common ones apart from *Mallotus and Z. mauritiana are Ehretia (4%) and Z. xylopyrus (12%)* (Table 4 and 11).

The common shrub species in these forests are *Adhatoda (36%), Lantana (16%) Mallotus (13%) and Colebrookia (10%). Helicteres (6%)* found mainly on the lower slopes. Nine out of the 16 species are known to be palatable. the common species are *Lantana, Mallotus, Helecteris and Ehretia (2%)* (Table 4 & 12).

Chloris, followed by *Cynodon and Imperata* are the most important grass species. *Cynodon and Chrysopogon* are the two species of the 4 species recorded known to have forage values for ungulates.

4.14. Mixed forest, riverain (MFR):

This forest consisted 10% of the sampled area, 85% of which occurred along valleys and 25% on the plains.

Mallotus (40%) dominates the area with occasional species such as *Z. mauritiana (7%), C. fistula (6%), Holarrhena (5%), C. myxa (5%), Syzygium (4%) and C. robusta (4%).* Sixteen of the 42 tree species present are known to have forage values. Apart from *Mallotus, Z. mauritiana and C. myxa*, some other species with forage values are *Ehretia (3%), D. sissoo (2%) and Phyllanthus (2%)* (Table 5 & 11).

Mallotus (24%), Colebrookia (22%) and Helicteres (20%) are the important shrub species. Eight out of the 17 species present are known to have forage values. The more common ones are *Mallotus, Helicteres, Ehretia (6%), C. myxa (5%)* (Table 5 and 12).

Chloris, Cynodon, Imperata and Chrysopogon are the common grass species. Five of the 9 spec..es that were re:corded are known

to have forage values. They are *Chrysopogon, Apluda, Arundinella and Cynodon* but their occurrence is low.

4.15. Mixed forest slope (MFS): (Plate 1,3 & 5)

This VT ocurred in about 23 % of the study area. Eight four percent of the plots occurred between south-east to north-west aspects suggesting a degree of association. These forests occurred mostly on slopes between 16 to 30° (46%) (Tables 13 & 14, respectively).

Mallotus (16%), S. robusta (13%), Anogeissus (9%), A. catechu (8%), Z. xylopyrus (8%), Nyctanthes (9%) B. variegata (6%) and Ougenia (5%) are the common tree species. Among these all except *S. robusta* (mature leaves) are known to have forage values. Twenty six of the 49 species present are known to have forage values (Table 6 & 11).

Shrub species such as *Colebrookia (25%), Mallotus (17%), Helecteris (10%), Holarrhena (9%), Woodfordia (7%), C. opaqua (5%)* are more common. eighteen of the 29 species present are known to have forage values, among them are *Mallotus, Helicteres, Woodfordia, C. opaqua, Z. xylopyrus* (Table 6 & 11).

Grass is usually more abundant in MFS than the previous types. *Chloris, Chrysopogon, Eulaliopsis, Heteropogon, Imperata and Neyraudia* are the more common grasses. Five out of nine grass species are known to have forage values.

4.16. Mixed forest, shady valley (MFSV)

These forests occur in about 14 % of the study area and form galleries, usually on the south-west, west, north-west and northern slopes (73.7%). They are shady due to the aspect, terrain and because they mostly have trees covered with Bauhinia vahlii.

Tree species such as *Mallotus (23%), S. robusta (19%), B. variegata (8%), Ougenia (7%) and Anogeissus* are more common. Twenty three out of 39 species that occur in this are known to be palatable. All of these except sal are known to have forage values (Tables 7 and 11).

Collebrookia (45%) followed by *Mallotus (32%)* forms the bulk of the shrub species present. Apart from *Mallotus, Helicteres (5%), Ehretia (3%), Dendrocalamus (2%)* there are 8 other species out of 29 species present in this VT known for forage values (Tables 7 & 12).

Neyraudia, Arundinella, Chrysopogon and Apluda are the more common grass species. Apart from these there are 2 other palatable species out of the species recorded for MFSV.

4.17. Mixed forest grassy slopes (MFSG): (Plate 1,2,3)

These forests were common mainly along the ridge lines and upper slopes.

The tree layer is dominated by such species as Mallotus (14%), *S. robusta (11%), Anogeissus (10%), Ougenia (9%), Z. xylocarpus (8%)*

and A. catechu. Apart from *S. robusta* the rest mentioned above are known to be palatable for ungulates. Others such as *B. variegata (6%), Ehretia (5%), and Nyctanthes (2%)* are also forage species (Table 8 & 11).

The common shrub species are *Collebrookia (23%), Holarrhena (13%), Mallotus (12%), Woodfordia (10%), Z. xylopyrus (8%).* Eleven out of the 25 species present have forage values. Some of them are *Mallotus, Woodfordia, Z. xylopyrus, A. catechu (7%) and B. variegata (6%) and Ehretia (5%).*

Chrysopogon, Heteropogon, Imperata and Chloris dominate the grass layer which is always significant. Five species of the seven recorded are known to have forage values. These are *Chrysopogon, Heteropogon, Neyraudia, Apluda and Eulaliopsis.*

4.18. Mixed forest slope with sal (MFSS):

Ninety six percent of the plots under this VT occurred on moderate slopes, from 0 to 30° on the slopes (Table 14) between south-east and southwest aspects (Table 13).

S. robusta (39%) forms the dominant tree layer followed by *Mallotus (15%), Ougenia (7%), Lagerstroemia (7%), Ehretia (5%), C. fistula (4%),* etc. Nineteen out of 29 tree species are known to have forage values (26.4% are with available branches). Tables 9 & 11). Some of them are *Mallotus, Ougenia, Ehretia, Z. xylopyrus (3%).*

Mallotus (15%), Holarrhena (21%), C. fistula (20%), Collebrookia (15%) and Ehretia (9%) are the dominant shrub species.

Only 7 out of the 14 species of shrubs present are palatable (contributing 59% of the forage) (Table 9 & 12). *Mallotus, Ehretia and Helicteres (1%)* are the relatively common palatable species present.

Grass layer is poor and patchy *Neyraudia, Chrysopogon, Chloris and Heteropogon* are the important grasses present. Four *(Neyraudia, Chrysopogon, Heteropogon and Eulaliopsis)* out of the 6 species present have forage value for ungulate.

4.19. Sal Forest slope (SFS):

Among the more common tree species are *S. robusta (47%), Mallotus 914%), and Ehretia (9%).* Eleven out of the 18 species present are known to have forage value and provide about 26.6% of the available branches (Tables 10 and 11).

Mallotus (41%), Adhatoda (15%), C. fistula (8%) and Holarrhena (8%) are the dominant shrub species present. Six species with forage values are present out of 12 species present. The dominant are *Mallotus* (Table 10 and 12).

Chloris and Chrysopogon are the common grass species present. Their distribution is sparse. *Chrysopogon and Heteropogon* are the two grasses of the 4 present that have forage value.

4.2. Habitat Utilization (Based on Utilization-Availability Analysis)

Habitat selection by sambar in the study area as determined by calculation of the Bonferroni Confidence intervals (CI) is the major focus of this section. Preferred (+) (when the CI>relative area (RA) signifies that that habitat category is used significantly more than its availability; avoided (-) (when CI< RA) signifies that the category is utilized significantly lower than its availability and 'o' (CI includes the value of the RA) means that the category is used in proportion to its availability. Categories have been merged if the number of sightings in the category was low (<5).

4.21 Results

The data on utilization and availability of habitat categories were directly analyzed by the program available (see Chapter 3.0) without subjecting the data to a Chi-square test for significant differences between used and available habitats. The significance presents itself in the output of utilization-availability analysis itself (see Table 16).

The null hypothesis is that all the habitat categories are used in proportion to their availability.

Hills & Plains: The null hypothesis is rejected. Hills are preferred and plains avoided in both seasons.

Vegetation type: The null hypothesis is rejected. In winter the MFS is preferred and the plain VTs, MFP and SF are avoided. The

other categories are used in proportion to their availability preferred trends are some during summers (Kurskal-Wallis 1-way ANOVA, Chi square = 0.026; p>0.05).

Tree cover: The null hypothesis is rejected. During winters low tree cover (0-15%) is preferred whereas the others are used proportionately. The 0-15% category is preferred during summers too but the higher category of >45% is avoided.

Shrub cover: The null hypothesis is rejected. During winters the category 16 to 30% is preferred and the categories 31-45% and 61-75% are avoided. In summers however, the 0-16% category is preferred and the shrub cover from 16 to 60% is avoided. The other categories in the two seasons are used in proportion to their availability.

Grass cover: The null hypothesis is rejected. A high grass cover (>75% is preferred in winters whereas the lower grass cover classes 0 to 45% are avoided. The categories 46 to 75% are used in accordance to availability. During summers lower category 46 to 60% is preferred and the lowest category 0 to 15% is avoided., The others are used according to availability.

Disturbance: The null hypothesis is accepted during winters i.e. both categories (lopped & unlopped areas) are used in proportion to their availability. In summer, however the null hypothesis is rejected and the lopped areas are avoided.

Terrain type: The null hypothesis is rejected. The moderate to high slope categories of 16-30', 31-45' and 46 to 60' are preferred during winter. The very steep slopes of 46 to 60' and the low category 0-15 and 16-30' are avoided. During summers the 16-30' slopes are preferred and others are avoided.

Aspect: The null hypothesis is rejected. During both seasons the southern aspects (SE to W) are preferred and northern aspects (NW to E) are avoided.

4.22. Discussion

Owen (1972) (quoted from Johnson 1980) noted that animals can exercise selection at different scales. This fact has been recognized by Wiens (1973) (quoted from Johnson 1980) while studying breeding birds. Johnson (1980) explains the ordering of the selection process. First order selection can be defined as the selection of the physical or geographical range of a species within this range, the second order selection determines the home range of an individual or social group. Third order selection deals with the usage mode of various habitat components within the home range. The fourth order selection deals with the food species or plant parts selected by the animals.

In the present study, the first order selection is known i.e. sambar are present within the study area. The data collected in the study pertains only with the third order selection.

Data regarding the fourth order selection was not recorded. As evident in the Section 1.1, information regarding the feeding ecology of sambar is lacking. The selection of a vegetation type by an animal may be induced due to the plant components within it. In this analysis, first, the preference of VTs is being considered followed by other biotic and abiotic factors.

4.221. Habitat preferences

Hills are preferred (Table 15 a) but plains are avoided in both seasons. This is consistant with the findings of Schaller (1969) and Johnsingh (1983). The MFS which contributes 23% to the sampled area shows preference by sambar in both seasons where as the plain VTs, MFP (12%) and SF (22%) are avoided in both seasons. The other VTs are used in accordance to their availability except MF which is preferred during summers (no. of sightings-39). Most of these sightings however occurred in broad valleys in the hilly region.

Preference of VTs should not be seen in isolation but should be considered in relation to food and cover requirements. The habitat variables recorded in the study, may be included under these habitat requirements as follows:

1. Food:

a) Assessable branches of tree species with forage value,

b) shrub species with forage value,

c) grass cover species with forage value.

2. Cover:

a) tree canopy cover (TCOV) for shade,

b) shrub cover (SCOV) for thermal and escape cover.

c) terrain type (TTY) for escape and thermal cover,

d) aspect (ASP) dealt with as a factor influencing temperature on slopes (western and northern aspects are expected to be cooler).

3. Disturbance: In terms of proportion of lopped and unlopped areas in the sampling and their respective proportions represented in animal sightings. Lopping is expected to open up canopy thus enabling greater shrub growth (with food and cover values or as a

weed) and provide forage from otherwise in accessible tree branches. It is also expected to cause disturbance to animals due to the direct presence of humans and grazing livestock which may compact the soil.

The terrain type along with aspect may influence the VT distribution (as suggested by Tables 13 & 14). Factors such as the TCOV, SCOV and Grass cover (GCOV) are correlated (TCOV & SCOV, r = 0.21, P<0.0001; TCOV & GCOV - r = 0.18, P <0.0001; SCOV and GCOV - r: 0.309). This would suggest a similarity in trends (positive or negative) in selection of these factors.

In MFS, and also MFSV and MFSG the available forage in terms of number of trees (with forage value) with assessable branches (30, 51 and 35% respectively and number of shrubs (54, 49 & 59% respectively and grasses with forage value is moderate to high (Tables 11 & 12). What may further be noted in that within these VTs the number of palatable species present in the dominant 80% of the tree species is 8, 7 and 7 respectively and 6, 2 and 4 palatable shrubs respectively is relatively higher (Table 7, 11 & 12). On the other hand, VTs such as SF and MFP that are avoided have lower number of palatable species (2 trees, 2 shrubs, 4 trees and 0 shrub respectively and the bulk of forage is provided by a single species in SF (*Mallotus* 25% for trees and 48% for shrubs). A similar trend is seen for MFSG and SFS (Tables 2 to 12). MF and MFR are used in accordance to availability during winters but during summers the level shifts to preference. This may be owing to increased availability of succulent leaves of *Mallotus, Z. mauritiana and Ehretia*. These VTs also have a higher proportion of assessable branches of palatable trees and shrubs. The abundance

of 'cover' shrub species is almost equal for all VTs. In SF, however, the average height is low (0.96 m) which enables good visibility. this may discourage sambar to use the habitat. Literature (Prater 1965; Schaller 1967; Richardson II 1972; Johnsingh 1983; Aynn 1986) suggests that sambar prefer areas with dense cover (especially undercover). This, (as will also be discussed in the next section) holds true in the study only for the plain forests of MFP and SF where all sightings occurred in areas with > 50% shrub cover, > 1.5 m high. The hills (MFS, MFSV and MFSG) however show a different trend. These areas dominate in the tree and shrub cover category of 0-15 % and 16-30 % (Tables 16 & 17). These categories also show preference (Table 15 c & d).The hills usually command a good view of the area around. This proves to be a contradiction of what the literature suggests. A possible explanation follows:

Schaller (1967) and Rodgers (1988[b]) include sambar under the feeding style 'generalist grazer/browser' which suits its body size (it is the largest cervid in south-east Asia (Whitehead, 1972). However, it is known to occur in small groups of about 3 animals and is said to rely on 'crypsis' to avoid detection (Schaller 1967) a typical character of a concentrate selector, forest loving species (Geist 1974). This latter concept suits the preference of dense cover suggested in literature. It is hypothesized that "the requirement of 'crypsis' as a anti-predatory strategy in hills is abandoned by sambar to some extent because of its greater ability to spot danger from where it is, and take appropriate action for escape (into possibly the steeper slopes").

As is expected from preference of relatively lower tree and shrub cover by sambar in both seasons, it prefers higher grass cover in winter. In summer it prefers grass cover in the range of 46-60%. This however does not match well with the dominance of these categories in MFS, the preferred VT. It may be possible that sambar actually prefer to feed in areas with a higher grass cover within the MFS, MFSV and MFSG.

The southern aspects (west to south-east) that largely have MFS, MFSV and MFSG in slopes between 16 to 60 degrees are preferred (Table 15 g & h). The slopes above 31° show avoidance in summer. This may occur due to an overall drying of grass on these higher, steeper slopes but other succulent browse (Nyctanthes, Ehretia and grasses in shady valleys) are present in the lower slopes. Rodgers (1988) says that the green leaf fraction is 22 to 40% during November-December but goes below 10% as summer advances in Rajaji National Park.

4.222. Role of disturbance

The disturbed sites (in terms of lopping) are avoided by sambar during summers but are used in proportion to availability in winters. The level of lopping was relatively lower at the time of initial sampling in November (34%) but it increased to 50% by April.

The overall synthesis suggests that sambar prefer the hills which have:

Greater interspersion of habitat types (in terms of VTs and terrain (valleys, slopes, etc. which provide a good blend of food and cover values). Riney (1983) quoting A. leopold says "For a given species of herbivore, the more interspersed the habitat elements....the greater the potential for the land to carry higher populations of that species". It is the composite VT of the hills with the MFS, MFSV and MFSG, that provide browse, grass as well as good (shade) cover and escape cover that makes the hills more habitable for sambar. In the plains, probably, sambar have to relay more on avoiding detection by being cryptic in dense under cover, as a anti-predatory strategy.

4.3 Sambar Abundance in the Study Area

4.31 Sambar density on the transects:

The sambar density and encounter rate (numbers sighted per kilometer transect walk) is presented in Table 19 for the winter and summer seasons. It is evident from the table that during winters the hilly, disturbed transect TH6 shows the highest density (94/sq.km.) followed by the relatively undisturbed hilly transect, TH4 (69/sq.km). The undulating, disturbed transects TH1 and TH5 show moderate density (29 and 24/sq.km. respectively). The other disturbed, hilly transect TH2 has a density of 17/sq.km. and the relatively undisturbed hilly (with a major riverain element) shows a very low density compared to the rest (8/sq.km.). In the plains the density is some what lower. It is highest in the relatively undisturbed sal forest (SF) transect, TP4 (45/sq.km) followed by the transect in the disturbed mixed plantation forest transect (MFP), TP2 (29/sq,km.), the disturbed SF transect, TP2 (23/sq.km.) and last, the disturbed SF transect TP 1 (4/sq.km.) which is characterized by a high shrub cover but of a very low height.

During summers the encounter rate on all transects except TH3 was lower than their corresponding values for winter. TH4 had the highest density (44/sq.km.), followed by TH6(27), TH2 (2), TH1(14), TH5(7) and TH3 (6/sq.km.). In the plains, TP4 again recorded the highest density (26/sq.km.) followed by TP2 and TP3 (3) and TP1 (2).

4.32. Discussion

4.321. Density in different seasons

a) Winter: The sambar density on transects TH1, TH4, TH5 and TH6 (29, 69, 24 & 96/sq. km. respectively) are high (Table 19) whereas density of TH2 and TH3 is lower. The proportion of areas under the VT, MFS, the preferred VT (Table 15b) in the transects with higher density is greater (Table 20). The transect TH2 17/sq. km.) has a high proportion of area under MFSG (Table 20) which is degraded (Plate 4 & 5). It however has shady valleys and relatively undisturbed slopes where most of the sightings occurred. The transect TH3 first passes in a wide valley and then goes in the lower slopes of hills. This transect has large proportions of area under MFR which is avoided by sambar during winters and summers (Table 15).

In the plains the sambar density is comparable in transects TP2 and TP3 (29 & 23/sq. km. respectively) (Table 19) but is much lower in TP1 (4/ sq. km.) and much higher in TP4 (45/sq. km.). TP1 dominates in the VT, SF (Table-20) which is avoided so is TP2 which dominates in MFP which is avoided (Table 15b). The transect TP3 dominates in SF but has a significant area under MF which is not avoided (Table 15 b). The transect TP4 shows a very high density although it dominates in SF. The possible reasons have been discussed in a later section.

An important point to note here is that although the encounter rate is low for TP2 (0.4/sq.km. walk), the density is fairly high

(29/km²). All the 4 sightings occurred in the first 1.15 km of the transect. In this area the shrub cover is high and visibility is restricted. The mean sighting distance for this transect, thus was very low (9 m) causing an inflated density figure. No sambar was sighted in the remaining 1.5 km. of the transect.

b) Summer: There is a decline in the overall density for all transects, especially in the two plain transects TP2 and TP3 (Table 19). Possibly reasons are discussed below.

4.322. Between season density

The overall density (Table 21) between seasons within the category hills is significantly different (One tailed $t=8.83$; $P<0.05$). The same trend holds true for the plains (one tailed $t = 2.16$; $P<0.05$). It is clear that the over all density for the hills and plains, respectively is higher during winters. There is a decline in the encounter rate in all the transects (except TH3) during summers. This decline may be a result of an outward migration towards the northern, sheltered slopes and other 'raus' which had more water. A carefully designed study to test the temporal changes in density is required.

Another reason for the lower density figures during summers may be due to the higher temperature regimes during the sampling period (0630 hrs. to 1000 hrs. approx.) which would have made sambar to retreat to cooler vallleys, away from the transects.

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5.0. CONCLUSIONS

Based on the utilization-availability analysis of the habitat types for a number of habitat variables it is inferred that sambar in Dholkhand prefer hills and the VT mixed forest slopes (on the southern aspects and with moderate slopes). Hills have greater interspersion of habitats which provide the required food and cover. Sambar prefer areas with low to medium shrub cover in the hills whereas in the plains, the reverse was found the case. This preference of dense undercover is reported in literature too. The unexpected result indicating preference by sambar for low shrub cover in the hills may largely be due to its antipredatory strategy. It may prefer denser cover in plains to escape detection whereas in the hills its ability to detect danger may be enhanced. Terrain itself may act as escape cover. These conditions in the hills may encourage it to use more open habitats which have a greater availability of grasses and browse.

Abundance of sambar was also found to be higher compared to that of plains. The sambar abundance in areas with lopping in the hills did not differ significantly from the areas that lacked lopping in the hills. The same trend is revealed in the utilization-availability analysis where in winters the lopped and unlopped areas were used in proportion to their availability. It was however avoided to some extent during summers when the extent of lopping increased significantly.

Some limitations of the study:

During the course of this study, certain habitat variables have not been given due weightage. Few of them are, the availability of water, or in other words the distance to water from the sightings and the distribution of resting and bedding sites in the study area. All the areas sampled in the study were within 3 km. of water sources. The optimal distance between a feeding/resting site and the water source is, hence not clear from this study. The four resting/bedding sites encountered in the study occurred in the mixed forest shady valley (MFSV) on the northern and western aspects. These may be a crucial habitat component, especially during summers.

Owing to greater availability of water and resting sites on the northern and western aspects, sampling of these areas is important.

Suggestions for a future study on sambar habitat use in this area:

For applying Neu et. al.'s (1974), utilization-availability method, it is crucial to get a large number of sightings. Apart from the regular transect walks, the walks along ridge lines (there is a profuse network of low and high ridge all over the Siwaliks that may exceed 2 km in length) were especially rewarding in terms of number of sightings. However, great care must be exercised in obtaining proportionate sampling for each of the habitat categories present.

To infer the influence of water on distribution and abundance of sambar, sites that are far from water sources should be chosen with comparable sites closer to water to assess the role of 'distance to water' as a habitat variable.

The areas closer to the main Siwalik ridge that have a distinctly different habitat type (see Rodgers, et. al. in prep. for more details) should be employed for sambar habitat use.

Some conservation questions:

The Rajaji sanctuary, like other protected areas in India is characterized by the presence of human population in and around the park that are dependent on the forests for lopping, grazing of livestock by Gujjars and villagers in the forests, grass cutting by villagers and occasional MFP collections (honey etc. that enhance the risk of warm season fires). Certain amount of wood poaching also goes on mainly along the perephery of the sanctuary (Verma 1982; Pers. obs.).

Such practices, if in certain limits may not be detrimental to the habitat but as is realized by conservationists, these practices may often go beyond the threshold and visible signs of deterioration may be seen in the habitat.

Lopping: Lopping may result in opening of canopy which may in turn encourage greater shrub growth. These shrubs in all probabilities may be weeds such as *Adhatoda* and *Lantana* as observed in plains. This may have negative effects on ungulate use of the habitats. On

the other hand, freshly topped leaves are known to be utilized by wild ungulates. This may have short-term benefits.

In the two highly lopped areas sampled in the hills there were patches of areas with dense shrub cover which were mainly *Woodfordia, Nyctanthes* which are palatable and *Colebrookia* which has good cover values. This area, thus did not show lesser use by sambar. This emphasizes that the intensity of lopping by gujjars is an important factor for both short term and long term conservation significance. Carefully designed studies are required to assess these values.

Grazing: Grazing within the study area does not form a significant factor.

Grass cutting: involves cutting the leaf blades of *Eulaliopsis* which is used for manufacture of paper and for rope making by the villagers. The selective cutting of a single grass species may decimate its abundance. There are also possibilities of enhancing the problem of soil erosion which is already significant in the Siwaliks. The physical presence of humans while they cut grass may temporarily scare away the wild ungulates. Again, the extent of disturbance or the impact this would make on ungulate distributions is not yet clearly known.

REFERENCES

Aynn, L.B. 1986. Sambar deer on St.Vincent NWR: Population statistics, Health and habitat use. M.Sc. thesis. University of Georgia, Athons, Georgia, USA. 90 pp.

Begon, M. J.L. Harper and C.R. Townsend 1990. Ecology-Individuals, Populations and Communities. Boston, Blackwill Scientific Publications. 945 pp.

Ben-Shahar and J.D. Skinner 1988. Habitat preferences of African ungulates desired by uni and multivariate analysis. Ecology. 69(5): 1479-1485.

Byers, C.R. ,R.. Steinhorst And P.R. Krausman 1984. Clarification of a technique of analysis of utilization-availability data. *J. Wildl. Manage.* 48(3):1050-1053.

Champion, H. and S.K.Seth 1968. A revised survey of the forest types of India. Nasik. Manager of Publication, Govt. of India.

Clements, F.E. and V.E.Shelford 1939. Bio-ecology. New York. John E.Wiley & Sons.

Dinerstein, E. 1979. An ecological survey of the Royal Karnalibardia Wildlife Reserve, Nepal. Part II: Habitat/animal/interactions. *Biol. Conserv.*, 256-300.

Eisenberg, S.F. and John Seidensticker 1976. Ungulates in southern Asia: A consideration of biomass estimated for selected habitats. *Biol. Conserv.*, 10:293-307.

Eitchberger, .C. , P.R. Krausman, and R. Hazaika 1989. Mountain sheep habitat characteristics in Pusch Ridge Wilderness, Arizona. *J. Wildl. Manage.* 53(4):902-907.

Flynn, L.B., S.M.Shea, J.C.Lewis and R.L. Marchinton 1990. Part III: Population statistics, health and habitat use. pp. 63-96. In : Ecology of sambar deer on St.Vincent National Wildlife Refuge, Florida. Bulletin No.25, Tall Timbur Research Station, Tallahassee, Florida.

Geist, V. 1974. On the relationship of social evolution and ecology of ungulates. *Am Zool.* 14:205-220.

Green, M.J.B. 1987. Ecological separation in Himalayan ungulates. *J. Zool. Lond.* 1:693-719.

Jarman, P. 1974. The social organisation of antilope in relation to thus ecology. *Behaviour.* 48:215-267.

Johnsingh, A.J.T. and K.Sankar 1991. Food habits of chital, sambar and cattle on the Mundanthurai Plateau, Tamil Nadu, South India. *Mammalia*. 55(1):57-66.

Johnsingh, A.J.T. 1983. Large mammalian prey predators in Bandipur. *J. Bombay Nat. Hist.Soc.* 80(1):1-57.

Johnson, D.H. 1980. The comparision of usage and availability measurements for evaluating resourse preference. *Ecology*. 61(1):65-71.

Karanth, U. 1988. Population structure, density and biomass of large herbivores in a south Indian tropical forest. M.S. Thesis. University of Florida, Florida. P 91.

Kelton, S.D. 1981. Biology of sambar deer (C.V.Kerr 1972) In N.Z. with particular reference to diet in a Manawal flax swamp. M.Sc. thesis, Massey Univ. 143 pp.

Kelton, S.D. and J.P.Skipworth 1987. Food of sambar deer. (C. unicolor) in a Manawatu (New Zealand) flax swamps. *New Zealand Journal of Ecology*, 10:147-152.

Leopold 1961. Game management. Second ed. New York, Charles Scrilner's Sons. 481 pp.

Lo,Peter 1985. Movements, home range and habitat utilization by sambar deer (Cervus unicolor) in Santoft state forest, Manawatu. Env. forestry, N.Z forest service Palwestern North.

Marcum, C.L. and D.D. Loftsgaarden.1980. A non-mapping technique for studying habitat preferences. *J. Wildl. Manage.* 44(4):963-968.

/ Neu, C.W. , yers, C.R. and Peek, J.M. 1974. A technique for analysis of availability-utilization data. *J. Wildl. Manage.*38(3):541-546.

Osmaston, B.B. and J.B.Sale 1989. Wildlife in Dehradun and adjacent hills. Dehradun, Natraj Publishers.

Panwar, H.S. 1982. Project tiger. In V.B.Saharia, (Ed.) Wildlife Institute of India. Natraj Publishers, Dehradun, India.

Prater, S.H: 1965. The book of Indian animals. Bombay, *Bombay Nat. Hist. Soc.*

Putman, R. 1988. The Natural History of Deer. New York, Comstock Publishing Associates. 191 pp.

Rashid, M.A. 1982. The gir lion sanctuary project. In V.B.Saharia (Ed.) Wildlife Institute of India. Natraj Publishers,

Dehradun, India.

Richardson II, W.A. 1972. A natural history survey of sambar deer (*Cervus unicolor*) on the Powderhorn Ranch, Calhoun Country, Texas. M.Sc. (Wildlife Science) thesis, Graduate College of Texas, A & M Univ., Texas.

Riney, T. 1982. Study and management of large mammals. Chichestio, John Wiley & Sons. 552 pp.

Rodgers, W.A. 1988 a. A field mammal of techniques in wildlife census in India. Dehradun. Wildlife Institute of India.

Rodgers, W.A. 1984. Ungulate habitat selection in Sariska Sanctuary, Rajasthan. A report, Wildlife Institute of India, Dehradun, U.P.

Rodgers, W.A. 1988b. Wild grazing ungulates in India : an ecological review. In: Singh, P. and P.S. Pathak (ed.) Rangelands - resource and management. Proceedings of National Rangeland Symposium, IGFRI, Jhansi, Nov. 9-12, 1987. Rangeland Management Society of India, IGFRI, Jhansi. pp. 404-420.

Rodgers. W.A. , S.. Rawat and J.L. Sriwastawa in prep. The Vegetation of Western Rajaji National Park: Floristic and Community Analysis. A Report. Wildlife Institute of India. Dehradun.

Saharia, V.B. 1982. (Ed.) Wildlife Institute of India. Natraj Publishers, Dehradun. 278 pp.

Schaller, S.B. 1967. The Deer and the Tiger - a study of wildlife in India. Chicago, the Univ. of Chicago press.

Scogings, P.F. , S.. Theron and J. dn. P. Bothma 1998. Two quantitative methods for analysing ungulate habitat data. S. *Afr. J. Wildl. Res.* 28(1):9-13.

Van Dyke, W.A., A.Sands, J.Yoakcom, A. Polenz and J. Blaisdell 1983. Wildlife habitats in Managed Rangelands - The great Basin of southern Oregon - Bighorn Sheep. A general technical report No.159. USDA. 35 pp.

Verma, 1982. Motichur and Rajaji Sanctuaries. *Cheetal* 24(4):43-50.

Whitehead, S.K. 1972. Deer of the World. London, Constable & Co. Ltd.

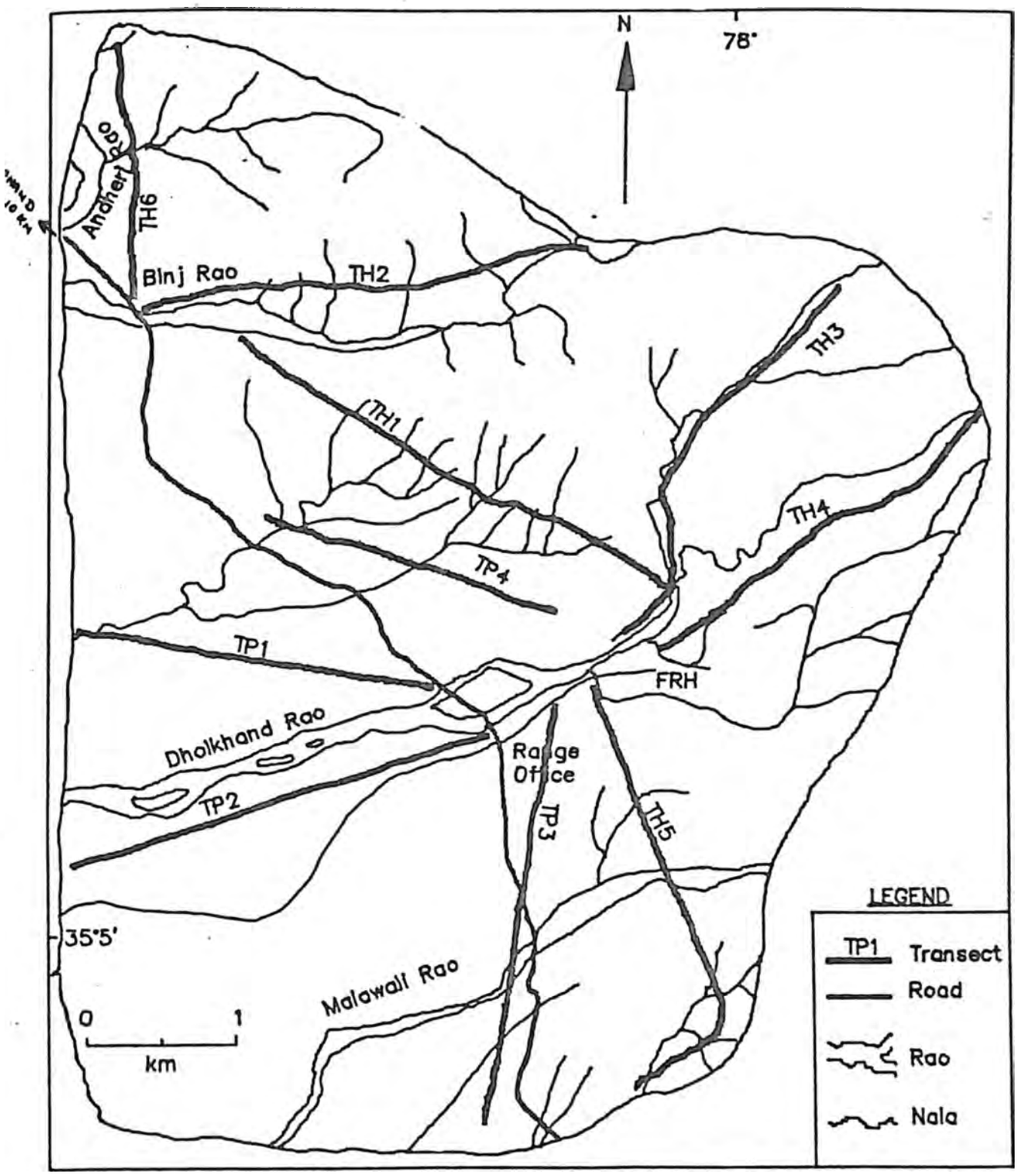

Figure 1. The study area in Dholkhand. (Refer to Table 1 for more details on the transects)

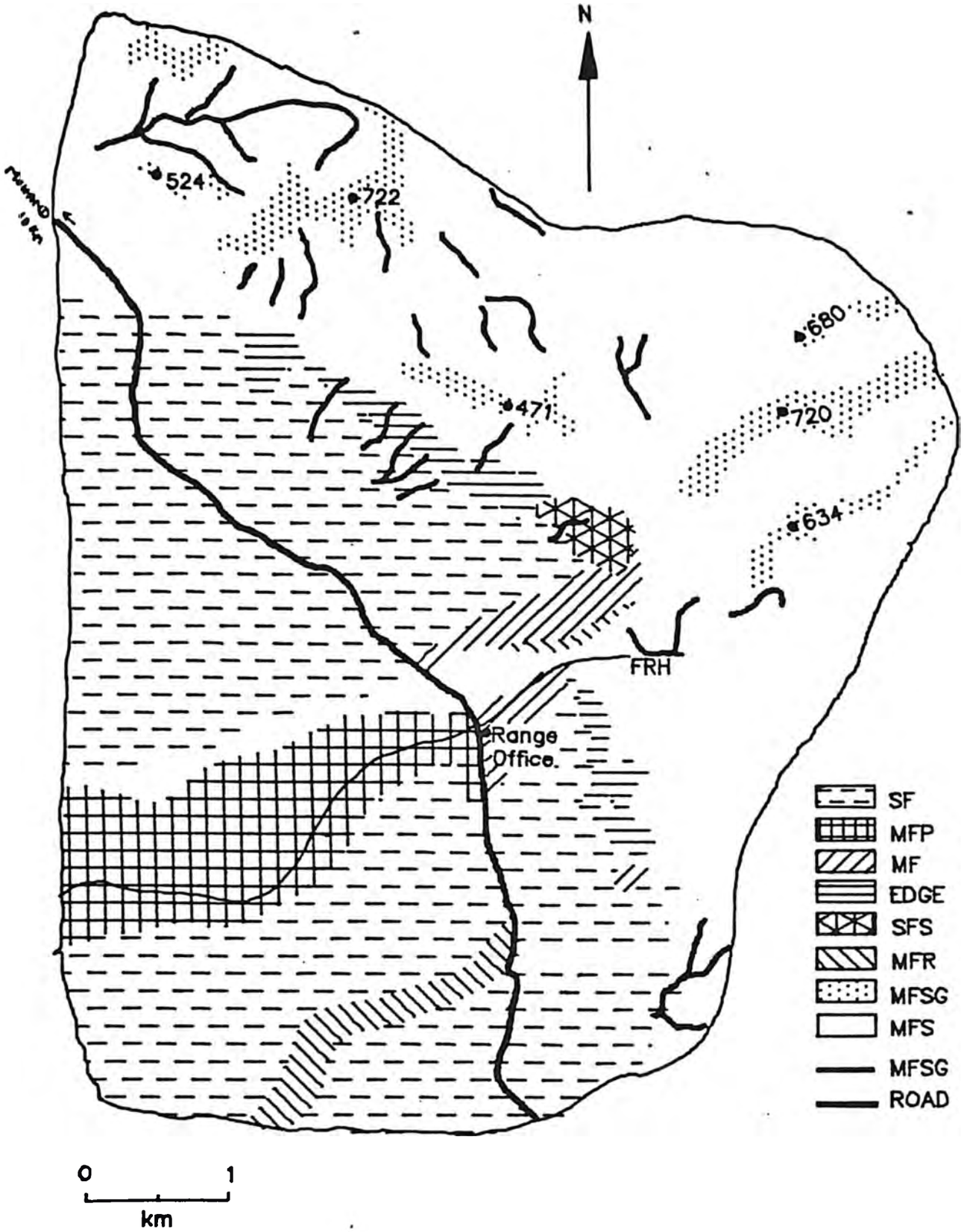

Figure 2. Map of study area showing the major vegetation types. (Edge refers to a zone between hills and planes that has thoroughly mixed elements of MFS,MFSS,SFS,MFSV & MFSG). Refer to section 4.1 for more details.

Table 1: Key features of the transects in the study area.

TRNO.	LENGTH (Km.)	TERRAIN	DISTU-RBANCE *	MAJOR VEGN. TYPES REPRESENTED ^
TH1	3.4	UNDULATING	3	MFS, MFSS, MFSG
TH2	3.0	HILLY	3	MFSG, MFS, MFSV
TH3	3.0	VALLEY	1	MFR, MF, MFS, MFSG
TH4	3.0	HILLY	1	MFS, MFSG, MFSV
TH5	3.0	UNDULATING	3	MFS, MFR, MFSV
TH6	2.0	HILLY	3	MFS
TP1	3.0	PLAINS	2	SF, MF
TP2	3.0	PLAINS	3	MFP
TP3	3.5	PLAINS	2	SF, MF
TP4	2.0	PLAINS	1	SF

* 1. very low biotic disturbance, grass cutting 2. low to medium, grazing, lopping & grass cutting 3. heavy incidence of grazing, cutting and lopping.

^ MFS:mixed forest slope; MFSV:mixed forest shady valley; MFSG:mixed forest grassy slope; MFSS:mixed forest slope with sal; SFS:sal forest slope; MFR:mixed forest reverain; SF:sal forest; MF:mixed forest; MFP:mixed plantation forest. For more details see section 4.1.

Table 2: Density of the dominant tree and shrub species in sal forests. (n: the total no. of trees/shrubs in the sample).

TREE SPECIES	%OF TOTAL	DENSI-TY (/ha)	PBR*	AVTH (m)	SHRUB SPECIES	% OF TOTAL	DENS-TY (/ha.)	AV. SH. HT. (m)
S. robusta	34	255	10	10.6	Mallotus	48	2037	1.1
Mallotus	26	199	94	4.6	Militia	9	366	0.7
Lagerstroemia	19	144	70	6.3	Lagerstroemia	7	279	0.9
Ehretia	7	51	36	6.4	Holarrhena	6	268	0.9
Others (26spp)	14	108	8		Adhatoda	4	174	1.3
Total	100	757			Flacortia	3	145	0.4
n=2712					Colebrookia	3	126	1.4
					Others (16spp)	20	876	
					Total	100	4271	
					n=3822			

* % nos. of palatable species with branches accessible (≤ 2.5m) to samba

Table 3: Density of the dominant tree & shrub species in the mixed planta forests (MFP). (n: the total no. of tree/ shrub species in the sampl

TREE SPECIES	% OF TOTAL	DENS-ITY	PBR*	AVTH (m)	SHRUB SPECIES	% OF TOTAL	DENS-ITY	AV. SH.HT (m)
A. catechu	24	201	9	9.9	Adhatoda	62	1552	1.3
Mallotus	18	147	98	5.1	Colebrookia	13	320	1.2
Ehretia	17	142	59	5.6	Holarrhena	12	311	1.2
Holarrhena	8	67	16	6.2	Others (11 spp.)	13	321	
D. sissu	5	43	1	8.8	n=1119	100	2504	
T. grandis	4	31	10	8.9				
Lagerstroemia	3	27	14	9.0				
Z. xylopyrus	2	20	85	5.5				
Other (29 spp)	19	150	3					
total	100	828						
n=1585								

* % nos. of palatable species with branches accessible (≤ 2.5m) to samba

Table 4: Density of the dominant tree & shrub species in the mixed forests (MF). (n: the total no. of tree/ shrub species in the samples).

TREE SPECIES	% OF TOTAL	DENS-ITY	PBR*	AVTH (m)	SHRUB SPECIES	% OF TOTAL	DENS-ITY	AV. SH.HT (m)
Mallotus	25	94	90	4.7	Adhatoda	36	843	1.2
Lagerstroemia	11	41	20	7.5	Lantana	16	382	1.6
Holarrhena	10	38	59	5.2	Mallotus	13	294	1.0
C. fistula	9	34	66	5.4	Colebrookia	10	222	1.4
Z. mauritiana	8	32	92	4.9	Helicteres	6	180	1.5
S. robusta	6	24	17	9,1	Others (11 spp.)	19	428	
Ehretia	4	16	50	5.4	n=719	100	2349	
Milliusa	2	8	50	8.0				
Z. xylopyrus	2	7	33	6.0				
A. catechu	2	7	33	7.0				
S. pinnata	2	7	0	10.7				
Others (31 spp.)	19	74						
Total	100	382						
n=468								

% nos. of palatable species with branches accessible (≤ 2.5m) to sambar.

Table 5: Density of the dominant tree & shrub species in the mixed forests reverain (MFR). (n: the total no. of tree/ shrub species in the samples).

TREE SPECIES	% OF TOTAL	DENS-ITY	PBR*	AVTH (m)	SHRUB SPECIES	% OF TOTAL	DENS-ITY	AV. SH.HT (m)
Mallotus	40	200	100	5.1	Mallotus	24	341	1.0
Z. mauritiana	7	33	95	5.2	Colebrookia	22	317	1.2
C. fistula	6	30	52	6.2	Helectris	20	284	1.6
Holarrhena	5	27	40	6.0	Holarrhena	6	86	1.0
C. myxa	5	25	41	6.7	Ehretia	6	81	1.2
Syzigium	4	18	3	10.5	Adhatoda	5	72	1.5
S. robusta	4	17	10	12.2	Others (11 spp.)	17	252	
Ehretia	3	13	43	4.9	Total	100	1433	
Lagerstroemia	2	11	42	7.2	n=596			
D. sissoo	2	10	0	8.1				
Phyllanthus	2	9	13	7				
Others (31 spp.)	20	103	11					
Total	100	496						
n=862								

% nos. of palatable species with branches accessible (≤ 2.5m) to sambar.

Table 6: Density of the dominant tree & shrub species in the mixed fore slope (MFS). (n: the total no. of tree/ shrub species in the samples

TREE SPECIES	% OF TOTAL	DENS-ITY	PBR*	AVTH (m)	SHRUB SPECIES	% OF TOTAL	DENS-ITY	AV. SH.HT
Mallotus	16	90	99	4.6	Colebrookia	25	487	1.3
S. robusta	13	71	30	10.1	Mallotus	17	332	1.0
Anogeissus	9	48	20	10.6	Helicteres	10	196	1.6
A. catechu	8	43	70	7.0	Holarrhena	9	174	1.2
Z. xylopyrus	8	43	99	4.8	Woodfordia	7	135	1.1
Nyctanthus	7	39	96	4.2	C. opaca	5	108	1.0
B. variegata	6	32	46	6.9	Z. xylopyrus	5	95	1.0
Ougenia	5	29	62	6.6	Ehretia	4	79	1.1
Buchanania	5	26	32	7.9	Others (21 spp.)	20	352	
Ehretia	4	21	79	5.3	Total	100	1958	
Others (40 spp.)	19	118	12		n=1875			
Total	100	560						
n=2144								

* % nos. of palatable species with branches accessible (≤ 2.5m) to samba

Table 7: Density of the dominant tree & shrub species in the mixed fore shady valley. (n: the total no. of tree/ shrub species in the sample

TREE SPECIES	% OF TOTAL	DENS-ITY	PBR*	AVTH (m)	SHRUB SPECIES	% OF TOTAL	DENS-ITY	AV. SH.HT
Mallotus	23	119	97	4.5	Colebrookia	45	1033	1.3
S. robusta	14	70	33	9.8	Mallotus	32	724	1.2
B. variegata	8	42	74	7.3	Helicteres	6	134	1.5
Ougenia	7	34	55	6.4	Others (16 spp)	13	392	
Anogeissus	6	29	31	7.8	Total	100	2283	
Ehretia	6	28	50	5.7	n=681			
Kydia	5	24	45	7.5				
Z. xylopyrus	4	19	74	5.0				
Buchanania	4	18	24	7.9				
Syzigium	3	13	13	10.0				
Others (29 spp.)	19	92						
Total	100	508						
n=606								

* % nos. of palatable species with branches accessible (≤ 2.5m) to samba

able 8: Density of the dominant tree & shrub species in the mixed forests slope grassy (MFSG). (n: the total no. of tree/ shrub species in the samples).

TREE SPECIES	% OF TOTAL	DENS-ITY	PBR*	AVTH (m)	SHRUB SPECIES	% OF TOTAL	DENS-ITY	AV. SH.HT
allotus	14	68	98	4.3	Colebrookia	22	361	1.2
. robusta	11	54	17	10.0	Holarrhena	13	202	1.1
mogeissus	10	47	26	10.8	Mallotus	12	189	1.0
ugenia	9	43	67	6.2	Woodfordia	10	158	1.0
. xylopyrus	8	40	97	4.8	Z. xylopyrus	8	131	1.0
. catechu	7	33	49	7.0	Helicteres	7	106	1.4
. variegata	6	29	68	6.3	Ehretia	6	99	1.0
uchanania	6	27	43	7.8	C. opaqua	5	73	1.0
hritia	5	23	70	5.4	Others (15 spp.)	16	222	
. fistula	3	16	65	6.4	Total	100	1541	
thers 31 spp)	20	111			n=871			
otal =1110	100	491						

% nos. of palatable species with branches accessible (≤ 2.5m) to sambar.

able 9: Density of the dominant tree & shrub species in the mixed forests slope with sal (MFSS). (n: the total no. of tree/ shrub species in the samples).

TREE SPECIES	% OF TOTAL	DENS-ITY	PBR*	AVTH (m)	SHRUB SPECIES	% OF TOTAL	DENS-ITY	AV. SH.HT
. robusta	39	249	13	9.9	Mallotus	22	515	1.3
allotus	15	94	100	4.5	Holarrhena	21	475	1.0
ugenia	7	45	77	7.0	C. fistula	20	452	1.3
agerstroemia	5	33	74	6.4	Colebrookia	15	353	1.1
hretia	5	30	67	4.6	Ehretia	9	197	1.2
. fistula	4	26	61	5.9	Others (9 spp.)	12	313	
ucanania	4	25	12	7.6	Total	100	2305	
thers 22 spp.)	21	130			n=398			
otal =437	100	633						

% nos. of palatable species with branches accessible (≤ 2.5m) to sambar.

Table 10: Density of the dominant tree & shrub species in the sal for
slope (SFS). (n: the total no. of tree/ shrub species in the sample

TREE SPECIES	% OF TOTAL	DENS-ITY	PBR*	AVTH (m)	SHRUB SPECIES	% OF TOTAL	DENS-ITY	AV. SH.HT
S. robusta	47	270	5	11.8	Mallotus	41	1486	1.3
Mellotus	14	80	100	5.0	Adhatoda	15	552	1.0
Ehretia	9	53	40	5.8	C. fistula	8	276	1.5
Buchanania	6	32	17	8.0	Holarrhena	8	276	1.5
Miliusa	5	27	0	7.0	Murraya	6	234	1.0
Others (13 spp.)	19	116			Millettia	6	212	1.8
Total	100	579			Others (8 spp.)	16	1019	
n=109					Total	100	3609	
					n=170			

* % nos. of palatable species with branches accessible ($\leq$ 2.5m) to samba

able 11: Tree species richness, % trees with available branches (PTAB) along with the occurrence of the dominant tree cover category and its % occurrence (DTCP).

VT	SPP. RICHNESS	PTAB *	DTCP	OVERALL DENSITY (/ha)	NO.PAL-ATABLE SPP.	NO.PAL-ATABLE SPP.IN DOM.80%
F	31	29	46-60 (38)	757	20	2
FP	37	34	31-45 (44)	828	25	4
F	42	46	16-30 (48)	382	28	6
FR	42	57	16-30 (36)	496	16	6
FS	49	30	16-30 (37)	560	26	8
FSV	39	51	31-45 (42)	508	23	7
FSG	41	35	16-30 (61)	491	26	7
FSS	29	26	46-60 (59)	633	19	3
FS	18	27	31-45& 46-60(50 EACH)	579	11	2

CALCULATED FROM ONLY THE NO. OF TREES RECOGNISED TO HAVE FORAGE VALUE BASED ON JOHNSINGH,A.J.T; PRASAD,S.N.; RAWAT,G.S. & PERS. OBS.) THAT HAVE RANCHES ACCESSABLE TO SAMBAR.

Table 12: SUMMARY OF SHRUB SPECIES ABUNDANCE AND DENSITY AMONG THE NINE VTs.

VT	SPP. RICHNESS	NSPC	PCSPA	NSPB	PBSPA	DSCC&PO	SHRUB DENSITY (/ha)	AVSH. HT.(m)	DNSPB/ DNSPC
SF	23	5	56	11	56	0-15 (26)	4271	1.0	2/3
MFP	14	3	87	5	9	0-15 (46)	2504	1.2	0/2
MF	16	5	82	9	42	0-15 (49)	2349	1.2	3/5
MFR	17	5	77	8	61	16-30 (36)	1433	1.2	3/4
MFS	29	6	62	18	54	0-15 (70)	1958	1.1	6/4
MFSV	19	4	53	12	49	0-15 (55)	2283	1.3	2/3
IFSG	25	4	53	11	59	0-15 (89)	1541	1.1	6/4
MFSS	14	4	44	7	38	46-60 (53)	2305	1.2	2/2
SFS	12	3	62	6	61	46-60 (33)	3609	1.4	1/2

NSPC: no. spp. with cover value.
PCSPA: % cover spp. abundance.
NSPB: no. spp. with browse value.
PBSPA: % browse spp. abumndance.
DSCC & PO: dominant shrub cover class & its % occurrence.
DNSPB/DNSPC: dominant (80%) no. spp. with browse value / dominant (80%) no. spp. with cover value.

Table 13: Percent frequency o' sampling plot occuring in each vegetation category. (n = no. of plots under each vegetation category.

VT / ASP	MF (n=15)	MFR (n=45)	MFS (n= 122)	MFSV (n=38)	MFSG (n=72)	MFSS (n=22)	SFS (n=6)
N	0	8	8	16	6	5	0
NE	0	0	4	5	7	5	17
E	0	0	3	8	10	9	17
SE	0	0	13	11	13	14	0
S	20	18	17	3	22	9	33
SW	0	2	10	24	14	23	0
W	0	0	25	18	14	27	17
NW	0	13	18	16	15	9	0
VALLEY	80	62	0.8	0	0	0	17

Table 14: Percent occurrence of terrain types (TTY) in the 7 VTs (the VTs MFP & SF occur only in flat land). (n: no. of plots under each VT).

TTY	MF	MFR	MFS	MFSV	MFSG	MFSS	SFS
0-15	100	96	27	47	31	64	50
16-30	0	2	46	37	46	32	50
31-45	0	0	25	13	19	5	0
46-60	0	0	2	3	4	0	0
n=	15	45	122	38	72	22	6

Table 15: Bonferroni intervals and preference rating (PR) for the habitat variables during A. winter & B. summer. ('+' preferred; '-' avoided 'o' used according to availability).

			A				B			
HABITAT VARIAB.	HABITAT CAT.	REL. AREA.	NO. SIG T.	CONF.INTERV.		PR	NO. SIG T.	CONF.INTERV		PR
				LO.LI	UP.LI			LO.LI	UP.LI	
a. HILL/PL	HILL	.607	143	.841	.861	+	130	.888	.906	+
	PLAINS	.393	25	.125	.173	-	15	.077	.129	-
b. VT	MFS	.231	69	.306	.515	+	61	.239	.431	+
	MFSV	.072	20	.050	.188	o	21	.050	.181	o
	MFSG	.136	27	.083	.239	o	34	.107	.266	o
	MFSS&SFS	.052	10	.000	.132	o	6	.000	.068	o
	MFP&SF	.331	23	.113	.167	-	17	.090	.143	-
	MF	.074	8	.002	.093	o	43* .17	.273	.320	+
	MFR	.100	11	.013	.118	o				
c. TCOV	0-15	.069	26	.087	.234	+	26	.100	.279	+
	16-30	.330	55	.244	.435	o	55	.279	.480	o
	31-45	.272	44	.182	.361	o	43	.202	.391	o
	46-60	.253	29	.102	.250	o	21* .33	.072	.218	-
	>61	.073	8	.006	.093	o				
d. SCOV	0-15	.559	81	.426	.633	o	56	.319	.543	+
	16-30	.113	31	.119	.285	+	28	.122	.308	-
	31-45	.090	7	.003	.088	-	22	.084	.254	-
	46-60	.125	25	.087	.240	o	16	.049	.197	-
	> 61	.111	9	.010	.107	-	8	.007	.116	o
e. GCOV	0-15	.558	65	.308	.515	-	49	.237	.439	-
	16-30	.147	11	.016	.123	-	31	.126	.302	o
	31-45	.149	11	.016	.123	-	18	.053	.195	o
	46-60	.033	13	.025	.140	o	32	.132	.310	+
	61-75	.065	9	.008	.106	o	15* .11	.038	.169	o
	> 75	.048	49	.213	.407	+				
f. LOPPING	LOPPED	.338	47	.202	.357	o	41	.259	.307	-
	UNLOPPED	.662	121	.643	.798	o	104	.702	.732	+
g. TTY	FLAT	.392	25	.079	.219	-	15	.040	.167	-
	0-15	.280	32	.113	.268	-	22	.077	.226	-
	16-30	.216	69	.314	.507	+	60	.312	.516	+
	31-45	.094	31	.108	.261	+	48* .11	.233	.429	-
	46-60	.015	11	.017	.114	+				
h. ASP-ECT	N	.607	143	.841	.861	-	31	.163	.337	-
	S	.393	25	.125	.173	+	93	.663	.837	+

* CATEGORY HAS BEEN MERGED WITH THE ONE FOLLOWING IT.

RELATIVE AREA IS GIVEN IN THE NEXT LINE.

Table 16: Percent occurrence of different tree cover (TCOV) categories in the 9 vegetation types (VT). (n: the no. of plots in each category).

TCOV	SF	MFP	MF	MFR	MFS	MFSV	MFSG	MFSS	SFS
0-15	2	0	18	17	21	8	19	0	0
16-30	16	20	48	36	37	21	61	14	0
31-45	31	44	13	25	30	42	9	23	50
46-60	38	23	13	19	9	29	6	59	50
> 60	13	10	8	3	3	0	0	5	0
n=	144	61	39	53	122	38	72	22	6

Table 17: Percent occurrence of different shrub cover (SCOV) categories in the 9 VTs. (n: no. of plots in each VT).

SCOV	SF	MFP	MF	MFR	MFS	MFSV	MFSG	MFSS	SFS
0-15	26	46	49	17	70	55	89	0	17
16-30	20	13	15	36	7	15	7	14	17
31-45	19	6	5	24	5	8	0	23	17
46-60	20	15	13	19	10	10	1	58	33
> 61	14	20	18	3	7	10	3	5	17
n =	114	61	39	53	122	38	72	22	6

Table 18: Percent occurrence of different grass cover (GCOV) categories in the 9 VTs. (n: no. of plots in each VT).

GCOV	SF	MFP	MF	MFR	MFS	MFSV	MFSG	MFSS	SFS
0-14.9	16	98	69	55	49	39	6	46	84
15-29.9	7	2	16	12	26	26	12	5	0
30-44.9	12	0	14	17	19	16	27	18	0
45-59.9	2	0	0	2	2	5	12	0	16
60-74.9	0	0	0	12	4	17	29	5	0
> 75	3	0	3	4	3	3	12	28	0
n=	114	61	39	53	122	38	72	22	6

Table 19: SAMBAR DENSITY ESTIMATES USING KING CENSUS FOR WINTER AND SPRING / SUMMER (DECEMBER 1 TO FEBRUARY MID & FEBRUARY MID TO APRIL 30,RESPECTIVELY).

HABITAT CAT.		Tr. L. (Km)	WINTER			SPRING/SUMMER		
			NSSG	ER	DEN-SITY	NSSG	ER	DEN-SITY
Undulating disturbed	TH1	3.4	38	2.8	29	27	2.0	14
	TH5	3.0	15	1.3	24	6	0.5	7
Hilly disturbed	TH2	3.0	12	1.0	17	21	1.8	21
	TH6	2.0	28	4.7	94	13	2.2	27
Hilly relatively undisturb	TH3	3.0	11	0.9	8	15	1.3	6
	TH4	3.0	53	4.4	69	32	2.7	44
Dis.SF.	TP1	3.0	2	0.2	4	1	0.08	2
Dis.SF.	TP3	3.5	14	1.2	23	2	0.17	3
Dis.MFP.	TP2	3.0	6	0.4	29	1	0.07	3
Rel.undis. SF,Pl.	TP4	2.0	17	2.8	45	11	1.2	26

NSSG: no. of sambar sightings ; ER: encounter rate (nos.seen/ km).

Table 20: PERCENT FREQUENCY OF VTs OCCURRING IN THE TEN TRANSECTS.

TRNO VT	TP1 N=61	TP2 N=61	TP3 N=71	TP4 N=14	TH1 N=61	TH2 N=61	TH3 N=61	TH4 N=61	TH5 N=61	TH6 N=15
SF	80	0	22	100	0	0	0	0	0	0
MFP	0	100	0	0	0	0	0	0	0	0
MF	16	0	20	0	2	2	20	0	2	0
MFR	3	0	9	0	3	3	41	7	20	0
MFS	0	0	0	0	49	28	16	39	51	67
MFSV	0	0	0	0	10	13	7	16	16	0
MFSG	0	0	0	0	15	44	16	38	5	0
MFSS	0	0	0	0	20	10	0	0	2	20
SFS	0	0	0	0	2	0	0	0	5	13

Table 21: MEAN OBSERVED DENSITIES OF SAMBAR FOR HILL AND PLAIN HABITATS IN RAJAJI NATIONAL PARK DURING THE TWO SEASONS.

SEASON STRATA	WINTER	SPRING/SUMMER
HILLS (N=23)	41.61 '	23.00 '
PLAINS (N=15)	27.50 '	09.27 '

(a & b not significant at p=0.05; t=1.15
c & d significantly different at p=0.05; t=2.46
c & d are significantly lower than a & b, respectively at p=0.05; t=8.83 & t=2.16 for hills and plains respectively)

Table 22: OVERALL DENSITY (/Km.Sq.) OF SAMBAR ON TRANSECTS WITH SIMILAR DISTURBANCE AND TERRAIN FEATURES.

HABITAT CATEGORY	WINTER DENSITY	SUMMER DENSITY
DISTURBED,UNDULATING (TH1 & TH5)	30.43	11.65
DISTURBED,HILLY (TH2 & TH6)	50.99	28.12
REL.UNDIST.,HILLY (TH4)	78.50	48.25
REL UNDIST.,RIVERAIN & HILLY (TH3)	10.25	12.25
DISTURBED,PLAINS (TP1,TP2,TP3)	19.55	02.42
REL. UNDIST,PL. (TP4)	60.50	36.67

Appendix 1

The Dominant (a) tree, (b) shrub and (c) grass species in the study area.

(a) tree

Acacia catechu *
Anogeissus latifolia *
Bauhinia variegata *
Buchanania lanzan
Cassia fistula
Cordi. myxa *
Dalbergia sissoo *
Ehretia laevis *
Garuga pinnata *
Holarrhena antidysenterica
Kydia calycina *
Lagerstroemia parviflora
Mallotus phillipinensis *
Miliusa velutina *
Nyctanthes arbor-tristis *
Ougenia oogeinensis *
Phyllanthus officinalis *
Shorea robusta
Syzygium cumini *
Tectona grandis
Z. mauritiana *
Zizyphus xylopyrus *

(b) Shrubs

Adathoda vasica ^
Carissa opaca *
Colebrookia oppositifolia ^
Flacourtia indica *
Helecteres isora * ^
Holarrhena antidycentrica
Lantana camara * ^
Laserstroemia parviflora
Mallotus phillipinensis * ^
Millettia auriculata
Murraya koenigii
Woodfordia fruticasa * ^

(c) Grasses

Apluda mutica *
Arundinella setosa *
Chloris dolichostachya
Chrysopogan fulvus *
Cynodon dactylon *
Eulaliopsis binata *
Heteropogon contortus *
Imperata cylindrica
Neyraudia arundinacea *

* A palatable species.

^ A shrub species with cover value.

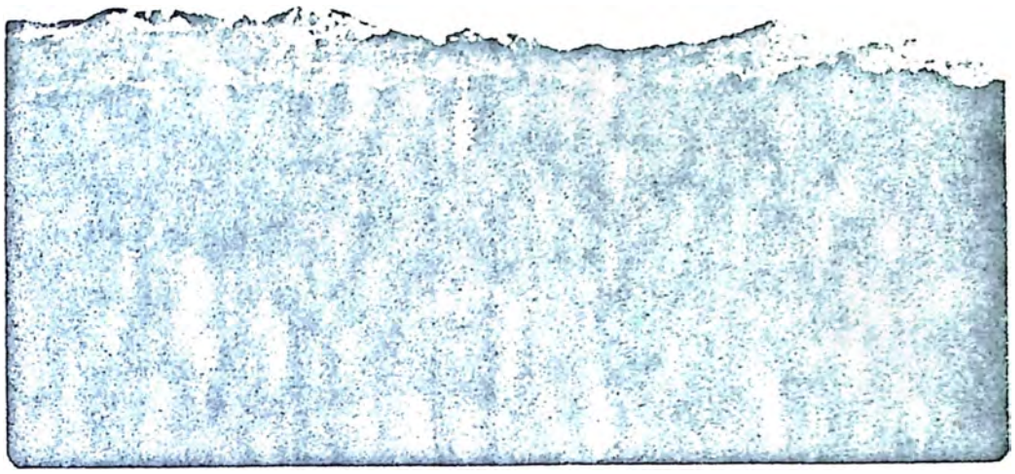

Plate 1: Siwaliks (in the fore ground) with reference to the (lower and greater) Himalayas.

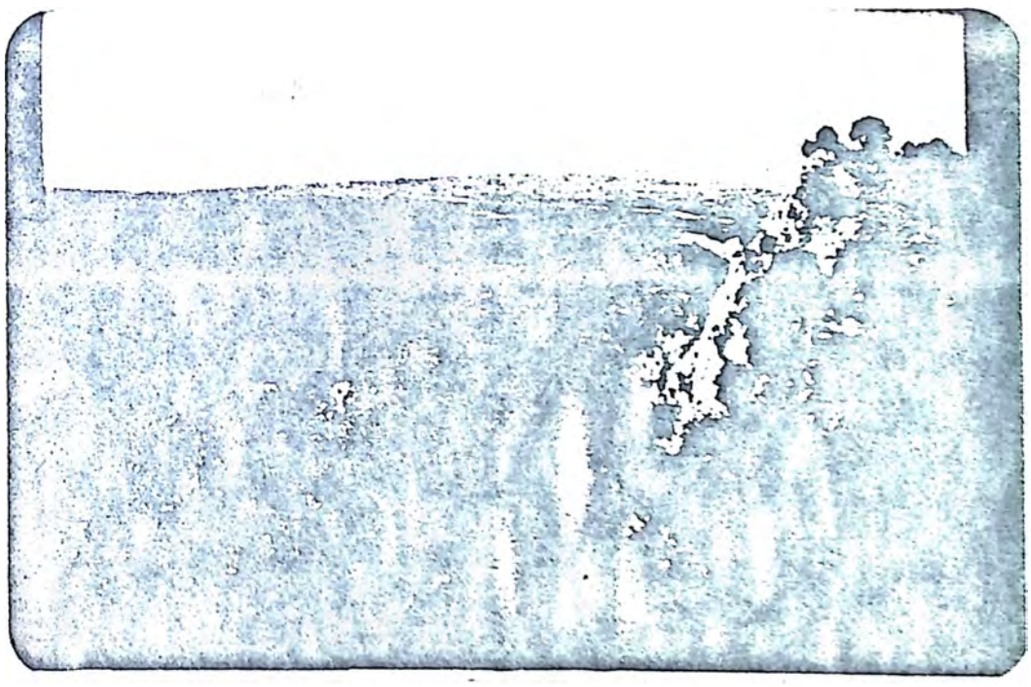

Plate 2: The Siwaliks have uplifted in a manner in which the higher, southern slopes tends to be more steep (South is to the left of the photo). Also note the grassy slopes (MFSG) on the ridge line, the Sal forests in the plains and the outlying areas devoid of forest.

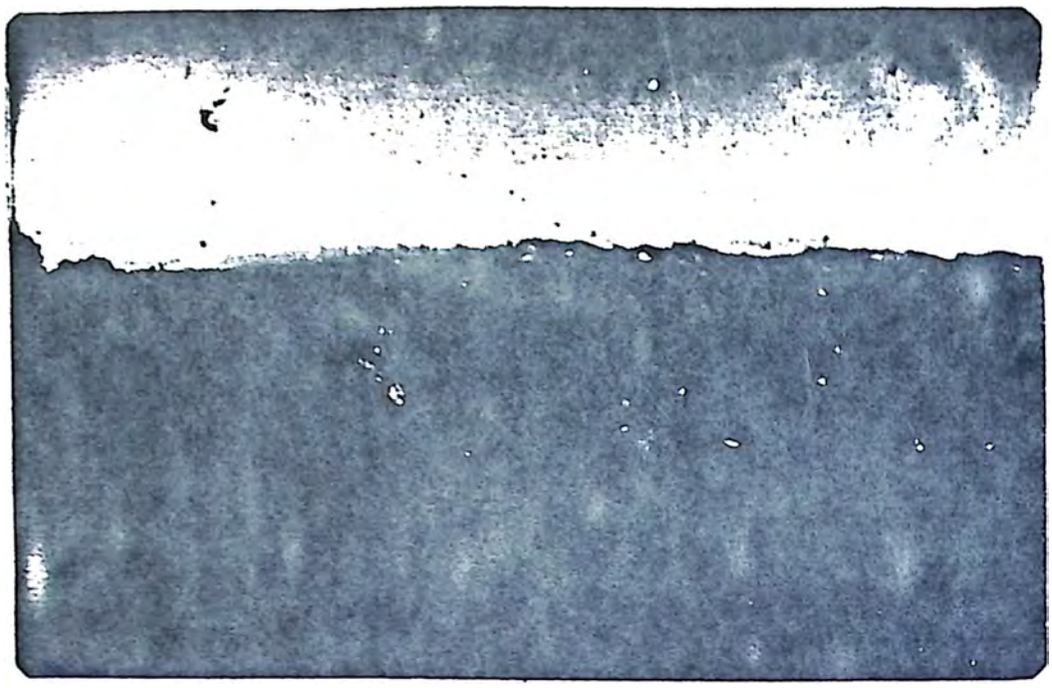

Plate 3: Dense forests on the northern slopes (in the fore ground) that dominate in species such as *S.robusta*, *Buchanania*, *B.variegata*. Note the denser mixed forest slopes, (MF5) and the relatively open mixed forest grassy slopes (MF5G) on the ridges in the background.

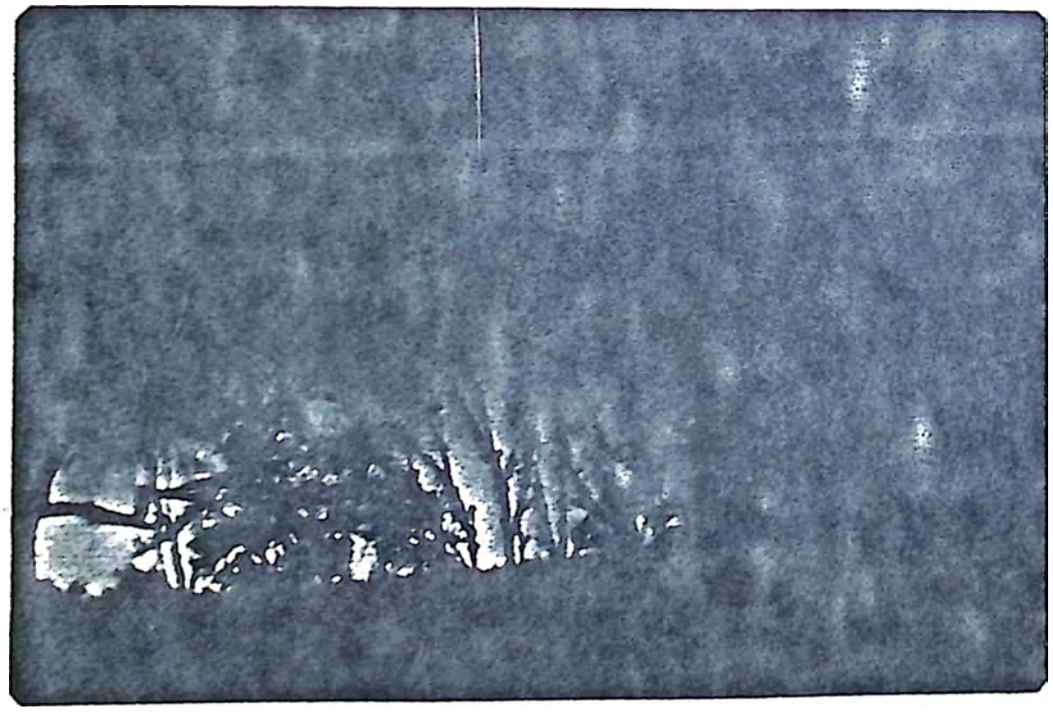

Plate 4: Degraded MF5G on TF2. Note the heavily lopped *Anogeissus* trees, the hay stock and the short but continuous grass layer.

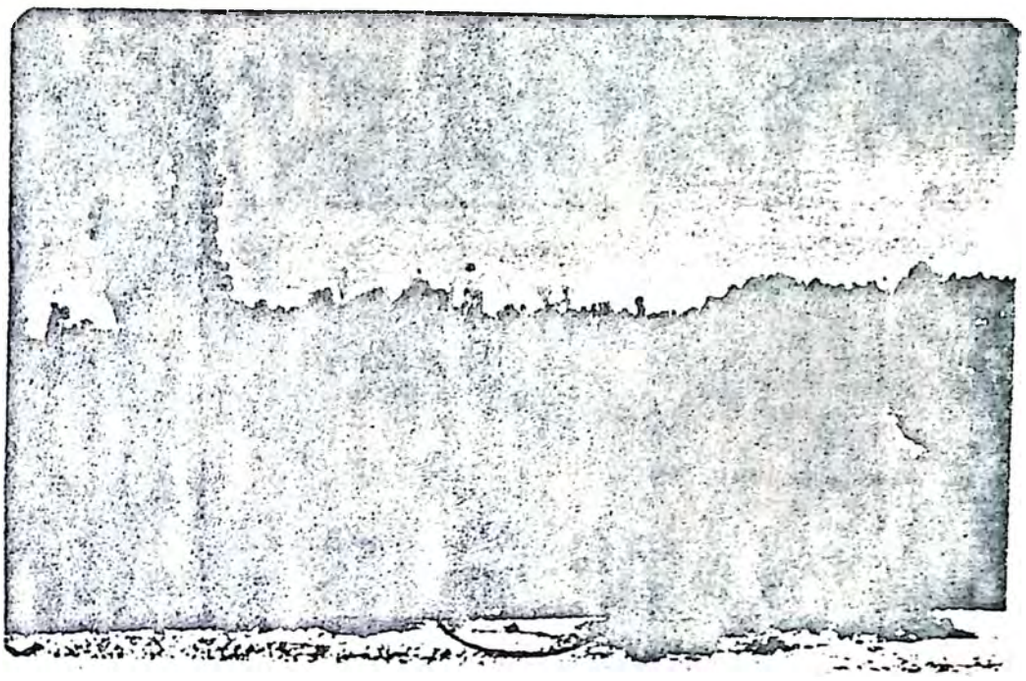

Plate 5: Degraded mixed forest slopes (MF5) and mixed forest grassy slopes(MF55) on a ridge behind a 'Dera' on the 'Rao' bank.

Plate 6: Buffalos feeding on lopped leaves of *Terminalia tomentosa* ar *Dugenia*.