FOOD HABITS AND FORAGING BEHAVIOUR OF INDIAN GAZELLE (*Gazella benneti*) IN RAJASTHAN DESERT

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CERTIFICATE

This is to certify that Mr. Ganesh Kodoth of the Wildlife Institute of India has carried out original research titled "Food habits and Foraging Behaviour of Indian Gazelle (*Gazella benneti*) in Rajasthan Desert." in partial fulfilment of the M.Sc. (Wildlife Science) degree of Saurashtra University. These investigations were carried out under my supervision from November 1996 to July 1997. I also certify that this research has not been submitted for any other degree to any University.

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SUMMARY

The Indian gazelle inhabiting the arid regions is studied with respect to their food habits and foraging behaviour. In arid areas the selection of a habitat by an animal is mostly governed by spatial and temporal distribution and abundance of food items and the food requirements of that species. This becomes critical especially in an semi-agricultural landscape where the ecosystem is altered without any consideration for the animal. The study was conducted in a habitat close to human habitation around Jodhpur after the harvest. This area is dominated by desert vegetation such as *Crotalaria burhia.* The study is conducted for a period of six months encompassing two seasons- winter (December 15, 1996 - February 20, 1997) and summer (March 20, 1997 - May 10, 1997).

The intensive study area was differentiated into six habitat types based on the structural and floristic composition of the vegetation-viz, crop fields, fallow lands, scrub area dominated by *Zizyphus*, and hedges of *Maytenus-Capparis-Zizyphus* among the agricultural fields. Differential habitat selection by gazelle was observed during summer and winter mainly due to selection of diet based on seasonal nutritional requirements.

Diet selection is looked in terms of use-availability and plant chemistry. Based on a relative preference ratio, the habitat and food types were ranked, and the observed trends are explained in terms of the existing theories on diet selection. Diet composition varies with the age and sex classes of the animal viz. breeding males, sub-adult males and adult females. In winter and summer differences in habitat use was exhibited by gazelle, also there was a difference in proportion of the food species in the diet between two seasons. The scrub area

was dominated by vegetation having higher crude protein and tannin, was used more than available in order to supplement their diet (especially in the case of females) and in summer the crop fields dominated by *Crotelaria burhia* were used more by all categories of animals. Females fed on a high protein and less tannin diets which is pronounced in winter, sub-adults also fed on a diet having higher protein and tannin, while males were not biased towards a high quality food both in winter and summer. These differences were influenced by the spatial distribution, of food species, plant chemistry , and the differential use of food species among different age and sex classes during the two seasons. Protein and tannins along with moisture seem to govern diet selection rather than just being a function of availability during winter and summer. Spatial distribution of food plants along the habitat types (in the current land-use pattern) does influence habitat use by gazelle. Selection and proportion of the time spent on food species during summer and winter suggest that Indian gazelle is a browser.

1. INTRODUCTION

The Indian gazelle or Chinkara (*Gazella benneti*), inhabits the arid and semiarid regions of India. Though their distribution is widespread, its density is low in most areas (Rahmani, 1990). The gazelle is well established in the more arid environments, inhabiting extreme desertic conditions having less than 100 mm rainfall. The antelope had faced enormous hunting pressure but still survives in the protected areas, and near settlements of the Bishnoi community. The Guda Bishnoi conservation area supports the highest density of chinkara and blackbuck in the wild (Prakash, 1988).

There has not been many serious study on the Indian gazelle, except on a few ecological aspects (Ashraf, 1989; Bohra *et al.*, 1992), however its close conspecifics like the Dorcas gazelle have been studied, especially on aspects like their foraging (Baharav, 1982). The conservation status of the Indian gazelle has been assessed by Rahmani (1990). Their food species and habitat characteristics have been reported by Ghosh *et al.* (1987) and Bohra *et al.* (1992).

The animals are shy of humans but do frequent crop fields and is considered a vertebrate pest especially during the growing season (July to November), (Prakash 1964). They forage mostly in the early hours of the day and during late afternoon but feed throughout the day in winter however, with the intensity of foraging subsiding during midday. Schaller (1976) reports that the gazelles retreat to the shade during the warmer part of the day.

The basic social unit is a female and her young, which may last for twelve months. Adult males are often territorial, where they exclude other males but attempt to retain visiting females. Schaller (1976) in the Salt ranges of Pakistan reports about changes in herd structure with the seasons; for instance males relinquished territories and females congregated in December. Schaller also notes about the territory size, which is about 200 m or more in diameter that is demarcated by dung piles. The social structure is reported to consist of lone males, family herd of a male and two females with young, bachelor herds and all female herds (Bohra *et al.*, 1992). The gazelle do not have any particular breeding season, although they might have a major birth period in April and a minor one in autumn. They usually gives birth to a single young (Roberts, 1977).

The preferred habitats are wastelands, broken up by dry streams, scattered bush and jungles (Roberts, 1977). They even inhabit sandy areas. Their altitudnal range is from the sea-level up to 1200 m (in Baluchistan). They are not found in wet areas. In Gujarart, Madhya Pradesh, Maharashtra and Andhra Pradesh gazelles are seen in forests having a rainfall range of 500-1500 mm, but with a low density (Rahmani, 1990).

Like other gazelles, Indian gazelle is a browser and selects plant species rich in quality (Bohra *et al.*, 1992). Feeding mode fits the pattern as described by Jarman (1974), with respect to body size classes of species of animals.

An animal's utilisation of the habitat is defined by its need for food and the constraints involved, both extrinsic and intrinsic (Krebs and Davis, 1984). Intrinsic constraints are related to the animals body size, psychological or behavioural constraints such as perception and discrimination while extrinsic constrains are derivatives of the nature of the food source (eg. nutrient content and moisture content). Crude protein is used along with energy content as an indicator of the value of the diet (Field, 1976). The value of food changes with the physiology of the animal. The underlying assumption of optimal diet selection is that the animal can perceive the profitability of each food item over the other available food items and should maximise energy intake so as to show preference of the most profitable ones, also diet should expand and contract depending on the quality and availability of the food items.

In deserts, vegetation is sparse and changes spatially as well as temporally. For an animal, if it is an optimal forager it can be detrimental if the status quo fails, provided food is a limiting factor (Pyke, 1984). Such changes in the ecosystem have been aggravated due to changes in land use pattern that alter the vegetation composition of the ecosystem (Rahmani, 1990). Even without taking optimality into consideration the foraging behaviour of the Indian gazelle needs to be understood as there is little information regarding the species in literature, and to understand its feeding with reference to spatial and temporal distribution of plant resources.

OBJECTIVES:

To understand food and foraging behaviour of the gazelle, the study was undertaken with the following objectives.

1. To determine feeding behaviour of Indian gazelle during winter and early summer.
2. To assess the seasonal variation in food preference among various age and sex classes of Indian gazelle.
3. To determine if gazelles used food species in relation to plant chemistry.

REVIEW OF LITERATURE

Theoretical considerations of herbivore food choice take two approaches, one based on optimal foraging models and other on necessity of nutritional requirements or dietary diversity (Westoby, 1978) .

"an activity should be enlarged as long as the resulting gain in time spent per unit food exceeds loss. When any further enlargement would entail a greater loss than gain no such enlargements should take place... the problem is to find which components increase and which decrease (of a budget).... as certain activities are enlarged." (MacArthur and Pianka 1966).

Optimal foraging theory has come a long way from this early precept, but still an overriding theory eludes most "optimal foragists" (Schoener, 1987). Of the many deterrents, the need for determining the right currency to be optimised by an animal is fundamental (Pyke, 1984; Schoener 1987).

The underlying premise in explaining diet choice by optimal foraging theory is that animals' forage to maximise benefits in a cost-benefit relationship such as foraging. The criteria that the animal is presumed to maximise may be; energy, nitrogen, or specific micro-nutrients (Belovsky, 1984).

The assumptions of optimal diet selection includes that the animal can perceive the profitability of each food item over the other available food items. Further the animal should maximise energy intake / or the currency, so as to show preference for the most profitable ones. Consequently the diet should expand and contract depending on the quality and availability of the food items available (Schoener, 1987).

Browsing herbivores try to maximise on energy gained and minimise the ingestion of plant secondary compounds, provided nitrogen and specific micro-nutrient uptake is adequate (Freeland and Saladin, 1989; Bryant *et al.*, 1992).

Crude protein is used along with energy content as an indicator of the value of diet (Field, 1976). The value of a food changes with the physiology of the animal. In the case of ruminants, ruminant activity depresses if the crude protein level is less than 7% and below 3%, the forage is deleterious due to their gut physiology.

The food plants need not necessarily be distributed equally in space. The structural characteristic of the vegetation would influence habitat selectivity by the animal (Senft, 1987). Nevertheless the habitat chosen by the animal involves a decision. Such decisions may also be influenced by environmental cues or by experience of the forager in terms of food quality or plant secondary compounds that serve the purpose of anti-herbivory (Haukioja and Lehtila, 1992).

Plant secondary compounds that are deleterious to the animal also inhibit feeding of the food item. Secondary compounds present are usually phenolics, alkaloids and terpenoids (Robinns, 1983). Secondary compounds depress digestibility by precipitating cellular proteins and, by inactivating digestive enzymes. The costs involved in feeding include the actual energy spent in feeding and energy spent in processing plant allelo-chemicals such as tannins (Freeland and Janzen, 1974).

Although many studies have been conducted on foraging of ungulates, no single plant constituent was correlated with food habits (Bergman and Jodin, 1987; Cooper *et al.*, 1988), because of the various competing costs and benefits of the array of plant constituents. Such differences in selection of food plants have been reflected in changes in habitat use during different time of the year (Lamprey, 1963; Senft, 1987).

Niche or food selection is presumed to be a function of two properties of the vegetation: abundance and quality, that interact with body size through the physiology of the animal (Illius and Gordon, 1987). Also differences in utilisation of resources have been observed across the sex, age and group size of a species (Beier, 1987; Fritz and Garine-Wichatitsky, 1996).

2. THE STUDY AREA

Within the Rajasthan desert, the study area selected is part of the Guda Bishnoi closed area near to Jodhpur (Fig. 1). The arid environment with its open vegetation is a suitable Chinkara habitat which is reflected in their abundance. Closed areas are so designated because it is considered closed for any hunting of animals. The closed areas in Rajasthan are situated around villages dominated by the Bishnoi community who protect the animals with a religious zeal. The area around Guda Bishnoi is mainly an agricultural landscape. The closed area lies in-between two rivers the Jogri and the Luni and is protected by the forest department. The present study covered two seasons winter (December 1996- mid February 1997) and summer (mid March 1997 - May 1997)

CLIMATE:

The climate of the desert zone is characterised by extreme temperatures and drought accompanied by high wind velocity (markedly in summer), with low relative humidity and evaporation far exceeding precipitation. January is the coldest month and the dry hot summer sets in after mid March which continues up to June till the arrival of the monsoon. From April to June, diurnal temperature variation increases. Temperatures start decreasing by September, and winter sets in by early December. Relative humidity is minimum in the summer season particularly in the months of April and May.

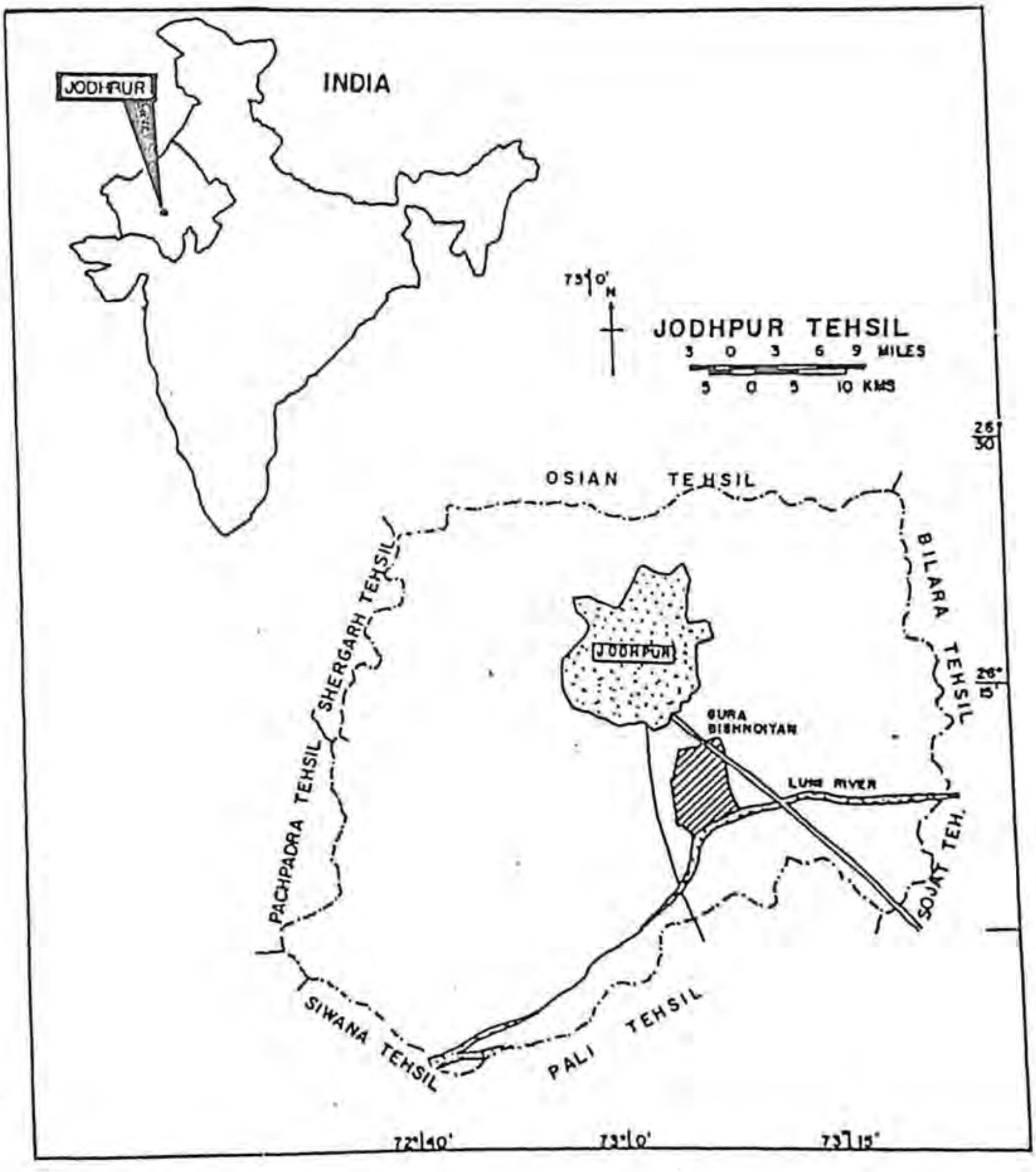


Figure 1. Location of the Study Area (Guda Bishnoi) near Jodhpur, Rajasthan.

The study area falls under the desertic zone with an annual rainfall between 200 - 400 mm mainly between the months of July to August. Rainfall is mainly restricted to monsoon and a few showers in winter, however this year the winter showers were meagre while erratic rains occurred during late April and early May. Temperature ranges from 24-29 °C in January to 45 °C in summer.

GEOMORPHOLOGY:

The sandy area preferred by Chinkara is mainly stabilised desert soil. The soil contain 90-95 % sand and 5-10% clay. The area is an undulating area with very few relief in the form of rock outcrops. Natural water holes or Nadis are scarce and perennial ones are rare and falls outside the intensive study area. Although water is not present, the area around the water hole forms part of the village common lands.

VEGETATION:

Broadly the area has been classified into two habitat types, based on topographical features. The two areas have different soil, and the salinity gradient is different, with the areas near the banks of Luni river being saline. The southern part on the banks of the Luni river is preferred by the blackbuck, the vegetation is dominated by *Prosopis cineraria, Tephrosia purpurea, P.juliflora* and *Capparis decidua*, and the sparse open area and crop fields are used mainly by blackbucks and a few bluebulls. While the northern part of the study area utilised by the Indian gazelle is mainly agricultural fields interspersed with scrub. Here the vegetation is dominated by *Crotalaria burhia, Zizyphus nummularia* and *Capparis decidua. Prosopis cineraria* trees are widely scattered in the study area. The ground flora is mainly of *Eleusine compressa, Cyperus arenarius, Heliotropium strigosum, H.sublatum* and *Boerhavia diffusa.*

The vegetation type is *Zizyphus* scrub as described by Champion and Seth (1968), under the sub group Northern tropical thorn forest, however the natural vegetation is sparse owing to the land use pattern and survives only as isolated patches in village common lands. The plants are mostly stunted, thorny shrubs and perennial herbs capable of drought resistance. Although the ephemerals come up after the rainy season they mainly last only for a few months.

FAUNA

The closed area being an agricultural landscape still supports Wolf (*Canis lupus*), Indian Fox (*Vulpes bengalensis*), Desert Fox (*Vulpes vulpes*), Indian Porcupine (*Hystrix indica*), Indian desert gerbil (*Meriones hurrinae*) apart from ungulates like Indian Gazelle (*Gazella benneti*) Blackbuck (*Antelope cervicapra*), and Nilgai or Bluebull (*Bosephalus tragocamelus*). Dogs form small packs and prey on the fawns and take a heavy toll especially on the fawns of gazelle, while an instance of a successful hunt of an adult male gazelle was observed. Among birds, Grey partridge (*Francolinus pondiceranus*) and Indian Peafowl (*Pavo cristatus*) are abundant. Cattle, buffalo and camel form the livestock of the Bishnoi. While the Bishnois do not keep goat and sheep, the shepherd community mainly keep sheep but very few goats. However the number of goats are augmented during summer when nomadic herds from other areas arrive. This is important with the dietary overlap of goat and gazelle being well documented (Ashraf, 1989).

INTENSIVE STUDY AREA (ISA)

The intensive study area of about of eight sq km was chosen in a sparsely populated area about 10 kms north of Guda Bishnoyan village (Fig. 2). The choice of the study area was with the following considerations (a) the abundance of gazelles in an area; (b) of the intolerance exhibited by gazelles towards excess human disturbance; and (c) density of human population.

The intensive study area had three widely separated pockets of scrub vegetation. The undulating plain forms the crop fields and hedges. The scrub is dominated by shrubs such as *Zizyphus nummularia*, other species found are *Capparis decidua, Maytenes emarginatus, Prosopis cineraria, P. juliflora, L. barbarium* and occasionally *Acacia senegal* in harder soil. A similar type of *Zizyphus-Capparis-Maytenus* type of vegetation grows on the hedges of every crop fields. *Crotolaria burhia* forms the dominant shrub species in the crop fields. The harvested land is dominated by *C. burhia* and *Z. nummularia* an associate, which is however removed by January for the purpose of fodder. Trees are sparse, however, in the vicinity of Bishnoi village preponderance of *Prosopis cineraria* highlights its religious significance. Other trees in the study area are *Acacia senegal* in rocky or gravely areas and occasional *Tecomella undulata* and *Balanites aegyptiaca* in the undulating terrain.

Though the harvest is completed by the month of December, presence of crop residue forms a food resource for gazelles. *C.burhia* grows in abundance in the harvested lands and have a life span of 2-3 years. Fallow lands of 2-3 years age are mainly composed of dry *C. burhia* and grasses such as *Cymbopogon martinii, Lasurus sindicus. P.cineraria* saplings are more in older fallow lands.

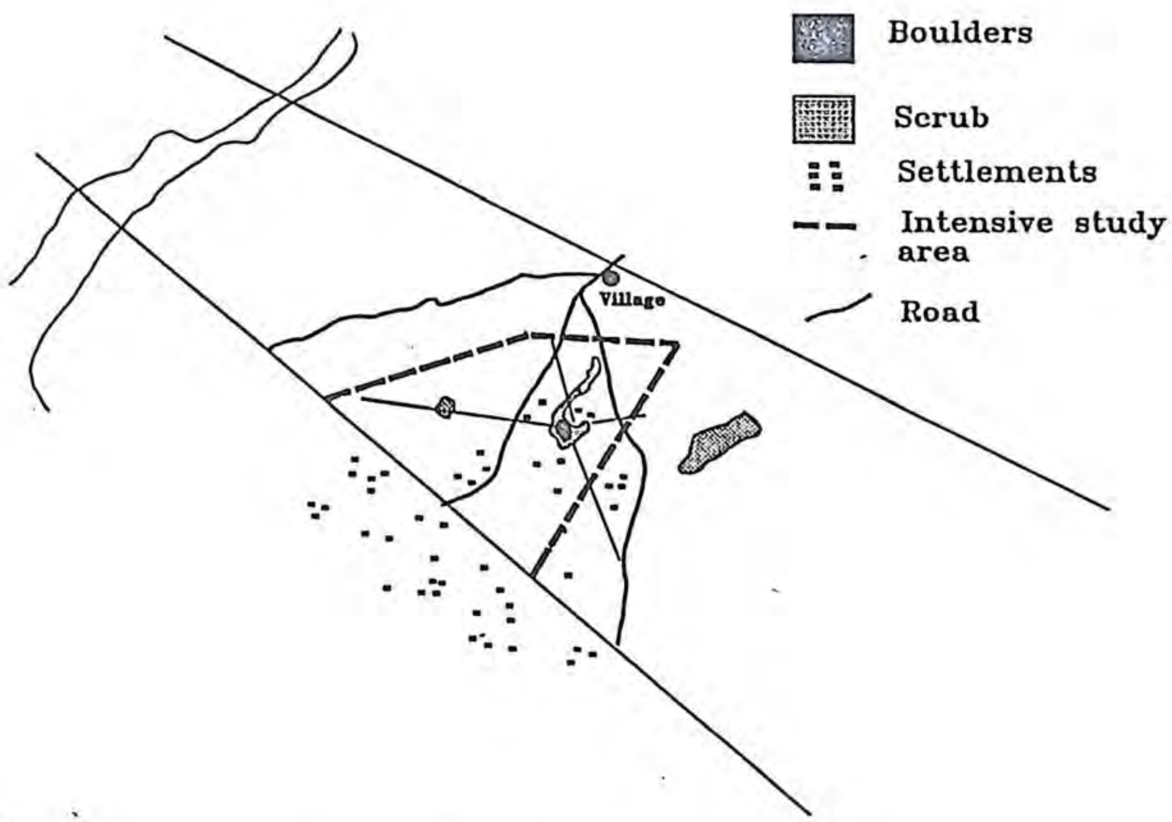


Figure 2. Intensive Study Area around Guda Bishnoi

Human activity was ever present with 10 dwellings and a temple in the study area. The animal was usually tolerant towards the people keeping a distance of 150-200 m . Disturbance was also present in the form of movement of people along the roads. Biotic pressure is mainly from nomadic livestock especially goats as their numbers increase during summer. The village common lands are used as a grazing ground for livestock especially during the period of cultivation.

The increasing human presence in the intensive study area during the six month period is a source of concern. Construction of new houses were undertaken and with people moving into their field homes permanently unlike in the past when they use to reside only in the villages, pressures both in the form of biotic and related to human activity is bound to increase.

3. METHODS

3.1 Habitat classification:

Four one km long transects, randomly placed within the ISA were used for quantifying habitat and vegetation parameters. At every 100 m point on the transect, habitat category was classified within a 10 m circular plot. Since, hedges were sparsely distributed and mostly found along the crop field, therefore, 20 m radius plots were used to quantify the presence or absence on each sampling point. The habitats classified were :

1. Recently harvested crop fields (RHCF)
2. Harvested crop field (HCF)
3. Fallow land since last three years (FL3)
4. Fallow land since last more than four years (FL4)
5. Scrub area (SA)
6. Hedges area (HA)

3.2 Vegetation Quantification :

At every 100 m point on the transect, a plot of 10 m radius was laid with 15 paces either to the left or right of the transect. The following were noted: 1. the shrub species 2. the number of individuals of each shrub species 3. the length, breadth and height of *C.burhia* along with its per cent greenness.

With the help of two 0.5 x 0.5 quadrates laid within the 10 m radius plot, I recorded the following :

a. per cent ground and grass cover and greenness of grass cover,

b. species and number of grass clumps, and

c. species and numbers of forbs and herbs.

Since the hedge rows were a linear strip of vegetation, a separate methodology was used. Hedges whenever encountered on the transect, a plot of 3 x 10 m was laid. Species and number of individuals of shrubs were recorded.

Food plants were collected for the purpose of measuring nutrient, and digestive deterrents based on plant part that was eaten by the animal. The plant part mainly the leaves were collected for the two seasons (summer and winter). About 100 grams of the food item of most commonly used species was collected weighed and left for air drying in paper bags. In case of *C.burhia* its flowers could not be separated from the rest of the plant while observing the feeding animal, hence a composite sample of *C.burhia* was taken during summer. Similarly, in the case of *M.emarginatus* the fruits were clumped along with the leaves in winter, as the tiny globular structures could not be easily distinguished from leaves at a distance.

3.3. Behavioural study

Behavioural sampling involved two methods, focal animal sampling and scan animal sampling (Altman, 1974). Behavioural data was so obtained as to nullify the effect of observer bias on the feeding animals. Hence a spotting scope with a magnification of 10-45X was used. Data was collected during the peak foraging period of the day as have been widely used to understand foraging behaviour. The peak foraging period was determined through observation of activity for a 12 hour period. In winter the animals fed mainly after sunrise till about 11:00 AM while in the evening, intense feeding was resumed around 3:30 PM till sunset. In summer the peak foraging time was early morning from 6:30 AM to 9:30 AM and in evening after 4:30 PM to well after sunset.

Due to restriction of the working environment, vantage points were selected in the intensive study area from where maximum area could be viewed without hindering the feeding of animals. Although human related disturbance were frequent this was very much a part of the animal's environment.

The animals seen during recording behavioural observations were classified into three identifiable classes viz. breeding) male, adult female and sub-adult male.

Breeding male (BM): The adult male that can hold a territory and keep a group of females within its territory is taken as the breeding male. It fits Schaller (1975) description of males with 'S'-shaped horns.

Sub-adult male (SAM): These animals are found in bachelor herds along with adult males that are not breeding, and separated from them in their horn shape. The horns although long (>6 inches) do not take an 'S' shape in profile. Adult males forming part of the bachelor herd were excluded from behavioural observation.

Adult females (AF): Adult females are separated from males by their horn length and from sub adult female or young immature male by size and horn length. Since some adult females had short horns less than the usual measure (horns up to the ear tip), a source of confusion was avoided by excluding those animals which tended to follow another female.

Sub-adult females also formed part of the female herd along with yearlings and fawns, all these categories were excluded from observation because of lack of easy cue in occularly differentiating them in the field.

3.3.1 Focal animal sampling:

The focal animal was chosen based on the category of animal to be studied (breeding male, sub-adult male and adult female). An *ad-libitum* sampling method was adopted (Altman, 1974), with the selected individual being the nearest to the observer especially in bachelor herds and female herds. The time spent on a particular food item (species), was recorded using a digital stopwatch to the nearest second, a cumulative record for a food item was maintained for the particular observation period. The focal animal was observed for a maximum period of 15 minutes and then a new animal was selected. If the focal animal is lost either due to disturbance, or obstructed vision because of vegetation cover or the topography, the observation was discontinued and the next nearest individual of that category was taken as the focal animal. This was necessitated since marking of individuals was not possible. Focal animal was discontinued at the time of scan sample. The habitat type during feeding observation was also noted.

3.3.2 Scan sampling:

Scan sampling was done on the whole group and among age and sex classes and the food item eaten was recorded. The time interval between two successive scan samples was 15 minutes and a scan lasted less than two minutes. The habitat type of the feeding individuals was also noted during behavioural observation.

3.4 Chemical Analysis:

3.4.1 Estimation of Crude Protein :

Estimation of crude protein was quantified by Kjeldahl method. 0.5 gm of oven dried sample is mixed with a catalyst ($CuSO_4$ + K_2SO_4) and 5 ml of concentrated sulphuric acid, and digested on a heater for 5-6 hours. The ammonia generated during distillation was absorbed in 2% Boric acid, which was then titrated against N/10 sulphuric acid. Total nitrogen (g/100 g dry matter) was calculated as follow :

volume of acid used x 0 .0014 x 2 x 100

Percent crude protein was calculated by multiplying total nitrogen by a factor of 6.25

3.4.2 Estimation of Fibre :

Neutral detergent (cell wall) was calculated following method of Georging and Van Soest (1970) and values were presented as % cell wall.

3.4.3 Estimation of Ash Content :

Percent ash was estimated by combustion of a sample of known weight in a Muffle furnace at 600 °C for 6 hours. The proportion of the residue left after the combustion of organic matter in the sample is the ash content for that species and presented as % ash content.

3.4.4 Estimation of Tannin :

Tannins were estimated in the leaf of different species by a modification of the acid-vanillin method (Burns, 1971) and values were presented as mg tannin/g d.m. sample.

3.5 Estimation of Crude protein consumption by Indian gazelle:

I estimated the quality of composite diet by assuming that food consumption constitutes in similar proportion as proportion of time spent on foraging various plant species. Quality of the composite diet in terms of total crude protein ingested was determined for sub-adult, adult female and breeding male by the following formula:

$$\sum_{t=1}^{t} (N_i B_i)$$

where Bi = amount of the *I th* food category consumed in proportion of their time spent; and N_i = amount of crude protein/ g d.m.

3.6 Statistical analysis:

The behavioural data was recorded in the ratio scale, vegetation data were also expressed in percentages. Since the sampling technique was random and the study area being more or less homogeneous, percentages expressed were translated to the whole habitat. Windows based SPSS and Excel programmes were used for statistical analysis and preparing graphs.

Since only a trend in relation to habitat and food use were necessary rigorous statistical analysis were given a go by. Utilisation in relation to availability is expressed in the form an index and classed into ranks. Relative preference index (PRI) was calculated using following equation of (Putman, 1986):

$$\frac{\%\ \text{utilisation}}{\%\ \text{availability}}$$

4. RESULTS

4.1. Habitat types :

Based on the soil texture, associate plant species, and land use pattern, habitat has been classified in six types , viz. Recently harvested crop field (RHCF), Harvested crop field (HCF), Less than Three year Fallow fields (FL3), More than 4 year fallow fields (FL 4), Scrub, and Hedge-rows or Hummocks. The proportion of the various habitat categories based on four transects is given in Table 1.

Table 1. Proportion and use of various habitat categories by Indian gazelle in ISA.

Habitat categories	**Per cent occurrence**	**Per cent use**	
		Summer	Winter
Recently harvested crop field (RHCF)	28.57	2.91	14.42
Harvested crop field (HCF)	26.19	85.34	40.65
Less than Three year Fallow fields (FL3)	9.52	4.30	3.90
More than 4 year fallow fields (FL4)	11.91	-	14.80
Scrub (SA)	7.14	5.20	14.64
Hedge (HA)	16.67	2.25	11.59

Study area being outside the PA and close to human habitation, 54.7 per cent of the study area is under cultivation (RHCF and HCF). While 21.4 per cent area is under fallow land. Scrub and hedges mainly dominated by Z. *nummularia* and *C. decidua* constitute 23.8% of the area.

4.2 Vegetation Characteristics:

4.2.1. Plant species composition with reference to habitat types:

In all 29 species were recorded within ISA. The species composition among the various habitat categories did not vary much except between the crop fields and scrub. Scrub and the hedge row had similar vegetation composition with respect to a number of species (Table. 2).

Table 2. Presence or absence of species found inside ISA

Plant Species	Habitat category					
	RHCF	HCF	FL3	FL4	SA	HA
C. burhia	*	*	*	*	*	*
P. cineraria	*	*	*	*	*	*
M. emarginatus			*	*	*	*
B. agyptiaca		*	*			*
T. purpurea	*	*	*	*	*	*
L. pyrotechnica				*	*	*
L. barbarium					*	*
F. indica	*	*			*	*
Z. nummularia	*	*	*	*	*	*
C. decidua			*		*	*
C. procera			*			*
T. undulata	*	*				
Acacia senegal					*	*
Aerva sps.			*	*	*	*
Cenchrus sps					*	*
Aristida sps.				*		*
E. foveolatus		*			*	

Although the shrub layer did not show much variation in the crop fields (RHCF, HCF, FL3, FL4), the ground cover varied among the habitats. Abundance of shrub species especially *C. burhia* was similar among HCF, FL3, FL4 except RHCF (Table.3). Detailed vegetation characteristics are as follows :

Recently harvested crop fields (RHCF) : The habitat is mainly dominated by *C.burhia,* forming about 86 % of the shrub layer. However, the shrubs are sparser, smaller and greener compared to the other crop fields. *Z.nummularia, Prosopis cineraria, Balanites aegiptiaca, Fagonia indica* and *Ermopogon foveolatus* are the other shrub species, but all forming not more than 3% each of the shrub species. The ground was mostly bare but few grass species like *Cybopogon martinii, Cenchrus sps.* that is mostly green in winter, herbs like *Euphorbia parviflora*, crop mulch of *Pennisetum typhoides*, and Jowar, Sorgum, Moong were also present in minor quantities.

Harvested crop field (HCF): Habitat is very similar to the previous category of habitat type, but differ mainly in the density of *C.burhia*. Among the habitat types the density of *C.burhia* is the highest and forms about 95% of the total vegetation within it. Further, 45% of the total *C.burhia* in the intensive study area occurs in this habitat type. The ground cover is similar to RHCF but more than the previous category, however crop mulch is absent. The *Z.nummularia* bushes are similar in number to the previous habitat but the volume of these bushes is higher.

Fallow land less than 3 year (FL3) : This habitat differs from HCF mainly in the ground cover. Though density of *C.burhia* was not very

Table 3. Per cent occurrence of most common plant species in relation to habitat types

Shrub species	Recently harvested crop field	Harvested crop field, < 1 year	Fallow land ,< 3 year	Fallow land > 4 years	Scrub	Hedge-row	Per cent of the habitats
C. burhia	86.56	93.35	95.85	94.20	58.77	42.29	83.63
P. cineraria	1.43	0.84	0.72	1.20	-	3.82	1.33
B. aegyptiaca	1.08	0.36	0.43	-	-	1.14	0.56
T. purpurea	1.97	-	2.72	2.40	-	3.34	1.47
L. pyrotechnica	-	-	0.14	0.60	1.32	0.63	0.26
L. barbarium	-	-	-	-	0.44	14.63	2.17
F. critica	2.69	3.54	-	1.20	1.32	0.16	1.96
Z. nummularia	3.23	0.96	-	0.2	30.26	21.62	5.61
M. emarginatus	-	-	-	0.2	2.19	4.13	0.75
C. decidua	-	-	-	-	1.32	2.39	0.42
C. procera	-	-	0.14	-	-	0.32	0.07
E. foveolatus	3.05	0.90	-	-	1.75	5.25	1.61
A. senegal	-	-	-	-	1.75	-	0.09

much different from rest of the habitat types, it differed mainly in the per cent greenness of the dominant vegetation from the rest of the habitat types .

Fallow land more than 4 year (FL4) : Habitat do not show any difference in the density or composition of the shrub species but has similar ground layer composition like FL3. The greenness value increases in this habitat type unlike the less than 3 year fallow.

Scrub area (SA) : The vegetation here is markedly different from the crop fields though *C.burhia* forming about 60% of the total individual plants, *Z.nummularia* is also abundant. Other plant species seen in the habitat are *L.barbarium*, *Maytenus emarginatus*, and *Capparis decidua*. *Prosopis cineraria* was totally absent probably due to the harder soil of the habitat.

Hedge area (HA) : Hedges have a species composition that is similar to the scrub vegetation and likewise is structurally dominated by *Z. nummularia*. Other large shrubs are *M. emarginatus*,and *C.decidua*. Although *C.burhia* forms more than 40% of the individual shrubs.

The ground layer composition is mainly by few species of grass like *Cenchrus* sps., *Heteropogon* and others.

4.2.2. Vegetation structural characteristics :

C. burhia being the dominant species of the study area and since the animals, were seen feeding on it most of the time, therefore, a relationship governing the greenness of the shrub and volume with the different habitat categories were looked into. The results obtained are summarised in the Table 4.

Table 4. Variation of structural characteristics of *C. burhia* in relation to habitat types

Habitat category	Mean height, cm	% Greenness	volume, cm^3 per shrub	Density, no/ha	Total greenness volume, m^3
RHCF	25.5	94.9	140517	1098	146.5
HCF	25.9	94.6	115043	3814	416.8
FL3	40.1	31.2	29562	3550	325.4
FL4	30.0	88.5	201709	2142	384.5
SA	28.3	78.6	89818	1066	75.6

It is seen that the total greenness volume increases drastically from RHCF to HCF. This is because (a) the percentage greenness is high in both the categories and (b) the large difference in the density of the shrub has resulted differences in greenness volume for HCF.

4.3. Habitat utilisation :

winter : The pooled data (n=51168 sec) indicates that gazelles spent 40% of their feeding observation in RHCF and the rest of the habitat categories were used between 11 and 15 per cent except category FL3 (Table 1).

summer : In summer, use of habitat was in order of HCF>SA >FL3>RHCF>HA. FL4 was not used for feeding (Table 1). Gazelle used HCF habitat more than two fold (85.3%) in summer compared to winter.

Fig. 3 indicates a differential use in habitat by gazelles. During summer, gazelle spents > 80 per cent of the their total time observed only in HCF habitat where as winter it comprised four habitats (HCF, FL4, SA, HA) during winter.

Table 5. Differential habitat use by sex and age categories of Indian gazelle in Guda Bishnoi area

Sex and age classes	Habitat categories						Total time spent
	RHCF	HCF	FL3	FL4	SA	HA	
	Per cent of time spent						
	SUMMER						
Total	2.9	85.3	4.3	0.0	5.2	2.2	55073
BM	4.3	85.7	5.0	0.0	4.8	0.2	19068
FA	3.5	76.7	8.0	0.0	7.3	4.5	17719
SA	0.8	93.3	0.0	0.0	3.7	2.2	18286
	WINTER						
Total	14.4	40.7	3.9	14.8	14.6	11.6	51168
BM	15.9	48.8	5.3	7.5	3.2	19.2	11056
FA	10.3	44.1	3.8	10.0	22.2	9.7	26330
SA	21.1	27.6	3.0	29.8	9.4	9.1	13782

Breeding male \female \sub-adult male in winter : Differential use of the various habitats with respect to breeding male, adult female and sub-adult male of the total time spent in feeding in various habitat categories is shown in Table 5 and Fig. 4. BA and SA used proportionately more HCF habitat than sub-adult which spent 20 to 30 per cent of foraging time in RHCF, HCF, AND FL4. Use of scrub was in the order of AF>SA>BA.

Breeding male \female \sub-adult male in summer : HCF habitat is used > 75% by all categories of gazelles. When compared to winter differences were seen only in use of HCF. Sub-adult males used 93% of the

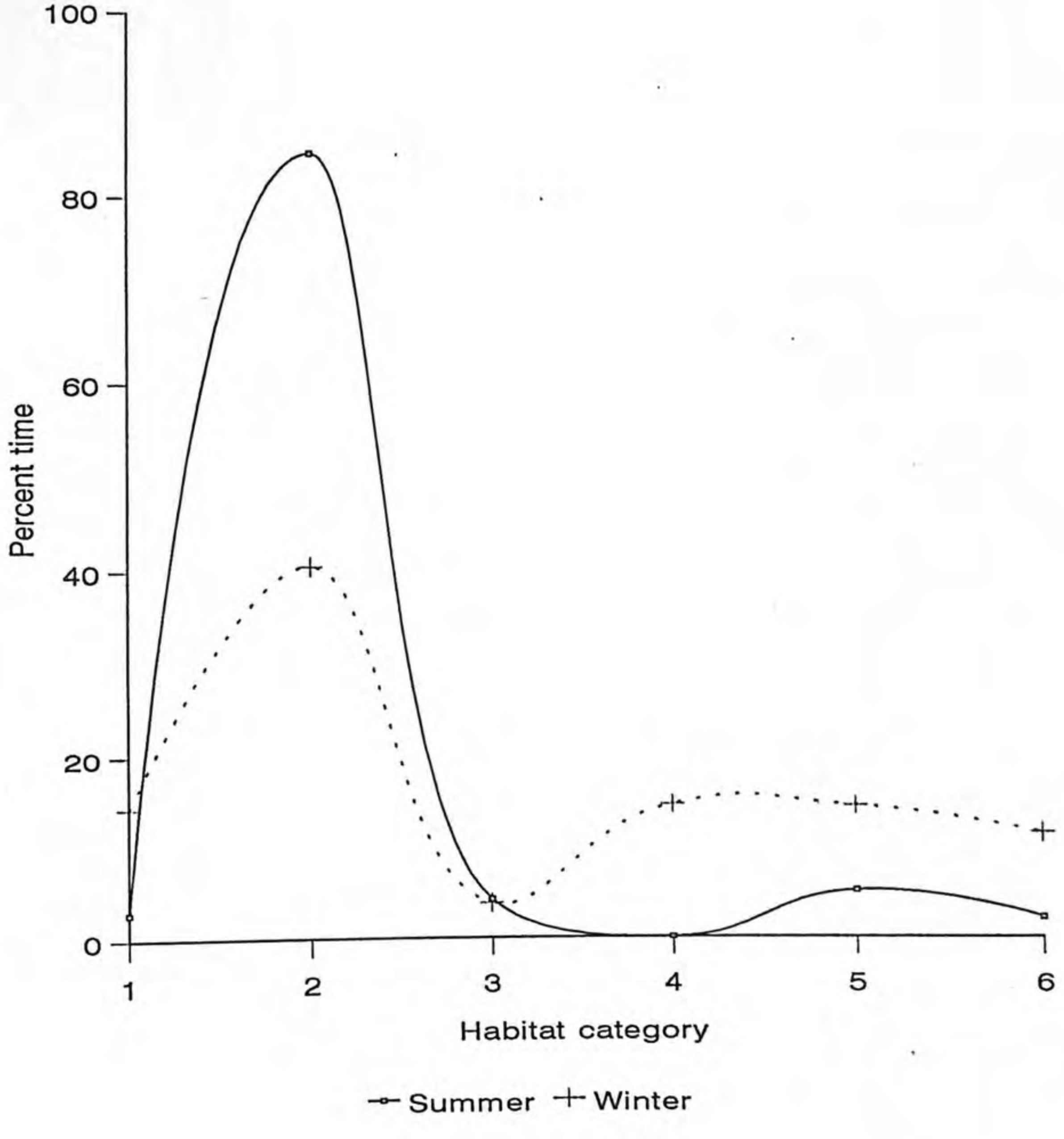


Figure 3. Differential habitat use by Indian gazelle during summer and winter

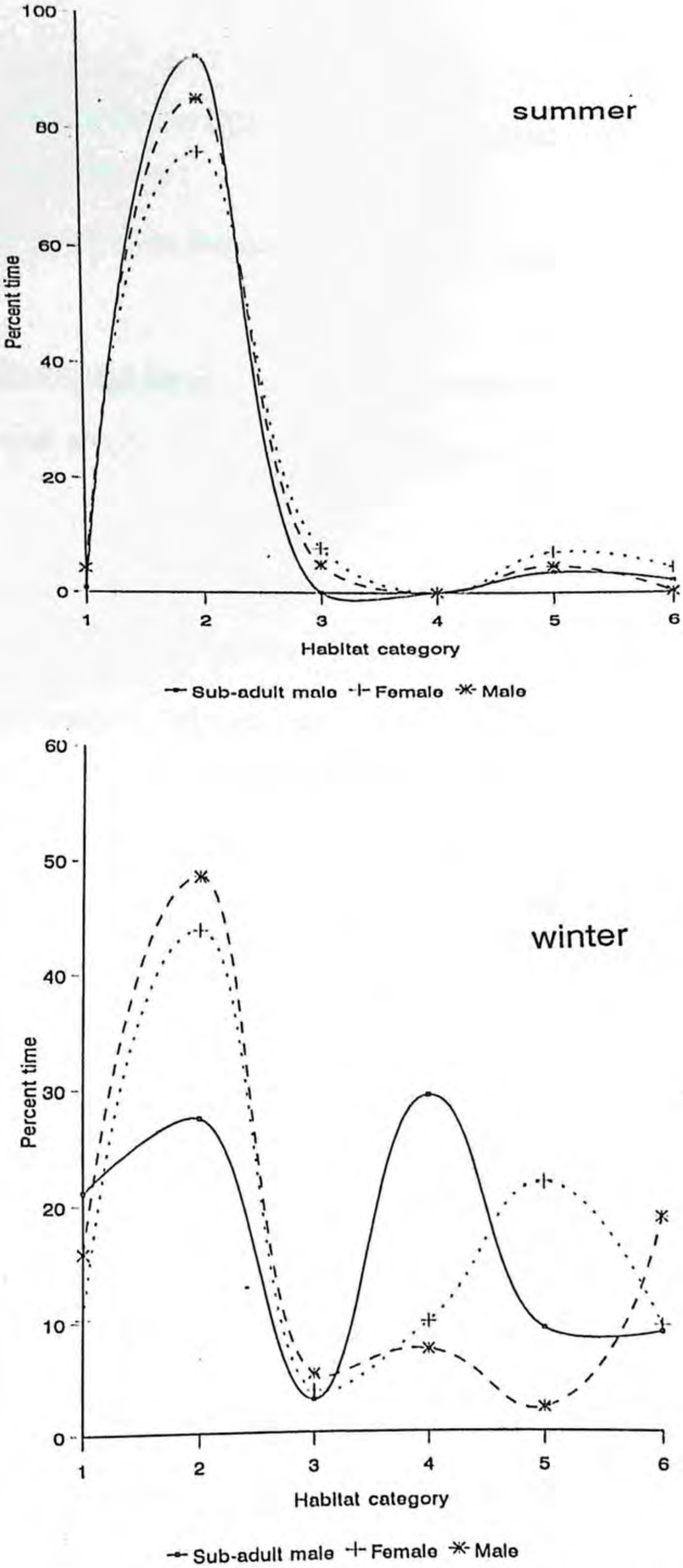


Figure 4. Differential habitat use by sex and age categories during summer and winter

the total feeding time in HCF habitat than compared to 27 % in winter.

4.4 Diet composition :

Table 4.6 gives the plant species and the parts eaten in winter and summer.

The ground layer : It is composed of grasses, crop mulch, dry leaves of trees and shrubs, herbs, flowers of *T.undulata*, pods of *P.cineraria* and herbs .

Shrubs or tree saplings: Among shrub or tree saplings, the food species are *Crotalaria burhia* , *Prosopis cineraria* , *Balanites aegyptiaca, Lycium barbarium, Ziziphus nummularia, Maytenus emarginatus, Capparis decidua, Calotropis procera*, and *Prosopis juliflora.*

Trees: *Tecomella undulata* leaves and flowers, pods of *P.juliflora* were used.

Table 6. Use of plant species and their parts in relation to phenophases by Indian gazelle

Plant Species	Phenophases		Parts eaten
	Summer	**Winter**	
Crotalaria burhia	flowering	twigs and leaves	succulent parts
Prosopis cineraria	fresh leaves	old leaves	leaf
Balanites aegyptiaca	fresh leaves	old leaves	leaf
Lycium barbarium	leaf less	old leaves	leaf
Zizyphus nummularia	old leaf /leafless	leaf present	leaf/fallen berries
Maytenus emarginatus	old leaf	fruiting	leaf
Capparis decidua	fresh flush/fruiting	old twigs	succulent twigs/fruits

Table 7 indicates differences in diet composition between summer and winter based on the per cent time spent on each food item.

Winter: During winter, the diet mainly comprises a number of plant species of ground layer, *Z.nummularia* and *C. burhia* and to lesser extent by feeding on *M.emarginatus*, *L.barbarium*, and *P.cineraria*. Flowers of *T. undulata*, berries of *Ziziphus* were also available and were classified under the ground layer.

Table 7. Per cent uses of various plant species by Indian gazelle around Guda Bishnoi closed area based on time spent during foraging periods during summer (n=55073 sec) and winter (n=51168 sec)

Plant species	Summer	Winter
Ground layer.	4.9	12.7
C. burhia	85.4	40.8
Z. nummularia	4.5	27.4
P. cineraria	1.2	2.7
M. emarginatus	1.0	9.2
P.juliflora L. barbarium	-	6.5
C. decidua	3.0	0.0
P.juliflora pods	-	0.2
B. aegyptiaca	-	0.2
C. procera	0.1	0.3

Summer: The available food resources shrunk during summer. *L.barbarium* shed its leaves in March and the ground layer was mostly devoid of crop mulch. Green grasses were less and also flowers of *T.undulata* and berries of *Zizyphus* were absent but an additional resource in the form of regenerating *Z. nummularia* was present. *C. burhia* was most favoured plant species.

Use by breeding male \female \sub-adult male in winter : Differential use of plant species by sex and age classes based on percentage time spent on each food species is given in Fig. 5. *C.burhia* is the most used food species among all the three categories of animals, however the female used *Z.nummularia* to a slightly greater extent than adult and sub-adult male. Males and sub-adult males indicated similar pattern regarding use of plant species and supplemented their diet with the ground layer. *M. emarginatus* was used more by breeding males and sub-adult males than females. *P.cineraria* was used more by sub-adult males than males or females.

Use by breeding male \female \sub-adult male in summer : During summer, there was no major differences in habitat use among sex and age classes (Fig. 4). Thus, I did not made an attempt to examine differences at species level.

4.5 Plant chemistry and use:

Crude protein (CP), levels in most of the preferred plant species ranged between 8.5 and 19.7 per cent (Table 8.). CP levels were the highest (ca.19%), in *C.decidua* and *L. barbarium* and the least in *C.burhia* (8.8 %), and *M.emarginatus* (6.78%). A decline in crude protein levels in the food species from winter to summer is seen except in *B.aegyptiaca* that showed a significant increase (from 15 to 21 %) (Fig. 6).

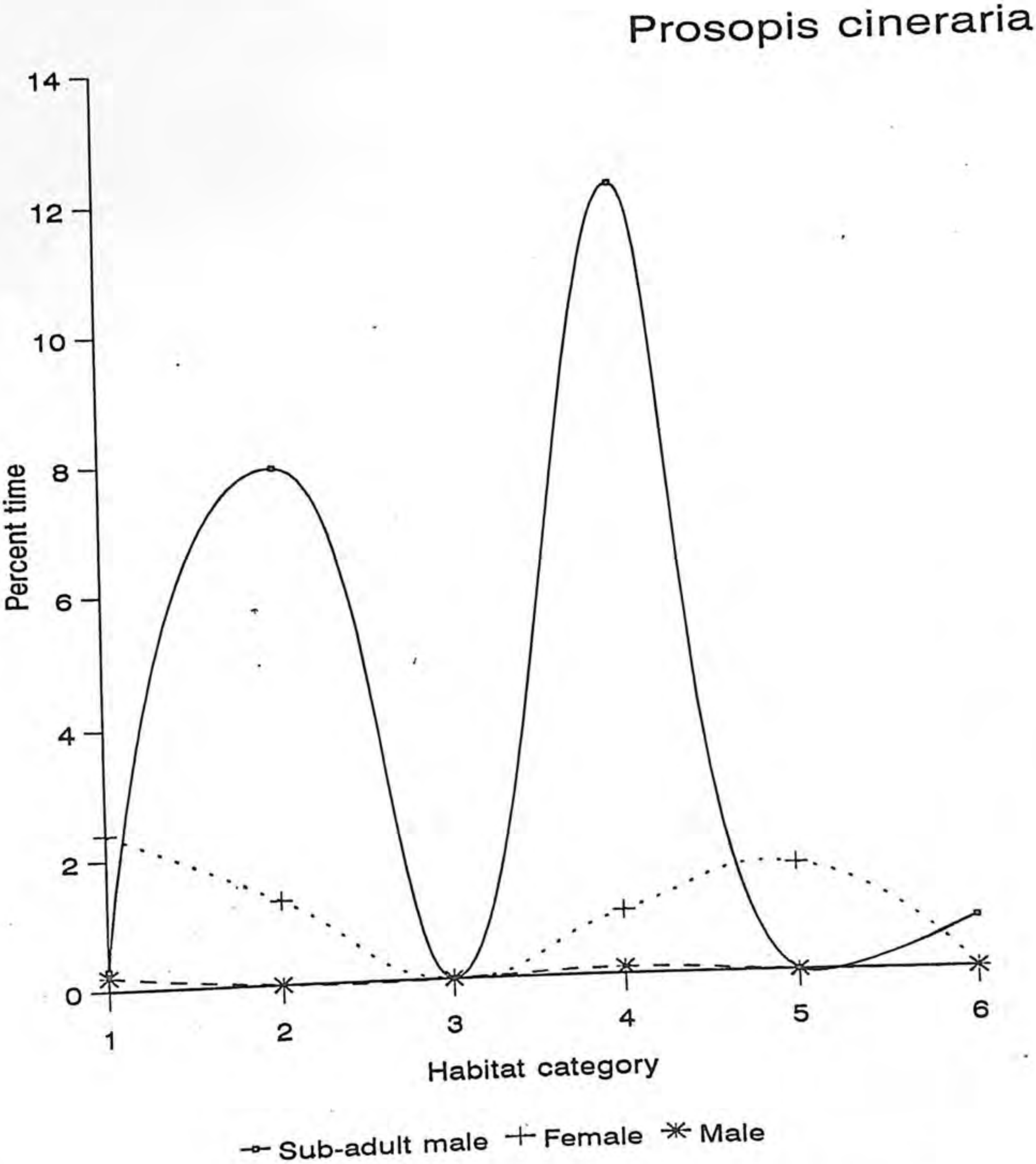
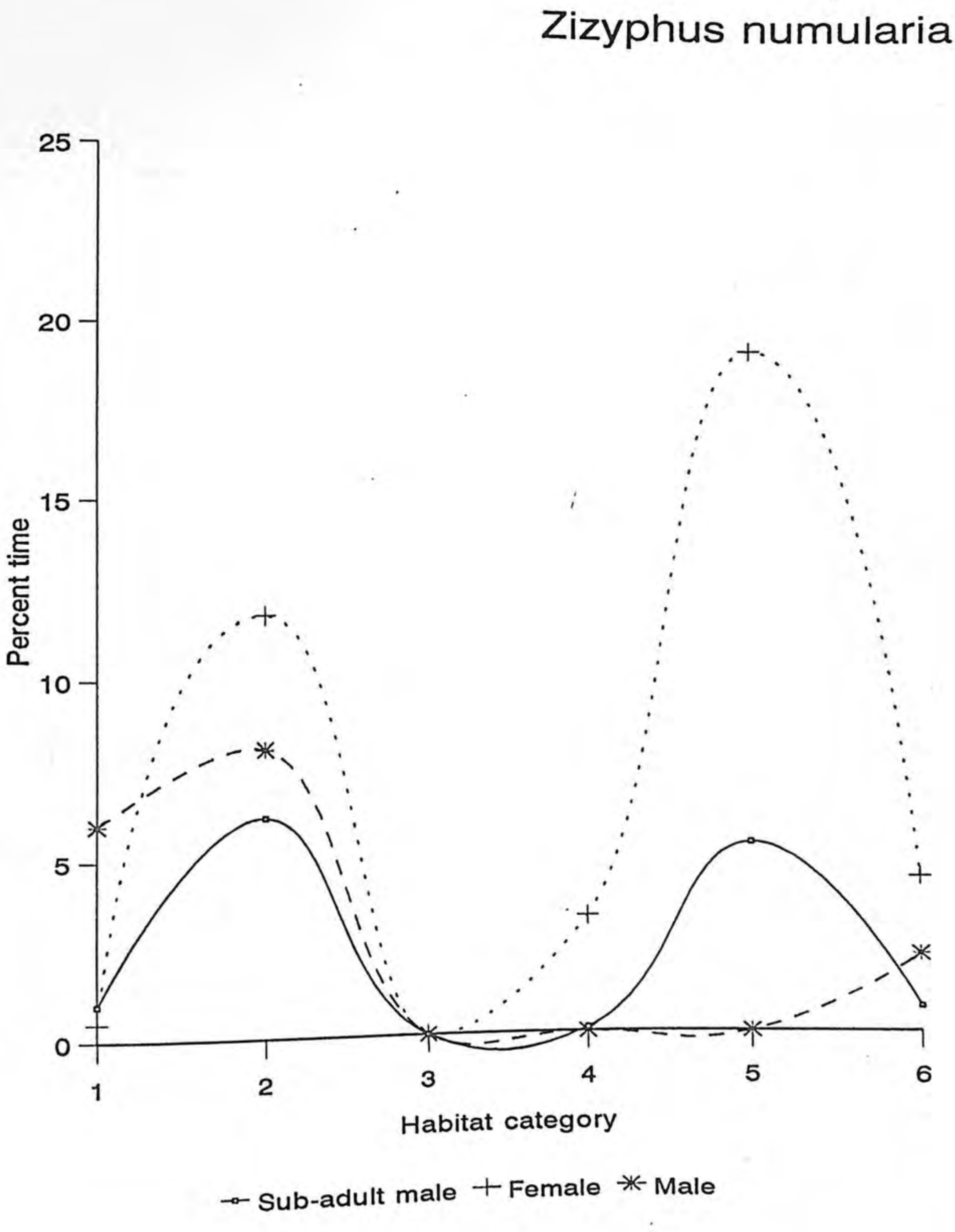
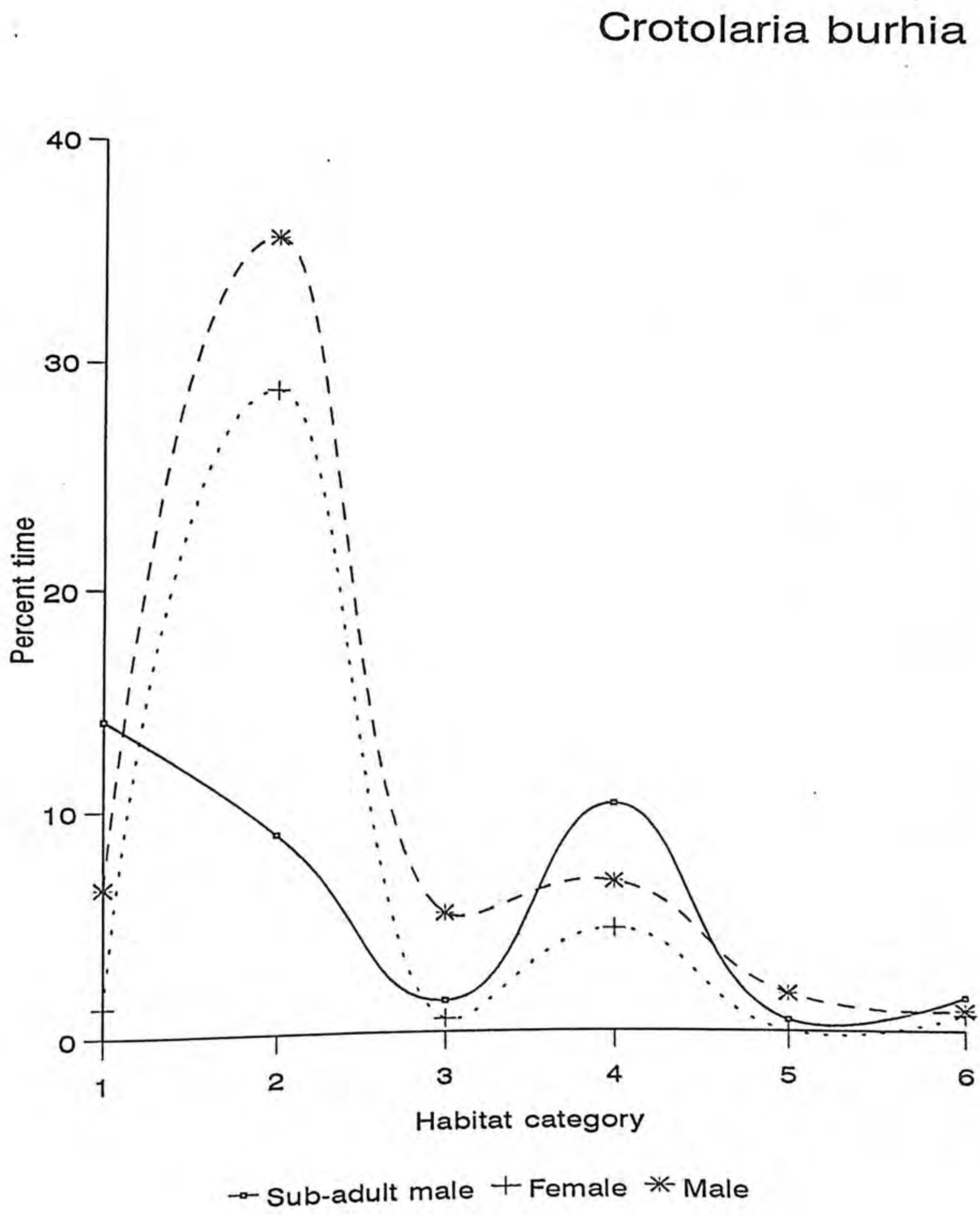


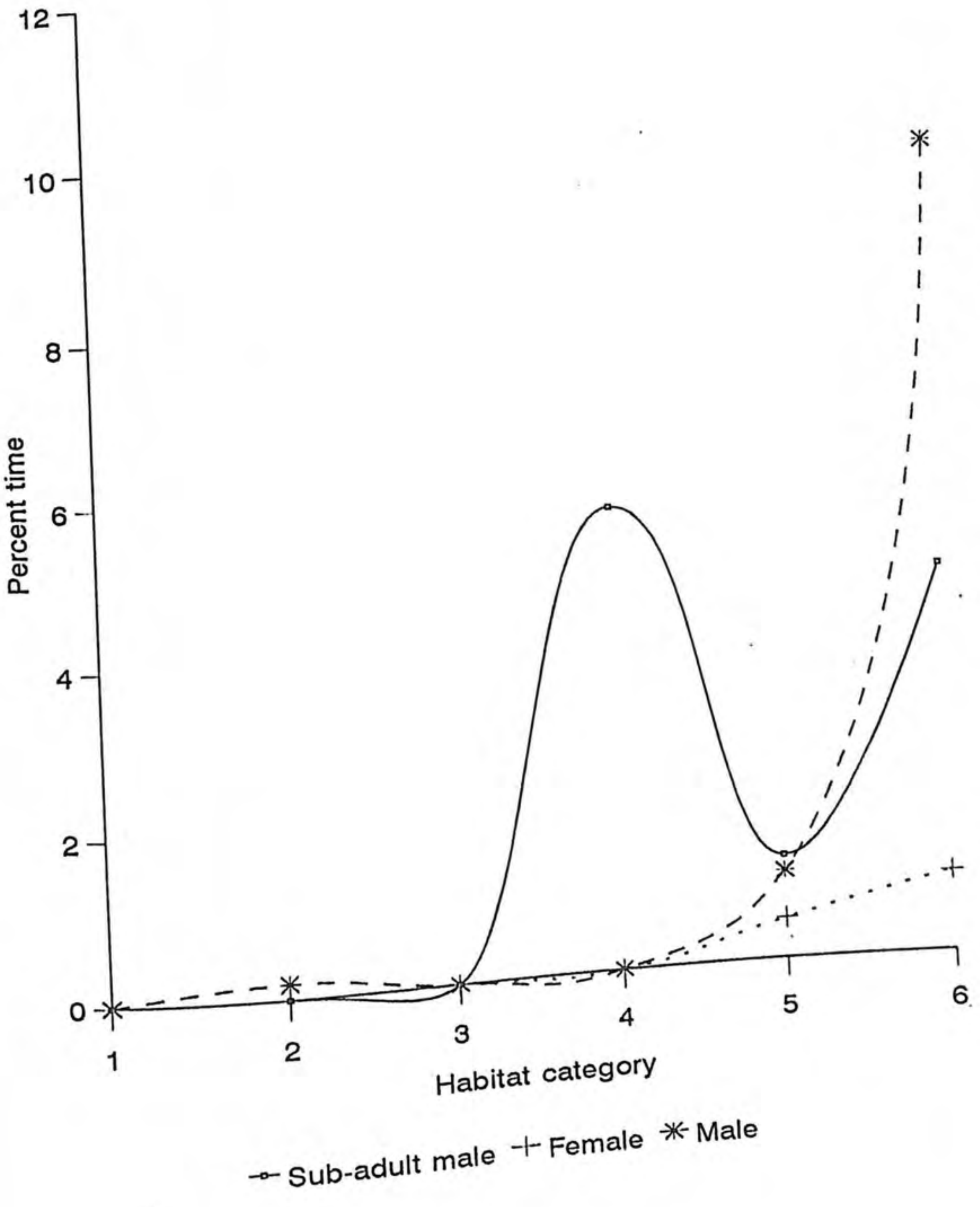
Figure 5. Differences use of plant species by sex and age classes of Indian gazelle (a) *Prosopis cineraria*; (b) *Zizyphus nummularia*; (c) *Crotolaria burhia*; (d) *Maytenus emarginatus*; (e) ground layer. Habitat categories are as Fig. 3



Zizyphus numularia
25
20
15
10
5
0
Percent time
1
2
3
4
5
6
Habitat category
Sub-adult male
Female
Male


Crotolaria burhia
40
30
20
10
0
Percent time
1
2
3
4
5
6
Habitat category
Sub-adult male
Female
Male

Maytenus emarginatus



ground layer

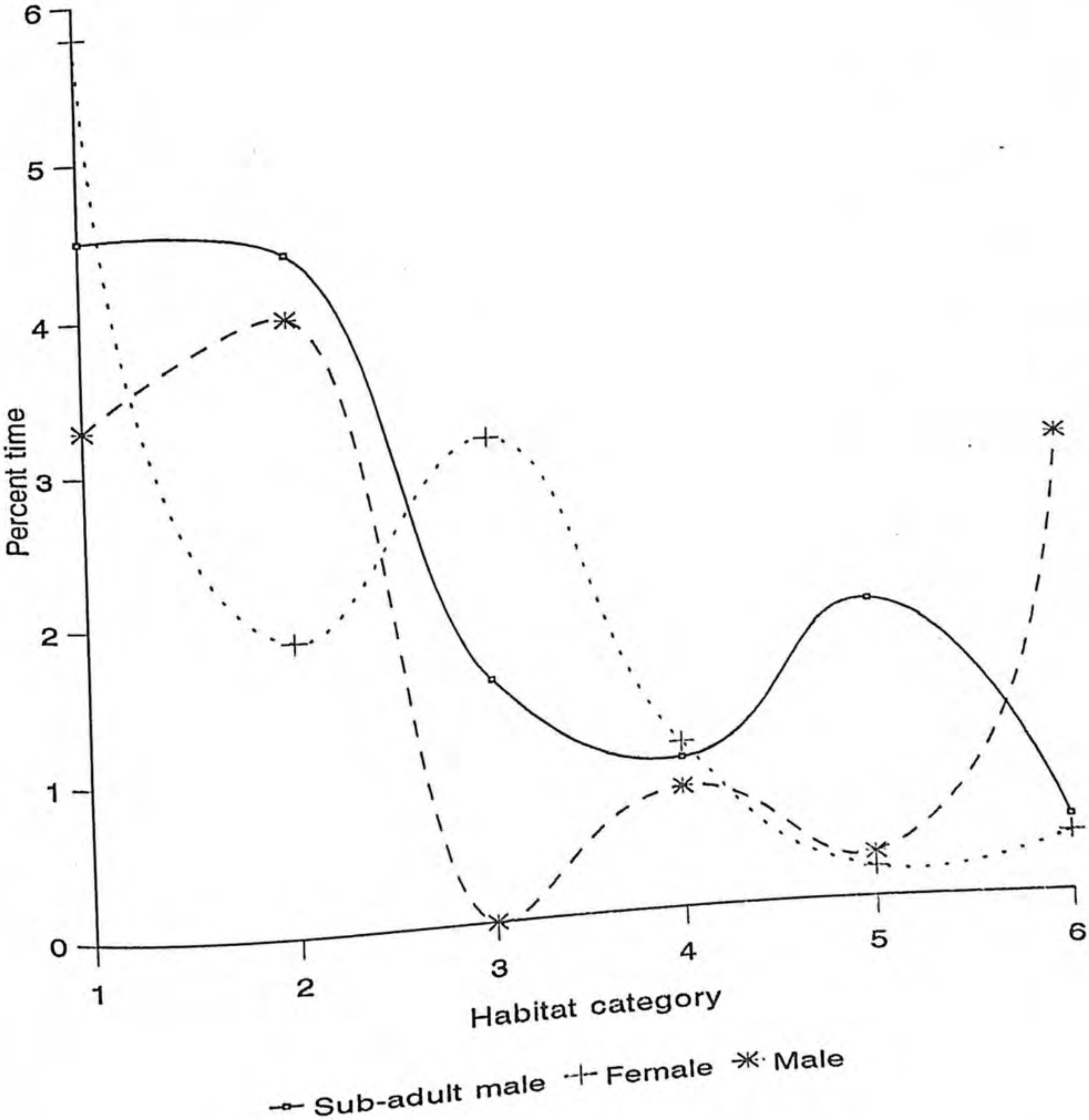


Table 8. Variation in crude protein and ash content of most commonly used food plant species by Indian gazelle during summer and winter

Species	Per cent dry matter			
	Crude protein		Ash content	
	Summer	Winter	Summer	Winter
C. burhia (CB)	8.51	8.82	4.80	4.50
P. cineraria (PC)	15.52	16.33	6.30	6.30
B. aegyptiaca (BA)	21.68	15.21	9.60	14.30
L. barbarium (LB)		18.90		10.00
Z. nummularia (ZN)	12.07	13.81	8.30	10.10
M. emarginatus (ME)	6.06	6.78	15.30	14.50
C. decidua (CD)	16.94	19.78	6.60	5.80

Ash content was the highest in ~~the~~ *B.aegyptiaca* (14.3%) and *M.emarginatus* (14.5%). Ash content increased in all the species except in *B. aegyptiaca* and *Z.nummularia* between winter and summer when it declined (Table 8).

The tannin content was the highest in the case of *M. emarginatus* and *B. aegyptiaca* and least in *C. burhia* (0.81%) (Table 9).

A number of species showed a higher level of tannin during winter than in summer. Tannin showed marked variation between two seasons in *B. aegyptiaca* where it decreased from 11.81 % to 2.5 % and in *M. emarginatus* it increased from 7.16% to 14.06%.

A scatter plot between protein content and tannin does not reflect any association of high protein with a high tannin content (Fig. 6). Per cent time

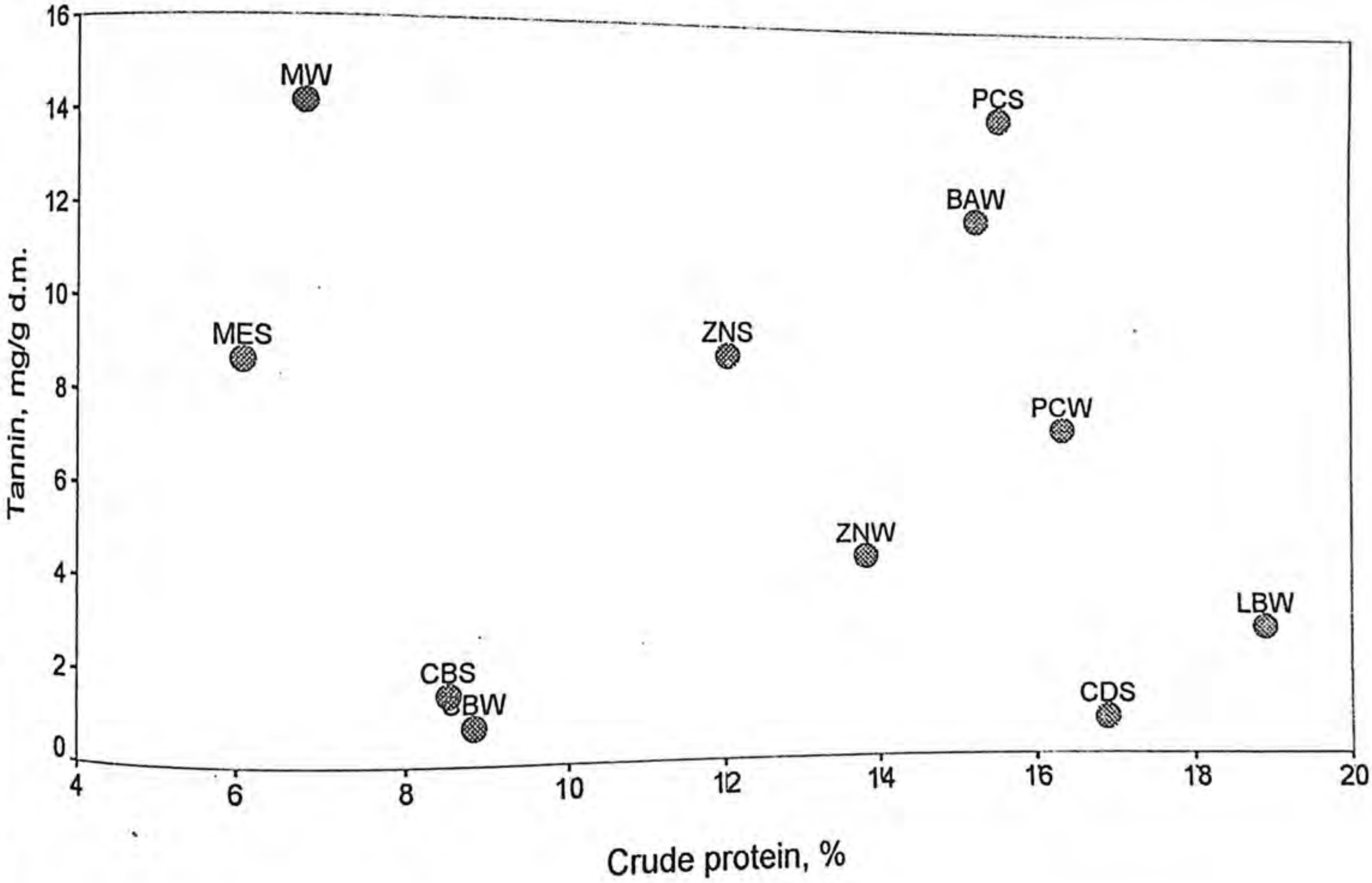


Figure 6. Relationship between crude protein and tannin estimated in leaves of plant species; S=summer; W= winter

Table 9. Variation in Tannin content of food plants species commonly used by the Indian gazelle

Species	Tannin, mg/g dry matter of leave	
	Summer	Winter
B. aegyptiaca	2.5	11.81
C. burhia	1.51	0.81
C. decidua	0.79	1.12
L. barbarium	0	2.81
M. emarginatus	8.69	14.18
P. cineraria	14.06	7.16
Z. nummularia	8.8	4.4

spent on a plant species is negatively correlated (R2 = 0.17) with the amount of tannin present in plant leaves. (Fig7).

Table 10 indicates that female selects a diet of relatively higher quality than male.

Table 10. Consumption of crude protein/ 100 g d.m. by different categories of gazelles

Plant Species	Summer			Winter		
	Sub-adult	Female	Male	Sub-adult	Female	Male
C. burhia	7.90	6.33	7.51	2.93	2.88	4.56
Z. nummularia	0.36	0.99	0.31	1.83	5.44	2.24
P. cineraria	0.03	0.53	-	3.55	1.04	0.03
M. emarginatus	-	0.18	-	0.82	1.02	0.78
C. decidua	0.15	1.10	0.31	0.20	0.66	0.52
Total	11.98	9.09	8.13	9.32	11.04	8.13

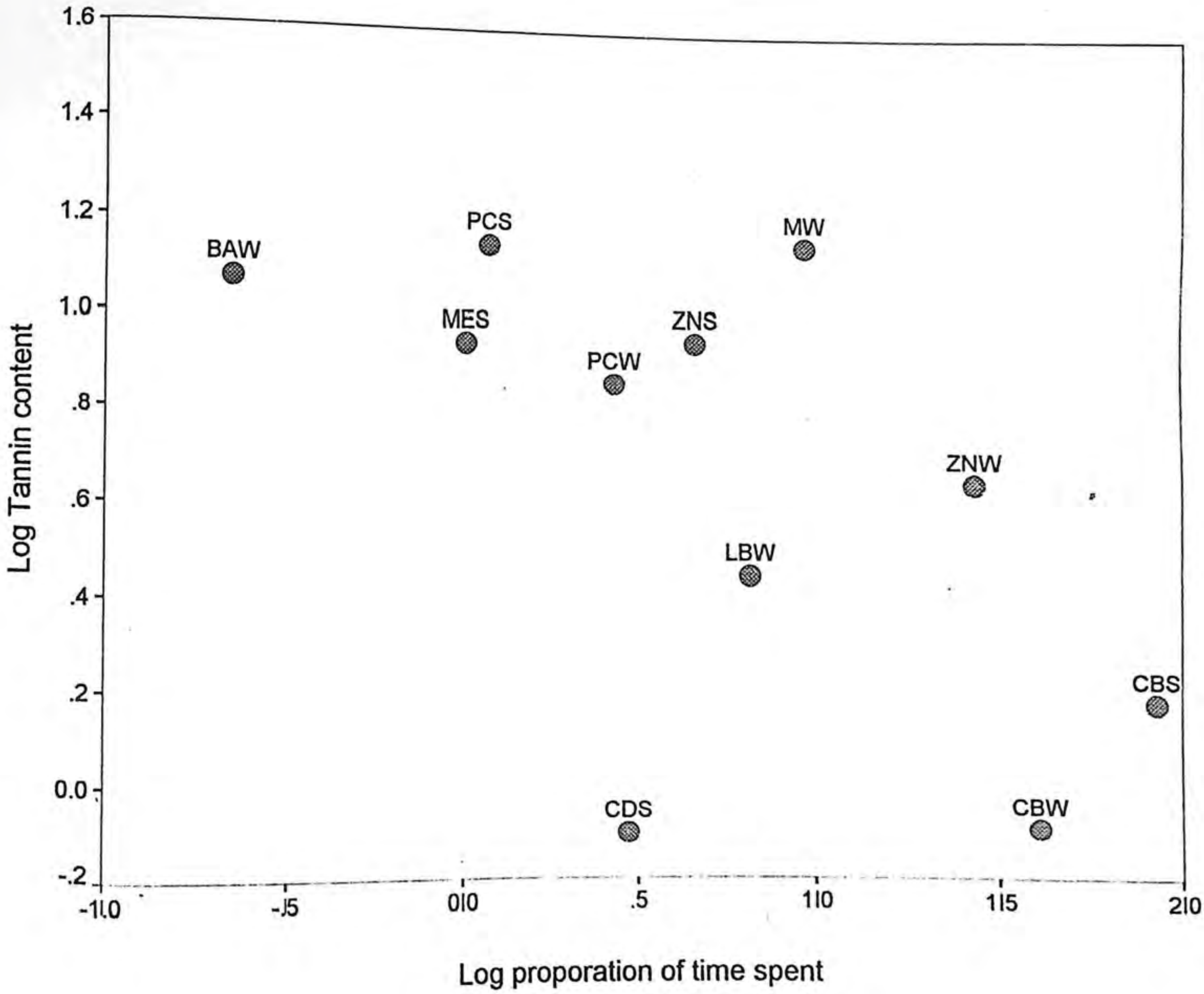


Figure 7. Relationship between proportion of time spent and tannin content of plant species

4.6 Relative preference index or PRI:

Preference index based on the use-availability ratio ranks the food species to classes of those used more than available, or less than available and those used in proportion to availability is indicated in Table 11. The PRI for habitat use indicates that during summer HCF is highly preferred against other habitats. During winter, Scrub was most preferred and followed by HCF and FL4.

Table 11. PRI in relation to habitat use categories by Indian gazelle

HABITAT CATEGORY	PRI	
	SUMMER	WINTER
RHCF	0.10	0.50
HCF	3.26	1.55
FL3	0.45	0.41
FL4	-	1.24
SA	0.73	2.05
HA	0.13	0.69

The PRI index during summer and winter indicates a differential preference of plant species over season (Table 12). During winter , *C. burhia* is used much less than available and used in proportion to availability in summer. PRI is the highest (12.27), for *M. emarginatus* in winter and only 1.33 in summer. *Z. nummularia* has a high index in winter. *C. decidua* has the highest PRI value (7.14), in summer but was not used in winter .

Table 12 . PRI of various plant species used by Indian gazelle while foraging

Plant species	Relative Preference Index (PRI)	
	Summer	Winter
C. burhia	1.02	0.49
Z. nummularia	0.8	4.88
P. cineraria	0.9	2.03
M. emarginatus	1.33	12.27
B. aegyptiaca	-	0.3
C. procera	-	-
C. decidua	7.14	-
L. barbarium	-	3.0

L. barbarium has an index of 3.0 in winter but the plant was mostly leafless in summer.

Relationship of crude protein content , tannin and % time spent feeding show that plants used highly by gazelles are clumped in to a section of low tannin and with medium levels of protein content a (Fig. 8).

Fig. 9 indicates a high PRI of species occurred in low abundance and approaches close to one with increase in biomass though there are gaps.

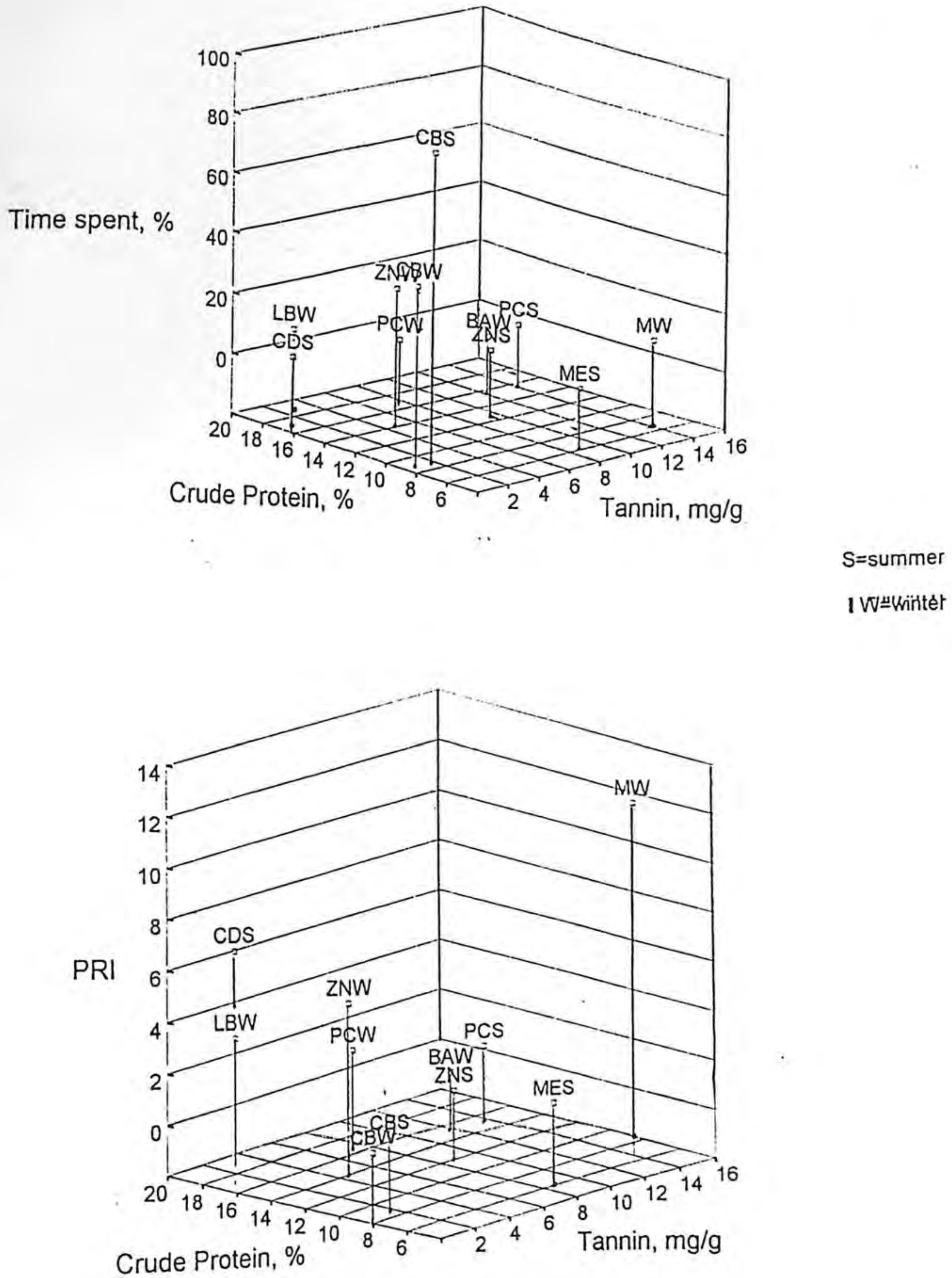


Figure 8. Crude protein and tannin content in relation to PRI and per cent time spent on plant species

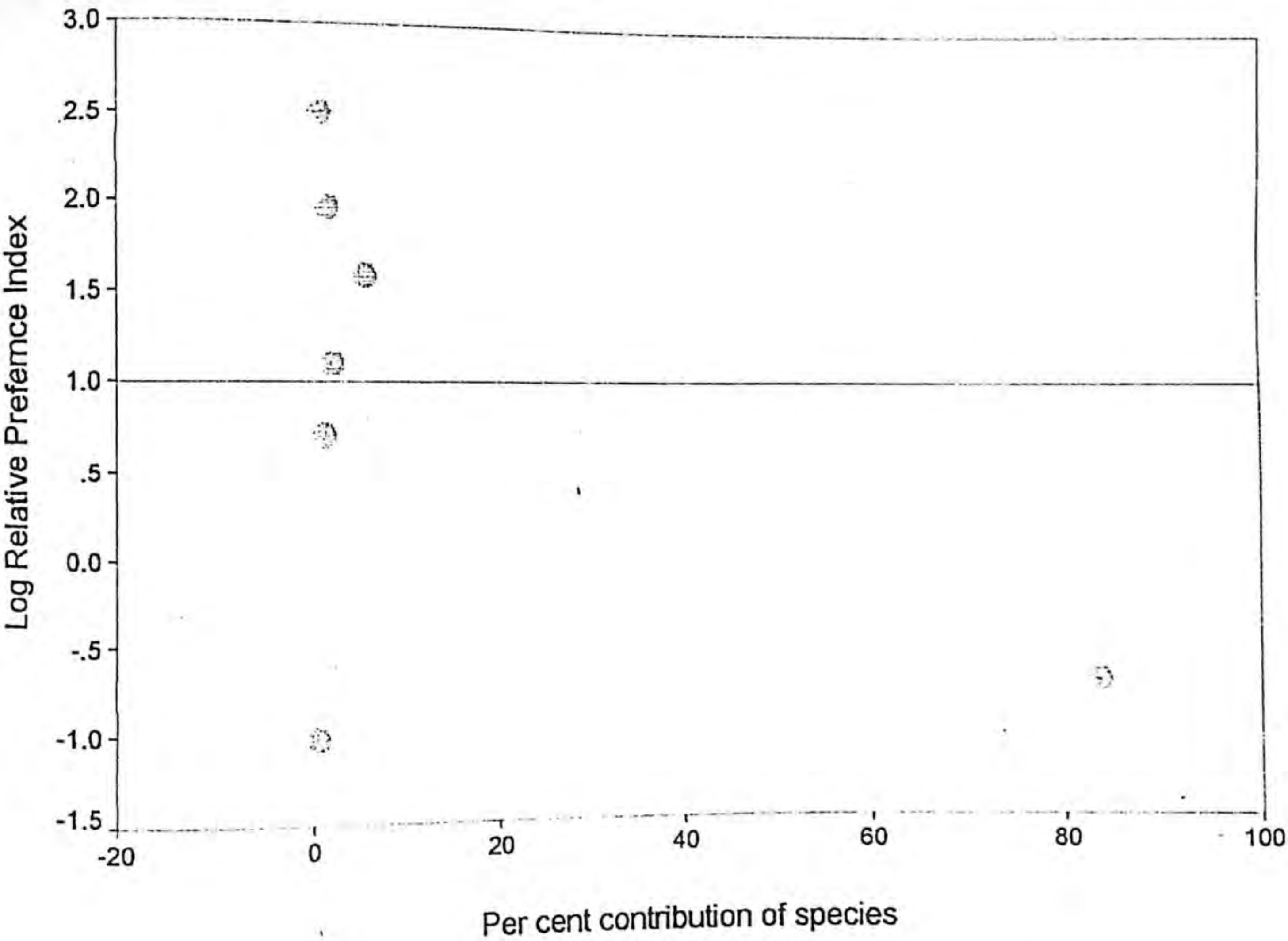


Figure 9. **Relationship between per cent plant species contribution while foraging by Indian gazelle and PRI**

5. DISCUSSION

Foraging behaviour is governed at two levels one at the landscape level where the animals select the feeding area or habitat types and the other at the level of the plant communities where plant species are selected in order to meet basic needs of food, cover, water, and micro-nutrients. Selection of feeding areas could be a function of spatial and temporal distribution of forage biomass and plant quality. Diet selection could be influenced by the nutritive quality, secondary compounds and plant architecture (Senft, 1987).

During winter, the gazelle used HCF more (40%), than any other category, although it formed only one fourth of the total study area (Table 1). The scrub area is also used more than its proportion in the study area. The relative preference index (PRI) for habitat use ranks scrub above HCF and FL4 as used more than available. FL3 and hedge-rows were used less than to what is available. Kutilek (1979) reported that nonmigrating African ungulate species in Lake Nakuru National Park, Kenya shift foraging by utilising six distinctly different forage-habitats. Such seasonal changes in habitats have been reported by a number of authors (Irby, 1982; Escos and Alados, 1992) and probably resulted in a seasonal selection of forage due to changes in forage nutritional quality.

Among six broad habitat categories (Table 1), a different proportion of use of these habitat by gazelles was observed during summer and winter (Table 5 and Fig. 3). In winter when *Zizyphus*, *L. barbarium* and ground flora (grass, flowers, berries) were available, per cent use of *C. burhia* in the diet was lower compared with summer (Table 1). Per cent use highlights the importance of *C. burhia* in the diet, but when preference ratio is taken into consideration it's seen that the shrub is used in proportion to availability. PRI is very high for *M. emarginatus* and followed by *Z. nummularia, L. barbarium* and *P. cineraria* (Table 11).

Vegetation characteristics i.e. composition and abundance is drastically different between scrub/hedge-row and the rest of the habitat types. The higher PRI value points to the fact that animals tend to prefer scrub more for feeding (Table 10). Presence of a higher proportion of *Zizyphus* (30%) in the scrub and differential use of food species in the scrub highlights the point that *Zizyphus* has a role in the disproportionate use of the habitat. This is further clarified in the use of scrub, and *Zizyphus* to drastically lower levels in summer (Table 10 and 11).

Food plants that show a high preference index are *M. emarginatus, L. barbarium and P. cineraria*, most of these food plants are distributed in the scrub and hedge area. All the high PRI ranked species have high protein and high tannin content (4.4 to 14.18 mg/gm) than *C. burhia*, except *M. emarginatus* that has a high tannin content and a low protein value (Table 8 and 9). All these plants constitute about 20% of the diet (Table 7). Consumption of plants with higher tannin content reduces the overall protein metabolism and digestibility. CP digestibility decreases with an increase in tannin content and when tannin exceeds 2% it drastically decreased (Negi, 1987). Per cent time spent on a plant species is negatively correlated with the amount of tannin present (Fig. 7).

Animals are capable of avoiding plants with high secondary compounds, like in deer, (Longhurst *et al.*, 1968). In nature, animals are seen very often foraging on plants having high secondary compounds and consume such plant species in such a proportion that they are not lethal. Foraging on such plant species enables the animal to meet its protein requirements from the environment when abundant species are lower in crude protein and unable to meet basic level of nitrogen in diet. Detoxification mechanisms should be present in gazelles too, as in other ruminants, which is brought about by enzymal action what requires conjugating proteins. The costs for detoxification limits the amount of any one food item at a particular time, also secondary compounds may interact antagonistically (Freeland and Janzen, 1974), and hence the need to supplement the diet with specific proteins. This might be the reason in winter why a wider variety of food is consumed and that too many with high secondary compounds (Table 9). Further animals previously exposed to plants having secondary compounds are adapted to such compounds and can tolerate a higher level of oils than animals without exposure (Nagy and Tengerdy, 1967). This would explain the feeding observed on plants having very high content of Tannins as these habitats have plants with high phyto chemical deterrents, an additional factor is that herbivore feeding also involves sampling of food (observed feeding on *B. aegyptiaca* and *P. juliflora).* Thus to minimise secondary compounds in the diet, *C. burhia* is used extensively in winter forming about 40% of the diet. During summer, *C.burhia* forms about 85.4% of the diet. Seasonal shifts in plant species by African non-migratory ungulates allowed forage-habitat alternate periods of use and recovery and was undoubtedly beneficial to the plants as well as to the herbivores (Lamprey, 1963; Kutilek, 1979). Distinctly low consumption of *C. burhia* during winter may be to ensure availability of the species for foraging when other resources are scarce in summer.

Available biomass of *C. burhia* has clumped distribution and the gazelle can efficiently forage. The high insolation during summer restricts ability of the gazelle to forage or explore other areas.

Use of HCF could be explained in terms of the structural characteristics of the vegetation. Greenness is taken as an indicator of available biomass (Owen-Smith, 1994), such visual estimates have been used in foraging studies of impala (Fritz and Garine-Wichatitsky, 1996). *C. burhia* that forms more than 80% of the total shrub vegetation is present in all the habitat categories, but their abundance and greenness values differ among the habitats (Table 4). The abundance and greenness is summed up in the form of a greenness volume which is the highest for HCF. Use of *C. burhia* is also high especially in summer, and the relatively low usage reflected in the PRI value for winter could be due to the dietary difference, when more nutritive diet was preferred particularly by the females and sub-adults during winter. Of the total *C. burhia* fed upon in summer (92%) was in HCF as it supports highest greenness biomass among all habitats (Table 4). Also not many other food species were present in the diet. Studies on Dorcas gazelle a close relative of the Indian gazelle in Israel has pointed out the influence of protein and moisture in food selection (Baharav and Rosenzweig, 1985). The Dorcas gazelle maximised on energy during winter but when the moisture level went down drastically in summer the animals shifted to maximisation of moisture content. *C. burhia* contains more than 60% moisture and hence a dietary shift by all categories of animals may be to maximise moisture content in diet during summer. Also a high quality diet in summer would cost the animal in terms of more water loss through Specific Dynamic Action.

An anomaly with PRI is the high value obtained for *M. emarginatus*, the plant has a low CP coupled with a high tannin content (Fig 8) and could be due to presence of high Ca and Na levels (Dhir *et al.*, 1983).

Senft (1987) pointed out that rare plants occurring in relatively lower biomass show preference indices vary widely from unity and tends towards unity as biomass of an abundant species increased. The large PRI values obtained may be due to the tendency of rare plants to show preference indices widely away from unity (Fig 9). With preference ratio, the graph shows plants with higher tannin was used more than available, but not necessarily one with a high protein content.

The gazelle is exclusively a browser in the arid zones of Rajasthan. The ground layer forms < 13 % of the total feeding time. Hence only shrubs were taken into consideration for the analysis of feeding behaviour.

Differential use of habitats reflects distinct use of plant species by sub-adult, male and female (Fig. 5). Such differential use of plants with higher nutrient content by breeding males, sub-adults, and females have been explained in terms of behavioural differences between sexes, their physiology or body size (Bowyer, 1984; Beier, 1987; Clutton-Brock *et al.*, 1987). Body size especially in sexually dimorphic species influences digestibility with the larger sized males capable of digesting a food rich in fibre than females (Demment and Van Soest , 1985, Gross *et al.*, 1995), however the data on fibre content could not be analysed due to time constraints. Males of a species tend to spent more time on vigilance against other males and in breeding related activities than on feeding compared to females. Hence males may try to maximise their food intake for body maintenance by spending more time in areas of high forage biomass (Table 4 and 5), than scouting for good quality forage.

The need for higher quality diet of an animal varies with the sex , age and season. Females has greater nutritive requirements due to their physiology, and hence maximisation of quality food is an essential strategy. It is widely accepted in ruminants that the nitrogen content of the food is positively correlated with forage quality, where as crude fibre is inversely correlated with it. Yalden (1975) found a direct positive relationship between nitrogen content of food plants eaten and nitrogen content present in rumen content in Scottish Red deer and suggests that crude fibre appears to be less useful than nitrogen as a single indicator of food quality for wild deer because of large variation around the regression line. Diet in similar composition was observed when determined by direct observations, rumen content and faecal samples. Reports on age differences in diets of ruminants and their ecological and management implications are scant (McCullough, 1985) but Illius and Gordon (1987) suggested a diet differences in the diets of juveniles and adults may be likely because of the differences in body size and constrains placed by gut capacity (Demment, 1983).

Differences in selection of diet quality has also been reported in Red deer (Yalden, 1975). Studies which examined inter-sexual diet and habitat use in cervids have reported differences in diet when the sexes occupy different habitats or areas within habitats (Bowyer, 1984; Clutton-Brock *et al.*, 1987). Consumption of crude protein is in proportion to their body size during summer i.e. sub-adult>female>male where as such a relationship was not found during winter. This may probably be due to the requirement of higher quality food by females to meet extra cost for reproduction. Sub-adults being the smallest in body size and constrained by gut volume and turn over rate of food, consumed plant species and their proportion in such way that it provide maximum protein intake. Among adults, female diet is of higher quality than male both during summer and winter.

If the differential use of the food species by age and sex categories is taken into consideration it is seen that males and sub-adult males mostly feed on *M. emarginatus* having contents of calcium and sodium (Dhir *et al.*, 1983). This might be the reason for the aberration, as reported in moose (Belovsky, 1981). Also the ability to detoxify secondary compounds differ with the age and sex and sexual state of the animal. (Freeland and Janzen 1974), feeding on *M. emarginatus* and *P. cineraria* may not be harmful for the animal, as males are probably physiologically capable for a higher tolerance towards secondary compounds due to presence of high levels of androgens (Mandel, 1972).

Differential use of food plants among age and sex categories does show a clear difference among the categories. *Z. nummularia* is eaten more in scrub area by females while the breeding males that move along with the female herd feed on it in HCF rather than in scrub, but it forms only 8 % of the diet in males compared to 20% of females in scrub (the overall percent use of *Zizyphus* by breeding males is only 16% while that of the females is 40%). Sub-adult males do not show marked differential usage of *Zizyphus* and has 14 percent of their diet composed of *Zizyphus*. The point could be further stressed as observations in the field showed that males usually do not feed when in scrub as they tend to feed during the early and late parts of the day. This is in tune with the argument that female movements are governed by resource needs and male's realm revolve around females. This leads to the assumption that males do not need a high protein diet. In the hedge-row females tend to feed mostly on *Zizyphus* and *L. barbarium* both with a high crude protein content and lower tannin content.

Use of FL4 is mostly by sub-adult male which seem to prefer this habitat and feed on the most varied diet among the categories of animals. They feed on *C. burhia* and *P. cineraria* along with the ground layer, *Zizyphus* and *M. emarginatus.* Although the PRI value is the highest for *M. emarginatus* they mostly grow in the hedge row and FL4, further when the differential use of males and females are considered it is seen that females rarely feed on the plant and it is mostly eaten by males and sub-adult males. They also use RHCF and HCF in similar proportions. Incidentally RHCF and FL4 are very less used by females and breeding males. It appears that differential use of habitat by sub-adults when compared with male and female are due to differences in use of space and habitats.

6. CONCLUSIONS

The present study was aimed at determining the food habits and foraging behaviour of the Indian gazelle or chinkara around Guda Bishnoi closed area in Rajasthan. This area is desert dominated by seasonal crop fields. The major focus of the study was to understand feeding behaviour, selection of habitat and plant species in relation to spatial and temporal distribution of natural resources and due to age and sex differences and plant chemistry during winter and summer.

The Gazelle's diet consisted mainly of browse as more than 90% of the total time spent feeding is on browse species distributed among the fallow crop fields and isolated pockets of scrub. The vegetation composition among various habitat types are different. Different habitats were used by gazelle during summer and winter and habitat use varied among age and sex-class viz. breeding male, sub-adult male and adult female, a reflection of differential diet composition. The habitat selection pattern reflected the overall food habits, both in winter and summer.

Variation in the diet of gazelle during winter and summer is probably due to selection of high quality of food during winter. The diet composition varied among age and sex classes, but not in summer when the habitats were used in similar proportions. Habitat selection would also have been influenced by the structural differences in the dominant food and vegetation: *Crotalaria burhia* which was pronounced in summer. Plant chemistry influenced food plant selection, both by crude protein and tannin (especially in winter), and possibly by moisture in winter. Variation among the age and sex classes in their food plant selection may be influenced by their specific dietary requirements determined probably by body size. These difference in use were found to equate well with the plant chemistry, also in the differential use by different age and sex classes. Consumption of crude protein during summer was proportional to their body size i.e. sub-adult>female>male. Female consumes plant species of higher quality than males during summer and winter. Based on selection and proportion of plant species, the Indian gazelle is a browser and selective in its food choice during winter and probably also in summer.

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