Habitat and food resources use in relation to sex, age and group size in Sambar (*Rusa unicolor*) during winter in dry tropical deciduous habitat of Ranthambore Tiger Reserve, India

Dissertation submitted to Saurashtra University, Rajkot, in partial fulfillment of Masters Degree in Wildlife Science

By

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CERTIFICATE

This is to certify that Mr. Amit Goswamy of the Wildlife Institute of India has carried out an original research titled, "Habitat and food resources use in relation to sex, age and group size in Sambar *(Rusa unicolor)* during winter in dry tropical deciduous habitat of Ranthambhore Tiger Reserve, India", in partial fulfillment of Master of Science (Wildlife Science) degree from Saurashtra University, Rajkot.

These investigations were carried out under our supervision at the Wildlife Institute of India from December 2010 to June 2011. We also certify that this work has not been submitted for any other degree of any university.

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The field was the high point of my work, working in a National park like Ranthambhore, has its own problems as well, as I was not technically allowed to get out of the vehicle, when tourist vehicles were around, and sometimes it becomes inevitable when I need to get out and go after the sambar for pellets. Apart from this, managing research work in the field has given me a lesson in life. The time spent in the park and the experience and sightings I had is something I am never going to forget.

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Summary

The study of habitat use depends on various factors like environmental conditions, resource availability, physiological condition of an animal and sex. The present research for my dissertation shows that it does exist and it attempts to explain how it is happening.

Sambar is a major prey species of tiger and other big cats across most of the parks in India. For the conservation of large predators it is important to evaluate and study the habitat requirement of its major prey species in detail to the level of its age and sex categories.

My field study was undertaken between Dec 2010 to March 2011. Intensive study area of 90 sq km was selected in Ranthambhore to quantify resource availability and use by different categories with respect to sex, age and group size during winter.

It was found out that there is a difference in the habitat use of sambar due to sex, age and group size categories, out of the many parameters evaluated and comparisons made it was seen that though in some cases the differences were not profound, and some showed only minor changes, but in majority of the cases the trend observed was as per the expectation. Where smaller body size male animals (< 3 yrs) and female associated with fawn and sub-adults always prefer areas having a good quality resource whereas the adult male and sambar in large group size were mainly in the areas of abundant resource rather than the quality.

1. INTRODUCTION

There have been ample studies in understanding relationship between distribution of resources and use by ungulates and herbivores across the world that suggest differential resource use patterns among different group sizes, season, sex and age categories (Klein & Fairall.1986; Shannon *et al.*2006; Dalerum *et al.* 2008; Smith & Cain. 2008). However, still there are some of the studies who reject it citing no difference in resource use by different categories that may be because of the different environmental conditions in different seasons that change the resource availability thereby changing the use pattern (La Gory. 1986; Ruckstuhl. 1998). Studies undertaken on foraging theory among herbivores clearly reveals that forage is selected as per availability and the nutritional quality of plant and use is different between sexes (Clutton-Brock *et al.* 1987; Main. 1998) as well as varies due to group size (Roberts. 1996 & Beauchamp. 2003)

1.1. Differential habitat use in relation to sex

It has been found that females having fawns have higher energy requirement during lactation and gestation period (Robbins. 1993), therefore the females are expected to be found in good quality habitats. For example in red deer (*Rusa elaphus*), the sexes are highly dimorphic (males: 113 kg; females: 71 kg; Clutton-Brock *et al.* 1987) and show a different pattern of habitat use, as the males use lower-quality forage habitat than females, particularly in winter. As a consequence, the diet of stags has a higher fiber and lower protein content than that of hinds (Charles *et al.* 1977; Staines & Crisp 1978; Staines *et al.* 1982; Osborne 1984;

Clutton-Brock *et al.* 1997). Published information available has been interpreted in various ways and below is some of the hypothesis and arguments that explains it:

Scramble Competition Hypothesis (SCH): Studies undertaken related to sex dependent habitat use patterns indicate that males are being forced into sub optimal foraging habitats through indirect competition by females. Habitat segregation as per sexes is particularly common in herbivores, as while foraging female graze the vegetation in high quality forage habitats so males are no longer able to obtain sufficient forage intake in these habitats apart from this females are thought to be superior competitors than males due to their lower absolute energy requirement and narrower muzzle, which enables them to reduce the sward height to such an extent that it is no longer profitable for the males to forage there. Thus males are forced into suboptimal habitats with low forage quality and high forage biomass due to indirect female competition (Clutton-Brock and Guiness, 1987).

Predation risk hypothesis: It says that the larger male ungulates are less vulnerable to predation than females and their offspring's, therefore male prefer habitat area with higher food availability while female that of safety (Jakimchuk *et. al* 1987). Males as compared to females take more risk while foraging than females (Sukumar & Gadgil, 1988) thus female with calf will try to avoid predator and may retreat into safe but poor quality habitat. Apart from that it has been seen that males generally have longer feeding bouts, and lower bite rates as compared to females, and also ingested greater quantities of forage during each feeding bout as seen in African elephants as per a study in South Africa (Shannon *et.al* .2006).

Nitrogen content (or crude protein) and ratio of dicot to monocot in fecal matter have been used as an index of quality of habitat selected among herbivores like study undertaken on free ranging Impala and Blesbok in South Africa (Klein & Fairall. 1986). The differences in habitat utilization strategies due to sexes have also been reported in red deer (*Rusa elaphus*) sika deer (*Rusa nippon*) and white tailed deer (*Odocoileus virginianus*) and females are known to select high quality areas habitats foraging.

1.2. Differential habitat use in relation to age categories: A Jarman and Bell Principle

The metabolic rate scales with a coefficient of approximately 0.75 and as body size increases (Kleiber 1961; Peters 1983; Demment 1983; Owen-Smith 1992) this result in larger individual requiring less energy per kg of mass, due to greater efficiency and reduced heat loss. Secondly the larger the animal in body size, the greater was its gut capacity (Demment. 1983) and because of the large gut size, the forage is retained for a longer period thus greater level of digestion are achieved. Based on these facts, the Jarman and Bell principle says that larger bodied herbivores have increased gut size, thus longer retention time; this allows them to digest greater quantity of low quality food than smaller individuals (Bell 1971; Jarman 1974; Mysterud 1998). Thus larger herbivores are predicted to trade off quality against quantity, as the benefit of abundance outweigh the cost of searching for forage opportunities of high nutritional returns (Demment & Van Soest 1985), in contrast to that the smaller size herbivores with greater relative energy demands and lesser gut efficiency will tend to forage on the high quality forage selectively (Demment & Van Soest 1985).

Thus body size of an individual somewhat governs the relationship between the herbivore with its environment. Therefore one would expect feeding differences and will thus result in the differences in the occupation of the habitat and its uses by the various age classes and sex if herbivores are dimorphic. Published studies have clearly documented that body size plays an important role as metabolic energy/gm tissue is much higher in small sized animal than large sized animal and accordingly energy requirement is achieved through better foraging efficiency and selection of appropriate habitat. In view of this a differential resources use have been documented in dimorphic ungulate species which vary in body sizes between male and female and due to different age classes. In view this, I expect a differential selection of resource use in sambar to meet daily energy requirement because it is dimorphic and there is a variation in body size classes across age categories.

Putman expected that the dietary compositions of ungulates would be different, between the sexes if dimorphism exceeded 1: 1.2. Thus it becomes more applicable when dimorphism is high between sexes

1.3. Differential habitat use in relation to group size

Foraging in a group is beneficial for a herd as it allows the animals to reduce the vigilance time and allow it to spend more time in foraging, at the same time it may be counter-productive as it may lead to intra-specific competition for the available resource (Elger. 1989; Beauchamp. 2003). Vigilance behaviors have been linked to various factors like predation risk and group size (Roberts. 1996). It has been reported that in larger groups due to intra-specific competition the rate of foraging is increased and the amount of time spend in other activities is shortened (Elger. 1989; Blumstein *et al.*2001; Beauchamp & Ruxton 2003) .The understanding distribution and behavior of the herd in herbivores is important while studying foraging patterns related to resource use as these vary with respect of group size (Elger. 1989; Blumstein *et al.* 2001; Beauchamp & Ruxton 2003)

Foraging competition, vigilance and group size in gregarious antelopes (Dalerum *et al.*2008)

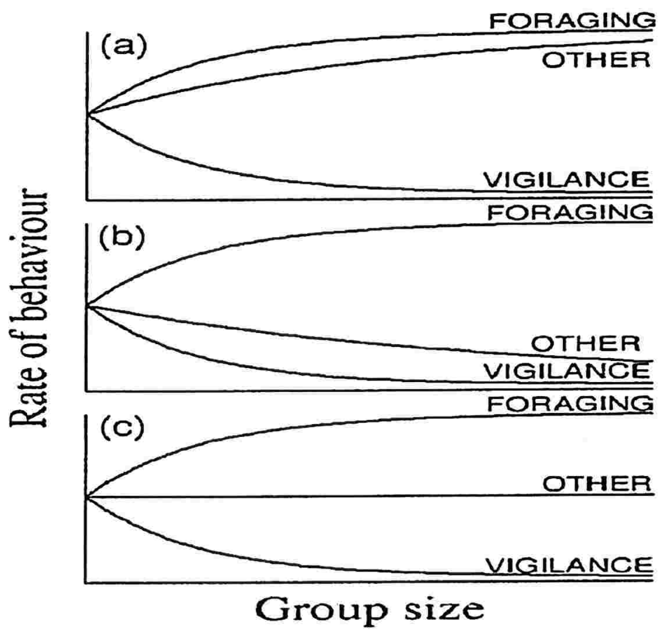


Figure 1. Relation between group size and rate of behaviour (Dalerum *et al.* 2008)

It shows the relation between group size and the rate of behaviour (Fig. 1) for three possible strategies of behaviour:

a) Decreased vigilance in big groups is compensated by an overall increase in other behaviors.

b) Increased rate of foraging is compensated by an overall decrease in other behaviors.

c) Only vigilance and rates of foraging behaviour are affected by group size.

1.4. Study Animal

Sambar (*Rusa unicolor*) is the largest deer species native to South and South-east Asia. Sexual dimorphism is apparent, a sambar stag weighs between 225-320 kg and the hind weighs between 135-225 kg (Prater, 1971). Sambar is closely related to Red deer (*Cervus elaphus*) and Rusa deer (*Cervus timorensis)*. It is found in 208 PAs of India (Wildlife Database cell, WII). A typical group size is fewer than 6 individuals (Schaller, 1967) but the group size may vary as per regions due to various factors like environmental conditions, spread of forage etc. Mean group size as per a previous study in Ranthambhore was 3.7 (Bagchi *et al.* 2003).

Sambar is predominantly a forest dwelling species, favoring tree cover; it comes out in open only in the night time, late dusk and early dawn and usually rest in the day (Schaller, 1967). Habitat wise it prefers undulating slopes or hills, where it resides and as per my observations in Ranthambhore it starts moving down of the hills in the early morning time and spends most of the day time in the plains and start moving up the slopes in big herds at dusk.

1.4.1. Rutting season

In India peak rutting season of sambar occurs between October and December (Schaller 1967), the hard antlers are shed in summer, and the velvet antlers start growing in the monsoon season, remaining part of the year the antlers remain hard.

1.4.2. Food Habit

Sambar has been observed to feed on 139 species of plants (Schaller, 1967) during my study I saw sambar feeding on 24 species of plants (including trees, shrubs, herbs and grasses).

Sambar as per its food habit is not a specialist feeder (Schaller, 1967), it graze or browse depending upon the forage availability.

1.5. Previous Studies

In Favour : Past studies on understanding relationship between distribution of resources and use by ungulates and herbivores across the world that suggest differential resource use patterns among different group sizes, season, sex and age categories (Klein & Fairall.1986; Shannon *et al.*2006; Dalerum *et al.* 2008; Smith & Cain. 2008)

Against: Some studies reject this theory (LaGory. 1986; Ruckstuhl. 1998). That may be because of the different environmental conditions in different seasons that change the resource availability thereby changing the use pattern

Studies undertaken on foraging theory among herbivores reveals that forage is selected in relation to 'availability and the nutritional quality' of plant and use is different between sexes (Clutton-Brock *et al.* 1987; Main. 1998;) as well as vary due to group size (Roberts. 1996 & Beauchamp. 2003)

1.6. Objectives

The present study is aimed to:

1. To determine differences in selection of habitat quality and quantity by sambar in relation to different group sizes during winter, and

2. To quantify variation in use of resource quality by sambar in relation to sex and age categories during winter.

Hypotheses

Ho – *There is no difference in use of resource quality and quantity by sambar in relation to group size, sex and age categories during winter in dry tropical deciduous habitat of Ranthambore Tiger Reserve, India.*

1.7. Project justification

Management of habitat resource is key issue in wildlife management and in understanding prey-predator relationship. The project is aimed to study if there is any differential habitat use shown by the sambar in its various age classes' sex and with respect to group sizes and document key habitat resources needed for survival. The information on crucial habitat resources will help to manage the habitat of sambar in a better way in Ranthambore Tiger Reserve for sustaining tiger population because sambar is an important prey species. As it is famously said that "Sambar conservation is tantamount to Tiger conservation in Indian Context"

2. STUDY AREA

General description of the study area

Ranthambhore Tiger Reserve lies between latitudes $25^0 41'$ N to $26^0 22'$ N and longitudes $76^0 16'$ E to $77^0 14'$ E. The reserve is situated in south eastern part of Rajasthan in Sawai Madhopur and Karauli districts of Rajasthan, India (Fig. 4).

According to the Bio-georaphic classification (Rodgers & Panwar, 1988), Ranthambhore Tiger Reserve falls in 4 B (Semi-arid zone and Gujrat-Rajwara biotic province). The area forms a transition zone between the true desert and seasonally wet peninsular India.

Ranthambhore Tiger Reserve is located on the Western bank of river. Chambal. The other river Banas divides the reserve into two parts, the north eastern part being the Keladevi Wildlife sanctuary. Ranthambhore National Park covers an area of 392 km^2.

The physiography of Ranthambhore Tiger Reserve includes undulating terrain with rolling hills of low to moderate height traversed with perennial rivers and several streams. The altitude ranges from 244 m to 507 m above sea level (asl). The terrain of RTR is mostly rugged and hilly. The hills to the north-west of fault are typical Gwalior and lower Vindhyans and are characterized by ridges on one side and gentle slope on the other side. This Gwalior and lower Vindhyans tract are highly undulating except for a few small plateaus like Salawata ki dang , Rann ki dang and Mandook, and some small valleys like Kachida, Anantpura, Berda, Lakarda and Malik Talab. The highest point of this tract is Gazella peak, 507 m asl. The lowest altitude of this tract is 244 meters above sea level (asl) at Bodal village.

Drainage pattern - Streams flowing in northern tract form the catchment of the Banas and streams flowing in southern tract drain directly in the Chambal. Streams facing sharp ridges contain water for almost throughout the year, as the folded impervious rocky strata beneath does not permit the water to percolate. The hills on south west of Great boundary fault are Upper Vindhyans. The sand stone beds of these hills are particularly horizontal and form extensive table lands known as '*Dangs*' like Indala ki Dang, Dang Dood Bhatt and Karauli Dang, etc. These dangs rise abruptly from flat ground above a mass of crumbling shale where inclined sand stone forms continuous strike ridges along deep, long and narrow gorges of eroded shale. These gorges are locally known as '*Khohs*'. The Khohs are cool and retain moisture even in the hot summer and are heaven for wildlife of this dry and parched area. These Khohs are the main wildlife areas. In the Keladevi sanctuary particularly, the gorges are very long and wide, in some areas extending up to 10 km in length, up to 0.5 km wide and as deep as 100 meter or more. In this tract one hill range starts from Qualji, runs in north-east direction and goes up to Sawta. The hill range passes through Sawai Man Singh and Sawai Madhopur sanctuaries.

Geology - The area includes the confluence of the ancient Aravalli system with Vindhyan system, where in the later are brought against the former at the Great Boundary fault. It has a unique geomorphology. The Vindhyan system is characterized by flat topped hills. The soils of the RTR are formed by the Aravalli, Gwalior and Vindhyan system of rocks. The Aravalli system rocks cover a small portion on the north-west side of the reserve while Gwalior and Vindhyan systems share most of the RTR. A part of the terrain comprises of pre-Cambrian Igneous, Metamorphic and Sedimentary rocks belonging to pre-Aravalli-Vindhyan system. Pre-Aravalli rock units are made up of Quartzite, Mica Schists, Gneiss and Migmatites. The rocks of the Vindhyan super group are made up of sand stones, shales, limestone and breccias of widely variable composition & characters occupying most part of the reserve. The Gwalior systems are made up of slate and shale. The soils though shallow on the hills, are, suitable for supporting forests of *Anogeissus pendula*.

Flora

Figure 2. Observed landscape of the higher grounds in the ISA

<u>Forest Types</u>

The forests are mainly of edaphic climax and belong to the sub group 5B- Northern Tropical Dry Deciduous forests and subgroup 6B -DS1-*Zizyphus* scrub (Champion & Seth, 1968). The area is representative of dry deciduous *Anogeissus pendula* Forests sub type in association with *Acacia, Capparis, Zizyphus* and *Prosopis* species (Project Tiger Management Plan 2002 - 2012).

The main floral habitats of Ranthambore can be classified as follows:

(a) Steep slopes: The vegetation on the steep hills is very scanty and the plants like *Sterculia urens, Euphorbia neriifolia* etc. are found scattered without having any significant under growths due to absence of deep soil. They are crucial habitats for a large number of reptile and birds, particularly the endangered Long-billed vultures.

(b) Gentle slopes of hills: The gentle slopes maintain comparatively luxuriant vegetation due to better soil formation and water holding capacity. The typical dry deciduous elements found here are - *Anogeissus pendula, Sterculia urens, Boswellia serrata, Acacia catechu, Acacia leucophloea, Cassia fistula, Butea monosperma* etc. *Anogeissus pendula* is the most dominant species here. The shrub mainly *Grewia flavescens* and *Capparice sepiaria* increase the density of flora. The biomass production in thee habitats is very high and these are very heavily used by almost all the wildlife.

(c) Plateaus: The open flat rocky areas maintain stunted and sparsely distributed trees and shrubs due to very thin layer of soil. However, the grasses, seasonal herbs and shrubs are abundant, except in the dry season. The biomass production is the plateaus or the *dangs* is very low and highly seasonal. During the monsoon months, there are abundant grasses and herbs in the plateaus but soon after they dry out. These habitats are heavily used by wildlife and domesticated animals during the monsoons but sparingly after that.

(d) Valleys: The valleys are characterized with fertile soil and sufficient water sources. As a result, it supports comparatively thick vegetation and some evergreen elements as well. The common trees found here are *Anogeissus pendula, Syzygium cumini, Diospyros melanoxylon, Ficus benghalensis, F. racemosa, Launea coromandelica, Butea monosperma, Ziziphus mauritiana, Bauhinia racemosa, Tamarindus indica, Mitragyna parvifolia* etc. The shrubs and under shrubs further make the vegetation dense and impenetrable at certain spots. The most common of these plants are *Adhatoda vasica, Capparice sepiaria* and *Grewia flavescens.* The valleys have the highest biomass production of all the habitats in the reserve and should be the prime wildlife areas. However, outside the Ranthambore national park, the valleys are inhabited by human settlements and are highly disturbed for the wildlife. Inside the Ranthambhore national park, they are having the highest density of wildlife that is found in the entire reserve.

(e) Lakes, reservoirs and its surroundings: These habitats provide variable plant communities controlled by the moisture content. The low-lying areas are also inhabited by certain trees like *Phoenix sylvestris, Ficus bengalensis, Flacourtia indica* etc.

(f) Sandy plain: The species like *Acacia nilotica, A. leucophloea, Capparis decidua, Prosopis juliflora, Calotropis procera, Argemone mexicana* etc. inhabit flat sandy localitie. These habitats are highly disturbed in the reserve. Grazing by cattle and goats has destroyed most of the ground cover and *Argemone mexicana* has invaded this habitat in many areas (Das & Singh, 1995).

Anogeissus pendula: - It is dominant species and constitutes about 70-80% of the vegetation cover. It represents the edaphic climax. Generally found in the hilly areas and maintains luxuriant growth on the gentle slope of the hills due to better soil formation and water holding capacity. It is a slow growing species with generally varying girth and height ranging from 10-15 meters with crown cover more than 60% found on hill slopes and valleys. The growth of *Anogeissus pendula* is generally stunted on plateaus where the residual soil is poor and shallow. *Grewia flavescens* in under-story is a common associate of it.

Fauna

Mammals: Ranthambhore park though famous for its tigers has many other species as well, other felines such as leopard, caracal, leopard cat, fishing cat and jungle cat. Apart from these mammals, sloth bear, striped hyena, jackal, desert fox are also found. Spotted deer, Indian gazelle, sambar and blue bull are also there in relatively high density other main species include some rare occurrences in nature like albino spotted deer which I happen to see in the Anantpura range of the park (Fig. 3).

Avifauna: Apart from that it has great diversity of avifauna as well which include cormorant, painted spur fowl, sarus crane, bronzed winged jacana, kingfishers species, nightjar, painted sand grouse and many more regular winter migrants which come from their nesting ground north of Himalayas to Ranthambore and surrounding areas.

Reptiles include fresh water crocodiles, monitor lizards, tortoises, banded kraits, cobras, Indian rock pythons, rat snakes, saw-scaled vipers and many other reptilian species.

Mugger crocodile (*Crocodylus palustris*)

Sambar (*Rusa unicolor*)

An Albino Spotted deer *(Axis axis)*

Royal Bengal tiger *(Panthera tigris tigris)*

Indian leopard *(Panthera pardus fusca)*

Figure 3. Some of the common faunal species recorded during study period

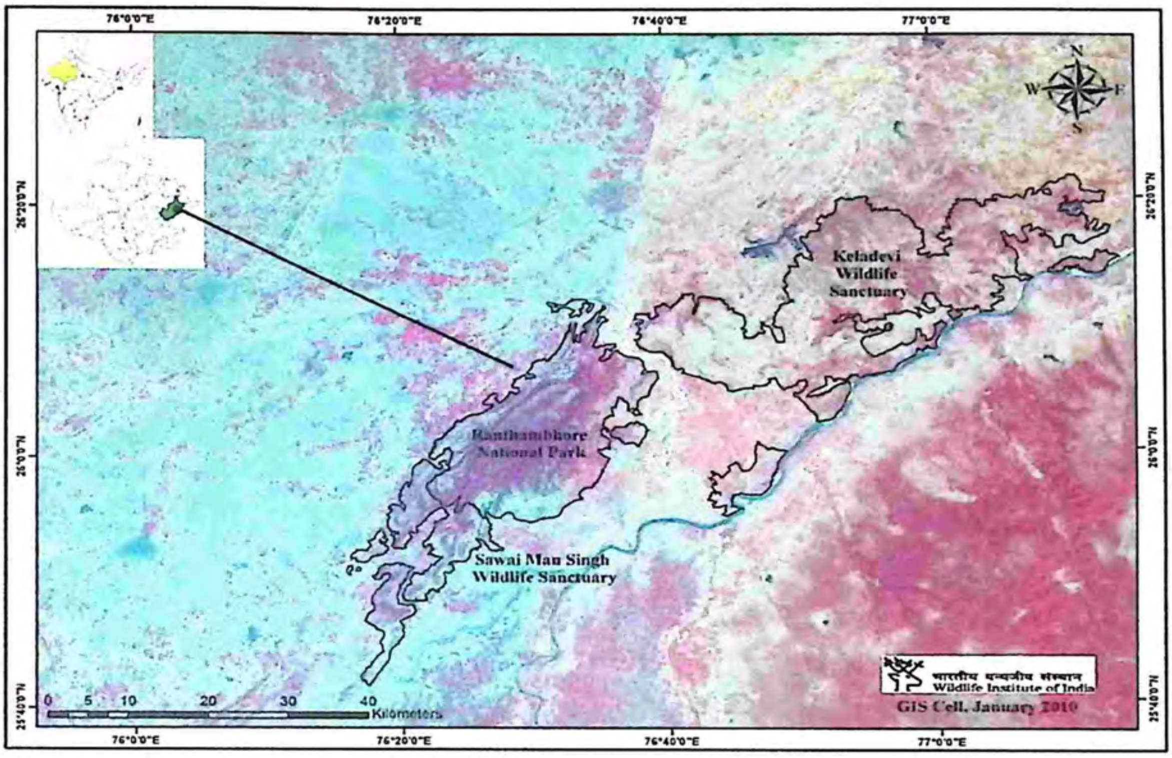


Figure 4. Ranthambore National Park (RTR), Rajasthan, India

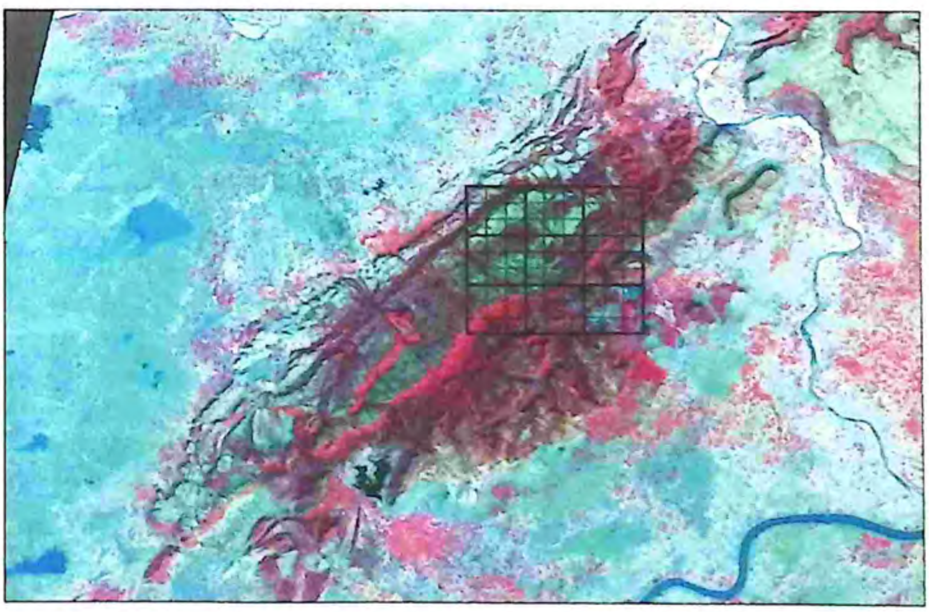
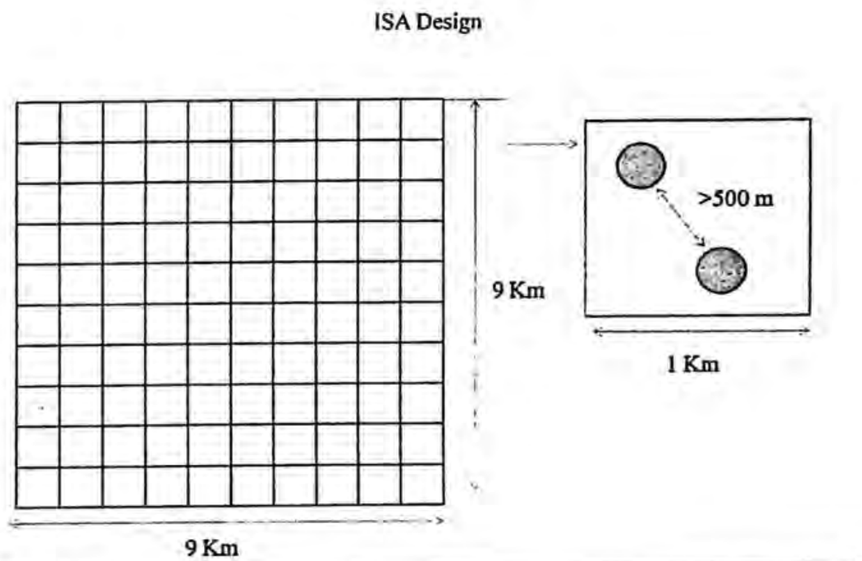


Figure 5. Selection of Intensive Study Area (ISA) in RTR

3. METHODS

3.1. Identification of Intensive Study Area (ISA)

Based on reconnaissance undertaken for direct sightings on sambar of different age, sex and group sizes and information available through ongoing project, an ISA of 90 sq km within RTR was selected (Fig. 5) having adequate number of sambar in each category. The field data was collected between December 2010 and March 2011.



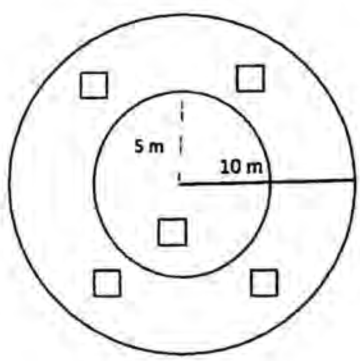


Figure 6. Circular plot taken for quantification of different parameters needed for availability of habitat resources and utilization by sambar in ISA

3.2. Quantification of habitat availability

For meeting objectives of study, a grid of 1x1 km was laid in the ISA (Fig. 6). Habitat parameters were quantified on two randomly selected points which were spaced at least by 500 m and a total of 81 grids were selected. In this way, data of habitat availability on 162 randomly selected points in ISA was collected. Selection of random points over using of systematic transects would minimize collection of data which are auto correlated and will cover all representative habitat types. Habitat in the present context of study comprises of vegetation characteristics, including trees, shrubs and ground layer, physical features, and level of human disturbance was also taken into account.

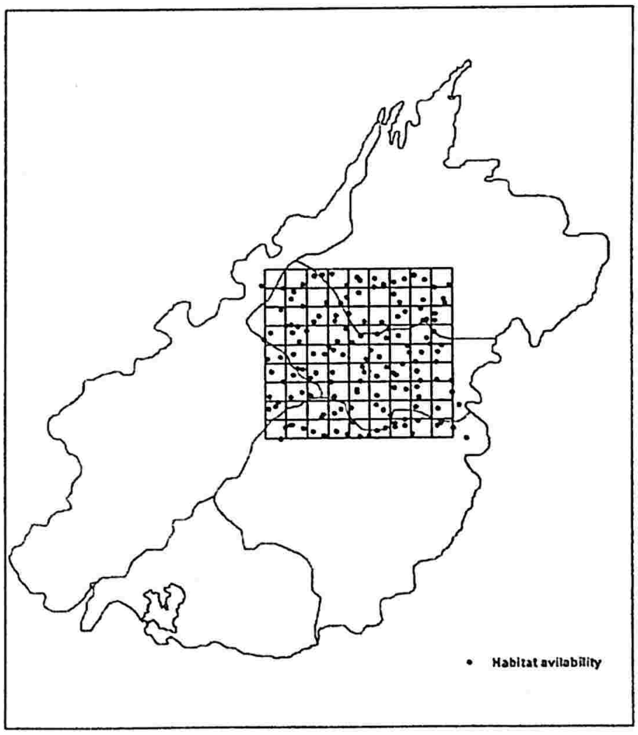


Figure 7. Map showing the points of the availability plots on the ISA

Following parameters were recorded on each sampling point:

Quantification of vegetation parameters

Tree: - On each selected random points, a 10m radius circular plot was laid using rope and data was collected on trees. All the individuals over 20 cm GBH was taken as trees, whereas any other below this value was noted under shrub. Following parameters were recorded for each species:

- Species
- number of individuals
- height (ocular)
- girth at breast height(GBH)
- Per cent canopy cover based on ocular estimation in different classes of 0-25%; 26-50%; 51-75% and >76% (A relationship between actual percent canopy cover estimated using densiometer and ocular estimate was established. This relationship was used to correct data obtained through ocular estimation).

Shrubs: - A 5m radius circular plot was laid within 10m plot from the same centre at each sampling point and the following observations related to shrub were recorded:

- Species,
- number of individuals
- average height (ocular)
- canopy spread – by taking maximum length and breadth of the shrub

Herbs and grasses: - ¼ m square iron frame was used to quantity per cent ground cover measured as ocular estimation on five different points within 10 m circular plot and dominating species was noted.

Other parameters: - Apart from above vegetation parameters, following information were also noted in each 10 m circular plot at each sampling point:

- Percentage of weed (ocular) - was estimated in 5 m circular plot.
- Number of trees found cut
- Slope (flat, slight, medium & steep)

Disturbance level: - Level of disturbance in terms of wood cutting, cattle dung etc was quantified at each 10 m circular plot.

Physical features: - parameters like terrain or slope was estimated in four levels at sampling point.

- Flat
- Gentle
- Medium
- Steep

3.3. Quantification of habitat utilization by sambar in relation to different categories

3.3.1. Classification of sambar with respect to sex and age categories:

For the present study, sambar was classified as follows:

Male:

All males sighted were classified into following four classes (Fig. 8):

Spike	-	6 month - 2 years
<1 Foot	-	2-3 years
1-2 Feet	-	3-4 years
>2 Feet	-	>4 years

Female:

Each female was classified as follows:

Adult

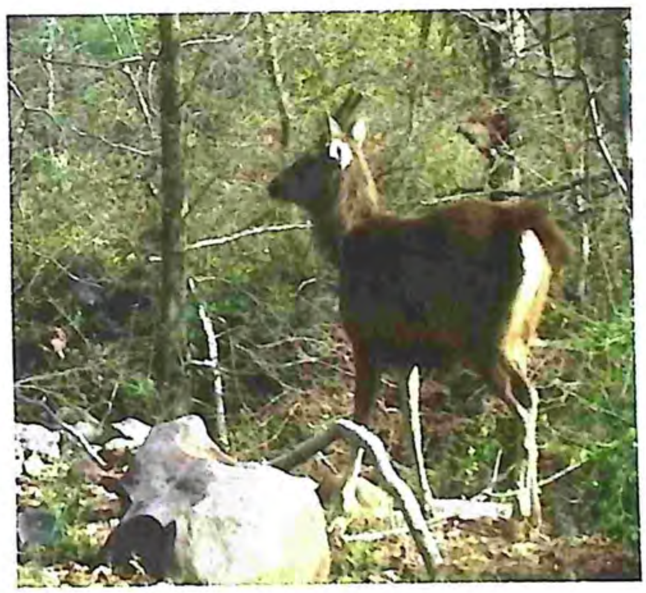
Sub-adult (reaching 3/4th of the belly of an adult female)

Fawn (reaching up to the belly height of mother)

a) >4 years (>2 Feet)

b) 3-4 years (1-2 Feet)

c) 2-3 years (<1 Foot)



d) 6 month - 2 years (Spike)

Figure 8. Male Sambar age categories based on antler sizes

3.3.2. Habitat utilization

Habitat utilization by sambar under different categories was recorded only during winter in ISA. On the basis of the survey, 6-10 transacts in ISA was marked and was used for recording observations on each group (Fig. 10). Each transect was walked during peak foraging time i.e. early morning and evening. On sighting of each group, data on its GPS location, group size and its composition with respect to sex and age categories were noted. In addition, whenever a sambar group sighted other than on the transects was also used to record data on habitat utilization. All habitat parameters was quantified at the centre point of each group when first sighted after completion of behavioural observations. All habitat parameters were quantified as listed above.

3.3.3. Selection of resources quality by sambar through palatable plant species and faecal matter analysis

The palatability of the plant species collected was determined by the nutrient quality estimated in these species, I also determined the selection of resource quality by sambar through chemical compositions and ratio of dicot to monocot present in the fecal matter, across different categories of sambar that signifies the quality of the diet selected by individual (Holecheck *et al.* (b). 1982). Nitrogen content (or crude protein) and ratio of dicot to monocot in fecal matter have been used as an index of quality of habitat selected among herbivores like study undertaken on free ranging Impala and Blesbok in South Africa (Klein & Fairall. 1986).

Faecal nitrogen has been repeatedly used to predict diet quality of ruminant's particularly crude protein (Arnold & Sudzinski. 1963; Jeffery. 1971; Arman *et al.*1975, Langlands. 1975; Wofford et.al 1985; and Shaabani *et al.* 1986). Therefore, quality of resource use due to each category of sambar was determined based on the crude protein, fiber, lignin, etc and these were determined in the faecal pellets using methods as described by AOAC 1990 (Association of Official Analytical Chemists)

Based on the direct observation in the field the palatable plant species were recorded, and samples of the plant species found in sambar diet was collected for analysis of its nutrient values.

3.4. Collection of faecal pellets

Fecal pellets of each category were collected whenever the animal was seen defecating, GPS reading (Fig. 9) and the age and sex categories of sambar were noted.

Collection of fresh faecal pellets was the integral part of the study, it was perhaps the only way we could make out how the sambar deer use the same habitat differently among different categories by analyzing there faecal matter for nutrient values.

Getting such data was quite typical, because of the fact that we can't plan when the sambar will defecate and where, so for that I have to be with the sambar as long as possible and wait till it defecates, based on the studies in zoo, it defecates 14-18 times in 24 hrs, so as per this it should defecate at least once in 2 hrs, but it wasn't the case in field condition.

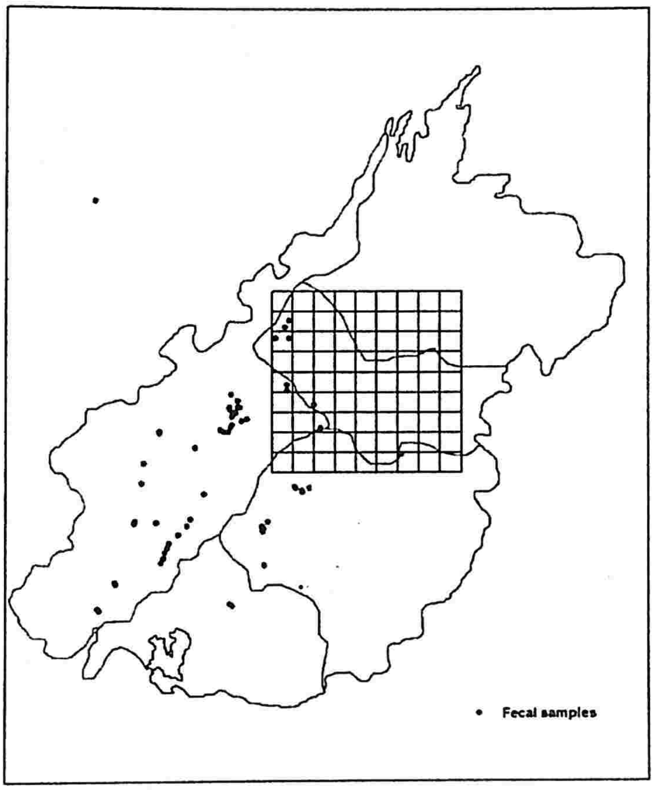


Figure 9. Location of the collected faecal pellets

I have spent 4-6 hrs waiting for defecation initially, after the first week of faecal pellet collection; I came to realize that one can't completely rely on studies in zoo conditions when working in the field. The best place to wait for the pellet logically should be the place where sambar is found in big numbers, but that wasn't always the case in Ranthambhore. As per my observations no matter how big the herd is they hardly defecate when they are eating mud in the salt licks. I have waited for hours together without a positive result. The best places to get the pellets for me was to try it in the open plain areas (where one can see them through the binoculars for a longer time before they get disappeared in the forest after running) near a water hole or big salt licks where they mostly rest in the day time. And the best way to get the pellets was to get out of the gypsy and gently approach them on foot, without making them too uncomfortable, the moment they stand up or start moving away, one should be observant with the binoculars, letting them move away, after some time most of the sambar defecate when they get up after taking rest.

The site of defecation must be visually marked without binoculars, taking the nearby trees or other prominent things as reference, as the data is likely to get lost in the homogeneity of the forest, as it has happened to me so many times. Apart from that getting faecal pellet for the 7 categories of sambar needs different approach as well, for me getting pellet for the adult-female was the easiest and for the male-spike was the most difficult.

Likewise 97 faecal pellet groups were collected. Approximately 10-15 pellets were collected at each defecation site. The pellets were collected in the paper bags and after collection they were sun-dried and packed in the same bags with GPS and category ID written on it for further analysis in the WII laboratory.

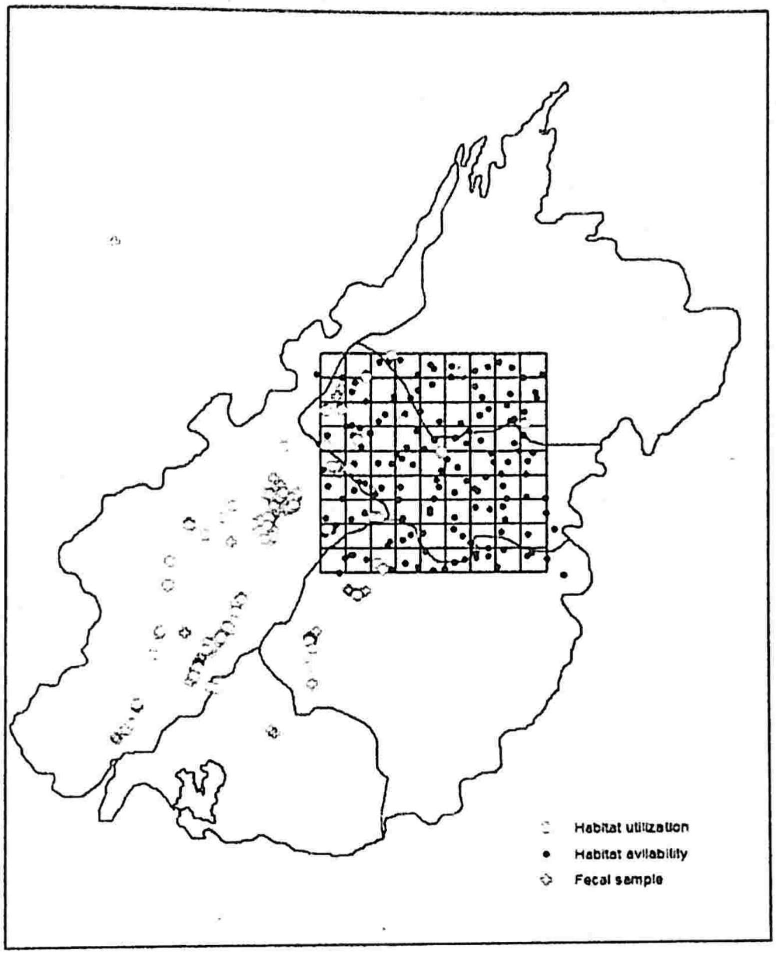


Figure 10. Map showing the GPS points where the plots for habitat availability, utilization and collection of faecal samples was done

3.5. Laboratory Methods

The faecal pellets and the plant samples were oven dried at 50-60°C for 48 hrs, thereafter they were examined for physical parameters and then grinded samples were stored in zip-lock bags for further laboratory analysis.

3.5.1 Physical parameters of faecal matter

Of the total of 97 pellet groups of various categories of sambar, ten random pellets were taken out from each pellet group, and the physical observations viz, length, breadth, weight and volume were recorded.

Length and breadth were taken using vernier caliper, weight was taken using the electronic weighing machine (with the accuracy of 1 mg), and volume of the ten random pellets was measured by looking at the displacement of water in a measuring cylinder.

3.5.2. Chemical parameters

a) *Percent Nitrogen and Crude Protein (CP)*

For getting the value of nitrogen and CP a FOSS Kjeltec 2300 Analyser was used to analyze the samples after digestion.

Preparation of samples:

i) 0.5 gm of the sample was taken and placed in a Kjeltec Tube

ii) One digestion tablet ($CuSO_4 + K_2SO_4$) was put in the tube

iii) 10 ml of concentrated sulphuric acid (H_2SO_4) was added in the tube

iv) The tube was placed in a digestor and heated to 400°C for 1 hour, or until the content became a clear, bluish liquid.

v) The samples were placed in the FOSS Kjeltec analyser and standard procedures were followed to obtain the value of percentage nitrogen.

Calculations:

Nitrogen (N) Percentage

$$N(\%) = (S\text{-}B) \times N \times 1.407 / \text{Sample weight (g)}$$

Crude Protein (CP) Percentage

$$(CP)\ \% = \%\ N \times 6.25$$

where, S = Volume of acid used against sample

B = Volume of acid used against blank

N = Normality of acid

b) *Determination of organic matter, sodium (Na), potassium (K) and calcium (Ca) content*

Powdered samples were taken and burned in a muffle furnace at 500°C for 4-5 hrs. Cooled, desiccated and was weighed to determine the ash content. 10 ml of 50 % HCl is added to the ash and this is heated on a hot plate. The solution is filtered with Whatman's No 1 filter paper to avoid inclusion of any inorganic impurities. The filter paper is again burned in the muffle furnace. The filtrate is made up to 50 ml by addition of distilled water, and tested for sodium content.

Apparatus: silica/sintered crucibles muffle furnace, beakers, measuring cylinders, conical flask, Whatman's filter paper, Flame Photometer, Atomic Absorption Spectrophotometer (Perkin-Elmer A Analyst 700™).

Reagents: 50 % Hydrochloric Acid

Procedure:

i) Take 1g of air dried, powdered sample in tared silica crucible.

ii) Heat in muffle furnace at 550°- 600°C for 4 hours.

iii) Allow the fired sample (100°C) in the furnace to cool.

iv) Transfer into the dessicator.

v) Cool to room temperature and weigh

vi) Prepare 50 % HCl solution

vii) Add 10 ml of the 50 % HCl solution to each crucible containing the dessicated sample. Cool the sample and put the sample in the dessicator.

viii) Heat on a hot plate till it starts boiling.

ix) Filter the solution with Whatman's filter paper.

x) Filter paper and residue - Place in the crucible and put it in the muffle furnace.

xi) Desiccate, cool and weigh the sample.

xii) Filtrate - The filtrate is made to 50 ml by adding distilled water.

xiii) Sodium, potassium and content are measured using a flam photometer .

Calculation:- $$\% \text{ Organic matter} = \frac{\text{wt of sample} - \text{wt of ash}}{\text{wt of sample}} \times 100$$

Sodium and potassium were analysed using flame photometer whereas estimation of calcium was done in a Perkin-Elmer AAnalyst 700 Unit. The values were estimated in part per million (ppm).

c) *Dicot to Monocot Ratio*

Micro-histological technique was used to quantify monocot to dicot ratio as per protocol

i) The dried samples were grounded to a sieve size of 1 μ (approx).

ii) Then we took a small amount of sample on a slide and a drop of Hoyer's Solution was added to it.

iii) The slide was heated gently with the help of a spirit lamp which dissolved the pigments from the dicot plant fragments present in the sample.

iv) The sample was spread in such a way that it formed a uniform layer on the slide.

v) DPX was added to the slide and a cover slip was put on it.

vi) We examined the slide with the help of a microscope and monocot and dicot plant fragments were enumerated 100 plant fragments

3.5.3. Statistical analysis

Discriminant function analysis (DFA) was used to assess the power of differentiation among pellets in various categories. Chi square was use to analyze the availability and utilization data. Statistical attributes such as mean, standard error (S.E.), coefficient of variance (C.V.), standard deviation (S.D.) etc were undertaken for data analysis using SPSS 16 & Excel 2007 software.

4. RESULT

4.1. Habitat Availability

The vegetation parameters were recorded in 162 random plots of 10 m radius and were analyzed for the various characteristics of the available vegetation.

4.1.1. Tree

A total of 1607 were recorded in 162 plots in each that mean an average of 10 trees per plot. Of the total trees 23 tree species recorded, the dominant species were *Anogeissus pendula, Acacia catechu, Butea monosperma,*and *Acacia leucophloea*(Fig. 11). Among these *Anogeissus pendula* was by far the most dominant tree species, comprising of 74% of the total tree recorded, *Acacia catechu* was a distant second with 9%. Three tree species viz: *Acacia nilotica, Holoptelia integrifolia and Wrightia tomentosa* were encountered only once in the plots.

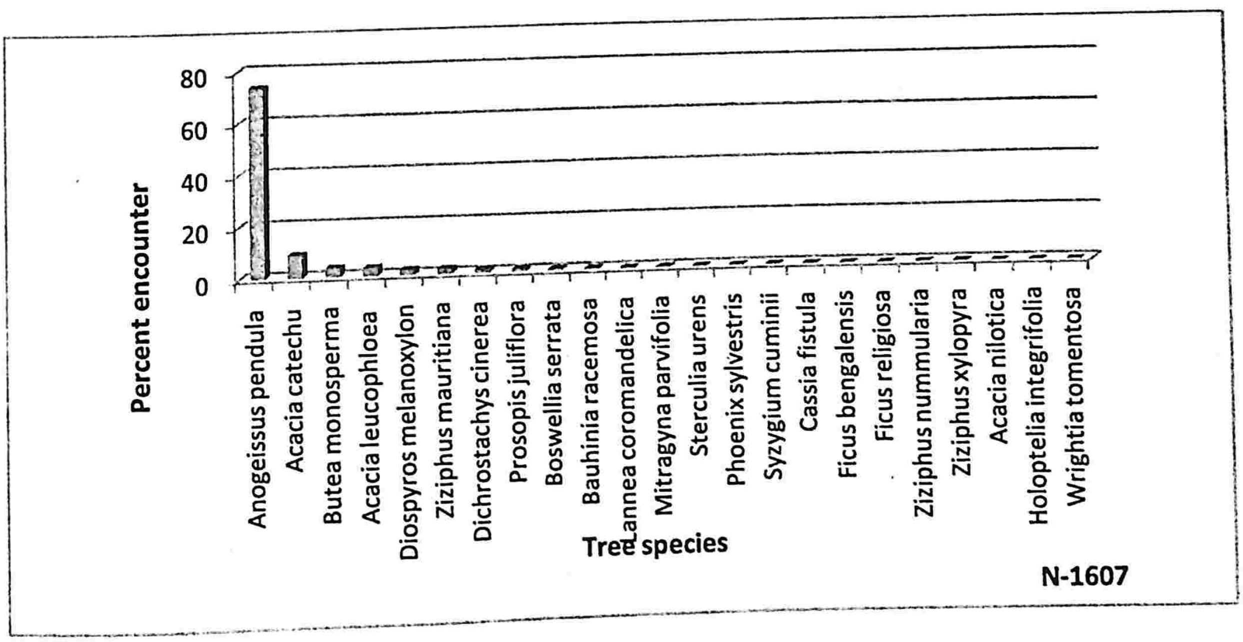


Figure 11. Percent distribution of tree species in ISA

The average canopy cover based on all the plots taken together was 44% in the random plots for availability, with a S.E of 2.13 and S.D of 27.14.

Tree structure based on GBH

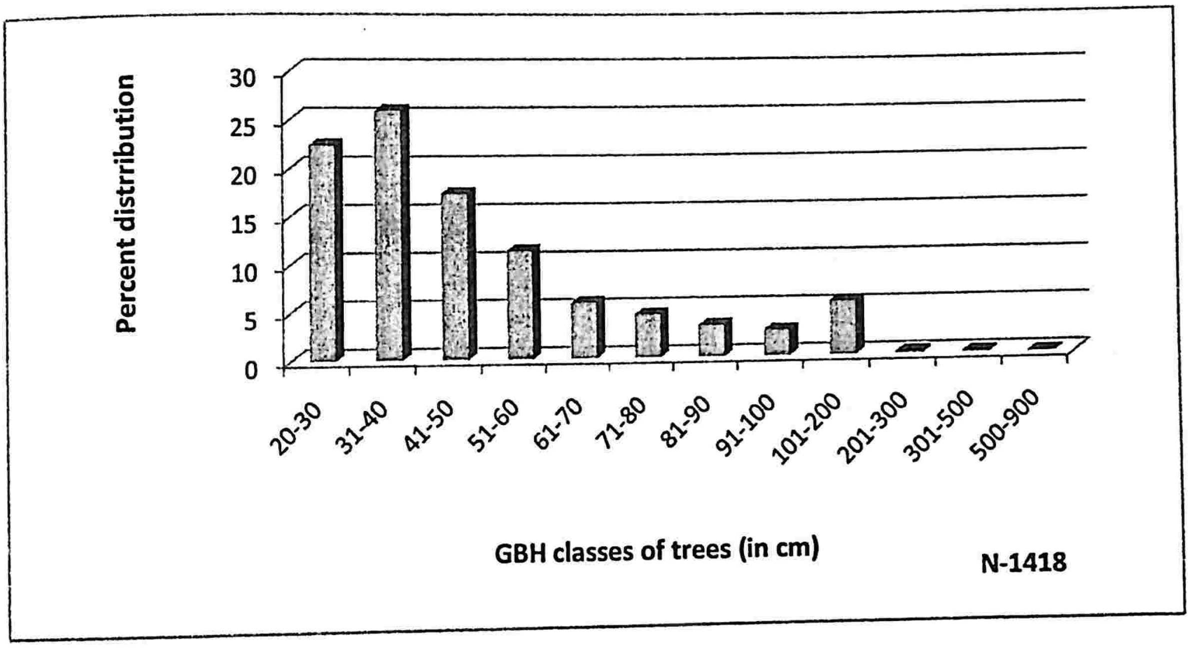


Figure 12. Structure of the trees encountered (as per GBH) having single trunk

Of the 1607 trees encountered 1418 (88%) were the trees with single trunk. There is a good regeneration occurring in the forest as a higher percentage of the trees were in lower girth class (Fig. 12), of which 90% of the lower girth trees encountered were *Anogeissus pendula.* The GBH of over 500 cm was recorded only twice with both of the trees being *Ficus religiosa*.

Branching in tree was seen in 239 (14%) trees. Branching of upto 7 trunks was observed in the trees, and was mostly seen in *Anogeissus pendula* more of such trees were in the open grassland in low density and low tree canopy cover, thereby having direct sunlight falling on them.

4.1.2. Shrub cover

In all, 8 species of shrub were recorded in the plots(in 5 m plot), of which *Grewia flavescens* was the most frequently encountered with a percent occurence in 47.65% of the total shrub species encountered, *Anogeissus pendula* as shrub was the next with a percent occurence in 15%. That indicates of good regeneration of *Anogeissus pendula* in the forest, resulting in high tree density of the species. Of the total 162 plots taken for available habitat 13 or 8% plots didn't had any shrub cover.

Apart from them *Grewia tenax, Capparis sepiaria,* and *Prosopis juliflora* were frequent occurring shrubs (Fig. 13), with the first one occurring mostly in the slope and hilly regions, while the second one in the forest with high canopy cover and the last shrub occurring exclusively in the plain and degraded area near the boundary of the park which were highly disturbed.

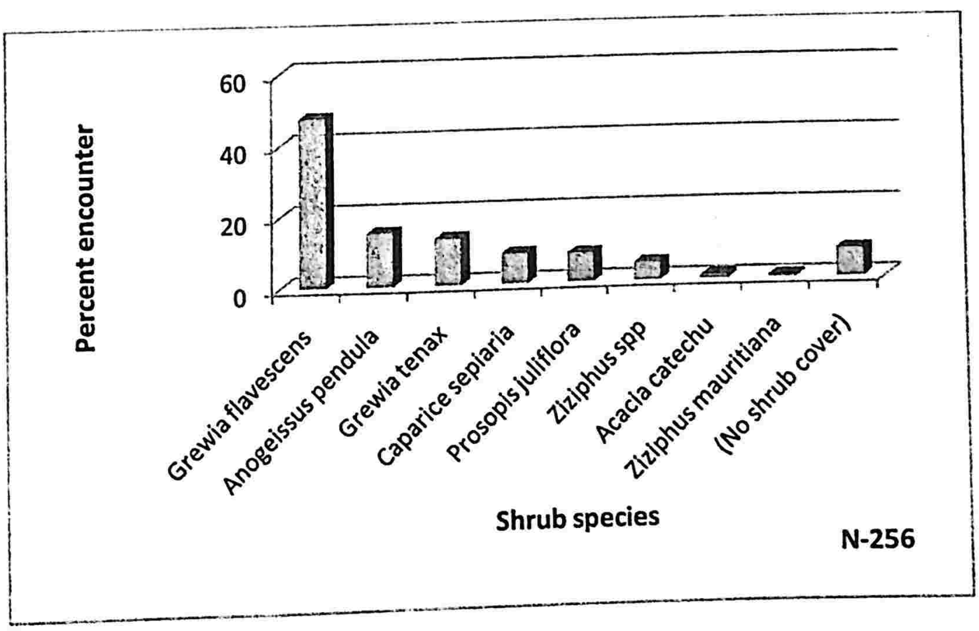


Figure 13. Percent encounter of shrub species in plots

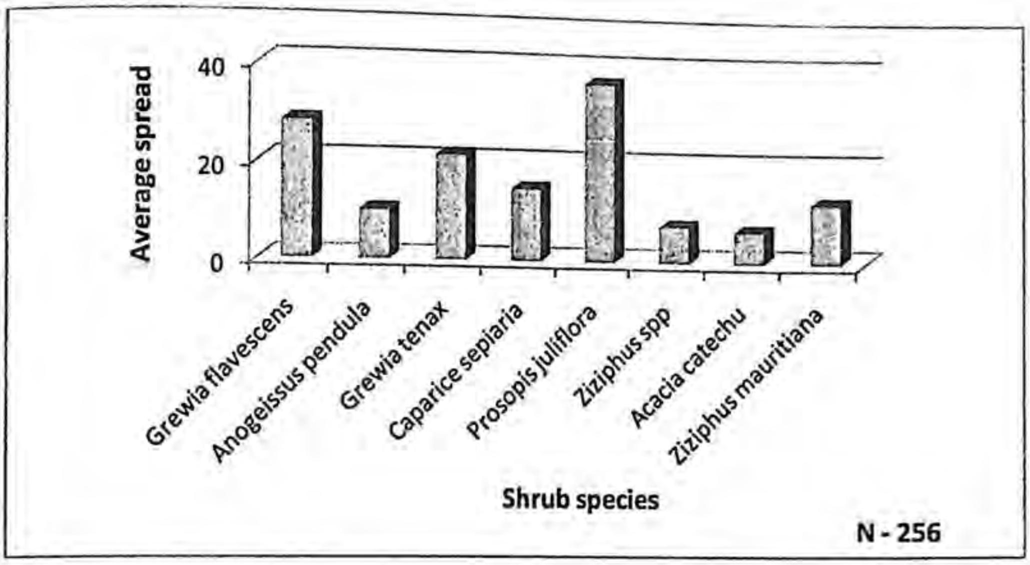


Figure 14. Average spread of shrub species

The average spread of a particular shrub species in a plot, the graph (Fig. 14) clearly indicates that the maximum spread is shown by *Prosopis juliflora* shrub, that means that wherever it occurs it occupies the maximum area, in the plot, or it occurs in high density wherever it is find, low or no understory vegetation was found wherever there was a presence of *Prosopis juliflora* in the plot.

4.1.3. Grasses and herb cover

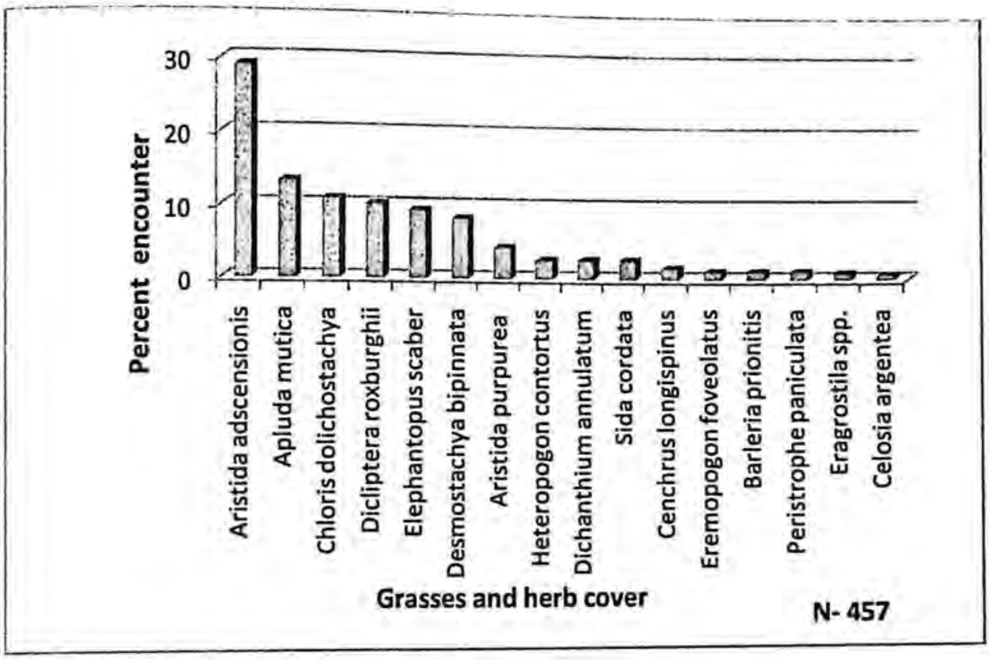


Figure 15. Percent encounter of the grasses, herbs and cover distribution

In the study, most encountered grass was *Aristida adscensionis* present in 29% of the plots, along with it, *Apluda mutica, Chloris dolichostachya, Dicliptera roxburghii,* were also frequently encountered with encounter percent of 13% 11% and 10% respectively (Fig. 15).

Heteropogon contortus, Apluda mutica, Eremopogon foveolatus, Aristida adscensionis have a high average percentage ground cover in the quadrate, inside the plot with the value of 74%,71%,68% and 66% respectively, that means that wherever they occur they are in a high density.

4.1.4. Terrain

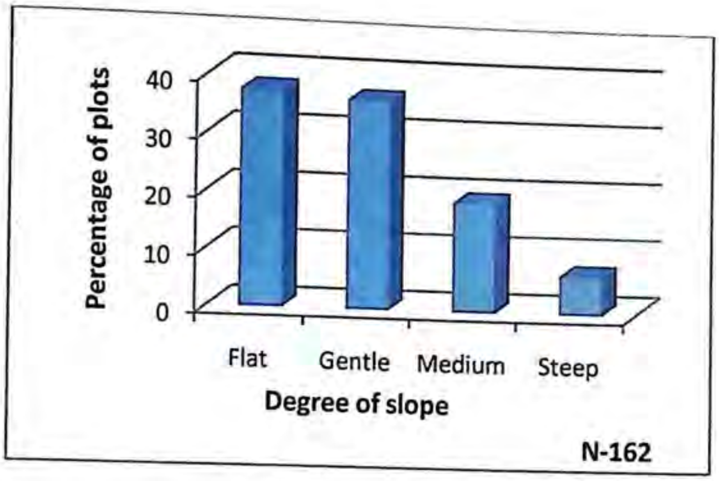


Figure 16. Proportion of different slope types (terrain) in the availability plots

Of the total random vegetation plot done majority of them falls in with zero and gentle slope area, with a proportion of 38% and 36% respectively (Fig. 16). Only 7% were in steep slope areas of Kachida, Kukraj and High point.

4.1.5. Weed/Invasive species

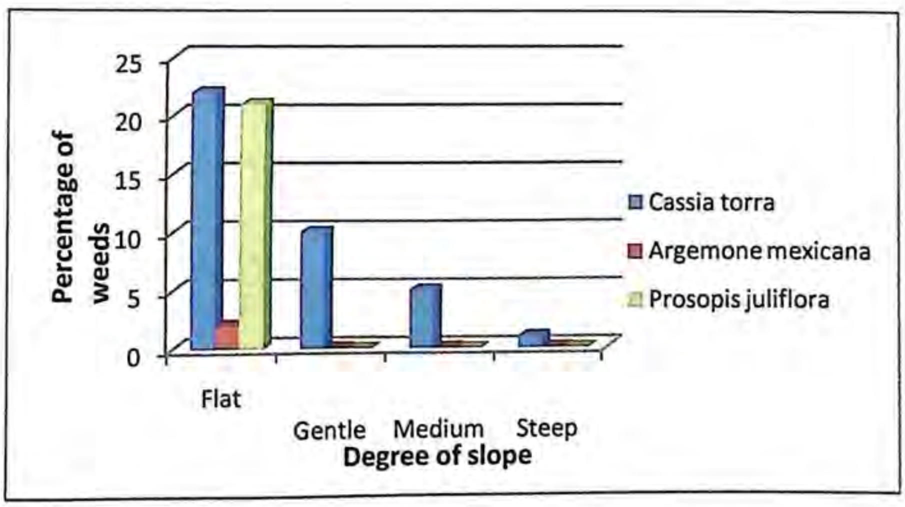


Figure 17. Percent occurrence of weed in relation to slope

Weed species were present in 45 or 28% of the plots, and their presence was inversely correlated with the increase in the slope (Fig. 17), *Argemone mexicana* and *Prosopis juliflora* were found only in the plains at the fringe areas of Khandar range which is prone to human disturbance and where the signs of human presence were encountered quite frequently.

4.1.6. Average spread of weeds

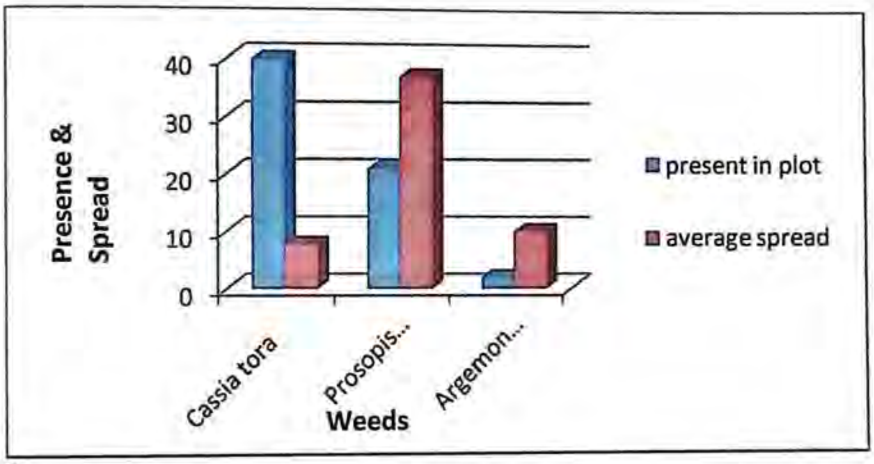


Figure 18. Weed presence and spread in the plot

The figure (Fig. 18) shows that *Cassia tora* is present in 25% of the plots with a limited average spread of 7%, whereas the presence of *Prosopis juliflora* was seen in 13% of the plot with a greater spread of 37%, which shows it doesn't encourage other species to grow nearby

4.1.7. Disturbance signs

Two disturbance signs in each plot were observed - wood cutting and the presence of cattle dung. Wood cutting was seen near 9 plots and cattle dung was seen in 8 plots. Thus disturbance was observed in 10% of the plots studied in the ISA.

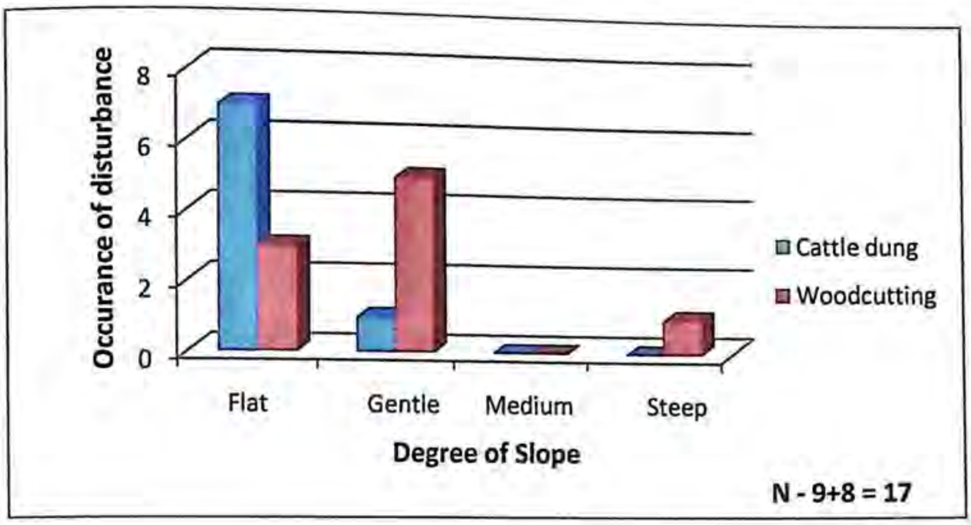


Figure 19. Slope and disturbance relationship

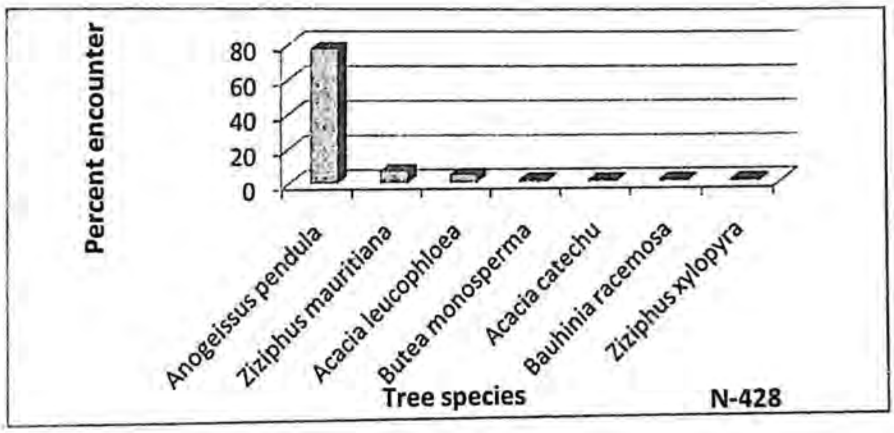
Absolute values were used because of the low occasions of disturbance. As per the figure (Fig. 19) slope has a negative correlation with disturbance, cattle dung was exclusively observed in the flat and gentle slope areas, whereas wood cutting was still observed in the area with a steep slope, which mainly was the Kachida range of the park, which lies near the northern park boundary, and is a area of constant conflict for the park administration. Despite the fact because of the hilly nature and good forage availability in the area this part holds a good sambar density.

4.2. Habitat Utilization

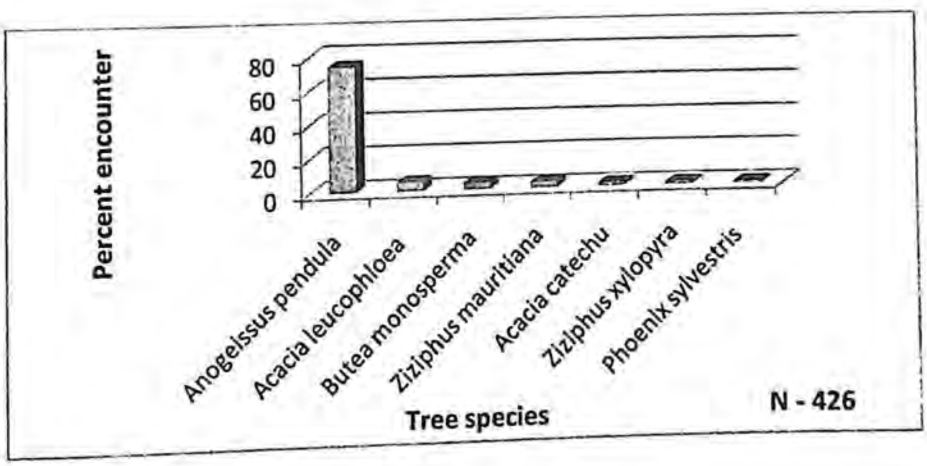
4.2.1 In relation to the 'Sex'

Tree cover

a) Percent encounter



a) Male

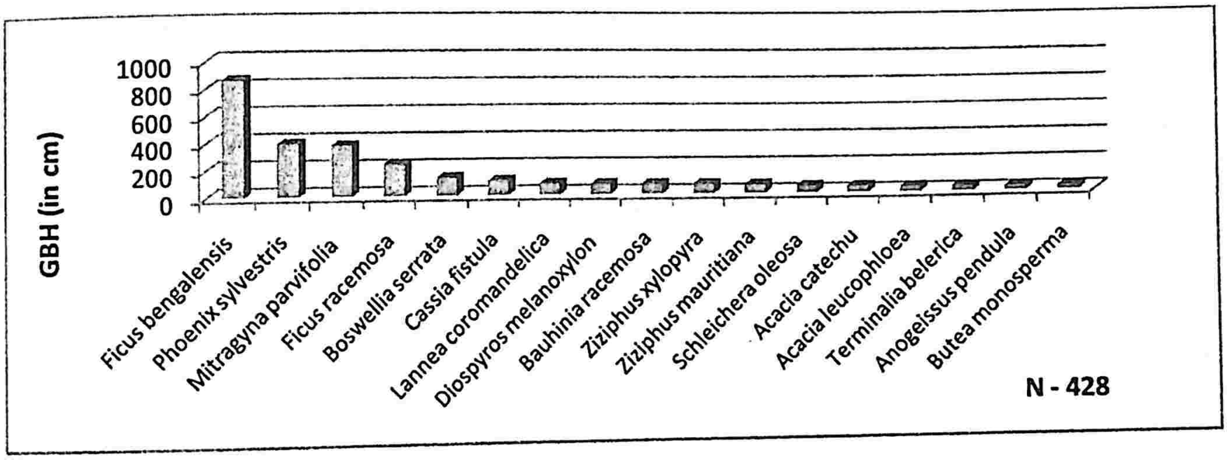


b) Female

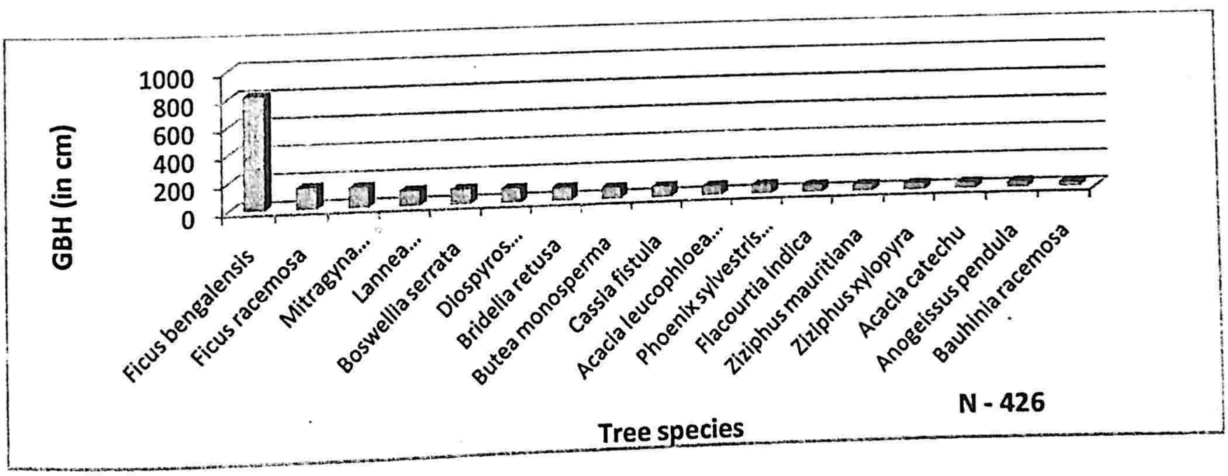
Figure 20. Percent encounter of species used by a) male & b) female in the ISA

The graph (Fig. 20) shows that the percentage occurrence of trees in the plots as per the sex categories. The trees with a percent occurrence of over 1% were only considered for making plot. *Anogeissus pendula* is the most dominant occurrence which was 77% and 75% in the male and female plots respectively. The percent occurrence of other plants is almost similar with slightly different arrangement in the order. Thus there is no significant difference in male and female usage of habitat in terms of tree cover.

b) Average GBH



a) Male



b) Female

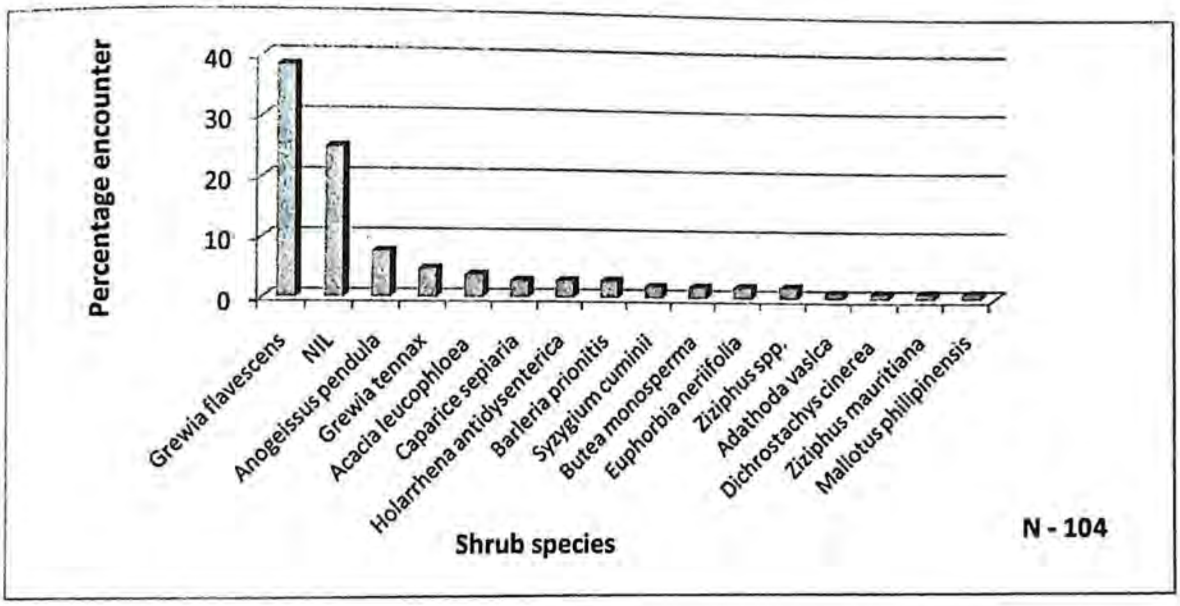
Figure 21. Average GBH of tree species used by a) male & b) female in the ISA

The graph (Fig. 21) indicate the girth classes of the trees under which sambar was seen using the habitat, it shows that both male and female sambar were seen under *Ficus bengalensis* and *Ficus racemosa* trees of big girth, and it was also observed during the field study that langur and sambar have some sort of association while feeding at big *Ficus* trees, this is because Sambar used to pick up the leaf and fruit dropped by the langur. Apart from that it was interesting to observe that male was seen preferring trees with higher girth class, as compared to female, this can be attributed to the fact that, trees of bigger girth have higher amount of leaf litter under them, and male feed more on the easily available poor quality leaf litter that feeding on the greener leaves of the same plant to optimally forage, and it can afford to do so due to lower energy requirement as compared to female (per capita body mass). Just to substantiate the fact that leaf litter have lower value of protein, I have analyzed the fresh and dry leaf litter of *Anogeissus pendula* and it has the value of 10.23% and 9.18% respectively.

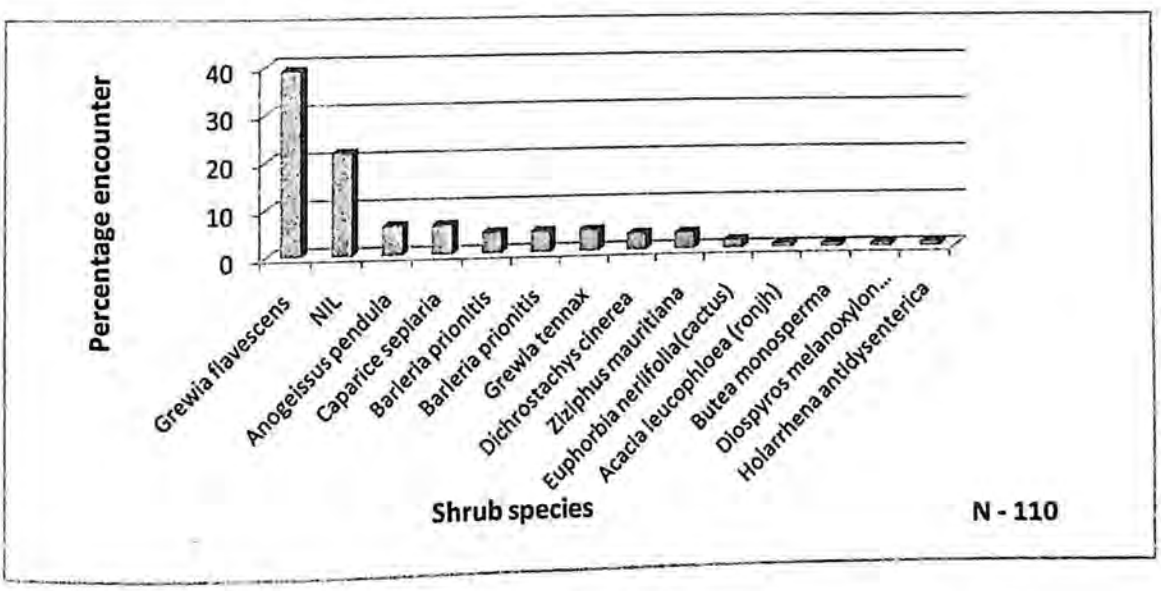
The average canopy cover used by the male and the female sambar was 47% and 43% respectively and the difference was slight.

Shrub cover

a) Percentage encounter



a) Male



b) Female

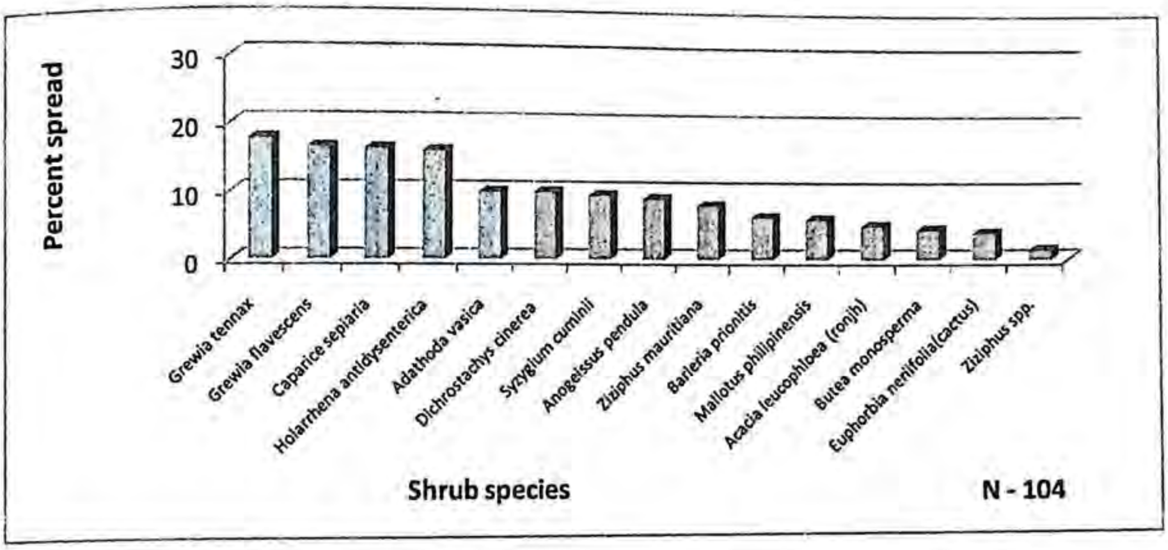
Figure 22. Percent encounter of shrub in the plot in which a) male & b) female were seen using the habitat

The graph (Fig. 22) clearly shows that the shrub which was maximum encountered when sambar (both male and female sexes) was using the habitat was *Grewia flavescens* which was seen 40% of the time in male and 39% time in the female study plots.

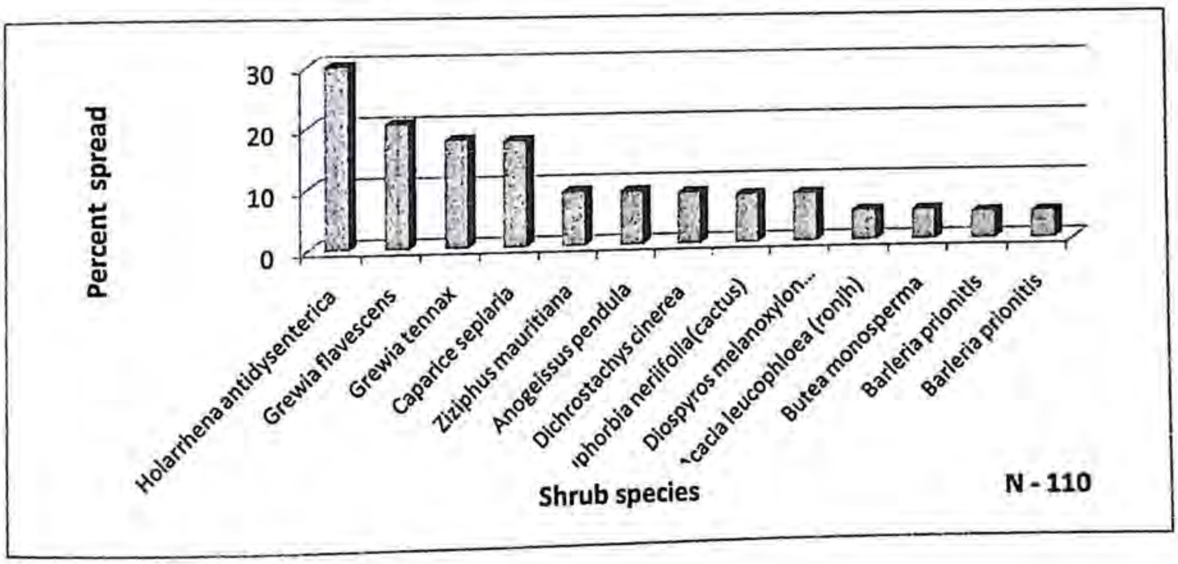
It was also interesting to see that the next dominant category was the plot with no shrub cover, which was 26% in case of male and 21% with female; this reflects the fact that, high shrub density may not be the only criteria for a Sambar to use a habitat.

One unlikely thing that came up from the graph is despite the high protein value of *Capparice sepiaria* (to check and correct all) (22.71%) which is even higher to *Grewia flavescens* (15.24%), and highest among the plant analysed in my study, it wasn't the most preferred in the habitat may be due to great differences in their availability as per my study availability plots, which was 75% for Grewia and mere 14% for *Capparice*, or due to presence of sharp spines on the its branches, that they may prefer to avoid. But as expected protein rich *Capparice* shrub was found more in the female plot as compared to the male ones.

c) Average percent spread



a) Male



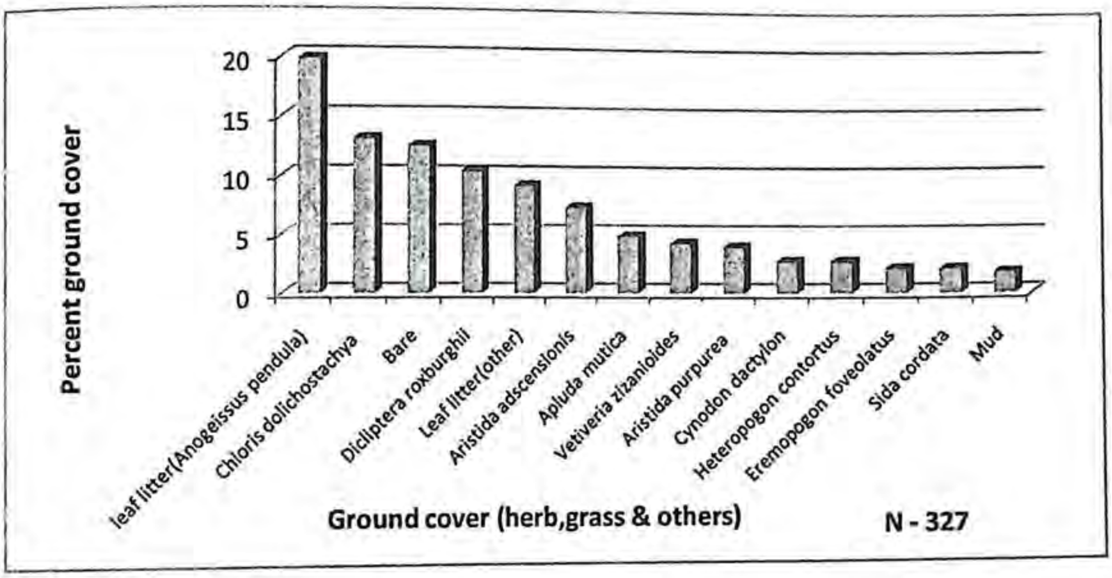
b) Female

Figure 23. Average percent spread of shrub in the plot in which a) male & b) female were seen using the habitat

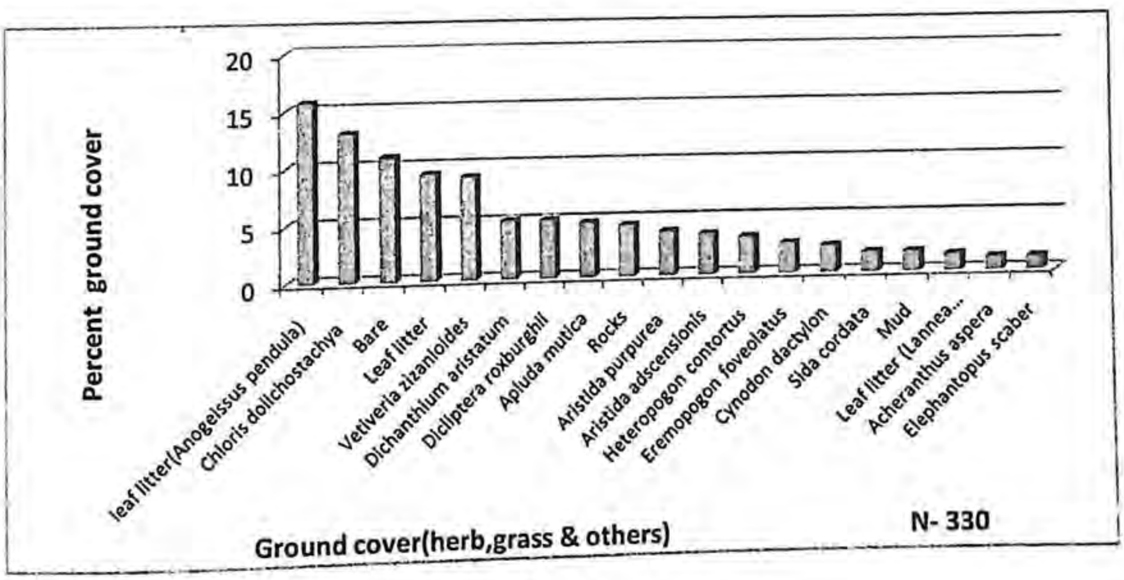
Grewia tenax, Grewia flavescens, Capparice sepiaria, and *Holarrhena antidysenterica* all the four species of shrubs shows a higher average percentage(more than 16%) spread in the utilization plot (Fig. 23) I took, and these 4 species were the preferred plant species as well.

Grass, herb and percent ground cover

a) Percent encounter



a) Male



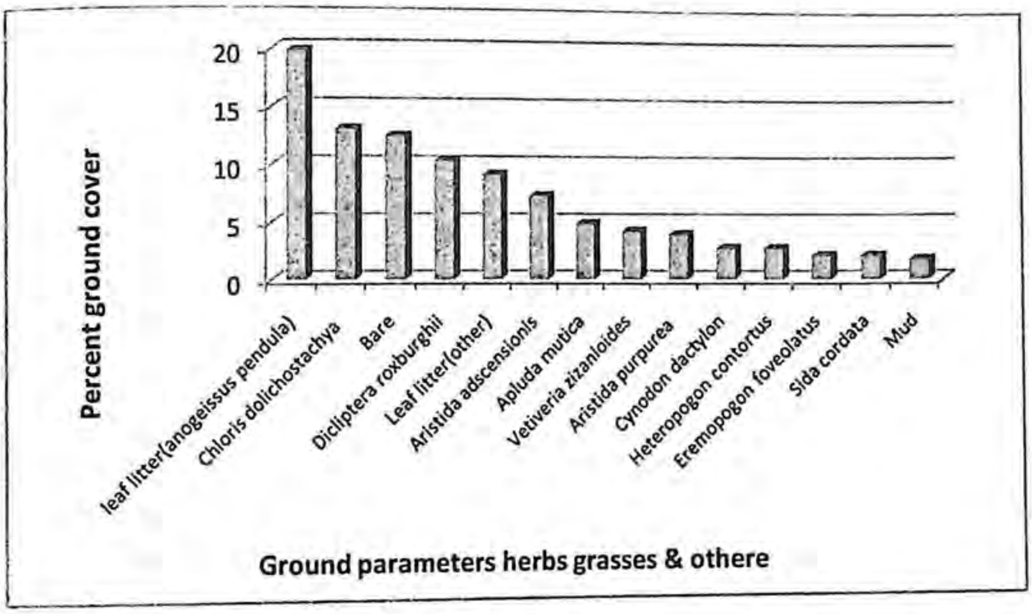
b) Female

Figure 24. Percent encounter (having values =>1 %) in the plot in which a) male & b) female were seen using the habitat

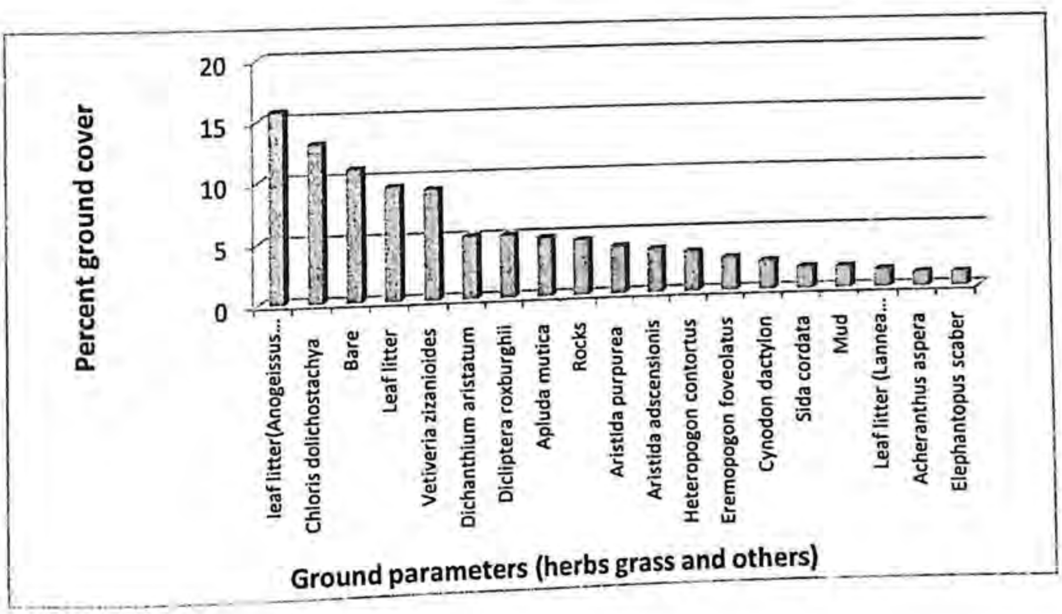
Easy availability of *Anogeissus pendula* leaf litter might be the reason why it was most preffered ground cover parameter, it was present in 20% of male and 15% of female plot (Fig. 24), female might be moving more as compared to males who preferred easily available food source due to its less energy requirements and its physiological features.

Dicliptera roxburghii herb was seen evenly spread in most green areas of RTR having good canopy cover, and it was one of the most preffered species of plant, as all the seven categories of sambar were seen feeding on it quite frequently, may be due to its easy avaialibility and high protein (17.65%), content, which was next only to *Capparice sepiaria.* this plant was most frequently seen with feeding signs. *Chloris dolichostachya* was also ubiquitous, but sambar was not seen feeding on it as frequently may be due to its less protein value (10.21%), and preference might have been given to Dicliptera occurring in the same area.

b) Average percent spread



a) Male



b) Female

Figure 25. Average percentage spread in a) male & b) female) female utilization plot

This clearly indicates that the top three most densely occurring ground cover species were *Vetiveria zizanioides, Aristida adscensionis*, and *Heteropogon contortus* for both male and female utilization plots (Fig. 25) .

Of the 70 plots taken for male habitat utilization, the weed *Cassia tora* was present in 39% of them in the average density of 9% per plot, where it was present in 32% of female utilization plot in 7% density; this indicates slightly better habitat preference of female.

Slope

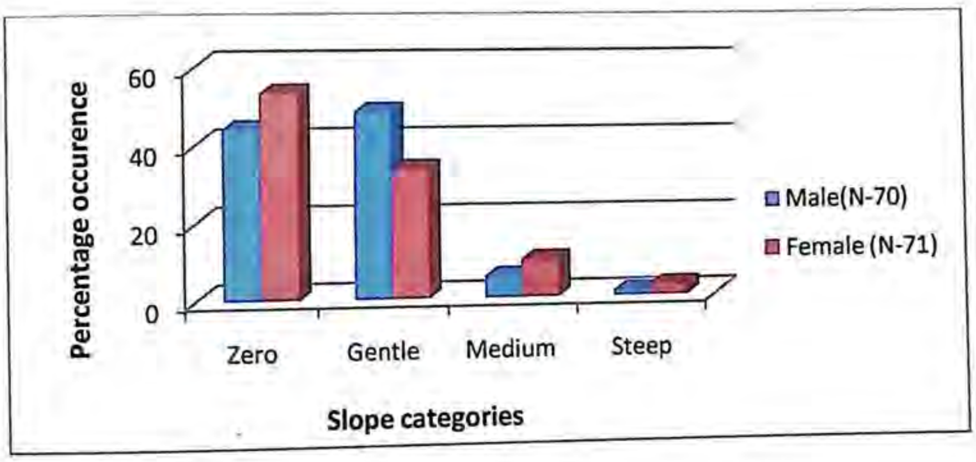


Figure 26. Slope of the plots taken for habitat use (male and female)

The graph (Fig. 26) clearly shows that both male and the female sambar, prefer flat or plain areas, while suing a habitat, this was seen in the field as well, when Sambar were seen coming down from the slope early in the morning every day, they started going up the hills as the evening progresses.

Thus gentle slope category was used by the male sambar than the female.

Table: 1. Use of vegetation by male and female sambar.

Sex						
	Availability	SE	Male	SE	Female	SE
Tree GBH	51.78	1.14	51.36	3.08	49.73	1.49
Shrub cover	17.37	1.16	8.78	1.38	11.34	1.58
Grass & Herb cover	37.3	1.36	35.69	2.12	31.05	2.07
Tree Canopy cover	44	2.13	47.47	2.75	43.84	2.75
Average weed cover	8.23	1.18	8.85	1.6	7.17	0.56

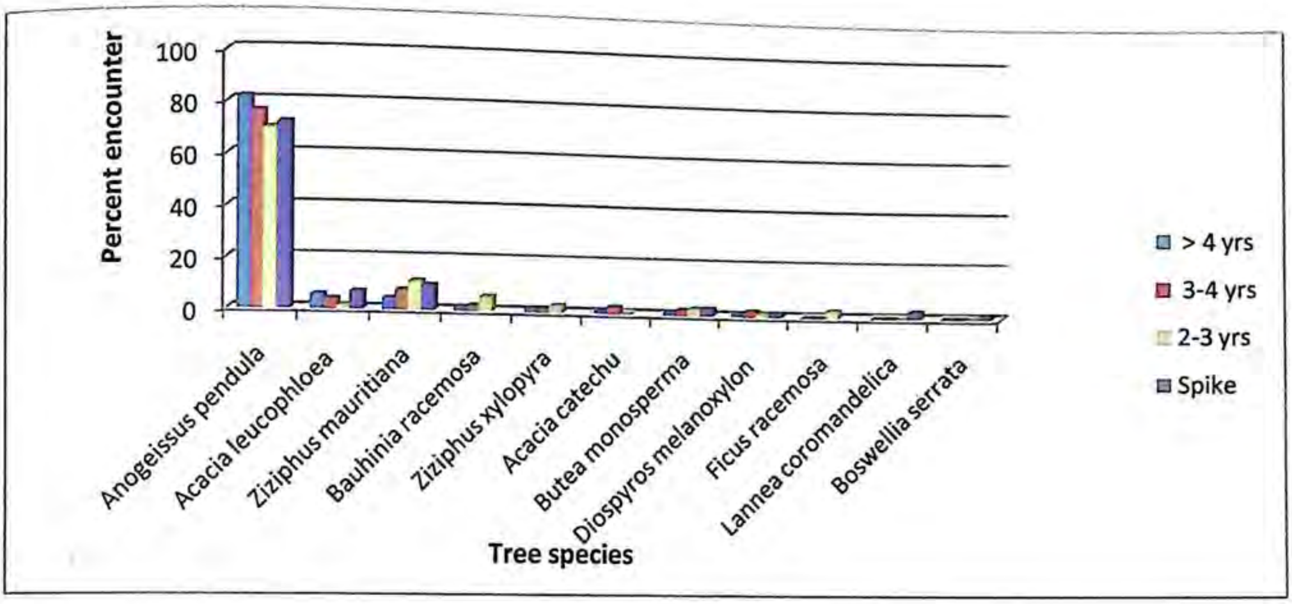
As per the statistical test done on the habitat parameters, the difference in habitat use in sambar as per sexes (male and female) was not significant ($\chi^2 = 0.72$, df = 4, P = 0.95).

4.2.2 In relation to 'Age' categories

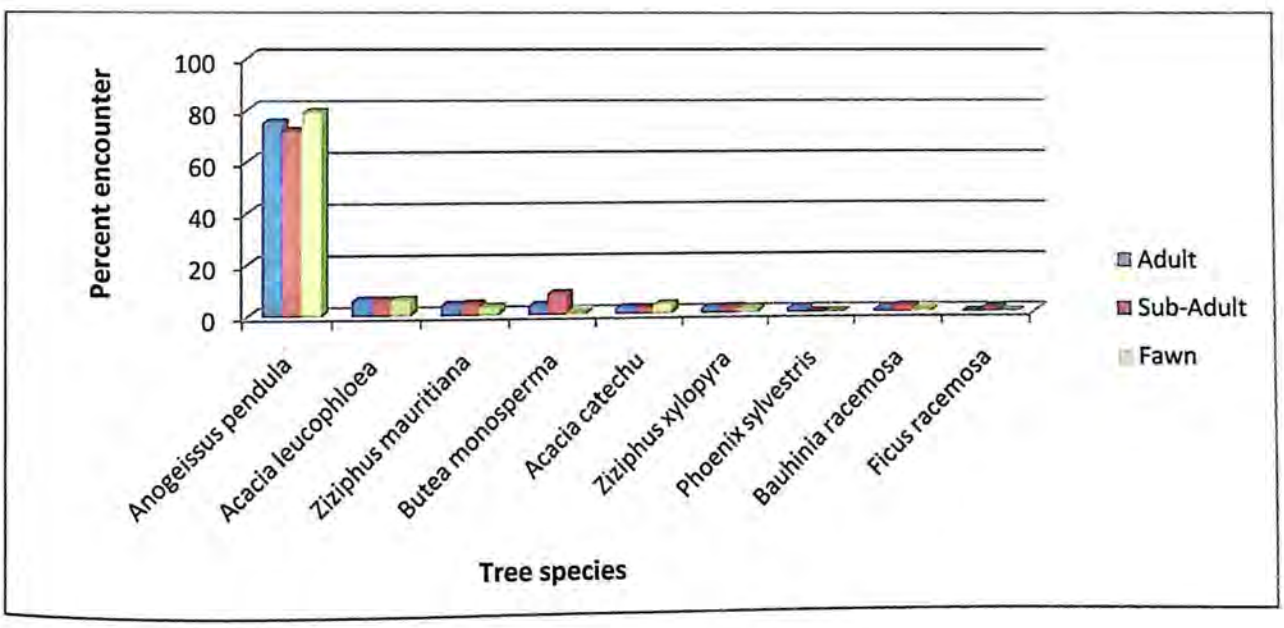
Table: 2. Number of utilization plot taken in relation to age category

Age categories	Sample size
M>4 yrs	45
M 3-4 yrs	28
M 2-3 yrs	12
M spike	12
F Adult	69
F Sub-adult	35
F Fawn	43

Tree



a) Male



b) Female

Figure 27. Percent encounter of trees in the plot where a) male & b) female sambar was seen using the habitat

The major difference in the utilization of habitat with respect to tree structure was seen in *Anogessus pendula* habitat, where adult male was seen using the habitat with 82% cover against the female cover of 75% (Fig. 27). It can be said that in relative terms males prefer to go for the easily available food and female try to go for quality. Also *Ziziphus mauratiana* was found more in male habitat especially the lower categories, as compared to female.

Use of the area was more affected by the mother as they are accompanied by the fawn and the subadult almost all the time, hence the use of the habitat shown by the later 2 categories gets affected by the use of adult female.

Apart from that the first four trees as per the order of preference were same for both male and female.

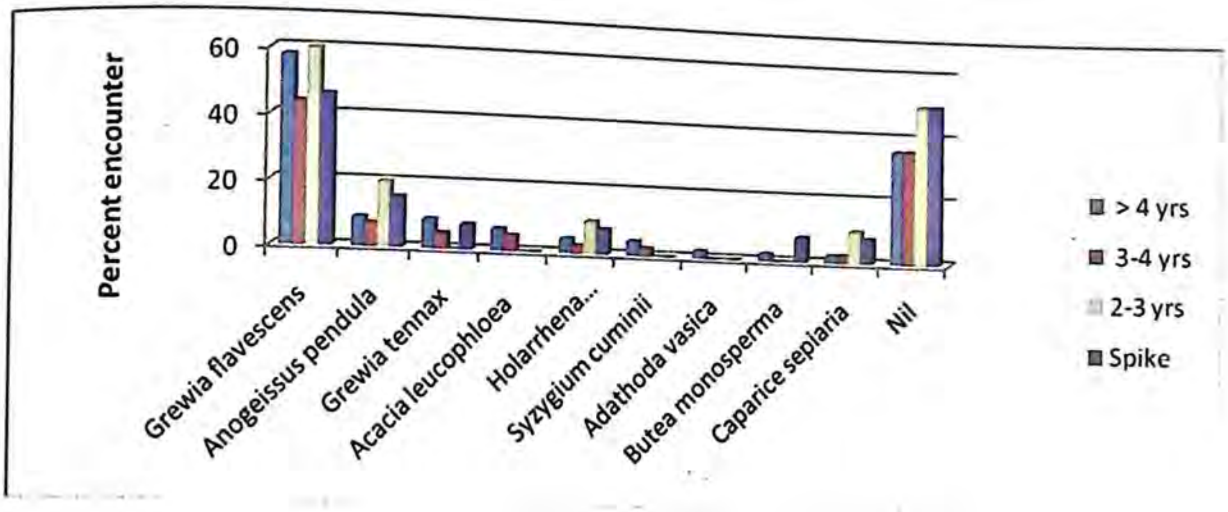
Canopy cover:

Table: 3. Average percent canopy cover usage across categories:

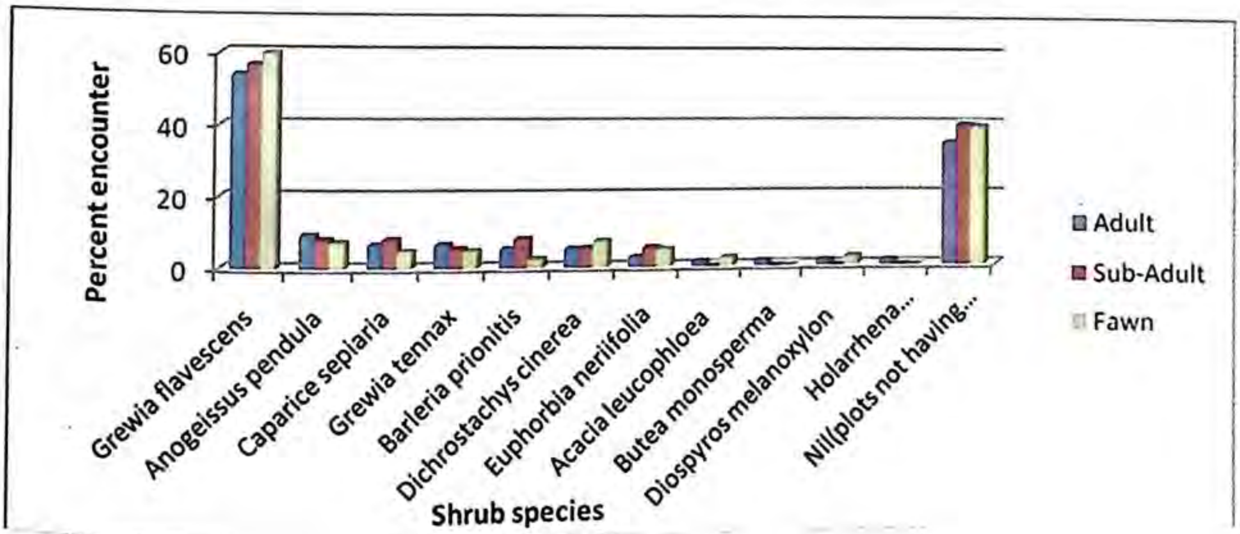
Sex category	Average percent canopy cover
Male> 4 yrs	46
Male 3-4 yrs	41
Male 2-3 yrs	53
Spike	44
Female- Adult	43
Female- Subadult	40
Female- Fawn	40

The Fig. 28 indicates that on an average males were found in dense canopy cover as compared to female, this can be attributed to the fact that they were found mostly under *Anogeissus pendula* which has a good canopy cover mostly

Shrub



a) Male



b) Female

Figure 28. Percent encounter of shrub in the plot where a) male & b) female sambar was seen using the habitat

Grewia flavescens and *Anogeissus pendula* were most dominant shrub used by both male and the female sambar (Fig. 28), mainly because of its high availability, but the interesting trend that can be seen in the usage of *Caparis sepiaria*, since it has the highest protein value its usage is expected to be high, but as evident from the plot it was seen more in the younger categories of male (>4 yrs-2.2%; 3-4 – 2.6% ; 2-3- 10 ; spike 7.7%) and good amount was there in female categories as well (Adult-6.6% Subadult-8.1% Fawn-4.9%) it is clearly a trend that suggest that growing and young stages of sambar require more protein in the diet as compared to adult male.

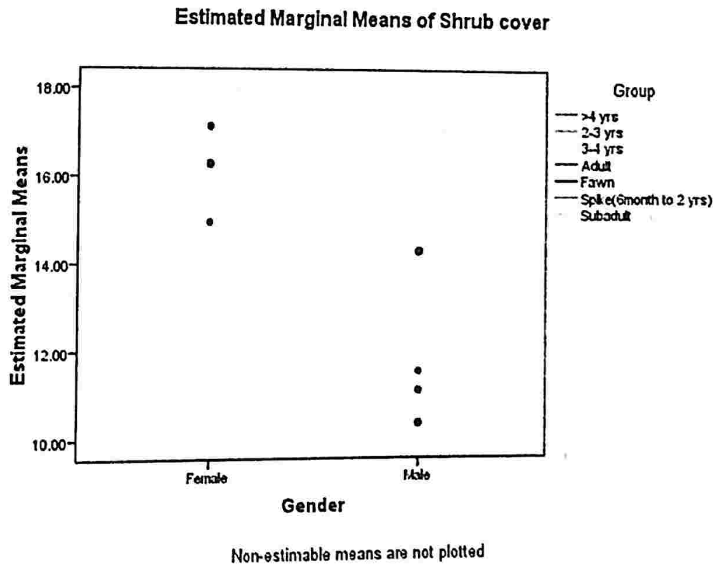


Figure 29. Shrub cover used by all the different age categories of Sambar

Females were seen using habitat with more shrub cover as compared to males, this clearly indicates the better quality habitat requirement of females due to their physiological need, and the fact is also in sync with the presence of higher amount of dicot in female during the slide observations.

Grasses Herbs and ground cover

Table: 4. Percentage ground cover across a) male & b) female age categories

a) Male

Cover	> 4 yrs	3-4 yrs	2-3 yrs	Spike
leaf litter(*Anogeissus pendula*)	25.23	12.21	15.78	12.5
Leaf litter (other species)	13.33	7.63	5.26	3.5
Chloris dolichostachya	9.04	17.55	12.28	16.07
Aristida adscensionis	**8.09**	**12.21**	**0**	**0**
Aristida purpurea	**6.19**	**3.8**	**0**	**0**
Bare	6.19	4.58	8.77	17.85
Dicliptera roxburghii	**5.71**	**16.03**	**28.07**	**19.64**
Apluda mutica	5.23	6.1	0	0
Vetiveria zizanioides	5.23	3.05	10.52	5.35
Cynodon dactylon	4.28	2.29	1.75	1.78
Sida cordata	2.85	2.29	0	0
Heteropogon contortus	1.90	5.34	5.26	3.57
Eremopogon foveolatus	1.42	0	7.01	7.14

b) Female

Cover	**Adult**	**Sub-Adult**	**Fawn**
leaf litter *(Anogeissus pendula)*	16.87	**13.85**	18.36
Bare	15.92	**9.63**	12.04

Chloris dolichostachya	13.05	**9.03**	13.61
Leaf litter (other species)	9.23	**8.43**	6.28
Vetiveria zizanioides	8.91	**13.25**	9.94
Apluda mutica	5.09	**7.83**	5.23
Dicliptera roxburghii	**4.45**	**5.42**	**4.71**
Aristida purpurea	**4.14**	**5.42**	**5.23**
Aristida adscensionis	**3.82**	**5.42**	**4.18**
Heteropogon contortus	3.50	**3.61**	2.61
Eremopogon foveolatus	2.86	**4.81**	0
Cynodon dactylon	2.54	**2.40**	2.61
Sida cordata	1.91	**0**	3.14
Paspalum distichum	0.63	**1.20**	1.04
Desmostachya bipinnata	0.63	**1.20**	1.04
Dichanthium aristatum	0.63	**1.20**	0.52

Table 4 indicates the highest ground cover comprising of *Anogeissus pendula* was there is male>4 yrs (25%) and all the other categories have a lower value for it. This shows that male>4 sambar mostly rely on quantity and easy of forage available than the quality for which it has to work for in searching and moving around.

Similarly both the *Aristida* grasses, having low protein value were present in a higher proportion in the both the adult male categories, and in lower quantities in the adult female category, they were absent in the two lower categories of male (2-3 yrs and spike), this clearly indicates the above trend of quantity vs. quality.

Another interesting trend observed was the fact that a female fawn has similar values of habitat parameters as for a adult female, because of the fact that mother and the fawn were together most of the time, this may not necessarily indicate that a fawn is using the same habitat as a adult female.

Dicliptera roxburghii herb is present quite commonly in the habitat and it has a high protein value of over 17%, the presence of this herb more in the lower categories of sambar indicates the higher protein requirement of the young, the effect is more substantiated in the male categories, where the difference is quite substantial.

Weed (Cassia tora)

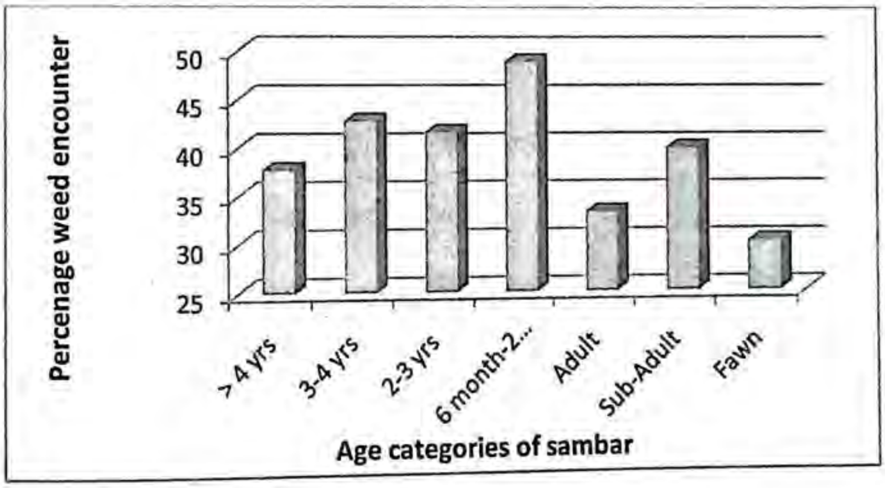


Figure 30. Percent encounter of weed (*Cassia tora*) in plots where various categories of sambar were seen utilizing the habitat

The percent weed cover was higher in the male utilization plot as compared to female, and it was even higher for the lower categories of male sambar, female fawn was found in the least *Cassia tora* cover (Fig. 30).

Terrain/Slope

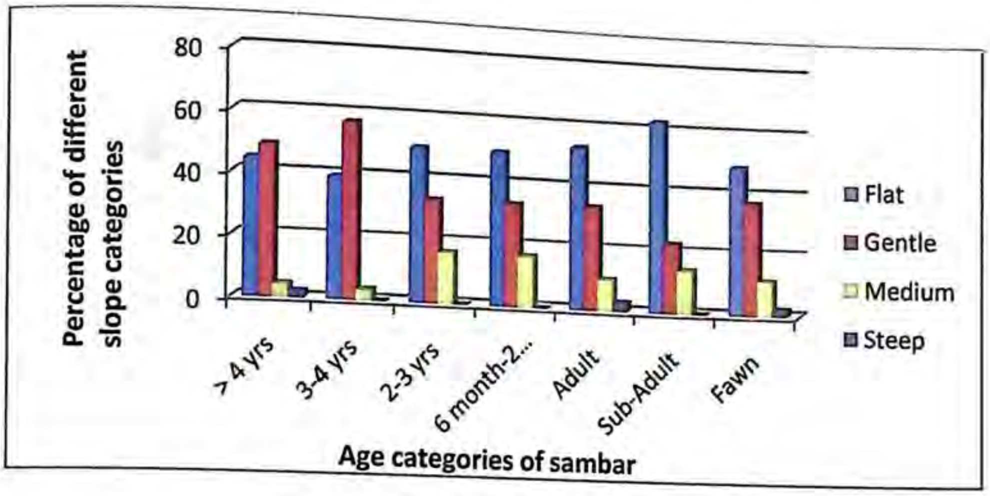


Figure 31. Slope of the utilization plot of sambar as per sex categories

Slope of the utilization plot, followed a almost common trend for all the categories of sambar across age and sex, all of them were mostly in the flat and gentle slope area while using the habitat (Fig. 31). The only aberration from the general trend was shown by the two adult categories of male sambar, which were least found in the medium and high slope areas, and prefer the flat the low slope area on maximum occasions.

Table: 5. Use of vegetation by different age categories by sambar

Age Categories														
	Male								Female					
	>4 yrs	SE	3-4 yrs	SE	2-3 yrs	SE	6mnth - 2 yrs	SE	Adult	SE	Subadult	SE	Fawn	SE
Tree GBH	49.59	4	47	2.6	52	4	55	5	50	2	51.4	2.38	46.8	2
Shrub cover	14.28	2	12	1.74	11	2	10.4	2	16	2	17.1	2.46	15	2
Grass & Herb cover	29.26	1.8	33	2.78	38	4	36	3	31	2	35.3	2.38	30.4	2
Tree Canopy cover	46.02	3.2	41	4.66	53	6	44	7	43	3	40	3.74	40	3
Average weed cover	7.52	1.6	11	2.87	7.8	2	8.16	2	7.2	1	6.5	0.7	7.53	1

Male

Source of variation	df	F	P-value
Among groups	3	0.03212	0.99195
Within groups	16		
Total	19		

Female

Source of variation	df	F	P-value
Among groups	2	0.01958	0.98064
Within groups	12		
Total	14		

The higher P (P = 0.98064) value indicates that there are no significant statistical differences in habitat use in sambar as per its age categories.

4.2.3 Group size

During my study the mean group size I observed was 4.15 (ranging between 1-22) most of the solitary individual observed were adult males. All the sambar seen was divided into 5 categories as indicated by the Fig. 32, their respective sample size is also indicated in the Table 6.

Table: 6. Number of utilization plot taken as per group size

Division	**Sample size**
Group size 1	26
Group size 2	21
Group size 3-5	40
Group size 6-8	7
Group size >8	7

Group were divided in to 5 categories: as shown in the Table 6, group of 1 individual was made to target solitary animals, group of 2 individual was made to target the mother and fawn association. Percentage contribution of the various groups is shown in the graph below.

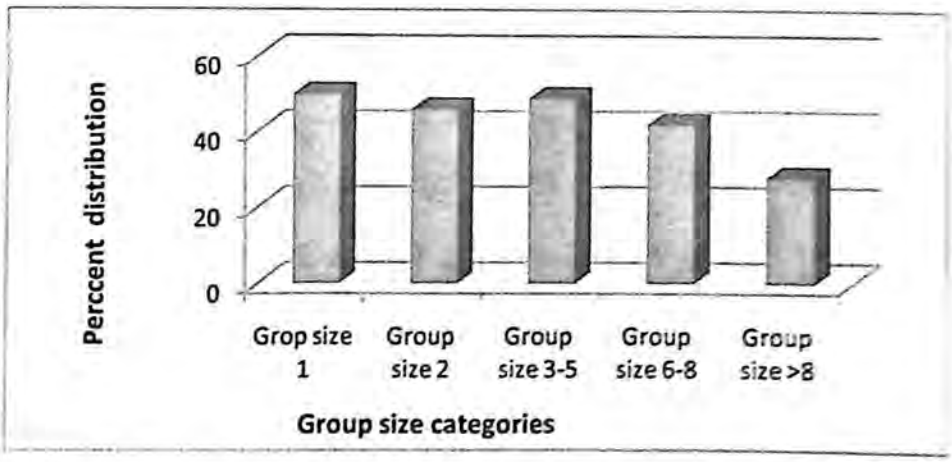


Figure 32. Percent contribution to different group categories

Trees

Table: 7. Percentage occurrence of trees as per group sizes

Tree species	Grop 1	Group 2	Group 3-5	Group 6-8	Group >8
Anogeissus pendula	67.72	73.64	75.24	63.63	85.71
Butea monosperma	10.12	1.35	2.42	0	2.85
Ziziphus mauritiana	6.32	6.75	6.31	9.09	5.71
Phoenix sylvestris	3.79	0.67	0.48	0	0
Acacia leucophloea	3.16	10.81	3.39	0	2.86
Ziziphus xylopyra	3.16	2.70	0.97	0	2.86
Bauhinia racemosa	1.26	1.35	0.97	0	0
Ficus bengalensis	1.26	0.67	0.97	0	0
Boswellia serrata	0.63	0	0	3.03	0
Bridelia retusa	0.63	0	0	0	0
Diospyros melanoxylon	0.63	0	1.94	6.06	0
Lannea coromandelica	0.63	0	0	6.06	0
Acacia catechu	0	1.35	4.36	3.03	0
Mitragyna parvifolia	0	0.67	0.48	3.03	0

There was a clear decrease in the number of tree species as the group size increases, showing that as the number in a group goes up (Table 7), they tend to prefer a habitat which has more percentage of dominant species, to avoid as intra-specific competition, and to fulfill the nutritional requirement of the herd, lower individual group tend to acquire a habitat with higher degree of heterogeneity.

Canopy cover:

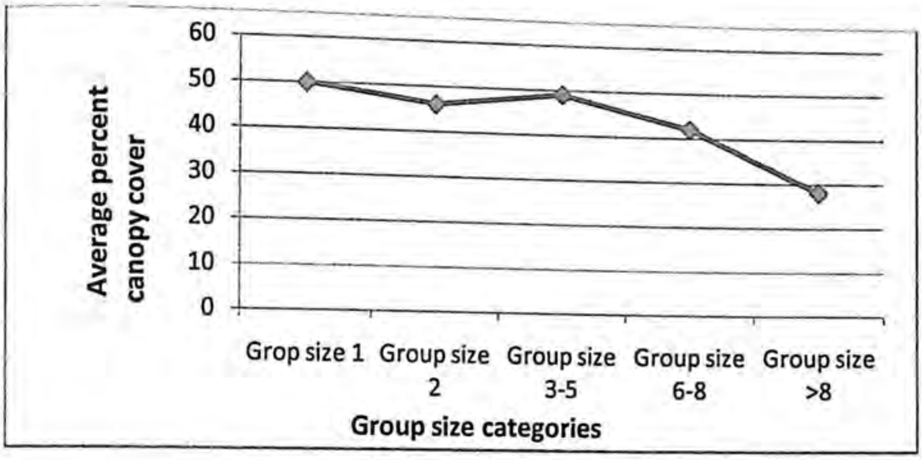


Figure 33. Canopy cover trend as per group size.

As the group size is increasing the canopy cover of the utilization plot is decreasing as shown in the graph (Fig. 33), this again can be attributed to the fact that the group size goes up mostly in the evening time, when they move up the slope in big herds, and the vegetation of the slope is mostly dominated by sparely spread *Acacia catechu* (Fig 2.) which provides a low canopy cover .

Shrub

Table: 8. Percent occurrence of shrub as per group size categories

Shrub species	**Group 1**	**Group 2**	**Group 3-5**	**Group 6-8**	**Group >8**
Grewia flavescens	**43.59**	**72.22**	**42.62**	**45.45**	**33**
Capparice sepiaria	10.26	5.55	3.28	0	*0*
Anogeissus pendula	7.69	0	8.20	9.09	*0*
Holarrhena antidysenterica	2.56	0	3.28	0	*0*

Barleria prionitis	10.26	11.11	1.64	0	*0*
Euphorbia neriifolia	5.13	5.55	0	0	0
Syzygium cuminii	2.56	0	1.64	0	0
Adathoda vasica	2.56	0	0	0	0
Grewia tenax	5.13	0	4.92	0	0
Mallotus philippinensis	2.56	0	0	0	0
Butea monosperma	2.56	0	0	9.09	0
Acacia leucophloea	2.56	5.55	3.28	0	0
Ziziphus mauritiana	2.56	0	1.64		66
Dichrostachys cinerea	0	0	4.92	9.09	0
NIL	**26.92**	**33.33**	**32.5**	**28.57**	**71.42**

Like for trees the diversity of the shrubs also goes down as the number of individual in a group increases, it moves from 12 to 2 from group size 1 to >8, most commonly available species, have a higher percentage value in bigger group sizes (Table 8) . An important trend is that the percentage of plots having no shrub cover has increases with the increase in group size.

Grasses, herbs and ground cover

Table: 9. Percent occurrence of ground cover parameters (grasses, herbs etc) as per group sizes

Species	**Group 1**	**Group 2**	**Group 3-5**	**Group 6-8**	**Group >8**
Leaf litter*(Anogeissus pendula)*	17.6	20.59	13.07	0	32.35
Leaf litter (other species)	17.6	3.92	9.09	17.65	5.88
Chloris dolichostachya	10.4	16.67	14.77	5.88	14.70
Aristida adscensionis	9.6	4.90	4.55	5.88	0

Bare	9.6	19.61	13.64	2.94	20.59
Dicliptera roxburghii	7.2	5.88	14.20	20.59	0
Vetiveria zizanioides	5.6	9.8	10.23	0	0
Apluda mutica	4	0.98	3.40	14.70	0
Aristida purpurea	3.2	5.88	3.40	0	2.94
Heteropogon contortus	3.2	1.96	0	2.94	8.82
Cynodon dactylon	2.4	2.94	0	0	0
Eremopogon foveolatus	2.4	0	3.40	5.88	11.76
Sida cordata	1.6	1.96	2.84	2.94	0
Desmostachya bipinnata	1.6	0	0	0	0
Paspalum distichum	1.6	0	0	0	0

Like the tree and shrub cover trend the diversity of grasses and herbs also goes down with the increase in the group size, notable feature is that one of the most commonly available grass *Aristida adscensionis,* never occurred in the utilization plot of >8 group due to its low nutritional quantity, *Eremopogon foveolatus* was present in high percentage in bigger groups because they are mostly found in the medium to steep slope with *Acacia catechu* and it was seen many times that as the sambar move up in the evening time they forage on *Eremopogon* grass while moving up. Also the number of shrub species encountered shows a decreasing trend as the group size is going up (Table 8).

Apart from that as in the table indicate that the bigger groups mostly rely on the leaf litter of *Anogeissus pendula,* as it is most commonly available and thus reduces the competition for the food resource.

Weed (Cassia tora)

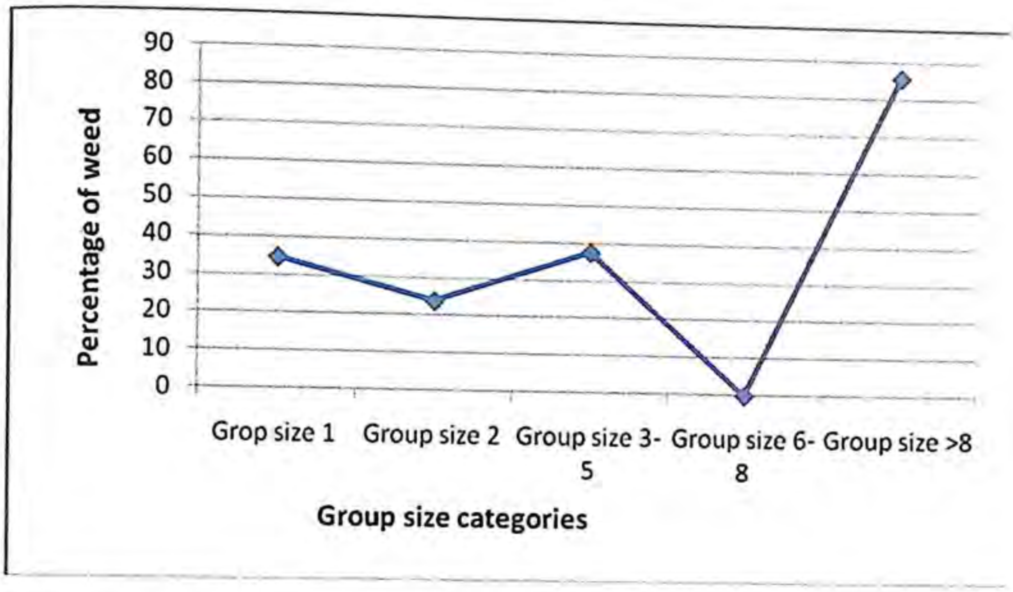


Figure 34. Percentage weed occurrence in a plot

Percentage weed cover shows an uneven trend, it remairis almost study upto the group size of 5 then it plummets to zero and again goes up to over 80%, this is a rather uneven trend and requires more sample size to have a proper trend (Fig. 34).

Terrain/Slope

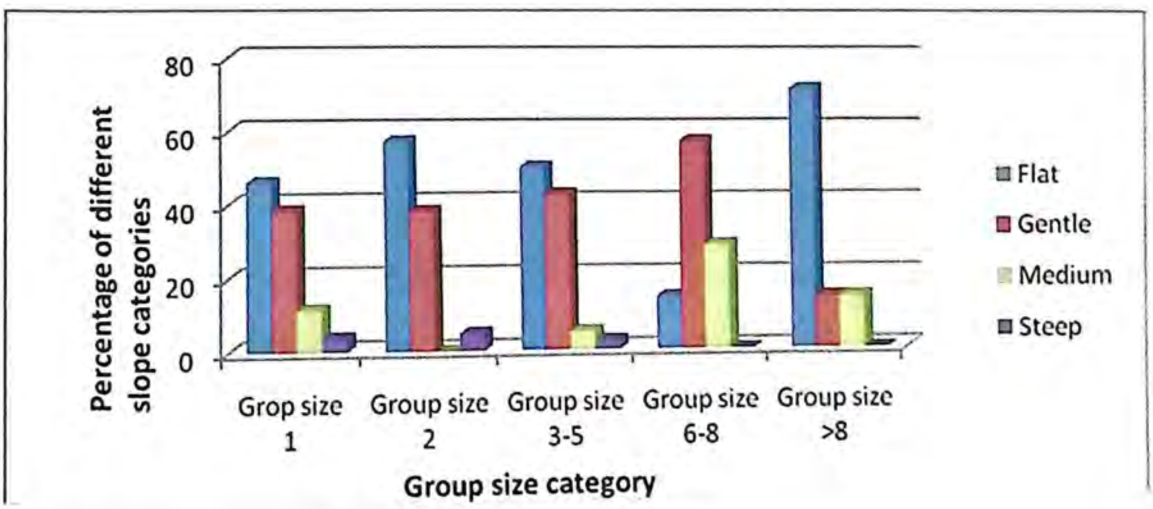


Figure 35. Percentage of different slope categories across group categories

As evident from the graph the slope does not shows any stark dissimilarities across group size categories, but the lower group sizes if 1, 2 individual and the middle group size of 3-5 prefer flat to gentle slope (Fig. 35). The more percentage of medium and steep slope was seen in the higher group sizes of more than 6 individuals, that is because in the evening time, sambar go back to the hilly areas having high altitude and when they move up in the evening they form, big groups, I have observed a maximum of 22 individuals moving up the hill, and foraging as they gradually go up, again they come down in the early morning period next day, but not like a big group.

Table: 10. Use of vegetation by different group size categories of sambar

Group size										
	Group - 1	SE	Group - 2	SE	Group / 3-5	SE	Group/ 6-8	SE	Group > 8	SE
Tree GBH	51.19	3.4	57	8.91	51	2	70.7	7	40	2
Shrub cover	16.17	2.7	11	2.11	12	1	18	6	16	5
Grass & Herb cover	20.31	2.5	18	2.52	22	2	35	6	15	4
Tree Canopy cover	50	4.8	46	5.36	49	4	42	9	28	8
Average weed cover	9.77	3.8	8	1.54	8.7	2	0	0	7.7	2

Source of variation	df	F	P-value
Among groups	4	0.21601167	0.92641251
Within groups	20		
Total	24		

There were no significant statistical differences in habitat use in relation to group sizes as well. This can be attributed to the fact that the habitat is more or less homogenous in Ranthambhore and the available forage is evenly spread. So though there were differences seen as per graphs but they were not found to be significant enough statistically.

4.3. Laboratory analysis

4.3.1 Crude protein

Fig. 36 indicates the variations in the crude protein in the pellets of different age categories. The highest crude protein >11% in the pellets was observed in the animals such as m>4 yrs female fawn and male and male 3-4 yrs old. The lowest crude protein was observed in female sub-adult which was around 8%. The adult males probably feeding on the *Anogeissus pendula* to get the crude protein required whereas the observed higher percentage of feeding on grasses is probably to meet the fiber content for the fermentation purposes. (Fig.36) the observed low percentage of the nitrogen in the pellets of lower 3 categories could be that the minimum amount of the crude protein is being obtained by selecting more number of the plant species probably for getting micronutrients which are crucial for body growth then exclusively feeding on the plant resources having a higher crude protein.

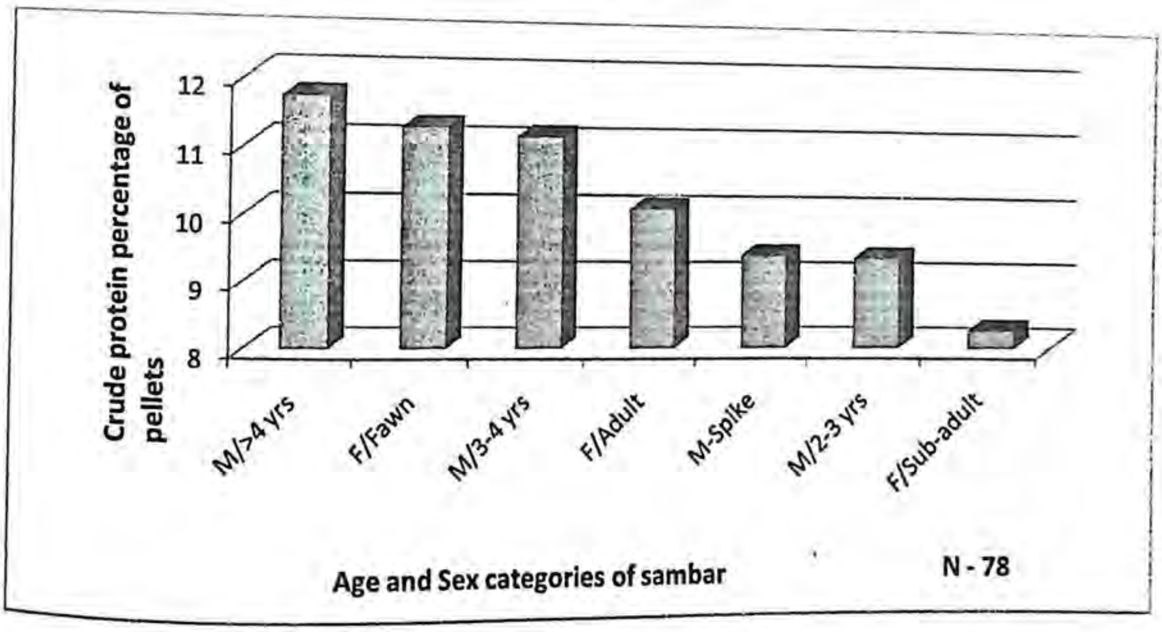


Figure 36. Percentage Crude protein in sambar pellets across age and sex categories

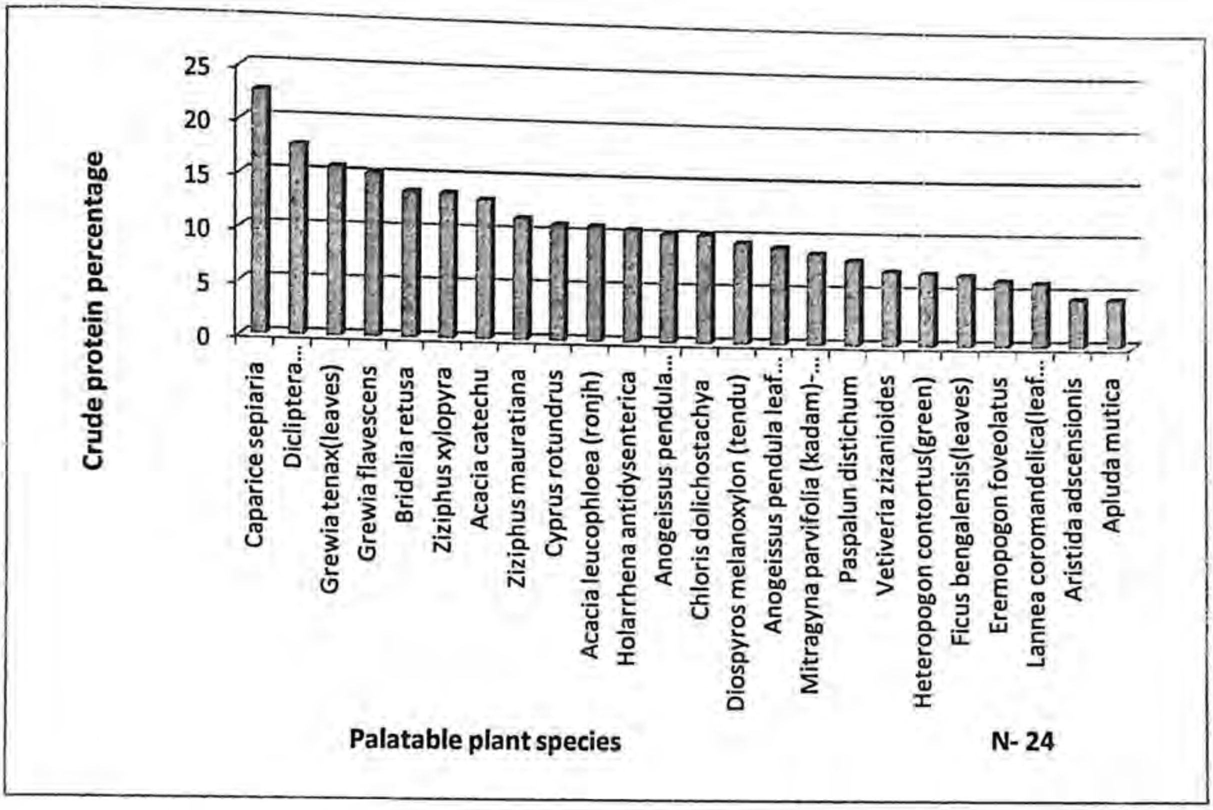


Figure 37. Percentage of crude protein in palatable plant species recorded during field study

After analyzing the 24 palatable plant species for the percentage crude protein value, this graph (Fig. 37) was obtained. It clearly shows that *Capparice sepiaria* (22.71%), *Dicliptera roxburghii* 17.65 %), *Grewia tenax* (15.71%) and *Grewia flavescens* (15.24 %) are the 4 species with high value of CP, of these species all of them were present in high abundance, only *Capparice sepiaria* was found in relatively low abundance when we compare among these 4 species, and *Grewia tenax* was found in greater abundance in slopes and *Grewia flavescens* was widespread in the flat areas.

4.3.2 Organic matter

Highest amount of organic matter was found in the male >4 yrs category, and the minimum value of the mean of organic matter for spike male of < 2 yrs age (Fig. 38). The higher value of organic matter was seen in males as compared to females. All the > 2 yrs male individuals have highest values of organic matter in their faecal pellets.

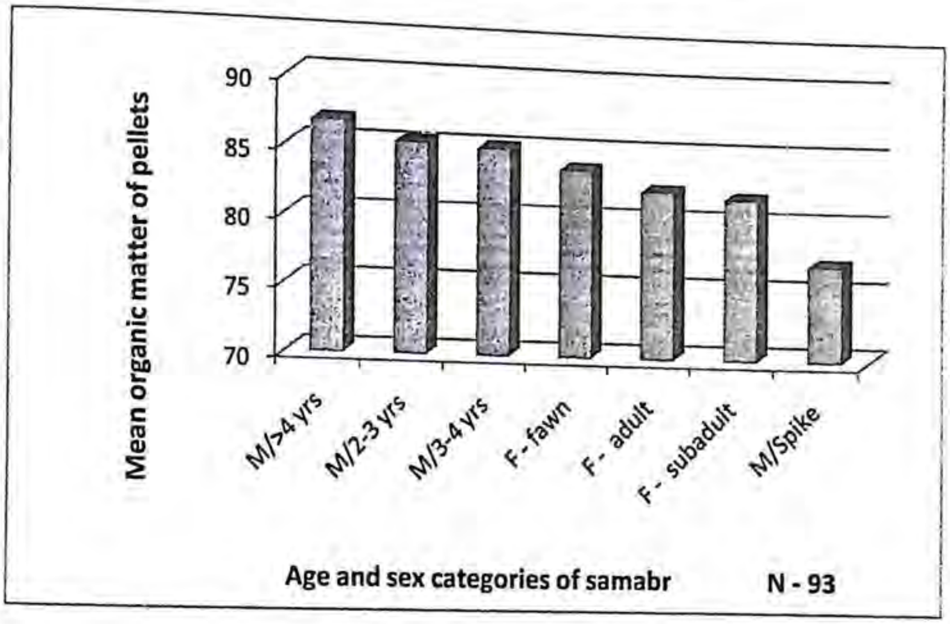


Figure 38. Mean organic matter of the pellets across age and sex categories

4.3.3 Dicot to Monocot ratio

It shows that more dicot was seen in the adult female diet and the female categories in general (Fig. 39), whereas the male categories, showed more monocot diet, as they were found to eat dry grasses more often than females, also *Aristida adscensionis* and *Aristida purpurea* grasses were encountered more in the male utilization plot more as compared to female ones (Fig. 25).

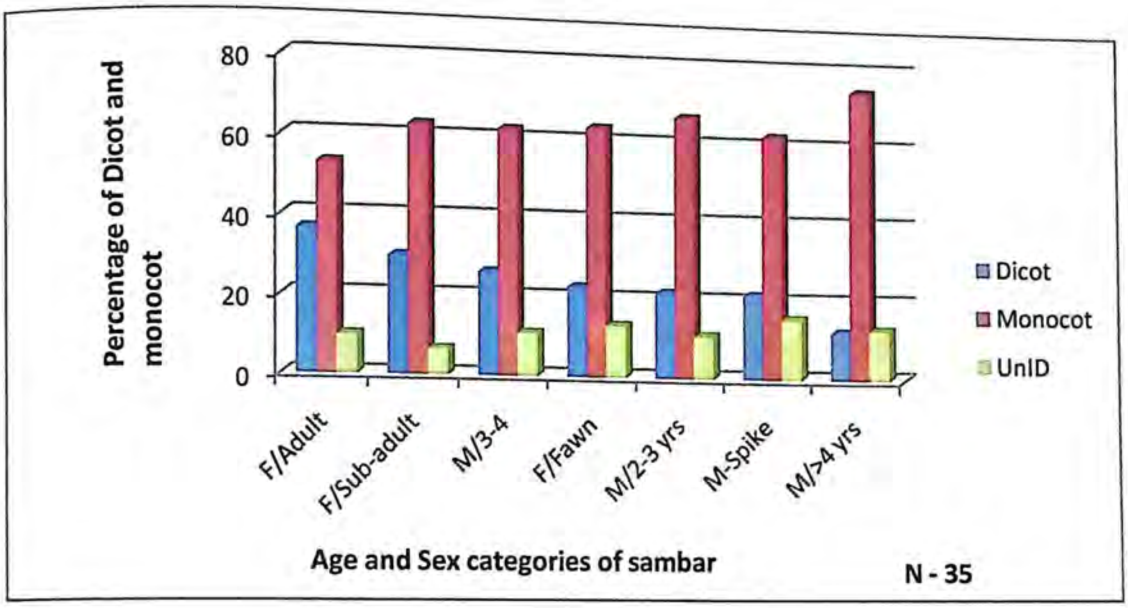


Figure 39. Dicot to monocot ratio in the faecal matter as per age and sex categories

4.3.4 Physical parameters of pellets (length, breadth, weight & volume)

After measuring the physical parameters from 967 pellets of the seven categories, it was found that the average length of the adult female pellets the longest, and the smallest one was of female fawn, similar trends were observed for the breadth and volume as well (Fig. 40).

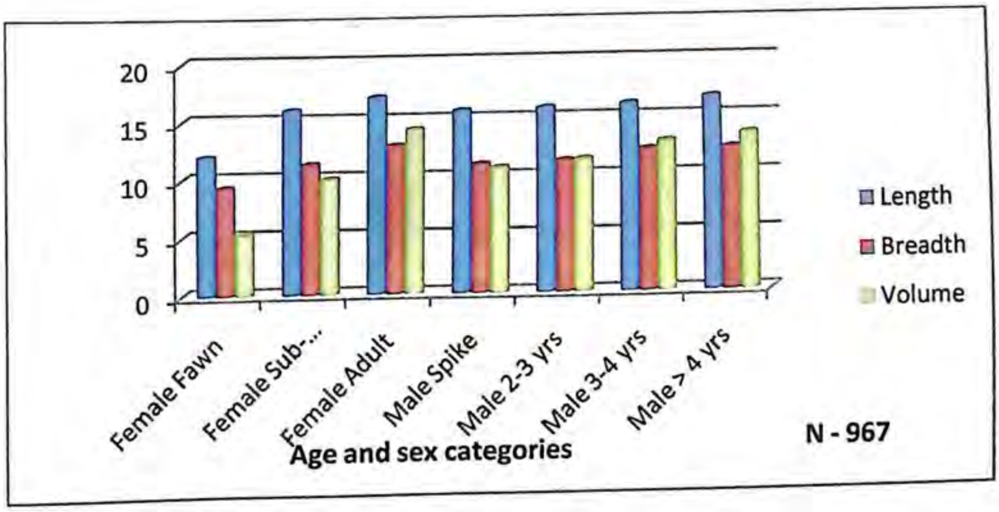


Figure 40. Physical attributes (length, breadth and volume) across the seven age categories of sambar

From the values of the weight of pellets, it was found that the heaviest pellets were of adult female, the next heavy was of male > 4 yrs, (Fig. 41)

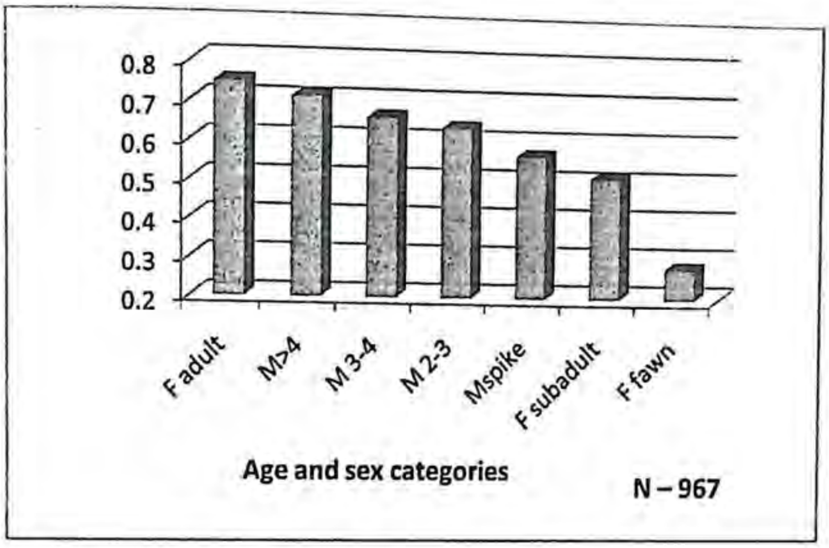


Figure 41. Average weight of pellets across the seven age categories of sambar

The data obtained on the physical parameters have enough sample size (n-967) to conclude about the average measurements of a pellet. It can be used in the field to assign an age and sex category of a pellet group found in the wild, this will take away the burden of getting the fresh pellets from the field to study habitat use differences.

Discriminant functional analysis

Discrimination of sambar (sex and age) using the pellet group parameters (length, breadth, weight). The male 3-4 and male 2-3 yrs were combined as subadult male for this analysis.

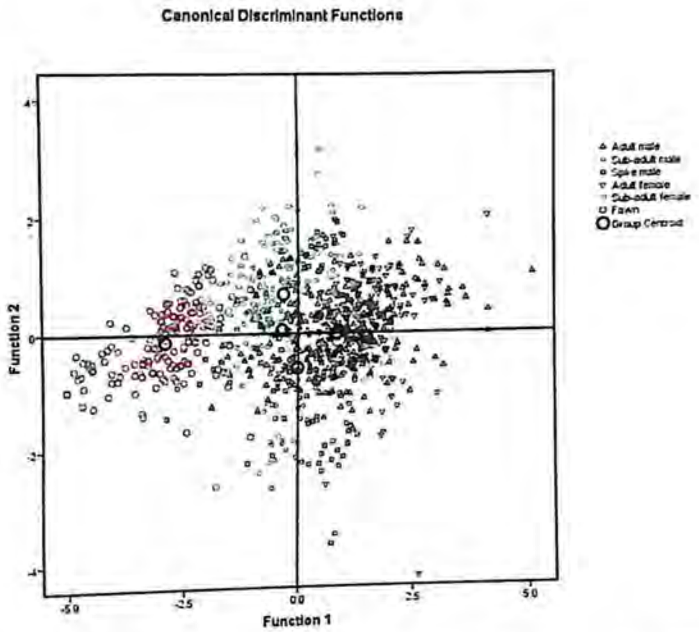


Figure 42(a). Discriminant functional analysis in all six categories of sambar

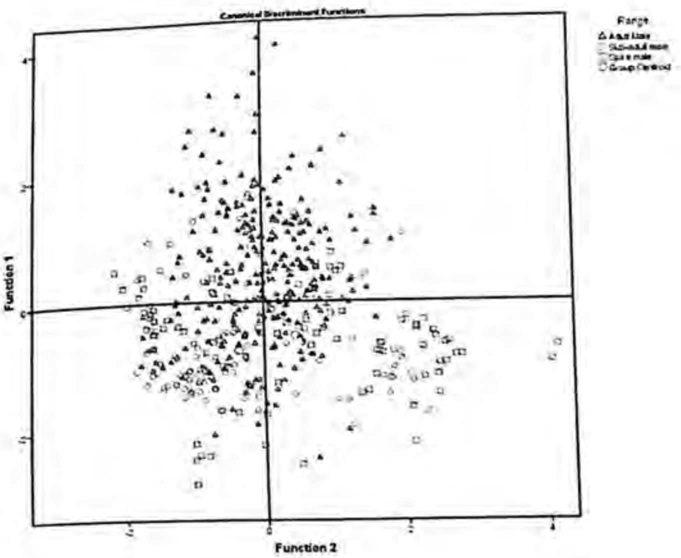


Figure 42(b). Discriminant functional analysis in male categories

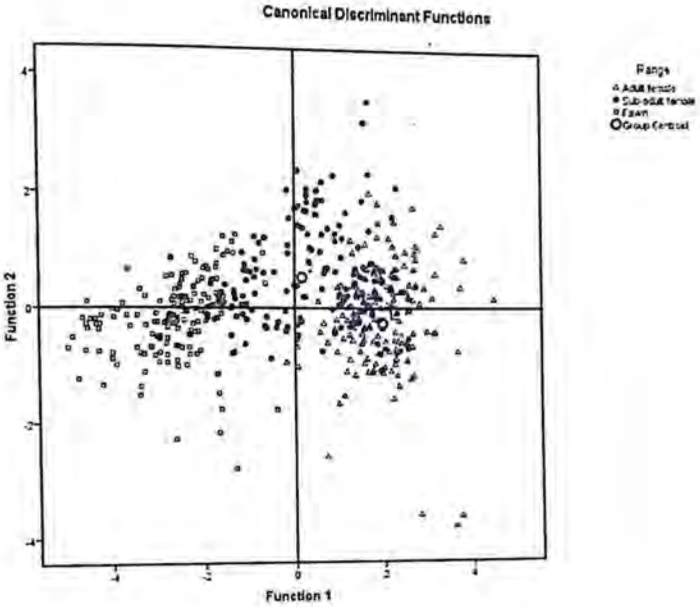


Figure 42(c). Discriminant functional analysis in female categories

The power of discriminating sambar (Adult male, sub-adult male, spike male, adult female, sub-adult female and fawn) group with respect to age category by analyzing length, breadth and volume of each pellet using discriminant function analysis (DFA) was somewhat low with an accuracy level of 50% approximately (Fig. 42(a)).

Whereas the power of discrimination of the male sambar (Adult, Sub-adult and Spike) group with respect to age category using discriminant function analysis (DFA) have 59% accuracy level (Fig. 42(b)).

The power of discrimination was the highest in the female sambar categories (adult, subadult and fawn) with 85% accuracy. The lower accuracy level in males can be attributed to the fact that spike male shows a high degree of variability with respect to its pellet dimensions(Fig. 42(c)).

5. DISCUSSION

Many studies have reported this fact that forage is selected as per availability and the nutritional quality of plant and use is different between sexes (Clutton-Brock *et al.* 1987; Main. 1998) as well as group size (Elger. 1989; Blumstein *et al.* 2001; Beauchamp & Ruxton 2003; Fortin *et al.* 2009). It was already explained in the introduction that why there is a difference in habitat use in sambar according to its age, sex and group size, due to various reasons as discussed earlier. Such selection basically revolves around optimal foraging theory where every gain should be more than what energy is being spent for acquiring that resource. Differential use of habitat can work only when there is a great heterogeneity in the available habitat with a difference in the energy values of the food resource, and energy rich resources are limiting. Then only we can find a substantial change in the habitat use patterns

Phenomenon: Various age and sex categories of sambar, use the habitat in a different way as it has come up from the study, even we have seen variations in different group sizes as well. This is mainly due to the different requirements of the individual and the group. I have cited many studies who have accepted and rejected this phenomenon with their own study animal and area, there may be several reasons to prove it either ways, but physiological requirements, environmental conditions and nature of the available habitat can be called the soul reason of the differential use by a species. Here we shall discuss what the study reveals relating to sambar in Ranthambhore national park, sambar is an adaptable animal it can adjust its diet as per the availability in the habitat, so it can graze or browse depending on the forage available.

Distribution of resource: The available plant resource in Ranthambhore is somewhat relatively less heterogeneous. This is because most of the food resource available to sambar is dominated by a few species, among trees *Anogeissus pendula* is the most dominant tree acquiring 74% of the total tree species in the intensive study area (Fig. 11), *Acacia catechu* was the second most dominant and the most dominant in the higher slopes and plateaus, the average canopy cover of all the tree species taken together in the plots in ISA was 44%. It was seen that 90% of the lower girth class trees comprises of *Anogeissus pendula* which is a good sign of regeneration (Fig. 12). In the shrub *Grewia tenax, Capparis sepiaria,* and *Prosopis juliflora* were a frequent occurring shrubs (Fig. 13), *Grewia tenax* was occurring mostly in the slope and hilly regions, the second one in the forest with high canopy cover and the last shrub occurring exclusively in the plain and degraded area near the boundary of the park which were highly disturbed. *Grewia flavescens* is the most dominating, with a percent occurrence of 48%, of the 162 plots 8% of them were devoid of any shrub (Fig. 13). As for the grasses and herbs, most encountered grass was *Aristida adscensionis* with a present encounter rate of 29% of the plots along with it, *Apluda mutica, Chloris dolichostachya, Dicliptera roxburghii*, were also quite frequently encountered with encounter percent of 13% 11% and 10% respectively (Fig. 15). Study clearly reveals that most of the food resource available in ISA is dominated by a few species and are mostly widely distributed and abundant.

Of the total 162 random vegetation plot done majority of them falls in with flat and gentle slope area, with a proportion of 38% and 36% respectively. Only 7% plots were in steep slope areas. Weed species were present in 28% of the plots, and their presence was inversely correlated with the increase in the slope, *Argemone Mexicana* and *Prosopis Juliflora* were found only in the plains at the fringe areas of Khandar range, which is prone to human disturbance and where the signs of human presence were encountered quite frequently.

Differential use of resources in relation to 'Sex' categories – For the tree layer there was no substantial difference in the tree occurrence but there was some difference in the GBH class of the tree (Fig 20). As the males were found to prefer the trees of higher girth class unlike females, who were found in lower girth class trees, percent occurrence of shrub species was slightly differing with females going for protein rich shrub species more often than male (Fig. 22). For the value of ground cover, males were going for easily available *Anogeissus pendula* leaf litter more often than females as expected. Among herbs *Dicliptera roxburghii* is an easily available protein rich resource, which was found in both male and female plots, with good percent occurrence and spread, even more so in males due to its easy availability and its ubiquitous spread (Fig. 24). Female were found in relatively less disturbed area, in terms of low percent spread of *Cassia tora*. But use of terrain wasn't much different across sexes (Fig. 26).

Differential use of resources in relation to 'Age' categories – in examination of differences due to the age levels within the sex categories, the differences were more profound, in the trees though the order of percentage occurrence was more or less same, but its percentage availability varied to a certain extent (Fig 27), especially in the adult female and in the two higher categories of males, (i.e. >4 yrs and 3-4 years) due to males preference for resource available in larger amount and ease. Males were also found in good relative canopy cover. Among shrubs, protein rich species like *Capparis sepiaria* were found more in the younger categories of the males to a large extent and all categories of females to a relatively higher extent as expected (Fig 28). It suggests the fact that growing and young stages of sambar require more protein resource. From the data of the ground cover it was found the adult male sambar mostly rely on most dominantly available resource, like the leaf litter of *Anogeissus pendula* which is higher in availability but may not be as nutrient rich, dry grasses like *Aristida adscensionis* and *Aristida purpurea* were found in relatively high density in sambar of > 4 yrs but was absent in the two younger categories of male (i.e. 2-3 yrs and Spike) whereas I did not found differences in fawn and subadult of females as they were always with the mother (adult female) most of the time. Thus it would have been seen in a habitat with mother (adult female) without actually using it.

Also protein rich *Dicliptera roxburghii herb* was found more in the younger categories of sambar and the effect was especially substantial enough in male categories to suggest a difference in habitat use because of different requirements (Table 4). For the percentage of *Cassia tora* the percent spread was more in all the male categories of sambar, and was lowest in adult female and the fawn category (Fig 30). Differences in the terrain as per the sexes were not as much with all the categories showing equal trends, with a slight preference shown towards the flat areas by the two adult male categories(i.e >4 yrs and 3-4 yrs)(Fig 31).

Differential use of resources in relation to 'Group size' categories – It was found that there was a decrease in tree species diversity as the group size increases, this shows that with the increase in group size they tend to prefer a more homogenous habitat with dominantly available species. This may be to avoid an intra-specific competition, and to ensure that the food requirement of the group is taken care of. Same trend was seen with shrub, grasses, herb cover and leaf litter with lower individual group acquiring a habitat with lower species diversity (Table 6,7 & 8) (Fig. 43). Also it was seen that the canopy cover decrease with the increase in group size (Fig 33), this may be due to the preference shown by the large groups to open areas or due to the daily evening movement of sambar up the slope where the canopy cover is generally low due *Acacia catechu* dominated forest in slopes and plateaus (Fig 2.).

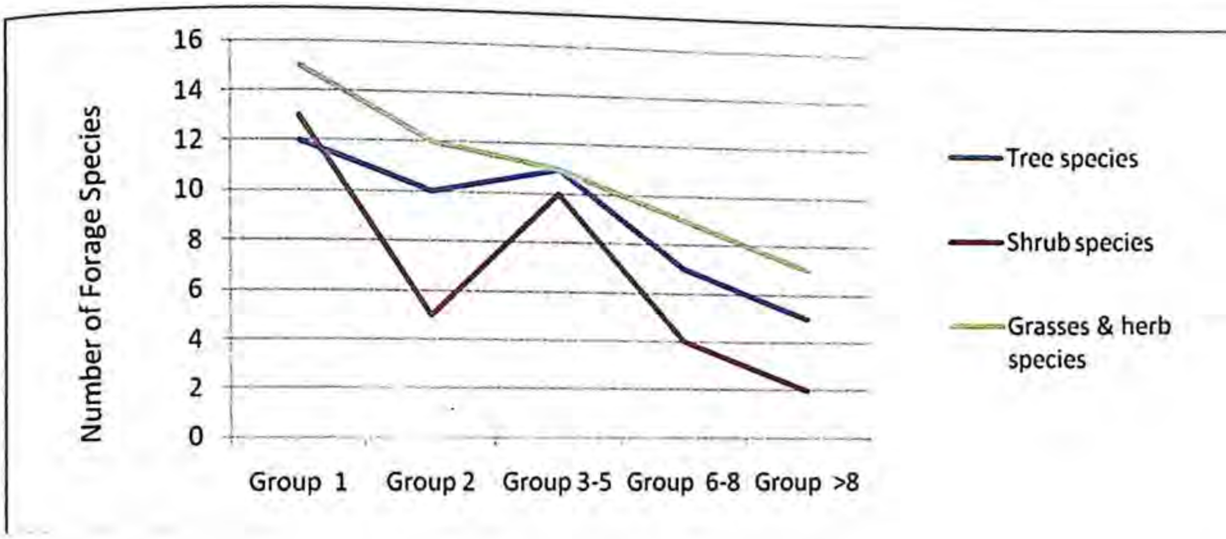


Figure 43. Group size in relation to forage species

Even grasses of relatively low nutritional quality was avoided by a group size of >8 individuals. Use of slope was slightly different as the sambar of bigger group was mostly seen on the medium to high slope while using the habitat (Fig 34).

To conclude I can say that the there were differences seen in habitat use of sambar in relation to sex, age and group size categories, where smaller body size male animals (i.e. <3 yrs age) and females associated with fawn and subadult always prefer areas having high quality resource, whereas adult sambar male and sambar in large group size were mainly in areas of abundant resources than the quality. In some cases the trend might have been uneven like in the percentage weed occurrence in the plot with respect to the various group size (Fig 33) classes and in such cases we need larger sample sizes to substantiate the fact.

Some trends seen were subtle, and some didn't show major changes, but in most cases the trend observed was expected. We can say that the differences seen were obvious when the data was plotted in various ways by graphs, but the level of heterogeneity in the area in terms of available habitat was not as profound, that is why the result obtained were not showing any significant difference statistically.

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