SPATIAL AND TEMPORAL PATTERNS IN DEBARKING BY INDIAN CRESTED PORCUPINE (*Hystrix indica Kerr*) IN SARISKA NATIONAL PARK

DISSERTATION SUBMITTED TO THE
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MASTER'S DEGREE IN WILDLIFE SCIENCE
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CERTIFICATE

This is to certify that Mr. Diwakar Sharma has carried out an original piece of research in partial fulfillment of his M.Sc (Wildlife) degree of the Saurashtra University, Rajkot. The topic of dissertation is **"Spatial and Temporal Patterns in Debarking by Indian Crested Porcupine** (*Hystrix indica* Kerr) **in Sariska National Park"**. The investigations were carried out at the Wildlife Institute of India, Dehradun under my supervision from May to December 1989. I hereby certify that this work has not been submitted for any degree of any university.

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SUMMARY

A study on debarking by porcupine was conducted in Sariska National Park form 6th May to 10th October 1989. The climate is semi-arid with mean annual rainfall 650 mm but most of it during monsoon (June-September). Rainfall is variable seasonally and spatially.

4021 trees of nineteen species were examined for debarking in six Intensive Study Sites (ISS). Of these *Anogeissus pendula* (1932), *Balanites aegyptica* (174) and *Capparis decidua* (101) were not found debarked. Twelve species were rare (<20). Remaining four species *Acacia catechu, A. leucophloea, Butea monosperma* and *Zizyphus mauritiana* provided the data to study spatial and temporal variations in debarking. Both old and new debarking evidences were recorded.

In *Zizyphus* and mixed woodlands the intensity of debarking high. *Anogeissus* woodland (ISS-5) did not have any tree debarked. Debarking evidences were lower in *Zizyphus* scrubland, *Butea* woodland and degraded *Zizyphus* woodland. The overall difference in debarking in different sites was significant ($p < .0001$).

Percentage of different species debarked in each ISS varied greatly. This intensity of debarking was positively related to the overall density of trees that could be debarked in a site. *A. catechu* and *Z. mauritiana* were significantly more debarked ($p < .05$) than other species in respective ISS.

Less debarking was observed in lower and higher girth classes. The girth classes within 41-100 cm. were debarked more than any other class. The preference for this range was significant for *A. catechu* and *Z. auritiana* ($p < .001$) in all cases.

Intensity of debarking changed significantly between seasons. Of the 59 trees recorded debarked 58 were debarked in summer and only 1 was consumed in monsoon. Thus debarking of trees occurs mostly in summer when no other food is available for the porcupine.

Microscopic analysis of porcupine faeces shows that 75-95% of the food in summer was bark and stem. In monsoon/post-monsoon season grass seeds and monocot formed 33% and 41% of food respectively.

Average density of porcupine in Sariska valley based on direct counting was calculated to be 8 ± 2 animals per km^2.

Debarking does not have severe effects on the life and phenology of the tree. From the total density of debarked trees (77/ha) only 0.79% of the debarked trees were dead. Hence no special measure is required to control debarking but any occurrence of fire should be prevented. If there is fire, these trees will be most severely affected because of their exposed hardwood.

CONTENTS

1. INTRODUCTION

1.1 WHY THIS STUDY?

Porcupines are known all over the world for their habit of debarking trees (Ahmad & Chaudhary 1977, Chaudhary & Ahmad 1975a, Sullivan et. al 1986, Yeaton, 1988). The animals in different parts of the world may belong to different genera but they invariably feed on the bark of trees during dry and snowfall periods.

Debarking of trees by animals is a habit which can affect tree growth and survival (Von Deuson & Myers 1962, Storm & Halvorson 1967). A debarked tree is more susceptible to the attacks of micro-organisms (e.g. fungi), fire and, termites and may die eventually.

An alarming incidence of tree debarking by Indian Crested Porcupine (*Hystrix indica* Kerr) was observed in 1987 in Sariska National Park (SNP) (Prasad, S.N. pers. commun.). During a field tour of the M.Sc. programme of the Wildlife Institute of India (May 20^{th} to June 1^{st} in 1988), a large number of debarked trees were observed in SNP. The trees in the area are deciduous and the number of seedlings is very little in the woodland areas where the debarking intensity is extensive. Hence it was felt that studying the tree-porcupine interactions in SNP would be of biological interests and management relevance. A field study was designed to investigate spatial and temporal patterns in debarking of trees by the porcupine.

Sariska Valley in the park was selected as the study area based • the observat:ons in 1988 when it was realized that trees in this area are debarked more and the valley had maximum density of the «pecies which were utilized for debarking.

1.2 :VIEW OF LITERATURE

1.2.1 INDIAN CRESTED PORCUPINE (*H. indica* Kerr)

The Indian Crested Porcupine (*Hystrix indica*) (Plate 1) is remarkably adaptable ecologically. This species is found over Western and South-East Asia and has been reported to occur at an altitude of 2500 m. in Pakistan (Roberts 1977).

Although widespread in India from west to east and, from the Shivalik foothills of Himalaya in north to Kanya Kumari in south, no field study has been conducted in this country on its ecology or behaviour. The lack of study on this animal in India may be due to two reasons. First, it is assumed to be abundant and therefore categorized under schedule IV of the Wildlife (Protection) Act 1986 and often treated as vermin. Secondly it is nocturnal, hence is difficult to study.

There are occasional natural history observations from India (Bhupathi & Haque 1986, Mangalraj 1983). Almost all scientific information on this species comes from recent research in Israel (Alkon 1983, Alkon & Saltz 1983-84, Alkon & Saltz 1988, Saltz 1985, Sever 1985, Sever & Mendelssohn 1989).

Porcupines live in burrows which can be extensive with more than e entrance (Roberts 1977). Prater (1965) describes a burrow which as 18 m. long. They are herbivores and in captivity they feed on many kinds of vegetables, grains and nuts. They also feed on agricultural crops such as maize, sugarcane (Roberts 1977) and potatoes (Alkon & Saltz 1985a & 1985b).

In the wild porcupines are reported to consume the bark of trees (Roberts 1977). However, these animals forage mainly on succulent plants and dig for underground parts (Gutterman 1982, 1987, 1988, Gutterman & Herr 1981). Digs sometimes may reach 2-3 m^2. Considerable amount of time and distance is covered for foraging activity (Alkon 1988, Saltz 1985, Sever 1985). The activity period is controlled by the phase of moon, moonlight being avoided probably as an anti-predator strategy (Alkon & Saltz, 1988a & 1988b).

A distance of approximately 2 km. is covered per night by the Indian Crested Porcupines but exceptionally attractive food items may induce these animal to travel more than 3 km. a night (Sever 1985). Roberts (1977) reports of a animal covering 4.5 km. during night foraging. The home-range of porcupines in pairs is smaller and is utilized more evenly than that of a solitary male (Sever 1985, Saltz 1985).

In a study on captive animal Alkon et.al. (1986) observed that porcupines consume more food in winter. These animal are water dependent and need more water in summer. Average digestibility is

68-80% depending upon season and amount of food. It is more in winter than in summer. In a separate study Alkon & Saltz (1985a) discovered the total intake of food by one animal as much as 1239± 83.3 gm. per day.

Indian Crested Porcupine is reported to reproduce throughout the year in captivity in Europe (Sever 1985, Greave & Khan 1978). Litter size ranges from 1-3. The gestation period is approximately 112 days (Roberts 1977, Weir 1974). New born animals weigh up to 350 gms. and the weight of adult is 12.5 kg. to 15.5 kg. (Alkon, 1983; Alkon & Saltz, 1985; Saltz, 1985, Sever, 1985). Females are heavier than males. In captivity they live up to 20 years but in wild their expected maximum age is 6.5 years (Alkon & Whittaker 1989).

1.2.2 DEBARKING IN GENERAL

The genus *Hystrix* which includes the old world porcupine is spread over Africa and Western & South Asia (Corbet & Jones, 1965). The animals are terrestrial and if debarking takes place, it is near the base of the stem (Chaudhary & Ahmad 1975a & 1975b, Yeaton 1988).

Systematic work on debarking by the Indian Crested Porcupine is lacking. One of the reasons for this paucity of information may be that debarking may not occur to any great extent in most of forests. Whatever work done on this problem is limited to methods of controlling porcupines (Chaudhary & Ahmad 1975a & 1975b, McDonald 1927). These methods include chemical poisoning, mechanical capturing by traps.

A high frequency of debarking of trees coupled with other factors such as insects, pathogens and fire can cause large mortality of trees and hence regressional and, successional changes in vegetation. In a recent study, Yeaton (1988) found the African Porcupine (*H. africae-australis*) partly responsible for the change in the tree layer in savanna.

Debarking by new world porcupine (*Erithizon dorsatum*) has been studied extensively in various parts of North America and Canada where it is considered as menace (Ludeman 1954). This species becomes arboreal and feeds on the bark of stem and branches of trees during winter when no food is available on ground to these animals due to snow (Curtis & Wilson 1953, Roze 1984, Sullivan et.al 1986, Tenneson & Oring 1985).

The damage by *Erithizon dorsatum* is intensive in coniferous forests (Curtis 1941, Curtis & Wilson 1953, Krefting et. al. 1962, Rudolf 1949). Porcupines strip off the bark by pruning the branches and debarking the stems. They select a few trees and feed heavily on them (Von Deuson & Myers 1962). All ages and size of trees are used as food during winter (Roze 1986, Strom & Halvorson 1967, Sullivan at. al. 1986).

Porcupines are not the only animal that debark trees. Various species of mammals from voles (Danell et. al. 1987) to elephant (Laws et. al. 1975) feed on the bark and vascular tissue of trees.

Voles (*Microtus agrestis*) feed on bark of *Pinus contorta, Salix spp. Populas tremula* etc. in Sweden (Dannel et. al 1987, Hansen et. al. 1986). These rodents utilize branches and stems for debarking.

Brenner (1962) calculates tree stem/bark in the food items consumed by beavers (*Castor canadensis*) and their preference for tree species in Pennsylvania. Jenkins (1980) reports debarking by beavers in central Massachusetts discovering a relationship between the tree size (GBH) utilized by the animal and distance covered from border of the pond.

The habit of debarking is different for black bear (*Euractos americanus*) since they do not feed on it (Glover 1955) but probably sharpen their claws. These animal damage trees by stripping off bark from the lower portion of the tree stems.

Laws et.al (1975) refer to the seasonal debarking (in March) of trees by the African elephant (*Loxodonta africana*) in East Africa and conclude that this incidence may be due to seasonal climatic factors which affect vegetation and nutritional requirements of the animals.

It can be inferred from the studies of debarking that the smaller animals from voles to beavers use bark of the trees as jor food it during dry and winter periods while large nimal such elephants feed on the bark to compensate for the nutrient deficiency in the food (Laws et.al. 1975).

1.3 STUDY HYPOTHESES AND OBJECTIVES

The major aim of the study was to examine the seasonal and spatial variations in the intensity of debarking by Indian Crested Porcupines in Sariska Tiger Reserve. Following null hypotheses (H_0) were set for the study:

1. There is no selection of [redacted] area by porcupines for debarking.

2. There is no selection of tree species for debarking.

3. There is no preference for any particular GBH classe .

4. Debarking is uniform in all seasons.

5. The food items consumed during summer (May-June) and monsoon do not differ largely.

To test these hypotheses the following objectives were set:

1. Study the change in debarking intensity from one habitat to another.

2. Study the change in debarking intensity for summer and monsoon.

3. Determine feeding preference of porcupines for different tree species.

4. Determine feeding preference of porcupine for different GBH classes (girth at breast height).

5. Estimate the proportion of different food items in the fecal matter of porcupines (microscopic analysis).

6. Estimate porcupine density in the study area using direct and indirect evidences and to correlate it with debarking intensity.

1.4 ORGANIZATION OF THE THESIS

Three chapters follow this introduction. Chapter 2 is about the Study Area and Methods used for the study. Analytical methods are described after the field methods wherever former were used. Chapter 3 describes the results of different parameters in the same order as they are given in the chapter 2.

Chapter 4 is about the discussion of the results. Although results are discussed in the same order as they are given in Chapter 2 but it is not divided into subsections. Chapter 5 is the overall conclusion from the study.

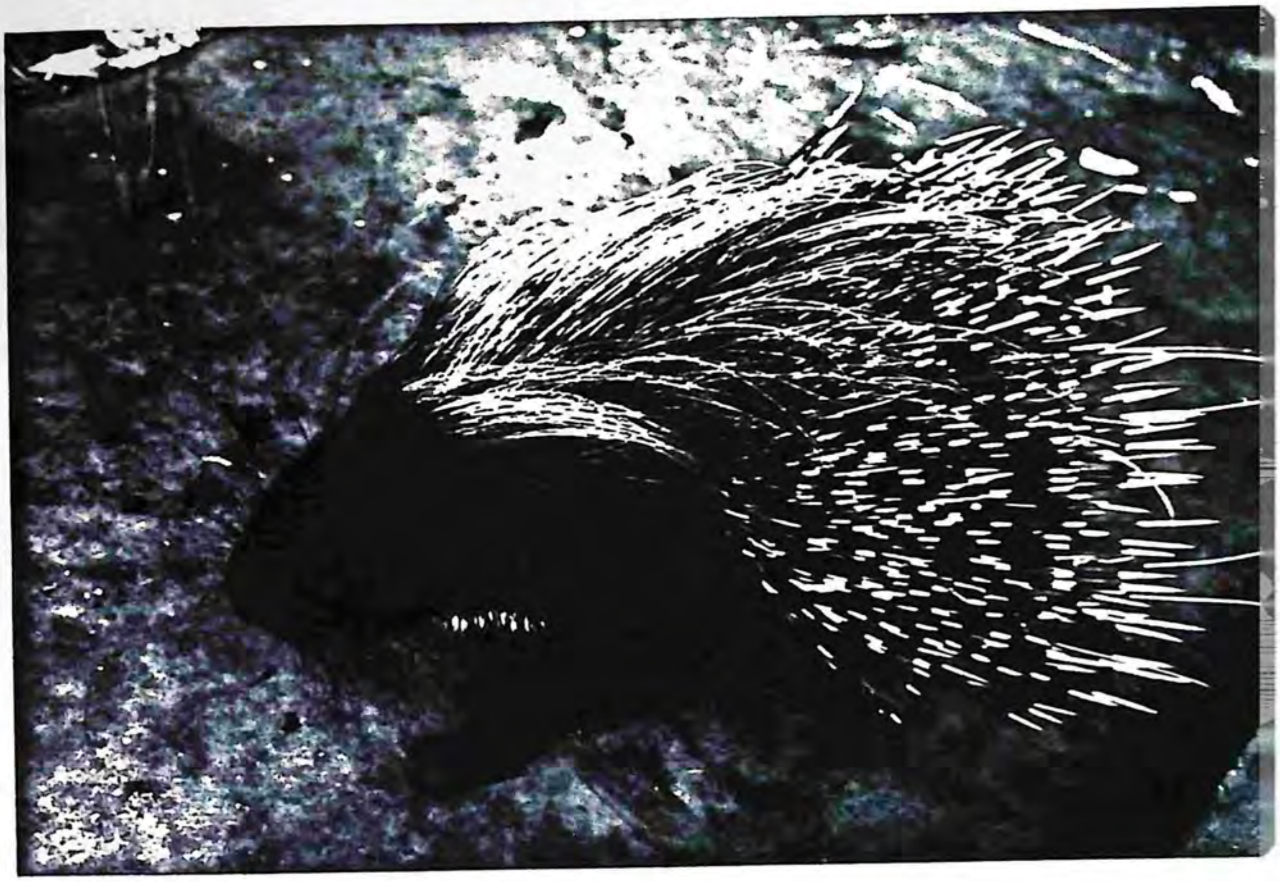

Plate 1. Indian Crested Porcupine (*Hystrix indica* Kerr)

2.2.1: RECONNAISSANCE SURVEY INTENSIVE STUDY SITE SELECTION

The main valley of Sariska National Park along the Sariska - Pandupole road (Fig. 2) was surveyed from 6^{th} - 12^{th} May to determine the vegetation composition, porcupine presence and, debarking intensity. This survey included the area on both sides of the road. The extent of debarking and indirect signs of animal presence (faeces) was assessed along systematically placed line transects perpendicular to the central road at one km interval. More extensive survey using a random or stratified random sampling could not be attempted due to lack of manpower and short period of the study.

Each transect started from the road and ended at the top of the first hill on either side of the road. Such transects varied from 175 m. to 1.5 Km. in length, averaging 500 m.. The density of tree (girth at breast height GBH >20cm) species was quantified in 10 m. radius plot every 200 m. along the transect. All trees along the transect were carefully examined for signs of debarking by porcupines within 10 m. on either side. Assessment of debarking was by categorization in the following classes:

0. No debarking
1. 1% - 25% of the total girth with bark removed
2. 26% - 75% " " " " " " "
3. 76% - 99% " " " " " " "
4. 100% (girdled)

mainly from July to September (Sariska Management plan 1984-1989). But there is large variation in the annual rainfall and it can be low as about 300 mm. as was observed from 1985-1987 (Rodgers, .A pers. commun.) and as high as 800 mm (in 1971) (Sariska Management plan 1984-1989).

.in varies both seasonally and spatially. Fig. 4 shows the pattern of rainfall during year 1989. Appendix-1 shows rainfall patterns for ten years for Alwar and Thanagazi (37 km east & 8 km west respectively from Sariska).

The terrain is mainly hilly with several narrow valleys. The hill are composed of quartzite, conglomerates, granites, schists and limestone rocks of Delhi geological systems. Earlier it was said be to part of Aravali. Soil composition differs depending upon the underlying rock (Sariska Management plan 1984-1989).

Sariska valley (Fig. 2 & 3) in SNP was selected for the study. The area includes a metalled road from Sariska Gate to Pandupole, two settlements (Haripura and Karnawas villages), and the adjacent Kirashka plateau supporting 3 hamlets, agricultural fields and natural vegetation. Sariska is a big valley joined by other small valleys. It is limited by almost parallel hills to the east-west and north-south. Red sandy soil covers most of the area, but changes to dark alluvial loam soil 6 km. before Pandupole - the last point of the Sariska valley.

2.1.2 VEGETATION

The vegetation of Sariska Tiger Reserve is categorized Tropical Dry Deciduous Forest (Champion & Seth, 1968). It includes *Anogeissus pendula* forest and *Butea monosperma forest under edaphic conditions and, Zizyphus* scrub under thorn forest. Recently Gadgil & Meher-Homji (1986) grouped the vegetation of this region as *Acacia catechu* - *Anogeissus pendula* series.

A. pendula is the dominating species over the area and forms more than 90% of the total vegetation. The trees are confined to hill slopes and are interspersed with *A. catechu* on the lower and *Boswellia serrata* on the upper slopes.

tea forest comprises *B. monosperma* and *Z. mauritiana* as dominant. This forest type occurs in valley where more fertile soil and moisture conditions exist.

Zizyphus scrubland has scattered *Z. mauritiana, Acacia leucophloea, Capparis decidua, Balanites aegyptica* and *A. catechu* in the tree layer. Shrubs such as stunted *Z. mauritiana* and *C. sepiaria* is extensive and form most of the vegetation of this zone.

2.1.3 FAUNA

Animals found in Sariska National Park besides the Indian Crested Porcupine are - spotted deer (*Axis axis*), fourhorned antelope

(*Tetracerus quadricornis*), sambar (*Cervus unicolor*), nilgai (*Boselaphus tragocamelus*) and wild boar (*sus scrofa*) among ungulates; Common langur (*Presbytis entellus*), rhesus monkey (*Macaca mulatta*) among primates; Jackal (*Canis aureus*), jungle cat (*Felis chaus*), caracal (*Felis caracal*), common leopard (*Panthera pardus*), tiger (*Panthera tigris*) among carnivores. The mammal list is given in more detail in Sariska Management Plan 1981-1985. More than 250 bird species have been recorded here (Tej Singh pers. commun.).

2.2: METHODS

INTRODUCTION

Each sub-section is categorized according to the different parameters of the study. For instance sub-section 2.2.1 describes the initial survey undertaken to estimate the debarking intensity in different parts of the study area. 2.2.2 is concerned with the methods of studies done in ISS. Sub-section 2.2.3 deals with studies done in transects outside the Sariska valley.

Sub-section 2.2.4 is about the microscopic analysis of porcupine faeces. 2.2.5 includes survey to record the mortality rate of trees due to girdling. 2.2.6 is about density estimation of porcupine. Cafeteria experiment on porcupine in captivity is given in 2.2.7.

TUDY

METHODS

INTRODUCTION

Study was conducted in Sariska National Park from 6^{th} May 1989 to 10^{th} October 1989. This chapter is divided into two major sections - 2.1 and, 2.2 dealing respectively with the description of the study area and the methods used for the study. Subsections of section 2.2 end with the brief description of analytical methods used for calculations wherever necessary.

2.1 STUDY AREA

In the following sub-sections location, topography, climate, vegetation and fauna of Sariska National Park is described briefly.

2.1.1 LOCATION, CLIMATE & TOPOGRAPHY

Sariska National Park ($27^{o}20'$N & $76^{o}25'$E) in south-eastern Rajasthan is spread over 288 km^2 (Fig. 1). The altitude ranges from 300 m. to 690 m. The region is semi-arid with subtropical climate, dominated by hot dry summer, a hot wet short monsoon and cool, dry winter.

Temperature is as high as 45.5 ^{o}C in summer but in winter it goes down to 4-5 ^{o}C. Annual rainfall averages 650 mm. and occurs of the trees measured. Qualitative data on tree phenology collected by visually estimating the amount of leaves, flowers and fruits as:

0 (nil) = if there was no amount

1 (low) = if the amount was between 1-25% of the branches in that tree

2 (medium) = if the amount was between 26-75% of the branches in that tree and,

3 (high) = if the amount was more than 75% of the branches in that tree.

2.2.2 INTENSIVE STUDY SITES (ISS)

Since it was not possible to do study in all of the Sariska Valley, some sites were selected on the basis of the reconnaissance survey for intensive studies. These sites were selected such that the major vegetation types were represented.

2.2.2.1 GENERAL DESCRIPTION

Vegetation type, frequency of trees debarked and porcupine dropping groups found along the transects were the criteria for selection of the ISS. Based on this four ISS were selected initially (fig. 3) -

1. A degraded area of *Zizyphus* Scrubland, about 3 km. south of Sariska Gate, where largest number of dropping groups but least

number of debarked trees were recorded in the reconnaissance survey. The vegetation consisted of *Acacia leucophloea*, *Balanites aegyptica*, *Capparis decidua*, and *Zizyphus mauritiana*. It had dense shrub cover of *Zizyphus mauritiana* and *Capparis sepiaria*.

2. A mixed woodland with *Zizyphus mauritiana* and *Butea monosperma* as dominating species but also had *Acacia catechu* and *A. leucophloea*. This site was situated near Tarunda. During the reconnaissance survey the number of dropping groups and extent of debarking were found to be moderate. The shrub cover was open and was patchy.

3. A *Zizyphus* woodland, near Brahmanath Ki Jodi, with *Zizyphus mauritiana* as dominant species in valley and *Anogeissus pendula* on hill slopes. Here signs of debarking were extensive but number of dropping groups was low. The shrub cover was not dense and was confined along a stream which passed across the ISS.

4. A woodland almost purely dominated by *Butea monosperma* and *Zizyphus mauritiana* in the valley. One of the two hill slopes adjoining this ISS was entirely rocky and the other had pebbles. The intensity of debarking and number of dropping groups found were moderate as in ISS - 2.

Two more ISS (Fig. 3) were laid in August-September after initial study of the first four sites.

5. In *Anogeissus* woodland near Bandipul to investigate whether the avoidance of *A. pendula* in other ISS's was due to the presence

of *Z. mauritiana, B. monosperma, A. catechu* and *A. leucophloea* trees or, *A. pendula* is avoided generally by porcupine.

6. Around the village Haripura to the determine the effect of human presence on debarking habit of porcupine. The vegetation around the village was similar to that of *Zizyphus* scrubland but was in more degraded conditions. Hence it was classified as Degraded *Zizyphus* Scrubland.

2.2.2.2 <u>TRANSECTS FOR TREE DENSITY AND DEBARKING EVIDENCES</u>

Each ISS consisted of four parallel belt transects 500 m. in length and 100 m. apart. The width of the transects on either side was 10 m.. Total area of each transect was thus one hectare (20 m. x 500 m.). All the trees within 10 m. width on either side of the transects were counted. Average density of trees in an ISS was quantified after dividing total number of trees by total area of the four transects.

Since the density and species of trees was different on the hill slopes and valleys, the density is calculated separately for these two topographic features. Density is described as mean$\pm$ SEM (standard error of mean).

Each tree within 10 m. of the transect on either side was examined for signs of debarking. Tree species, GBH, debarking class (see section 2.1) and height of debarking above the ground were noted. Debarking evidences were categorized as:

1. **New**, if the tree had fresh debarking estimated to be from January 1989. This was identified on the basis of the colour of the hardwood exposed after debarking. Hardwood exposed during January 1989 onwards was bright yellow with pink or light brown margins (Plate 2).

2. **Old**, if the tree was debarked before Jan. 1989. The colour of the hardwood was dull yellow with dark margins due to rains and deposition of dust particles (Plate 3).

3. **N/O** (New/Old), if the tree had both new and old signs. The debarking intensity was classified on the basis of new debarking evidences (Plate 2).

The data from 24 transects in the six ISS was pooled to analyze and to test the null hypotheses (H_0) described in section 1.4. [redacted] Chi-square (X^2) tests (Siegel 1956) were conducted using SPSS programmes to detect the significant differences in:

1. The overall debarking in six ISS.
2. Debarking in four species (*A. catechu*, *A. leucophloea*, *B. monosperma* and *Z. mauritiana*) in each ISS.
3. Debarking in different girth classes (four species) of trees in six ISS.
4. Debarking in different girth classes in each of the four species.

For all the tests the minimal significance value was set as .05.

GBH of the trees was categorized in 10 cm. classes on the basis of the number of trees in the samples and the range of girths. The minimal girth class was 20 cm. and maximum class was 120 cm. because most of the trees [redacted] were within this range. All trees bigger than this were grouped in a girth class >120 cm.

Median GBH of the four species was calculated separately for all the trees and the trees debarked to compare differences in the two cases.

All the trees within the transects with new debarking signs were marked with red nylon ribbons to avoid recounting. The ISS and transect numbers, debarking class and date of recording were noted on these ribbons. New debarking evidences were recorded whenever found and the trees were marked.

Temporal variation in debarking intensity was calculated taking into account only the new debarking signs recorded from 21^{st} May onwards. The cumulative total of new debarking evidences before this period was not taken into consideration for seasonal changes in debarking. The data were grouped in 15 days interval for determining the variation in debarking with time.

2.2.2.3 TREE PHENOLOGY AND DENSITY

In every transect in a ISS, 6 circular plots of 10 m. radius at 100 m. intervals were laid. These plots were prominently marked. Qualitative data on phenology of trees was collected in the same manner as in section 2.2.1. Density of trees and shrubs was quantified in each plot by counting the number of plants and dividing it by the area of the plot (314 m^2.). This density was converted to No./ha by multiplying the results with 10,000. All density calculations are depicted as mean$\pm$ SEM (standard error of mean).

2.2.3 SURVEYS OUTSIDE SARISKA VALLEY

Three transects (Fig. 3) were placed outside Sariska valley to estimate the pattern of debarking and to compare the findings with those of the Sariska valley. Each of these sites had sample plots at 100m. or 200 m. interval in different transects. The size of the sample plot varied in radius (10 m. or 20 m.) according to vegetation type. Debarking evidences on trees within sample plots were recorded as present or absent only. The sites where transects were laid included:

A: From Buja on Sariska - Pandupole road to Kirashka Plateau (Fig. 3) which is 2.5 km. east of Buja. This transect passed through various types of vegetation and topography. At intervals of 200 m. all trees within a 10 m. radius plot were examined for signs of debarking.

B: In a *Butea monosperma* patch on Kirashka Plateau (Fig 3). The transect was 1 km. long and 10 nearest trees at every 100 m. were examined for debarking evidences.

C: UdaiNath - a rocky scrubland in buffer zone West of Sariska Valley (Fig.3). The 3 km. long transect included circular plots of 20 m. radius (due to sparse vegetation) at 200 m. intervals. Every tree within the 20 m. radius plot was examined for debarking signs.

2.2.4 MICROSCOPIC ANALYSIS OF PORCUPINE FECAL MATTER

Dropping were collected from the field in summer (May-June) and monsoon/post-monsoon seasons (July-October) to investigate the proportions of different food items eaten by porcupines and to correlate these with the seasonal changes of debarking.

Food items were classified as follows:

A. DICOTYLEDONS

  I. bark

  II. stem

  III. leaves

B. SEEDS

C. MONOCOTYLEDONS

Fecal material was dried and then crushed in a pestle and mortar. One dropping was taken from a dropping group as sample. If the dropping groups were collected in the summer they were treated with 10% Nitric acid (Monro 1982) for a period of 24 hrs. before observing under microscope (trial and error testing). This material was ground again and thoroughly washed. This was then observed, under 20x power microscope, in a petri-dish having 16 grids of 1 cm^2 each at its base. All microscopic examinations were carried out under 'Getner (India)' binocular microscope with 20x power (2x objective and 10x eye piece).

The faecal matters of monsoon and post-monsoon were kept in water instead of 10% HNO_3 (trial and error testing) and examined after 10-12 hrs.

The ingredients of fecal matter were classified with the three categories (A, B & C) on the basis of reference specimens. Reference specimens of bark and stem were prepared by treating them with hot 10% HNO_3 (kept in boiling water for 15 minutes) and then leaving them out for 24 hrs.. Samples from grasses and leaves of herbs and shrubs were treated with 10% HNO_3 at room temperature and specimens were ready for examinations after 12 hrs.

Proportion of different food items in the dropping was calculated after quantifying their number in different grids. Mann-Whitney U-tests (Siegel 1956) was conducted (Kumar, A. pers. commun.) using SPSS to find out if the variation in the food items consumed during summer and monsoon/post-Monsoon period were significant.

2.2.5 SURVEY OF GIRDLED TREES

This survey, conducted from 6 August to 29 September, comprised the area from Sariska to Kalighati. In total 343 girdled trees were examined. Their state (alive or dead) was judged by the presence or absence of leaves. Since all the trees in the study area were expected to be with leaves after onset of monsoon, those with no leaves were recorded as dead. This data were used to estimate mortality of trees due to girdling.

2.2.6 PORCUPINE DENSITY ESTIMATION

Density of porcupines were estimated using animal sightings as well as indirect evidences.

2.2.6.1 DENSITY BASED ON ANIMAL COUNTS

Vehicle (open jeep) transects were made at night between 2100-2200 hrs. for a distance of 10 Km. (to Kalighati) along the Sariska - Pandupole road (Fig. 2). Animals were visible only in the headlights. This light covered a range of approximately 10 m. on either side, so the animals within this range only were recorded. Vegetation types in which animals were found along the road was recorded.

2.2.6.2 DENSITY BASED ON DROPPING SETS

In May, when the study began, an attempt was made to calculate the density of animals on the basis of indirect evidences. All dropping groups found within 2 m. on either side of the transects in ISS were recorded along with perpendicular distance to the transect.

Although there was no ground cover during summer and it was possible to record the dropping groups within 3 m. on either side of the transect, this would have required tremendous amount of time for one person to record all droppings in that area. Furthermore, the chances of missing dropping sets would had been more. Scanning in width of 2 m. on either side along 500 m. length took 30-40 minutes per transect. Hence the latter method was adopted. Dropping groups were removed every time they were encountered (collected for microscopic analyses or destroyed).

Defecation rate of porcupine was studied at the National Zoological Park, New Delhi. The Zoo was visited twice (20-22 May & 20-28 July). An enclosure with one porcupine was selected for study. The number of dropping groups of the previous day was recorded every morning before the cage was cleaned. The number of dropping sets found in wild were divided by defecation rate to estimate the animal number in that area.

Since the porcupine diet in Zoos is different from that of wild, the defecation rate would also probably differ (they differ in shape and size of the dropping in the two places). So this attempt to calculate density of the animals based on number of dropping groups was discarded and was used only for determining relative abundance of the porcupines in different ISS's.

Fixed width transect method (Caughley 1975) was used to calculate the density of the animals. Data from the night transects were grouped and, average number of animals seen per transect was determined. The following formula was used for density calculation (Caughley 1975):

$$\frac{N}{2\ L\ X\ D}$$

where

N is the number of animals seen

L is the width of the transect on one side and,

D is the distance covered (length of the transect),

The denominator is multiplied by 2 to include the width on both sides of the transect.

2.2.6.3 <u>DECAY RATE OF DROPPING</u>

Another attempt to facilitate the estimation of animals based on indirect evidences was to study the decay rate of the dropping. It helped in determining how old was the dropping group. This study was done in natural and semi-natural conditions. Dropping groups excreted during the night before encountered were collected for this purpose. Data on the condition on these groups was collected at interval of 7 days.

In natural conditions the decay rate of 5 dropping groups was studied. These samples were collected when encountered along transect and were put at the end of that transect.

In semi-natural conditions the collected dropping groups were kept in open in the backyard of my house. All other conditions such as ground cover, tree canopy were similar to that in the wild.

Since calculation of animal density based on the dropping abundance is discarded, dropping decay rate which was attempted to use as a supplement for density quantification will not be used further in this thesis.

2.2.7 CAFETERIA EXPERIMENT

Bark samples from eight tree species was fed to the porcupines in National Zoological Park, New Delhi for one week (July 20^{th} to 29^{th}). These eight tree species included the debarked and not debarked common species in Sariska.

Bark samples were stored in refrigerator, and were provided to the nine porcupines in random combination of two species at a time. Samples were weighed to an accuracy of 1 gram before and after the feeding bouts the porcupines. This information was inadequate hence will not be used further in results or discussion.

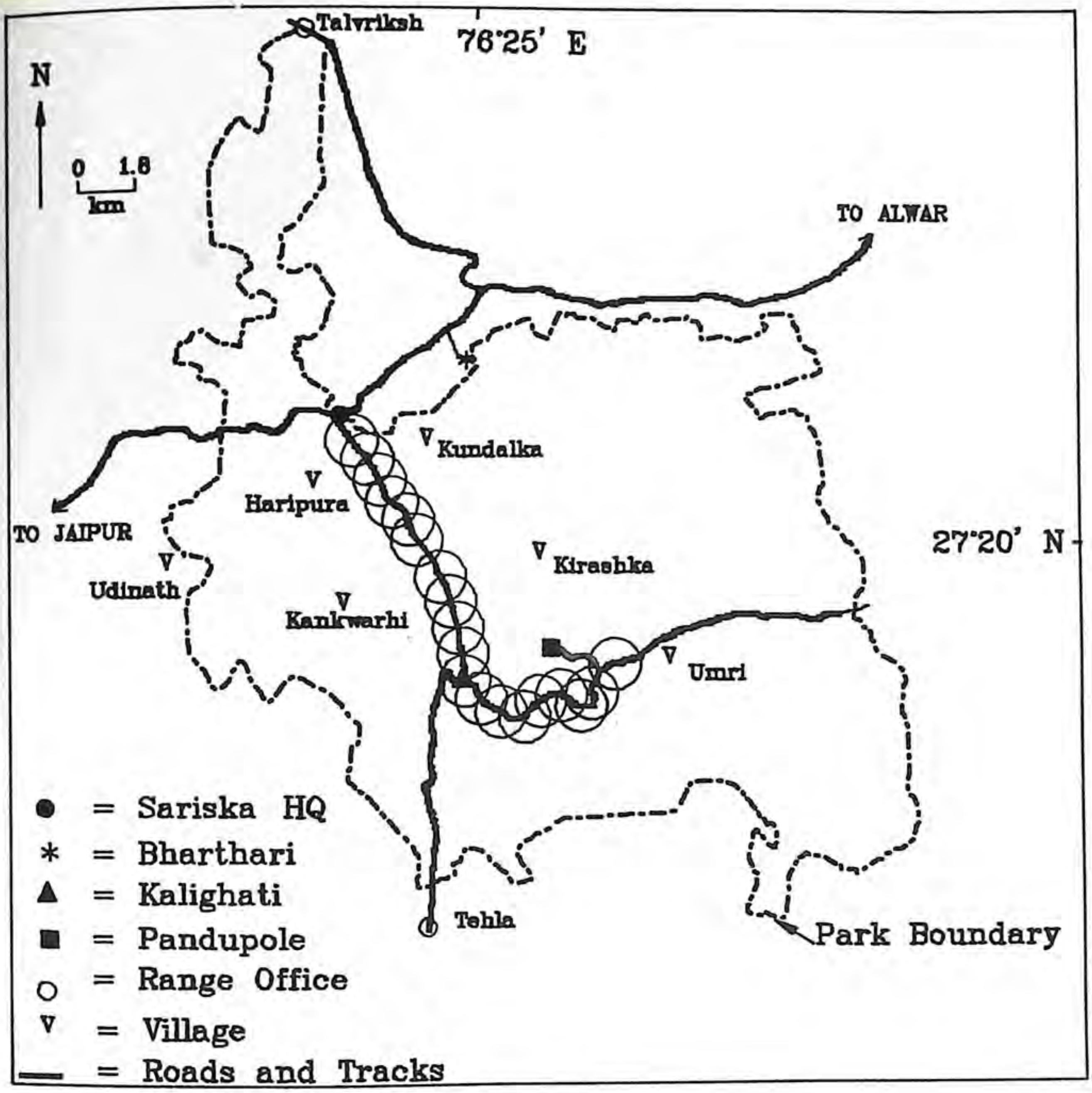

Fig. 1 Map of Sariska National Park. Study area (Circled) was along Sariska–Pandupole Road.

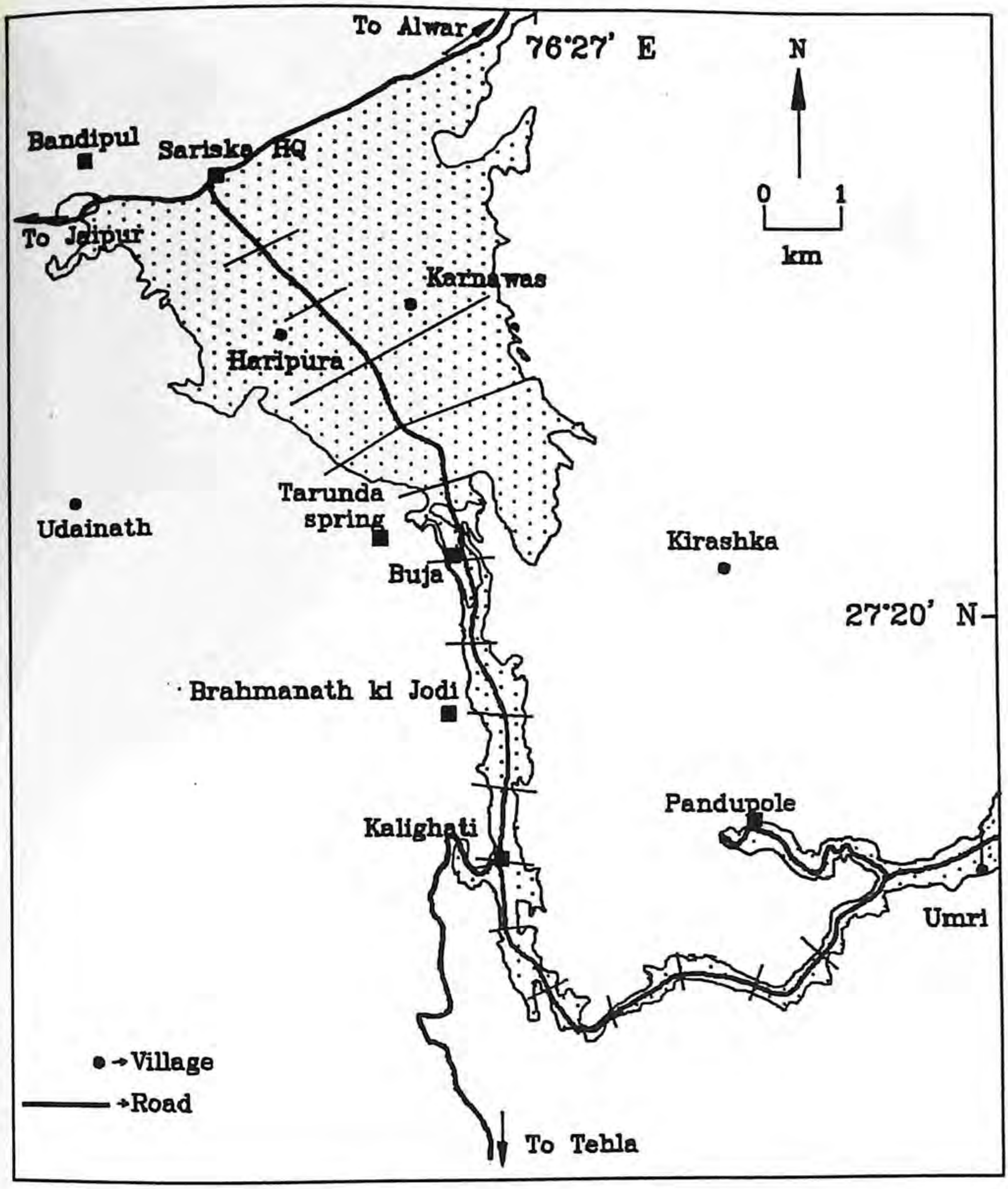

Fig. 2 Diagramatic view of Sariska Valley (Dotted) showing reconnaissance survey transects (——)

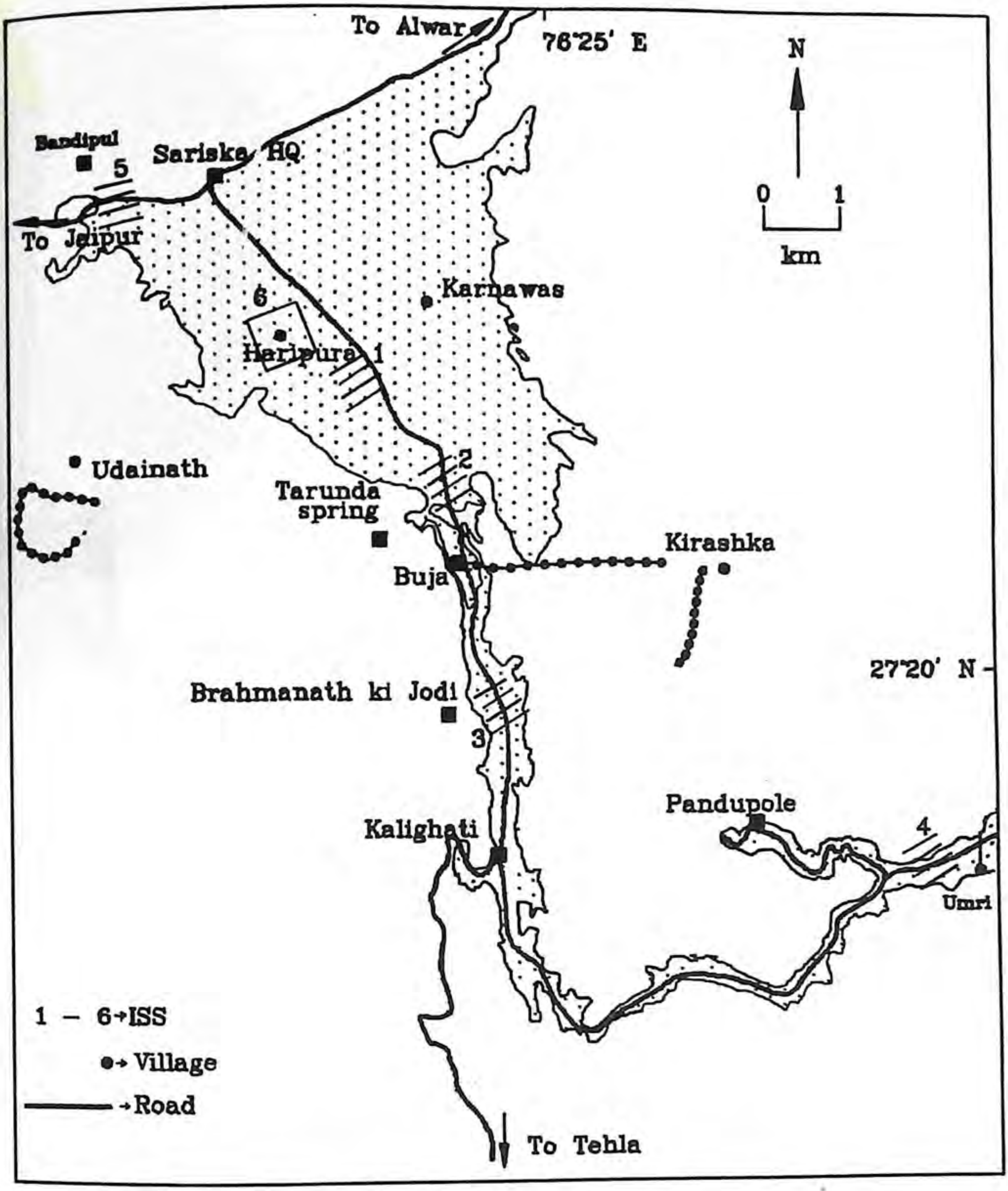

Fig. 3 Diagramatic view of Sariska Valley (Dotted) showing Intensive Study Sites (ISS) and surveys outside the valley.

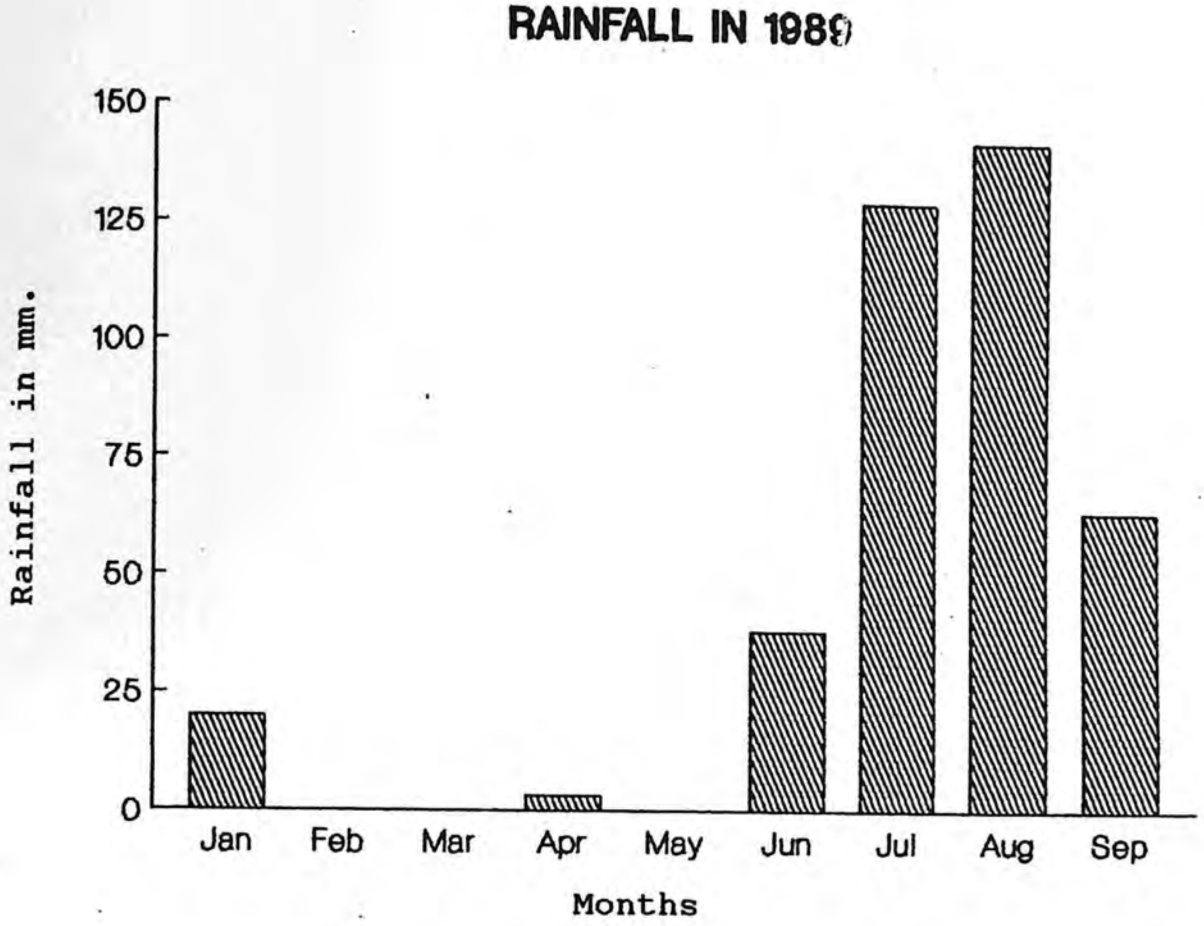

Fig. 4. Variations in rainfall (upto 10^{th} Oct) during the year 1989. (Source: K. Shankar).

Plate 2. *Acacia catechu* with old and new debarking signs.

Plate 3. *Zizyphus mauritiana* with two debarking evidences of debarking in different years.

3. RESULTS

INTRODUCTION

This chapter is divided into eight sections each of which deals with a different parameter of the study. Section 3.1 is about the results obtained from the reconnaissance survey to select Intensive Study Sites. The results of vegetation types in each of the Intensive Study Sites (ISS) are described in section 3.2.

Section 3.3 illustrates the spatial patterns in debarking evidences collected in different areas during the study. Section 3.4 is about the variations in the vegetation with time. 3.5 is concerned with temporal patterns of debarking between seasons and, years.

Results of microscopic analysis of porcupine faeces for dietary composition are illustrated in section 3.6. The effect of debarking on tree mortality is described in 3.7. 3.8 deals with porcupine density estimation.

3.1 SELECTION OF INTENSIVE STUDY SITES

Table 1 shows the results from the reconnaissance survey. The results are used to select or reject areas as ISS. The transects were grouped in fours for the ease of interpretation. Grouping was done in such a way that all four transects in a group passed through the same vegetation type. The vegetation description is given only for the valley section of the transects since the hills were invariably dominated by *Anogeissus pendula*.

Transect 1-4 were in the degraded *Zizyphus* scrubland where trees were scattered. This area was disturbed due to cattle presence. No debarking evidence was found along the transect in this area. Number of dropping groups was little. This area was not selected for intensive studies because the animal signs were few and debarking evidences were negligible.

In transects 5 to 8 the number of droppings found was the largest but the debarking intensity was less than others. It was a scrubland with high density of scrub (Table 1). *Acacia catechu* (35.5%), *Acacia leucophloea* (48.7%) and *Balanites aegyptica* (10.5%) were the dominating tree species. Part of the area falling under these four transects was selected as ISS-1.

Transects 9-12 were in an area dominated by *A. catechu* (35.7%), *Butea monosperma* (16.7%) and, *Zizyphus mauritiana* (47.6%). The number of droppings and debarking evidences found here were moderate (Table 1). The ISS number 2 was selected in part of this area and the vegetation was classified as mixed woodland.

The vegetation type, animal signs and debarking evidences were almost the same from transect 13-24 (Table 1). The vegetation was dominated by *A. catechu* and *Z. mauritiana* and was categorized as *Zizyphus* woodland since more than 50% of the trees were that of *Z. mauritiana*. The damage signs were extensive but animal signs were very little. The portion of this area which came under transect 13-16 was selected as ISS-3 since it was closer of access and the new debarking evidences were recorded in this region only.

Transects 25-32 passed through a very narrow valley and hence were short. *Butea monosperma* and *Z. mauritiana* were found as dominants. Although moderate debarking and animal signs were recorded from this area, the small spatial extent meant no ISS was chosen from this region. An area with similar vegetation type and animal and debarking signs was selected as ISS-4 on the Umri road form Sariska - Pandupole road.

3.2 VEGETATION DESCRIPTION

Vegetation is described separately for each ISS. For density calculation of each individual species in different ISS only the dominant species are taken into account, the rest of the species are shown as OTHERS.

3.2.1 INTENSIVE STUDY SITE - 1

This area was classified as *Zizyphus* scrubland. Trees were scattered (Plate 4) and density was low, 72/Ha (Table 2). Seven species were encountered of which *Acacia catechu* and *A. senegal* were in very low density ($\leq$1 tree/ha). The tree layer (Table 4) was represented by *Acacia leucophloea* (17/ha), *Balanites aegyptica* (28/ha), *Capparis decidua* (10/ha) and, *Zizyphus mauritiana* (7/ha). These species composed 27.0%, 43.2%, 14.7% and 10.0% respectively of the total tree stand.

The shrub density was high (Table 3). In the shrub layer *Z. mauritiana* formed the major part (71%). *Grewia flavescens* and *Capparis sepiaria* composed 25.5% and 3.5% of the shrub layer respectively.

3.2.2 INTENSIVE STUDY SITE - 2

This site categorized as Mixed Woodland (Plate 5) was near Tarunda Hide. Seven species contributed to the total of 565 trees recorded in the four transects. The overall tree density (table 2) was quantified as 160±15 individuals/ha. *A. catechu*, *A. leucophloea*, *Butea monosperma* and, *Z. mauritiana* formed the tree canopy, but *B. monosperma* and *Z. mauritiana* together composed 63.8% of the tree layer. *Z. mauritiana* was distributed, while B. monosperma was localized mainly in transects 1 & 2. Transect 4 ended at a hillock with *Anogeissus pendula* on it. Density of major tree species is given in table 4.

Average shrub density in this site was 79±28/ha. (Table 3) and was clumped in patches. The shrub layer was dominated by *G. flavescens* (75%), *C. sepiaria* (16%) and *Z. mauritiana* (9%).

3.2.3 INTENSIVE STUDY SITE - 3

This site was classified as *Zizyphus* Woodland (Plate 3 and Fig. 3). Approximately 16% of the site was occupied by hills which had a pure patch of *Anogeissus pendula* with a Density of 566 individuals/ha.

The total tree density in this ISS is given in table 2. Density in the valley was comprised by five species shown in table 4.

Balanites aegyptica and *Capparis decidua* were represented by one individual each.

Shrub density was the second highest among all the sites (table 3) but they were very small in size. Most of it was composed of *C. sepiaria* (61%) and *G. flavescens* (34%). Distribution was restricted to the edge of the stream passing through the site and, at the base of the hills.

3.2.4 INTENSIVE STUDY SITE - 4

This site, classified as *Butea* woodland (Plate 7) was situated along the Umri (a village) road - 19 km. from Sariska. Half of the site (two transects) was over hill slopes. A total of 556 trees with 14 species were counted in this site, which had a density of 273±22/ha (table 2), most of it *B. monosperma* (31.7%) and *Z. mauritiana* (25.3%). Besides these species *A. catechu* contributed 4.5% and *Anogeissus pendula* (on hill slopes only) 32.3% to the total number of trees in this site.

Density of dominating species is given in Table 4. *A. leucophloea*, *Anogeissus latifolia*, *B. aegyptica*, *Bauhinia racemosa*, *Ficus benghalensis*, *Lannea coromandalis*, and *Mitragyna perviflora* were very few in number (density <2/ha). Eleven individuals each of *Boswellia serrata* and *Phoenix sylvestris* were recorded. *P. sylvestris* occurred along the streams while *B. serrata* was on upper parts of the hills.

C. sepiaria and *Z. mauritiana* formed the major part of the shrub layer.

3.2.5 INTENSIVE STUDY SITE - 5

This ISS, categorized as *Anogeissus* woodland (Plate 8) was located 2.5 km west of Sariska along the Alwar - Jaipur Highway (Fig. 3)& had highest tree density of 415/Ha (table 2) dominated by *Anogeissus pendula*. A total of 1660 trees were measured in 4 transects. *A. pendula* comprised 86% of the total, followed by *Acacia catechu* (7.7%) and *A. leucophloea* (4.2). Density of *Anogeissus latifolia*, *Acacia senegal*, *B. aegyptica* and *Z. mauritiana* was little ($\leq$2 individuals/ha).

Shrub density was low (table 3). These were localized at the base of the hills. *C. sepiaria* and *G. flavescens* formed the major part.

3.2.6 INTENSIVE STUDY SITE - 6

This site classified as Degraded *Zizyphus* scrubland was around the Village Haripura (Plate 9), 2 km south of Sariska. Very low tree density 27$\pm$8/Ha (Table 2) was recorded in this site. Distribution of trees was clumped with large number of trees in transect 1. Transect 3 had least number of trees.

A. leucophloea was the dominant species and formed 51% of the tree layer. It was followed by *C. decidua* comprising 39%. *Acacia nilotica*, *Anogeissus pendula* and, *B. aegyptica* had very low density. The land was degraded to a large extent due to cattle grazing. The area in west and south of the village was almost barren and had mainly *C. decidua* in it.

Distribution of shrubs was also clumped. Most were in transect 1. *C. sepiaria* and the weed *Adhatoda vassica* formed the major part of this layer. The overall density of shrub is given in table 3.

3.2.7 SURVEYS OUTSIDE THE SARISKA VALLEY

The transect in the Udianath area (Fig 3) passed through scrubland with tree density 47±7 trees/ha. Eight species contributed to the total of 73 trees recorded in 12 plots along this transect. *A. leucophloea* composed 68.8% of the tree layer and was followed by *C. decidua* (9%) *B. aegyptica* and *B. monosperma* (each 6.5%).

In the transect on Kirashka Plateau (Fig. 3) *Butea monosperma* comprised 63% of the total stand and *A. leucophloea* formed 32.6%.

The third transect passed through various topographic features of valleys and hill slopes. Major part of this transect was composed of *Anogeissus* forest on the hills. The average density was 318±71/ha. *A. pendula* formed 60%, *Acacia catechu* 18.3% and, *Boswellia serrata* comprised 10% of the vegetation.

3.3 SPATIAL VARIATIONS IN DEBARKING

Results here include data on overall debarking incidence comparison among ISS's, [redacted] among tree species in different ISS's, among GBH classes in different ISS and, among size (GBH) classes in different tree species. Results of the surveys outside the Sariska valley are compared with that of findings in ISS's.

In 6 ISS, 4021 trees were examined for debarking incidence. Nineteen species were recorded of which nine species (*A. nilotica, Acacia senegal, Bauhinia racemosa, C. sepiaria, Ficus benghalensis, Lannea coromandalis, Mitragyna perviflora*, and *Sterospermum sp.* were represented by $\leq$5 tree in any ISS. Of the remaining 11 species, six were not found debarked in any of the ISS. These included *Anogeissus pendula* (1932 individuals), *A. latifolia* (8), *Balanites aegyptica* (174), *Boswellia serrata* (11), *Capparis decidua* (101) and *Phoenix sylvestris* (12).

The remaining 1742 tree individuals of 4 species formed the data for debarking incidence. Hence all types of analysis for debarking phenomena includes only 4 species - *A. catechu, A. leucophloea, B. monosperma* and *Z. mauritiana*.

3.3.1. OVERALL COMPARISON AMONG INTENSIVE STUDY SITES

The hypothesis under test is that there is no selection of area by the porcupine for debarking trees.

Table 5 shows the overall patterns of debarking of four species in six sites. The maximum debarking was in *Zizyphus* woodland where 378 (64.6%) out of total 585 trees were debarked. Second highest debarking percentage was in Mixed woodland in which 284 of the 461 (61.6%) trees were utilized. These are followed by degraded *Zizyphus* scrubland (25 out of 54; 46.3%), *Butea* woodland (131 of 211; 38.3%) and, *Zizyphus* scrubland (31 of 101; 30.7%). No tree was observed debarked in *Anogeissus* woodland out of 310 trees examined.

The observed difference in debarking among these ISS's was highly significant (X^2= 306.97, df=5 p <.0001). Hence H_0 was rejected in favour of H_1 that there were areas where debarking intensity was significantly higher (ISS-2 & ISS-3) and others where debarking intensity was nil[redacted] (ISS-5).

When debarking was related to vegetation type (Fig. 5) it indicated that the ISS that had relatively more percentage availability of *A. catechu*, *A. leucophloea*, *B. monosperma* and *Z. mauritiana* would have greater level of debarking. [redacted] The linear regression of percentage debarked on percentage availability shows that correlation is significant (r =.915, p <.03).

3.3.2 DEBARKING OUTSIDE SARISKA VALLEY

Areas surveyed outside the Sariska Valley had little evidence of debarking evidences, the intensity of debarking was not higher than 10% of the total trees examined along any of the three transects. Only *A. leucophloea* (5.2%) was observed debarked in transect laid in Udainath. Debarking incidence were low also in *Butea* Woodland near Kirashka Village in comparison to that in ISS-4. In 10 plots 4.2% (4) trees were recorded debarked out of 96 trees examined. The intensity of debarking is significantly different from that in ISS-4 (X^2 = 39.38, df = 1, p < .0001).

In 2.5 km. long transect from Buja to Kirashka 60 trees of 11 species were examined for debarking. Only 6 trees were discovered debarked, all *A. catechu*. Same factors (section 3.3.1) account for low debarking in Udainath and from Buja to Kirahska.

The Factor which limits the debarking in *Butea* woodland on Kirashka Plateau is lack of ground cover. It is based on the observations that only 2 dropping groups were found along 1 km. long transect during summer (June) when there was no cover on the ground, while large number of dropping sets (7) were discovered in small patch (1 ha) in October (post-monsoon). There was comparatively more cover on the ground during letter period.

3.3.3 DEBARKING IN DIFFERENT SPECIES IN EACH ISS

The null hypothesis is that there is no selection of tree species for debarking.

Debarking intensity was low in ISS 1. Only one of the five (20%) *A. catechu* was debarked. *A. leucophloea* was debarked 27.1% (19 trees) of the 70 individuals examined. In *Z. mauritiana* 11 trees (42.3%) of the 26 were debarked. Difference in debarking extent is not significant (Table 6) possibly due to low sample size.

A. catechu was debarked heavily in ISS-2. 31 (88.6%) of the 35 trees were utilized by the porcupine. This is the highest observed debarking in any of the species and ISS. *Z. mauritiana* ranked second with 67% (150 trees) of the 224 trees of this species were debarked. 52.3% (34 trees) out of 64 trees of *A. leucophloea* were debarked and 50.4% (69 trees) of *B. monosperma* were utilized. The observed difference between species is highly significant (X^2 = 27.17, df = 3, p < .001). This difference is contributed by *A. catechu* and *Z. mauritiana* which are debarked more than others (p <.05). The 88.6% debarking of the *A. catechu* is also significantly more than that 67% of the *Z. mauritiana* (p <.01).

A. catechu was again debarked heavily in ISS-3. 67.8% (101) of the total 149 trees were consumed. *A. leucophloea* was utilized 63.6% (7) of the total 11 trees and 63.5% of the total 425 trees of *Z. mauritiana* were debarked. It is inferred that there is no difference in debarking pattern (Table 6).

In ISS-4 39% *B. monosperma* was debarked out of total 141 trees. Similarly 43.7% of the total 174 trees of *Z. mauritiana* was utilized. *A. catechu* was represented by 25 trees - none of them debarked. There were only two individuals of *A. leucophloea* and were not debarked. The overall difference in debarking is significant (X^2= 18.92 df= 3 p< .0005). Even debarking in *Z. mauritiana* is significantly more than that in *B. monosperma* (p <.05).

No tree was debarked in ISS-5.

In ISS-6 only *A. leucophloea* was debarked 46.3% (25) of the total 54.

The null hypothesis that there is no selection of species was accepted for *Zizyphus* scrubland, *Zizyphus* woodland and degraded *Zizyphus* scrubland sites in which the difference is not significance. In *Anogeissus* woodland no tree was consumed. Null hypothesis was rejected for mixed woodland and *Butea* woodland in favour of alternative hypothesis that there is selection of some species for debarking in these sites (Table 6).

It can be inferred from Table 6 that whenever available for debarking in valley woodland *A. catechu* and *Z. mauritiana* were debarked most heavily.

3.3.4 DEBARKING IN DIFFERENT GIRTH CLASSES OF TREES IN EACH ISS

The null hypothesis is that there is no preference of any particular GBH classes.

The sample size was not large in ISS-1 (frequency was <5 in 59% of the cells). GBH class 20-50 cm had 57.4% of the trees. Fig.6a shows the pattern of debarking in different GBH in this ISS. The observed difference is not significant.

In ISS-2 which had mixed vegetation of *A. catechu, B. monosperma and Z. mauritiana* there was no significant difference in the debarking in different GBH classes (Fig 4b).

Site 3, the *Zizyphus* woodland which had 72.8% of trees in four lowest girth classes, had significant difference ($X^2 = 24.8$, df = 9, $p < 0.005$) in overall debarking in girth classes. Fig. 6c shows that GBH 41-100 cm is utilized more than any other girth classes. The large intensity of debarking (80%) observed in GBH in the two highest girth classes is not taken into account due to low sample size in these classes.

ISS-4 which had mean girth class 81$\pm$2 cm shows more damage in higher classes (51-110 cm.) (fig. 4d) than in ISS-3. This change is due to *B. monosperma* which has larger girth (121$\pm$3 Cm). In this ISS even the *Z. mauritiana* had higher GBH (62$\pm$2 Cm) than any other ISS (54$\pm$1 cm). The overall difference in debarking intensity in different GBH classes was significant ($X^2 = 42.33$ df = 10 $p < .0001$).

No tree in any girth class was found debarked in ISS-5, the *Anogeissus* woodland.

Fig. 6e shows the debarking pattern in ISS-6. Because of very low sample size in ISS 6 (degraded *Zizyphus* woodland) the observed difference is not statistically significant.

The null hypothesis was accepted for ISS-1, 2 and 6 since the difference in debarking in size classes of trees in these sites is not significant. Null hypothesis was rejected for ISS-3 and 4 in favour of alternative hypothesis that in these two ISS trees of particular girth classes were debarked significantly more.

3.3.5 DEBARKING IN DIFFERENT GIRTH CLASSES IN FOUR SPECIES

The null hypothesis was that there is no preference for any particular size (GBH) class.

A. catechu, A. leucophloea and, *Z. mauritiana* had an average low girth class (42±1 cm., 68±2 cm. and 54±1 cm. respectively). But mean GBH of the trees debarked in these species was higher (47±1 cm., 71±2 cm. and 56±1 cm. respectively). Situation is reversed in *B. monosperma* in which average GBH was higher (110±2 cm.) than the average GBH of debarked trees (108±3 cm.). X^2 tests were conducted to investigate the significance of these results.

Table 7 shows the percentage of trees of the four species debarked in different GBH classes. For each species debarking pattern in girth classes is described as percentage of trees debarked in a girth class out of total trees in that class (column WITHIN CLASSES) and, the percentage debarked in a girth class out of total trees debarked (column BETWEEN CLASSES).

It can be inferred from the table that in all species there is very little debarking in the lower girth classes than in any other class.

Referring to Table 7, a trend in the percentage of trees debarked in each GBH can be observed for both comparison within and between GBH classes. The intensity is low in the lower class, then increases with next 4-5 girth classes and decreases after that. In most of the cases there were not many trees in the lower and 2-3 higher classes. It means that trees are debarked in proportion to availability of trees in a girth class and, whatever variation indicated in Table 7 is not significant except in *A. catechu* and *Z. mauritiana* in both of which GBH class 31-70 cm. is debarked significantly more (X^2 for both spp. $p < .001$).

The null hypothesis was accepted for *A. leucophloea* and *B. monosperma* in which no size class was preferred or avoided significantly. But it was rejected for *A. catechu* and *Z. mauritiana* in favour of alternative hypothesis that some girth class(s) are preferred significantly.

The high percentage of debarking in 2-3 upper class is not considered since the sample size was low.

3.3.6 NEW DEBARKING EVIDENCES

A total of 136 trees were recorded freshly debarked. Largest amount of fresh debarking was recorded in ISS-2 where 50% (68) of the total fresh debarking was observed. Of these 68 trees 47 (69.1%) had old debarking signs. Least intensity of fresh debarking was observed in ISS-1 which contributed 8.1% (11) to the total. Four of these 11 were debarked in previous years also.

22% (30) trees were recorded for fresh utilization from ISS-3. 53.3% of these 30 trees also had old signs of debarking. The new debarking irtensity was 19.8% (27) in ISS-4. 11 (47%) of the 27 trees had debarking signs of previous years also.

3.3.7 DEBARKING EVIDENCES in 1988

New debarking evidences during 1988 was as high as 21.4% of the total debarking in *Acacia nilotica* plantation near Karnawas (Fig 3) while in *Zizyphus* woodland it was only 3.0%. This variation again shows that the intensity of debarking was not the same in all vegetation types.

Total new and old debarking intensity was 55.5% of the 117 trees examined (four species) in *A. nilotica* plantation while in *Z. woodland* it was 87.6% of the 166 trees observed. The difference in these two sites is significant ($p < .05$).

Comparison of debarking intensity in two areas (*A. nilotica* plantation and *Zizyphus* woodland) indicates that the site which had less debarking during previous years was debarked more i.e. in *A. nilotica* plantation only 31.2% of the trees were debarked before 1988. In *Zizyphus* woodland this intensity was 84.9%.

High percentage of trees with new and old debarking evidence in *A. nilotica* plantation may be because if species in an area are being debarked heavily it should be expected that every tree of that species will have more chances of being attacked by the porcupine than the tree in the area which is being used less for debarking.

3.4 PHENOLOGICAL VARIATION IN VEGETATION WITH TIME

3.4.1 TREE AND SHRUB LAYER

The median values for amount of leaf from all the species were compared for different time intervals in fig. 7a. Amount of flowers and fruits was not considered in this diagram since the median value for each of these was 0.

The calculated median values show that during the time interval 13^{th} to 30^{th} May (summer) the amount of leaves, flowers and fruits was 0 (nil) for all the trees of 8 species, except *A. leucophloea and B. aegyptica* which were in class 2, and, *B. mauritiana* and *C. decidua* were in fruit with value 1 (low) and 2 (medium) respectively. A total 387 trees were examined during this period.

In shrub layer only *C. sepiaria* was in leaf, condition 2. *Z. mauritiana* and *Grewia flavescens* did not have any leaf,flower or fruit on them.

From 28^{th} July to 9^{th} September (Monsoon) 522 trees were looked at for phenology and a median value of 2 was obtained for leaves and, 0 for flowers and fruits. *Z. mauritiana* was in flower condition 2. *C. sepiaria* and *G. flavescens* were in leaf condition 3 each, no flower or fruit.

During post-monsoon period from 9^{th} September to 9^{th} October, 579 trees of 10 species examined for phenclogy gave a median value of 3 for leaves and, 0 for flowers and fruit. But *A. catechu* and *Z. mauritiana* were in fruiting conditions 2 and 3 respectively during this season. *A. catechu* and *A. leucophloea* were in flower with median value 1.

C. sepiaria, *G. flavescens* and *Z. mauritiana* were in leaf condition 3. *G. flavescens* was in flower condition 2.

3.4.2 GROUND COVER

Grass cover was negligible (<5%) during summer and whatever present was dry. With pre-monsoon showers during 1^{st} week of June grass started erupting. It was during this time when the fresh debarking started decreasing. Showers after that were enough to keep the grass green till 3^{rd} week of July.

The Monsoon rains started in July (Fig. 7) and caused rapid growth of grass upto 1 m height by 1st week of August. No rains were recorded after 23^{rd} September. Total rainfall during the study period was 375 mm. Grasses started drying from second week of September, the time when *Z. mauritiana* started fruiting.

3.5 TEMPORAL PATTERNS IN DEBARKING

?.5.1 BETWEEN SEASONS in 1989

The null hypothesis was that the debarking intensity is uniform in all seasons.

Debarking was first noticed in SNP in the last week of February (K. Shankar pers commun.). Data show (Fig 7b) that debarking peaked in the month of May and beginning of June and then decreased continuously till middle of July. No debarking was observed in any ISS after that.

A total of 136 individual trees were recorded freshly debarked in ISS-1, 2, 3 and, 4. Since other ISS were laid in September after rains, it was not possible to differentiate new and old debarking. The number of trees newly debarked reveals that 7.8% of the total 1742 trees of 4 species described above were debarked this year.

Fig 7b represents the variation in debarking incidence with time period. Original data is clumped in 15 days intervals. The cumulative total of the trees debarked before 21st May is not included in the diagram since the time of debarking is not known. 59 trees were debarked during the study period. In ISS-1 42.8% of the total trees debarked during the study period were consumed in the 1st fortnight (21st May to 6th June). The intensity decreased to 28.6% during 2nd and 3rd interval and, no fresh debarking was observed after 3rd interval (21st June-4th July).

ISS-2 shows more abrupt changes. The new debarking decreased from 90.9% during 1st interval to 9.1% in 2nd interval (7th June to 20th June). The debarking extent decreased further to 4.5% for 3rd and 4th irtervals (21st June to 18 July). There was no fresh debarking incidence after that.

ISS-3 has comparatively more damage intensity in less time period. The fresh debarking incidence was confined only in 1st two intervals. It varied from 81.2% during 1st interval to 18.8% during 2nd interval.

66.7% of the total fresh debarking in ISS-4 was observed during 1st 15 days interval. It decreased to 33.3% during 2nd interval after which there was no incidence of fresh debarking.

3.5.2 BETWEEN 1988 AND 1989

Overall new damage in May'1988 amounted to 10.6% of the total trees of the four species (*A. catechu, A. leucophloea, B. monosperma* and, *Z. mauritiana*). This is not significantly more than the overall new damage (7%) this year.

3.6 MICROSCOPIC ANALYSIS OF FAECAL MATTER

71 dropping groups were examined microscopically during the study period. 38 of these were collected during summer (13th May to 28th June) and 33 during Monsoon/Post-Monsoon (8th August to 9th October). Table 8 shows the results.

Bark and stems composed the bulk of diet during summer. Leaves and monocot were not found in large amount. Faecal matter analyzed for Monsoon/Post-Monsoon period reveals large amount of seeds (of grass) and monocot which comprised large proportion in the diet.

Mann-Whitney U-test for the difference in the proportion of food items in summer and Monsoon/Post-Monsoon seasons reveals that difference in the proportion of bark, stem, seeds and monocot is significant (Table 8).

3.7 TREES IN DIFFERENT DEBARKING CLASSES

3.7.1 OVERALL PATTERN

In both the *A. catechu* and *Z. mauritiana* more than 30% of the trees were debarked in class 2 and 3 each. In *A. leucophloea* 46.4% of the total debarked trees were in class 2, while class 1 debarking was high (44.4%) in *B. monosperma*. Debarking in class 1 was more than 25% in any species. In all the species class 4 debarking was less than 5%.

3.7.2 EFFECT OF GIRDLING ON TREES.

334 tree individuals of only four species were observed girdled in Sariska valley from Sariska to Kalighati. Comparison of density of girdled trees with that of total trees of the same species (Table 9) shows that in all the cases the percentage of the trees girdled in any species is not more than 2.47. But the proportion

of dead trees varies greatly from 0% for *B. monosperma* to 100% in *A. leucophloea*.

Overall girdling of trees amounted to 1.68% of the total debarked trees in the study area. Of these 53.13% were dead which means that only 0.79% of the total debarked trees was dead due to debarking (girdling) by porcupine. The phenology of girdled trees which did not die was not affected.

Results in Table 9 show that there were very little chance of *A. leucophloea* being girdled, but once girdled it was highly susceptible to death. On the other hand *B. monosperma* was least susceptible to death whatever the chance of girdling.

A. catechu (Plate 10) had more chances of death after being girdled than that of *Z. mauritiana* (Plate 11) which had more chances of girdling. Hence it can be inferred from the Table 9 that *A. catechu* is more prone to girdling and death due to it than any other species.

3.8 PORCUPINE DENSITY ESTIMATIONS

Since the observations on the defecation rate of the porcupine were not acceptable, data is being used only for the relative abundance of dropping groups of the animal instead of estimating porcupine density on the basis of dropping groups and defecation rate. Hence only the data collected through night drive transect is used to calculate the density of the porcupines.

3.8.1 DIRECT COUNTING OF ANIMALS

Average porcupine density from 19 attempts and 28 animal sightings in Sariska valley amounted to 8$\pm$2 per km^2. Fig. 8a & 8b represent the number of animals and number of sightings according of distance.

Maximum number of sightings of animals were in Mixed woodland near Tarunda where usually two animals were seen. In the *Zizyphus* woodland near Brahmanath ki Jodi 4 sightings of the animals were recorded. Number of animal and sightings in *Zizyphus* scrubland was few.

No animal was sighted when it was bright/full moonlit nights.

3.8.2 DROPPING ABUNDANCE

This data comes from three sites (ISS 1,2 & 3) for twelve attempts that were made in summer. No statistical test are done because data set was not enough. Hence only the number of dropping sets recorded in three sites are being given as mean $\pm$ SEM (Standard Error of Mean).

Largest number of droppings 7.4$\pm$1.5 were observed in ISS-1. In ISS-2 this average was 3.1$\pm$0.7 dropping sets. No dropping group were found in ISS 3 except once.

DROPPING ABUNDANCE: ITS RELATION WITH SHRUB COVER

Dropping density was highest in *Zizyphus* scrubland which had largest density of shrubs and furthermore, the size of shrub was large. Although the shrub density in mixed woodland was less the size was large and they were thick as in ISS-1. Hence the porcupine dropping number was high in this ISS. ISS-3, the *Zizyphus* woodland had large amount of shrub but almost all of it were very small. Perhaps due to this negligible number of droppings were recorded here.

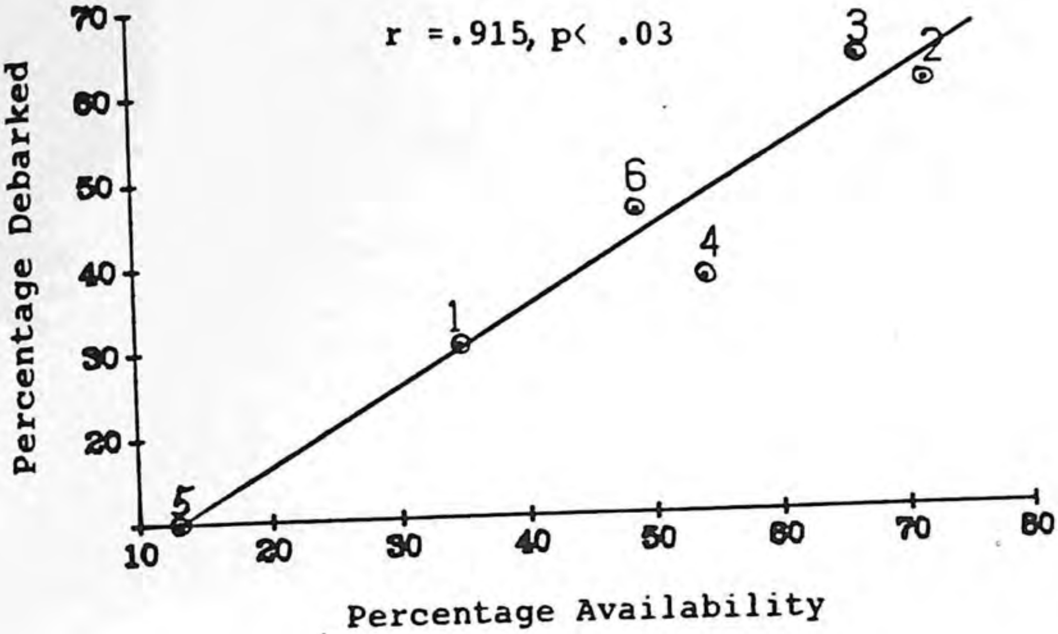

Fig. 5. Relationship between percentage availability and percentage debarked of the four species in all Intensive Study Sites.

1 = *Zizyphus* scrubland 2 = mixed woodland
3 = *Zizyphus* woodland 4 = *Butea* woodland
5 = *Anogeissus* woodland 6 = Degraded *Zizyphus* scrubland

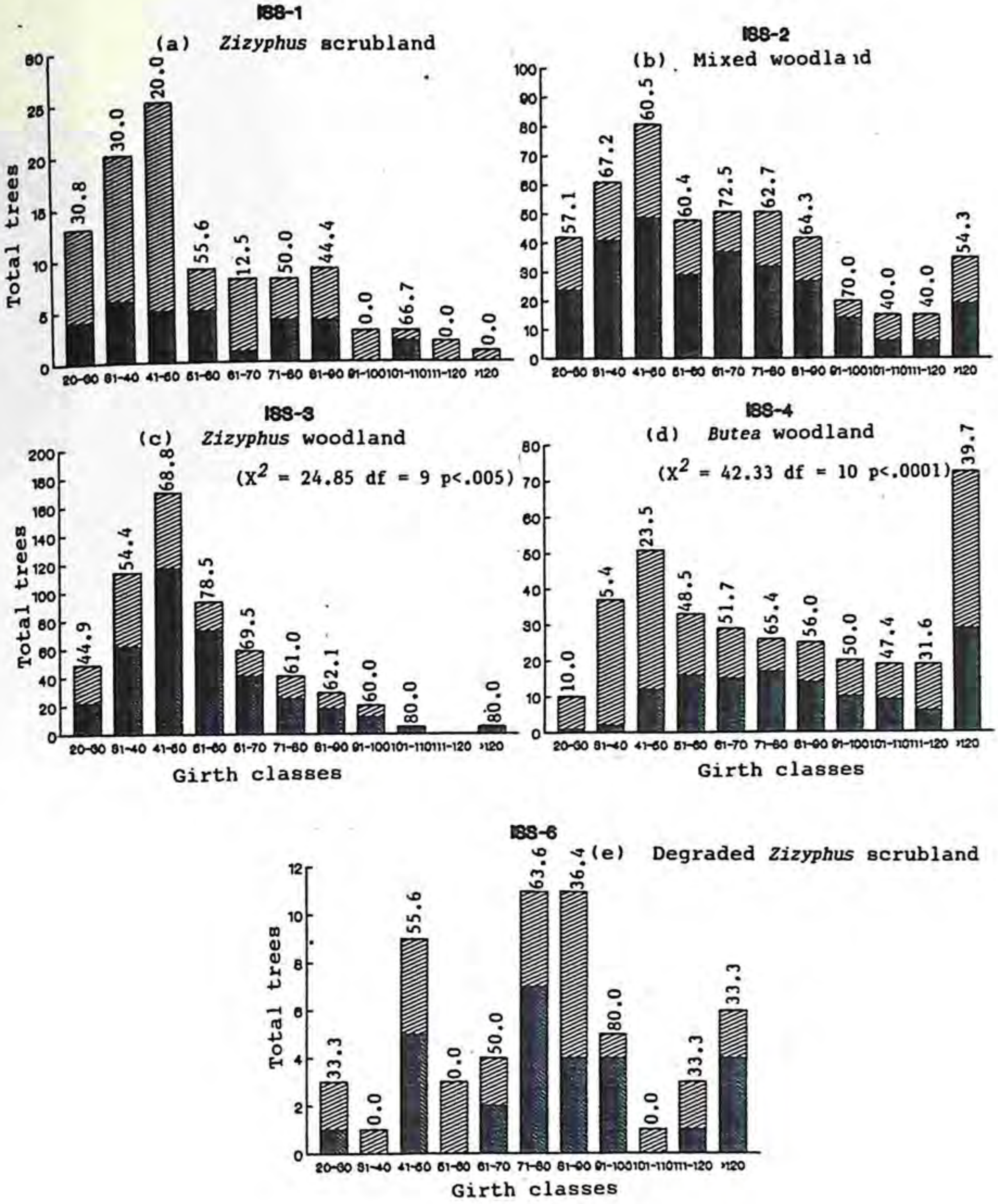

Fig. 6 (a-e). A comparison of percentage of debarking in different girth classes for each Intensive Study Site (1-4 & 6). The number on the tope of histograms is percentage of debarking in that girth class. ▩ Debarked ▨ Not debarked

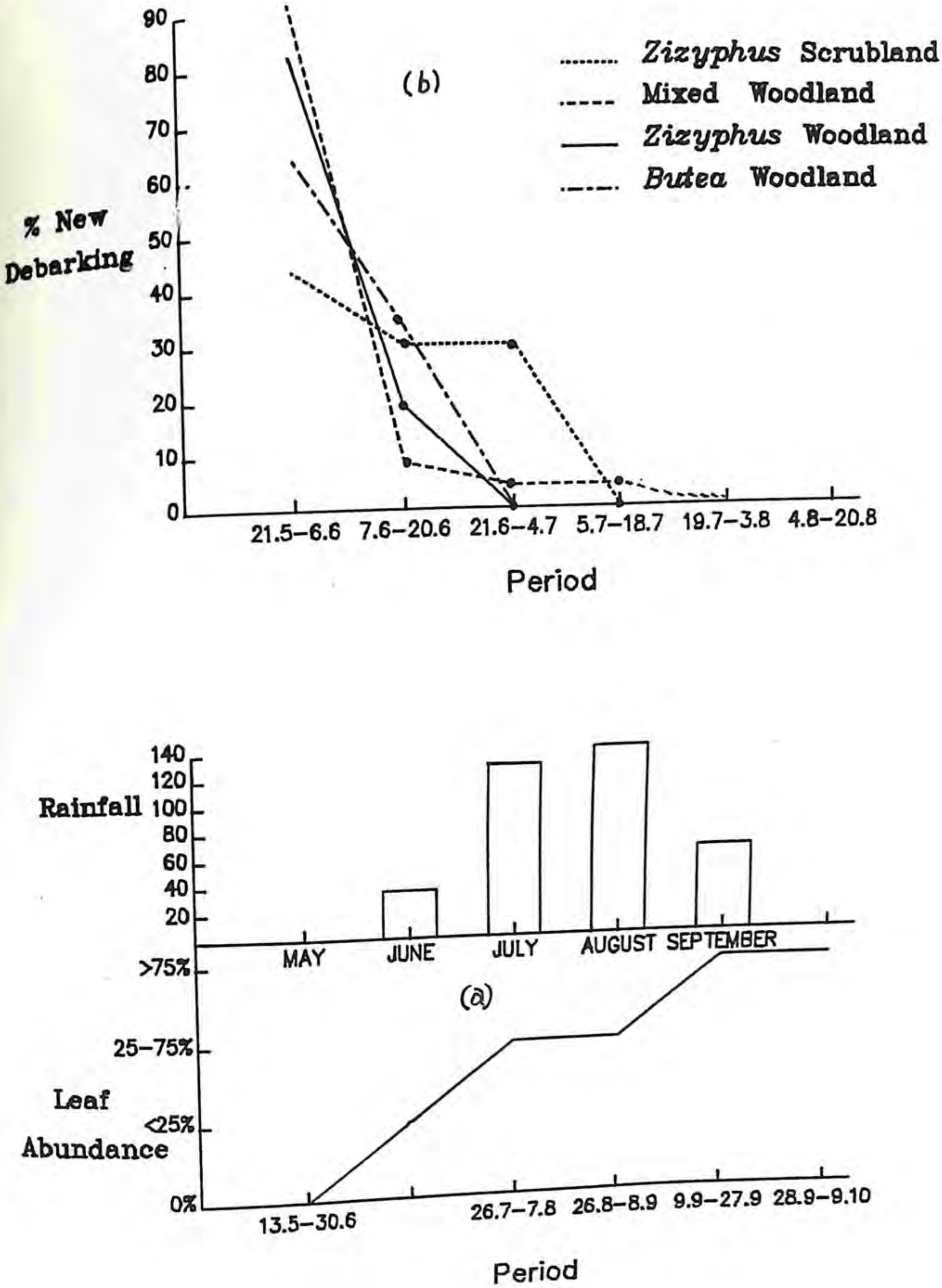

Fig 7. Seasonal changes in (a) tree phenology (leaf only) in all trees and (b) patterns of debarking in the four Intensive Study Sites. Amount of leaves increased and debarking decreased with increase in the rainfall.

TABLE 1. Results of Reconnaissance Survey to select Intensive Study Sites ISS (Valley Only).

TRANSECTS	KM POINT	TOTAL TREE NO.	TREE DENSITY	SHRUB DENSITY	PORCUPINE DROPPING DENSITY	DOMINANT TREE SPECIES	% DEBARKED (NEW	OLD)
1	2	3	4	5	6	7	8	
1-4	1-2	14	45	144	13.7	AC, CD,	0	0
5-8*	3-4	74	154	425	25.0	AC, AL, BE	12.2	9.5
9-12*	5-6	42	273	155	19.6	AC, BM, ZM	12.0	13.3
13-16*	7-8	24	199	247	0.0	AC, ZM	4.2	25.0
17-20	9-10	18	112	143	2.1	AC, ZM	0	66.7
21-24	11-12	13	112	127	3.2	AC, ZM	0	53.8
25-28	13-14	16	183	143	6.4	BM, ZM	18.7	31.3
29-32@	15-16	10	87	111	3.2	AC, BM ZM	0	10

(Column 4, 5, 6, 7 and, 8 formed the criteria for selection or rejection of an area for Intensive Study Site)
* Transects selected as ISS.
@ Due to little space to lay ISS, this transect was not selected. An area on Umri road with features similar to this transect was selected as ISS.
AC = *Acacia catechu* AL = *A. leucophloea* BE = *Balanites aegyptica*
BM = *Butea monosperma* CD = *Capparis decidua* ZM = *Zizyphus mauritiana*

TABLE 2. Density and distribution pattern of all tree species (valley only) in 6 Intensive Study Sites (ISS).

NO.	INTENSIVE STUDY SITE	AVERAGE TREE DENSITY/Ha (MEAN±SEM)	DOMINANT TREE SPECIES
1.	*Zizyphus* scrubland	72±9	AL, BE, CD
2.	Mixed woodland	160±15	AL, BE, BM, ZM
3.	Zizyphus woodland	197±16	AC, ZM
4.	*Butea* woodland	273±22	BM, ZM
5.	*Anogeissus* woodland	415±35	ANP
6.	Degraded Zizyphus scrubland	27±8	AL, CD

AC = *Acacia catechu*
ANP = *Anogeissus pendula*
BM = *Butea monosperma*
ZM = *Zizyphus mauritiana*
AL = *A. leucophloea*
BE = *Balanites aegyptica*
CD = *Capparis decidua*

TABLE 3. Density and distribution pattern of all shrub/herb species (valley only) in 6 Intensive Study Sites (ISS).

NO.	INTENSIVE STUDY SITE	AVERAGE SHRUB DENSITY/Ha (MEAN±SEM)	DOMINANT SHRUB
1.	*Zizyphus* scrubland	411±58	*Zizyphus mauritiana*
2.	Mixed woodland	79±28	*Grewia flavescens*
3.	*Zizyphus* woodland	137±32	*Capparis sepiaria*
4.	*Butea* woodland	34±10	*C. sepiaria, Z. mauritiana*
5.	*Anogeissus* woodland	67±19	*C. sepiaria, G. flavescens*
6.	Degraded *Zizyphus* scrubland	12±7	*C. sepiaria*

TABLE 4. Density of different tree species (in valley) per ha in 6 Intensive Study Sites (ISS).

SPECIES	INTENSIVE STUDY SITES					
	1	2	3	4	5*	6
A. catechu	1	9±8	44±5	12±11	32±15	
A. leucophloea	27±6	16±5	13±1	1	17±8	14±4
*A. pendula**		8±7	566±150	88±37	359±27	
B. aegyptica	28±5	14±8		1	2	2
B. monosperma		34±12		70±22		
C. decidua	10±1	3±1				10±2
Z. mauritiana	7±2	56±16	127±18	87±15		
OTHERS	2			15±6		

* occur on hill slopes only.

TABLE 5. Comparison of overall debarking of the four species in six Intensive study sites. The observed difference is significant ($X^2 = 306.97$, df = 5, $P < .0001$).

NO.	INTENSIVE STUDY SITES	TOTAL TREES	PERCENTAGE OF TREES	
			DEBARKED	NOT DEBARKED
1.	*Zizyphus* Scrubland	101	30.7	69.3
2.	Mixed Woodland	461	61.6*	38.4
3.	*Zizyphus* Woodland	585	64.6*	35.4
4.	*Butea* Woodland	211	38.3	61.7
5.	*Anogeissus* Woodland	310	0.0	100.0
6.	Degraded Z. scrubland	54	46.3	53.7

* Significantly more than other ISS ($P < .05$)

TABLE 6. A comparison of the percentage of trees debarked in four species in the six Intensive Study Sites (ISS).

SPECIES	% OF SPECIES DEBARKED IN ISS					
	1	2	3	4	5	6
A. catechu	20.0	88.6*	67.8	0.0	0.0	0.0
A. leucophloea	27.1	52.3	63.6	0.0	0.0	46.3
B. monosperma	-	50.4	-	39.0*	0.0	-
Z. mauritiana	42.3	67.0*	63.5	43.7*	0.0	-

- no individual in that ISS
* significantly higher debarking intensity within ISS ($p<.05$)

TABLE 7. Percentage of trees debarked within and between girth classes for the four species. The variation in *A. catechu* and *Z. mauritiana* is highly significant ($p < .001$).

GIRTH CLASSES (cm)	PERCENTAGE DEBARKED							
	A. catechu		*A. leucophloea*		*B. monosperma*		*Z. mauritiana*	
	WITHIN CLASS	BETWEEN CLASS	WITHIN CLASS	BETWEEN CLASS	WITHIN CLASS	BETWEEN CLASS	WITHIN CLASS	BETWEEN CLASS
20-30	14.46	.02	14.28	2.35	0.0	0.0	44.18	7.49
31-40	34.69	26.56	9.52	2.35	-	-	48.38	14.79
41-50	41.18	34.59	27.27	14.12	41.67	4.03	58.14	24.65
51-60	67.74	15.79	38.89	17.64	22.22	1.61	67.74	16.76
61-70	73.33	8.27	25.00	10.59	23.08	2.42	72.27	14.40
71-80	50.00	2.26	43.58	20.00	60.71	13.70	68.57	4.47
81-90	75.00	2.26	36.36	14.12	52.63	16.13	68.08	6.31
91-100	50.00	2.26	50.00	9.41	58.33	11.29	53.53	2.96
101-110			26.67	4.71	37.50	7.26	80.00	1.58
111-120			22.22	2.35	34.61	7.26	50.00	0.39
>120			28.57	2.35	43.69	36.29	66.67	1.18
TOTAL TREES DEBARKED		133		85		124		507

Table 8. A comparison of percentage of food items found in the faeces of porcupine collected during summer and monsoon.

FOOD ITEMS	MEAN % FOUND IN		MANN-WHITNEY U-STATISTICS	
	SUMMER	MONSOON	VALUE OF Z	SIGNIFICANCE
BARK	43.32±1.45	0.0	-7.584	.0001
STEM	45.59±1.02	17.37±3.87	-6.782	.0001
LEAF	6.60±0.86	8.81±1.36	-1.264	.206
SEED	0.0	32.76±2.90	-7.313	.0001
MONOCOT	4.43±0.46	41.32±2.54	-7.229	.0001

Table 9. A comparison of density of girdled trees with that of trees debarked in a species. Column 4 indicates the percentage of dead trees out of girdled.

TREE SPECIES	AVG. DENSITY (PER Ha.) OF DEBARKED	GIRDLED		% GIRDLED OF DEBARKED	% DEAD OF GIRDLED
A. catechu	14.29	0.25		1.75	63.43
A. leucophloea	11.21	0.04		0.35	100.00
B. monosperma	11.58	0.125		1.08	0.00
Z. mauritiana	35.42	0.87		2.47	48.99
TOTAL	76.75	1.29	MEAN	1.68	53.13

Plate 4. Intensive Study Site-1 in *Zizyphus* Scrubland.

Plate 5. Intensive Study Site-2 in Mixed Woodland.

Plate 6. Intensive Study Site-3 in *Zizyphus* Woodland.

Plate 7. Intensive Study Site-4 in *Butea* Woodland during pre-monsoon. Note the lack of ground cover

Plate 8. Intensive Study Site-5 in *Anogeissus* Woodland.

Plate 9. Intensive Study Site-6 in Degraded *Zizyphus* Scrubland.

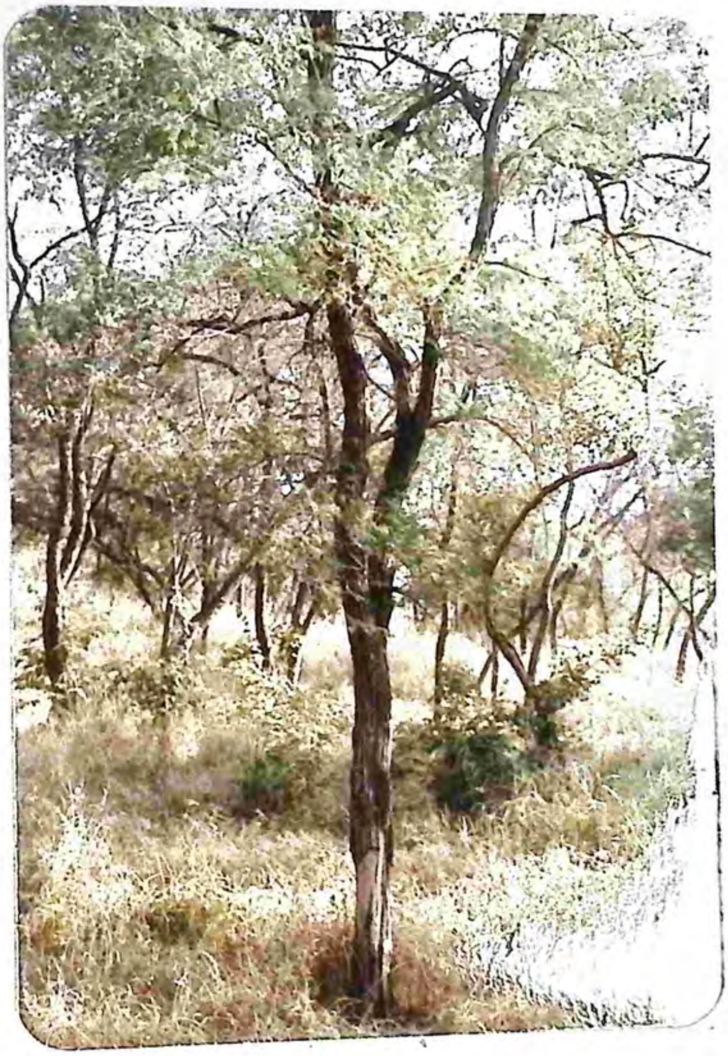

Plate 10. *Acacia catechu* girdled and live.

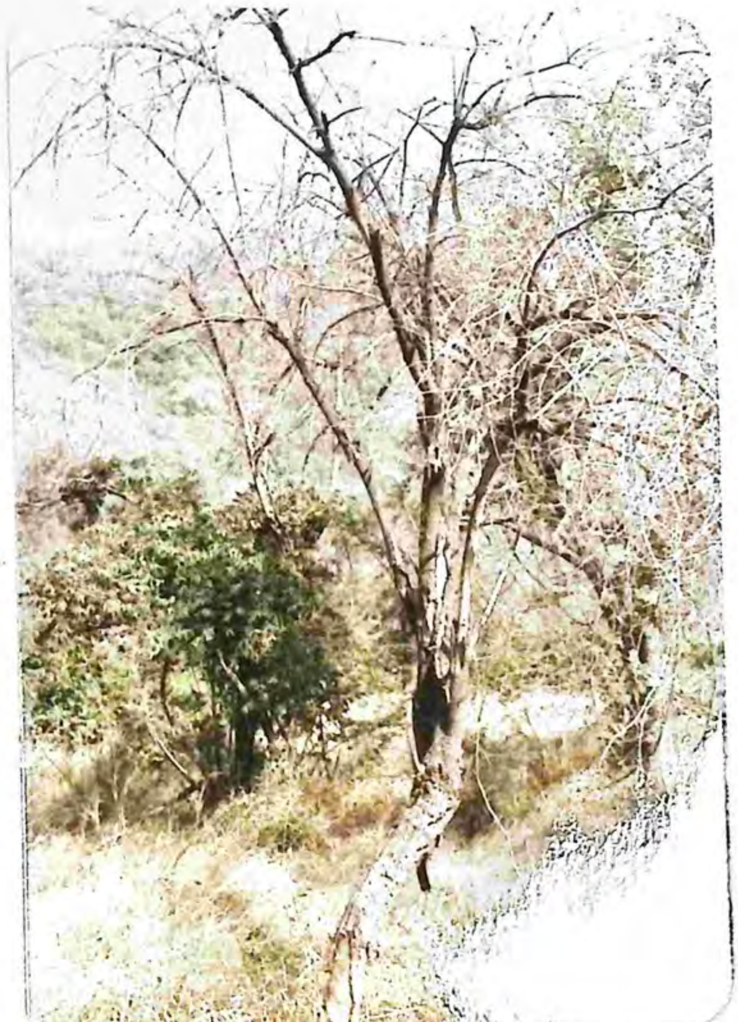

Plate 11. *Zizyphus mauritiana* girdled and dead. Note the bark coming off the stem

4. DISCUSSION

INTRODUCTION

This chapter discusses the results about spatial (4.1) and temporal (4.2) patterns in debarking. These sections are followed by the effects of girdling (4.3), animal abundance and its relationships with debarking intensity in ISS (4.4). Section 4.5 is about the biological and management implications that has emerged from the study.

4.1 SPATIAL PATTERNS IN DEBARKING

4.1.1 DEBARKING AMONG INTENSIVE STUDY SITES

The overall debarking pattern in ISS as inferred in results (section 3.3.1) was that debarking intensity increases with availability of preferred species. The relationship fits well in all ISS. The reason may be that high tree availability provides better chances to an animal to feed on an tree individual and less time is spent while searching for food. Thus by feeding in dense stands the animal conserves more energy per unit time (Krebs & McCleery 1984).

This higher extent of debarking by porcupine (*E. dorsatum*) in dense tree stands has been reported also in North America by Curtis (1941), Curtis & Wilson (1943) and, Von Deusen & Myers (1962) in pine plantations.

But in ISS-4 the debarking intensity was relatively low inspite of the high density of preferred trees. The factor responsible may be that trees here were comparatively older and as a tree becomes older it uses larger part of the consumed nutrients in defending itself by making secondary compounds against herbivores (Cates & Orions 1975, Howe & Westley 1988).

A greater intensity of debarking in the disturb area and ISS-6 where availability was more than that in ISS-1 shows that variations in debarking is only due to the availability of trees. Furthermore the animal is not affected by the human presence - probably because at night the human activities and hence disturbance are negligible.

4.1.2 DEBARKING OF DIFFERENT SPECIES

A. catechu, *A. leucophloea*, *B. monosperma* and *Z. mauritiana* were the species preferred in proportion to availability. *Z. mauritiana* was utilized most followed by *B. monosperma*, *A. catechu* and *A. leucophloea*. *Anogeissus pendula* on hill slopes and *Balanites aegyptica* and *Capparis decidua* in scrubland were common but they were not debarked.

The preference for four species and avoidance for others may be due to different level of nutrients, structural properties (smooth or rough) and anti-herbivory compounds in the bark of trees. Since the bark and stem form the bulk of the diet of porcupine during summer, the abundance of nutrients such as carbohydrate or lipids in the bark (Kramer & Kozlowsky 1960) of *A. catechu*, *A. leucophloea*, *B. monosperma* and *Z. mauritiana* may be responsible for high debarking intensity in these species than in others.

Avoidance of *A. pendula*, *B. aegyptica* and *C. decidua* may be attributed to the presence of large amount of deterring compounds in the bark. Deciduous trees are reported to have phenols (Hansen et. al. 1986) which are anti-herbivory. Generally large amount of such secondary compounds in any part of a plant repels an animal from feeding on that part (Howe & Westley 1988). No chemical analysis could be done in this study due to lack of time.

Preference to some species and avoidance from others for feeding has been reported in other studies also (Hall 1960 on beaver *Castor canadensis*, Sullivan et. al. 1986 on porcupine *E. dorsatum*, Laws et. al. 1975 on elephant *L. africana*) all of which state that phenomenon of avoidance and preference is controlled by nutrients and other chemical compounds.

4.1.3 DEBARKING IN DIFFERENT GIRTH CLASSES

Porcupine debarking intensity increased with size classes of trees (Fig. 6, Table 7). But this intensity decreased for the last 3-4 girth classes (91->120 cm). The reason why porcupines go for larger girth classes can be governed by two factors. A tree with larger size class is quite old and hence was available for debarking for a longer period. This resulted in overall high incidence of debarking in larger size classes.

The second reason may be that feeding on a large tree the animal gets most of its food hence need not travel more. On the other hand if the animal debarks a tree with lower size it may not get the required amount of food from one tree. This will force the animal to spend more time while walking. Since the latter reduces the energy gain the animal does not adopt this strategy and prefers to feed on a large trees to maximize energy gain (Krebs & McCleery 1984).

This selection of larger GBH classes has also been reported in *E. dorsatum* by Curtis & Wilson (1953), Faulkner & Dodge (1962), Rudolf (1949) and, Sullivan et.al. (1986).

4.2 TEMPORAL PATTERNS IN DEBARKING

The observed trend in fresh debarking that 98% of total new debarking was during summer is due to the non-availability of other food items (leaves, grass etc.) in this season. This is due to lack of rainfall in winter and summer (January-June) (Fig. 4) which causes withering of plants and grass. This lack of vegetation on ground forces the animal to feed on the bark/stem of trees which were also found in large amount in fecal matter.

Capparis sepiaria was the only evergreen shrub in Sariska during summer. This and fallen leaves from *Butea monosperma* (there was no other tree with leaves during this season) may account for the dicot leaves found in the droppings of the porcupine during both the seasons. The small amount of monocots discovered in the faeces can be attributed to the consumption of grasses near water-holes.

Absence of debarking during the monsoon and post-monsoon was due to availability of more plants at ground. Porcupines switched over to the green grass in this period. On three occasions porcupines were seen nibbling grass and a large percentage of grass was discovered in droppings (section 3.6). The observed low amount of dicot leaf in droppings would imply that even when plants started producing new leaves were not within the reach of the animal.

Presence of Stem (dicot) in the faeces collected during Monsoon/Post-monsoon period can be attributed to its utilization from the herb/shrub. This can be supported by the fact that no tree was found debarked during this period and no bark was recorded in the faeces found during this period.

The study reveals that porcupines debark trees for food as has been reported in case of other small mammals such as beavers (Brenner 1962, Jenkins 1980), voles (Dannell et. al 1987, Hansen et. al. 1986), new world porcupines (Curtis and Wilson 1953, Krefting et. al 1962, Rudolf 1949, Storm & Halvorson 1967, Sullivan et. al. 1986)

4.3 GIRDLING

The inference (section 3.7) that *Z. mauritiana* had greater probability of being girdled followed by *B. monosperma*, *A. catechu* and *A. leucophloea* is related with abundance and size of trees (table 8). More abundant trees have higher chances of being girdled. But at the same time chances of girdling a big trees are less. *A.*

leucophloea and *B. monosperma* being thick (GBH 68±2 & 110±2 cm respectively) have more potential bark for providing to a porcupine than *A. catechu and Z. mauritiana* (42±1 & 53±1 cm respectively). Thus feeding on a tree with more girth the animal gets satiated even without girdling it.

The difference in mortality after girdling by porcupine can be attributed to the physiology of the trees and perhaps to the depth up to which they were eaten. Physiology of trees depends upon the micro-climatic and edaphic conditions (Kramer & Kozlowsky 1960). The percentage of dead trees was high in drier areas with red soil which is nutrient deficient. Therefore it can be argued that the trees in this region could not recover after girdling and hence died. While trees in more moist areas (e.g. near stream bed) and on dark loamy soils were able to recover.

Measurements of new debarking evidences show that *A. leucophloea* was debarked more severely being as deep as about 3 cm. in comparison to the deepness of about 1.5 cm in *A. catechu* and *Z. mauritiana*.

Average depth of debarking in case of *B. monosperma* was about 2 cm. But considering the trees with average high GBH (110 cm) class, the phloem/bark layer may be thick enough to withstand the girdling by porcupine, which may account for no death due to girdling in this species.

This finding - all girdled trees were not dead - is different from studies by Sullivan et. al. (1986), Curtis & Wilson and

Krefting et. al. (1962) who invariably found all the girdled trees dead. Perhaps this is because of the short duration of this study; long term effects could not be monitored.

Thus it will be useful to observe all the debarked trees for long periods to investigate the mortality rate of these trees. This is supported by study on impact of damage to trees by elephants (*Loxodonta africana*) in Africa (Eltringham quoted from McNaughton & Sabuni 1988). The survival was monitored for long time (5 years) when it was found that trees with medium and heavy damage had lower survival rates.

4.4. ANIMAL ABUNDANCE

Road transects at night showed that more porcupines were seen in woodlands than in scrubland (Fig 8a & 8b). The difference in animal number and animal sightings in different vegetation types can be attributed to different visibility factors.

Although the area in which the animals were looked at included only 10 m. on either side of the road, there were comparatively more bushes along road in *Zizyphus* scrubland in first four kms. (fig 6a). Hence the chance of seeing a porcupine were very less even if they were using this area more (as revealed by the large number of dropping groups here). It might be the reason for few number of sightings in this area.

Large number of sightings near 5^{th} km stone in mixed woodland may be attributed to the findings that usually two animals were seen at a maximum distance of approximately 150 m.. Sightings of the two young porcupines in October indicate that a family of these animals might be inhabiting this area. Hence the porcupines being a member of the family were closer to each other, which resulted in the large number of animal sightings.

DROPPING ABUNDANCE: ITS RELATION WITH SHRUB COVER AND DEBARKING INTENSITY

Large dropping groups in sites with dense shrubs shows that these animals seek escape cover in the bushes as has been pointed out by Prater (1965). This relationship of cover and animal is supported by the observation that in summer very few droppings (2 groups along this transect) were recorded in *Butea* woodland on Kirashka Plateau when there was no cover. More dropping groups (7 in 1 ha) were seen in October during Post-Monsoon when there were high grass to provide and the maize crop in this area during this period was attracting the porcupine.

If animal abundance based on dropping groups found in an ISS is related with debarking intensity in that ISS there is not any definite pattern. *Zizyphus* woodland which had large amount of fresh debarking had least number of dropping sets, while *Zizyphus* scrubland with less debarking had maximum dropping groups. On the other hand mixed woodland and *Butea* woodland had moderate amount of debarking and dropping sets.

Why is there more debarking in an ISS when there are less animal abundance signs? The question is attempted to answer on the basis of previous studies on this species. These animals are reported to cover usually a distance of 2 km. per night and come back to their original point (Alkon 1983, Robert 1977). Hence it can be argued that during summer porcupines were using ISS-1 for activities other than feeding, but were debarking in adjacent vegetation type which had greater tree density for debarking.

For instance the mixed woodland was not more than 2 kms. from the ISS-1 the *Zizyphus* scrubland in which debarking extent was little (Table 5). The vegetation between *Zizyphus* scrubland and mixed woodland was an ecotone area and large number of trees were observed debarked here.

Similar argument can be applied for the few dropping groups but large debarking extent found in *Butea* and *Zizyphus* woodlands. Large extent of debarking and few dropping groups indicate that porcupines were using this site as feeding area only and adjacent areas were being used for activities other than feeding.

4.5 BIOLOGICAL AND MANAGEMENT IMPLICATIONS

Intensive debarking of four species followed by certain amount of mortality may alter the vegetation with time. Although survival of debarked trees was 47% and no variation in phenology could be seen, more of the debarked trees may die eventually. This mortality can effect forage availability to other ungulate since species such as *A. catechu* and *Z. mauritiana* are good source of food.

Conditions could become more severe if the survival of seedlings continue to remain low as it is now. For instance in the woodlands the seedling density is practically negligible so it can be imagined that after some time, if the scenario remains the same, these woodlands are going to be replaced either by weed *Adhatoda vassica* as it is happening in vicinity of Haripura village, or by *Grewia flavescens* a shrub which spreads fast.

Absence of debarked seedling indicated porcupine are not responsible for low levels of seedling occurrence. Porcupines also do not damage many seeds especially *Z. mauritiana* seeds which come out in dropping. All these indicate that porcupine may not be responsible for lack of regeneration.

Indeed the effect will be severe if the animal number increases. At present nothing is known about the growth rate and population structure of porcupine. May be the population of this animal is increasing. In any case it will be advisable to monitor population dynamics.

In case if porcupine numbers is not increasing other factors such as fire may affect the debarked trees drastically. Although fire is a rare phenomenon, even a chance occurrence in summer when all the wood are more susceptible to fire can change the vegetation structure drastically. Hence precautions must be taken to prevent fire.

5. CONCLUSIONS

All the null hypotheses set in the beginning of the study were rejected.

The first null hypothesis that debarking intensity is not different in different areas was rejected as porcupines debarked trees largely in dense stands of preferred species. They do this to maximize the energy gain while feeding.

Similarly the null hypothesis that debarking intensity is not different in various species was also rejected as porcupines debark more of *A. catechu*, *A. leucophloea*, *B. monosperma* and *Z. mauritiana* and avoid *Anogeissus pendula*, *Balanites aegytica* and *Capparis decidua*. This difference is attributed to different levels of nutrients, and secondary compounds in the stem.

Girth class (41-100 cm) was debarked more than other classes. This rejects hypothesis that porcupines do not prefer some particular girth class. The reason for this selection is attributed to the fact that a large tree is available for debarking for longer time and the return by debarking a bigger tree will be greater than debarking a smaller tree.

Debarking only in summer rejects the hypothesis that debarking is uniform in all seasons. The results are supported by analysis of faecal matter in summer in which 75-95% of the items were bark and stem. During monsoon/post-monsoon remains of grass formed the major constituent of dropping. This high variation in food items in different seasons rejects the null hypothesis that food items consumed in different seasons do not differ.

All the girdled trees did not die. Among the trees alive there was no variation in phenology. But lack of seedlings in woodlands is an indication of the regressional and successional changes that may start in future. Porcupine do not debark seedlings and saplings. So regeneration problem is not because of this animal. No special measure is required to control debarking at present but effort should be taken to promote regeneration and to protect the area from fire which can kill the surviving debarked trees.

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* Not seen in original.

APPENDIX -I

Variations in Annual rainfall for 10 years for Alwar and Thanagazi stations.

YEAR	ALWAR	THANAGAZI
1966	419.5	464.0
1967	763.7	539.4
1968	978.9	637.9
1969	924.0	671.6
1970	586.3	666.5
1971	816.3	808.4
1972	855.8	704.9
1973	776.2	774.8
1974	677.6	778.2
1975	824.3	764.4

Source: Administrative and Management plan (1984-1989) for Sariska Tiger Reserve.