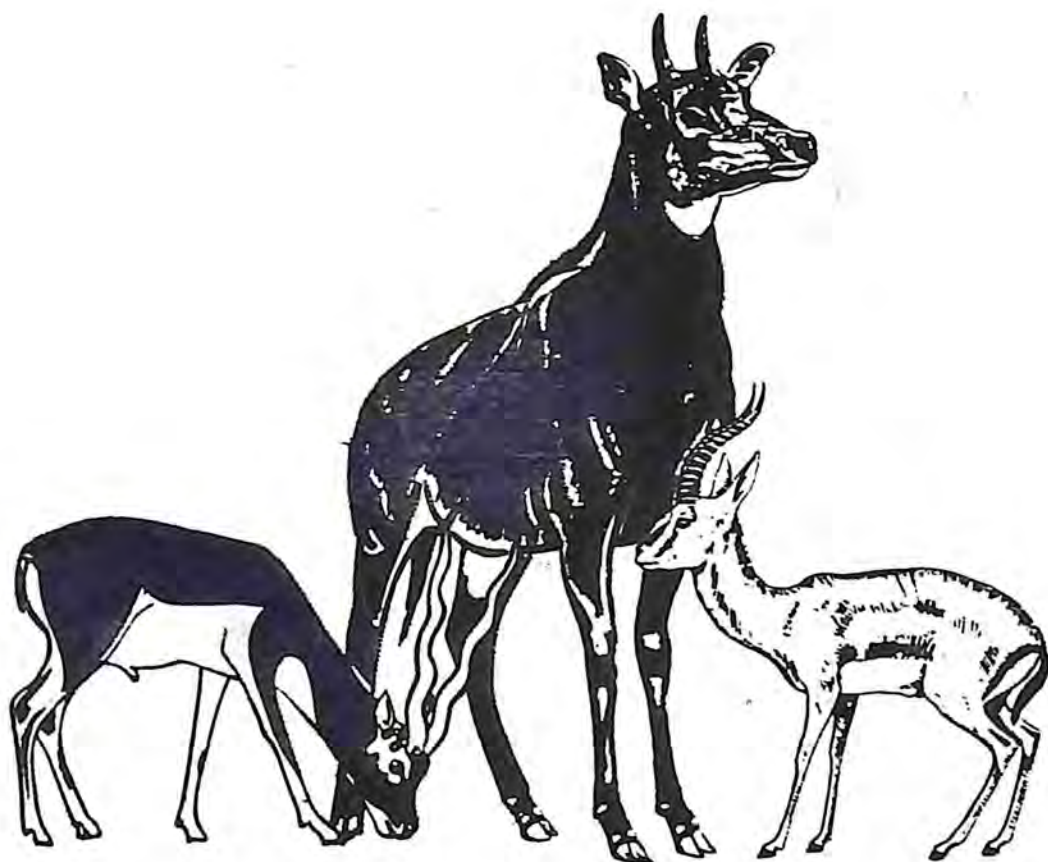


**FOOD RESOURCE PARTITIONING AMONG
SYMPATRIC BOVIDS : CHINKARA,
BLACKBUCK AND NILGAI IN
THE RAJASTHAN DESERT**



**DISSERTATION SUBMITTED TO THE
SAURASHTRA UNIVERSITY, RAJKOT
IN PARTIAL FULFILLMENT OF
MASTER'S DEGREE IN WILDLIFE SCIENCE
(1988-89)**

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91 pages

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CERTIFICATE

This is to certify that Mr. N.V. Ashraf Kunhunu has carried out an original piece of research in partial fulfillment of his M.Sc (Wildlife) degree of the Saurashtra University, Rajkot. The topic of dissertation is "Food resource partitioning among sympatric bovids : Chinkara, Blackbuck and Nilgai in the Rajasthan Desert". The investigations were carried out at the Wildlife Institute of India, Dehradun under my supervision from May to December 1989. I hereby certify that this work has not been submitted for any degree of any university.

S.P. Goyal

(Dr. S.P. Goyal)
Assistant Professor

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SUMMARY

Patterns of dietary selection, overlap and spatial distribution were investigated for three species of sympatric wild ungulates (chinkara, blackbuck & nilgai) and four species of domestic ungulates (goat, sheep, camel and cattle) during four seasons (summer, premonsoon, monsoon & postmonsoon) in Rajasthan desert. The objective was to determine the mechanisms of food resource partitioning among these seven species of ungulates and the factors allowing their coexistence.

Two study areas, Dhawa-Doli and Janwar-Doli were selected for the study, based on the density and distribution of the three wild ungulates. More emphasis was given to Dhawa-Doli where two of the three species (chinkara & blackbuck) were common.

Food habits were studied by direct observations. Feeding activity was recorded for feeding height, plant species and part eaten. Availability was determined by percentage cover classes.

Three major vegetation zones were identified at Dhawa-Doli. Six study sites were selected across the three vegetation zones.

Blackbuck were primarily grazers in monsoon when crops were beginning to grow and annual plants were abundant. Chinkara and nilgai browsed throughout the study and did not show any preference for monocots in periods of resource abundance (monsoon and postmonsoon).

Food habits of wild ungulates differed more between zones in summer and premonsoon, when resources were limiting and the effect of vegetation zonation on food habits was evident. In monsoon and postmonsoon when resources were abundant, the effect of vegetation zonation was negligible as opportunity for selection increased.

Though dietary similarity was more in terms of plant species eaten between chinkara and goats and between sheep and blackbuck, they differed greatly in proportion of utilization. Greater overlap between chinkara and blackbuck during premonsoon suggest a possible temporary interspecific

competition. In scrublands, dietary overlap was more between species with similar feeding strategies (goat & chinkara - sheep & blackbuck) and was less between species with dissimilar feeding strategies.

Nilgai was spatially separated in summer and premonsoon and showed a seasonal spatial overlap with chinkara and blackbuck at Dhawa-Doli during crop season. While blackbuck and nilgai exhibited a spatial divergence in response to temporal and spatial availability of food resources, chinkara was largely sedentary.

Though utilization of different habitat subunits (crop fields, cultivated fields and scrublands) were largely determined by the amount of disturbance, chinkara showed a random utilization of these subunits. Blackbuck showed a slight avoidance for crop fields, at least at day time, eventhough they consumed more crops than chinkara.

Mean feeding height for domestic ungulates decreased towards postmonsoon as they spent more time feeding on annuals. However the mean feeding height for wild ungulates increased in response to the growth form of plants. The difference in utilization of different foraging strata was more evident between browsers and more similar between grazers.

Broadly, this study suggests that dietary differences among all species were more important than spatial differences, in food resource partitioning.

CHAPTER.I.

INTRODUCTION

One of the basic principles of ecological theory is that sympatric species with identical ecological requirements cannot coexist. This so called Gause's principle has been subjected to much controversy over years questioning the validity of the concept (Hardin, 1960 : Pianka, 1976). It would also be difficult to prove or disprove the theory simply based on exclusion or coexistence of two species having the same ecological characteristics (Hardin, 1960). In cases of coexistence there must be some factor (or a combination of factors) which prevent them from effectively competing and allowing coexistence.

In Rajasthan desert, the Indian gazelle (Gazella benneti Sykes), blackbuck (Antilope cervicapra, Linnaeus) and nilgai (Boselaphus tragocamelus, Pallas) are broadly sympatric. The ecological relationship among these species of bovids to determine how they differ in their habitat use and food habits has not been documented in detail. A search of the available literature gave insufficient data to show how these desert ungulates differed in resource utilization. The only published literature pertaining to this aspect of resource partitioning between wild and domestic ungulates of the Rajasthan desert (by Ghosh et.al. 1987) was more of a preliminary approach to the subject, to the extent that

little was quantified to determine preferred and principal food plants of chinkara and blackbuck. Moreover, aspects like dietary overlap and diet diversity were not well defined. Hence, one of the main objectives of this study was to add to the meagre knowledge of the food habits of these bovids but more particularly to determine how these three bovids differ in their food habits and avoid competition. Aspects like gut volume, mouth morphology, stomach morphology and digestive rate - which govern the food selectivity and foraging behaviour were not considered here as it was beyond the scope of this 6 months study.

A detailed review at the available literature on these three species of wild ungulates revealed that the food habits of blackbuck has been comparatively well studied (Schaller, 1967 ; Prasad, 1982 ; Mungal, 1982 ; Goyal et.al., 1988 ; Chattopadyay and Battacharya, 1986 ; Ghosh et.al., 1987). All these authors agree that the blackbuck is primarily a grazer. Studies done on food habits of nilgai in its native distribution (Schaller, 1967 ; Berwick, 1974 ; Mirza & Khan, 1975 ; Dinerstein, 1979) reveal that they are browsers. However they are reported to be grazers in Texas (Sheffied et.al., 1983). Chinkara has been the least studied of all and only recently some pioneer study on their ecology (ecophysiology and resource partitioning) by Ghosh et al (1987) in the Rajasthan desert has revealed some aspects of their food habits. They report that chinkara is a browser like goats. Most of these studies only name the plant species eaten, rather than the proportion of dicots and monocots in their diet.

Moreover, these studies do not reflect a specific situation where these three bovids coexist in a similar vegetation type where there are no topographical barriers to their dispersal.

Dhawa-Doli and Janwar-Doli are places where three species of wild ungulates and six species of domestic ungulates coexist. The study had to be carried out in these two areas based on the distribution and density of these wild ungulates, particularly because of nilgai which was restricted to localities with irrigated crops in summer.

Livestock outnumbered wild ungulates (approximately 15 times more) in these study areas. Since it may not be a meaningful interpretation if the role played by these livestock in resource partitioning is not considered, their food habits were also studied whenever their presence was felt in the different study sites.

Emphasis on food habits was placed during summer and premonsoon when food resources were most limiting and animals were confined to their natural food plants, and the effect of competition was expected to be greatest. Food items were considered to increase as resource availability decreases (Shoener, 1971 ; Pianka, 1976) during these periods.

The prime aim of this study was to determine the factors which prevent them from competing for food resources. Under this broad aspect of food resource partitioning, following were the specific objectives to arrive at the factors determining their coexistence.

- 1) Principal and preferred food plants of the three wild and four domestic ungulates.
- 2) Temporal variations in diet selectivity, dietary overlap and diet diversity - as possible measures for determining the extent of competition.
- 3) Diurnal change in feeding pattern during crop-season.
- 4) Difference in dietary composition in a season between zones and between sites within zones to determine spatial difference in selectivity.
- 5) Spatial aspects of food resource partitioning between species with similar dietary requirements.

CHAPTER.II. STUDY AREAS

The study needed two study areas in order to cover the three species of wild ungulates. Since Dhawa-Doli had no resident population of nilgai, an additional study area Janwar-Doli had to be considered.

In 1976, under the Govt of Rajasthan notification, an area of 424.76 sq.km area consisting of 21 villages was declared as closed area for a period of 10 years. This has been further extended by 10 years by the government notification issued in 1988. These villages are 14 of Jodhpur district including Dhawa and 7 villages of Barmer district including Doli. Looking at the distribution of these villages on the map, it could be seen that this was primarily aimed to protect blackbuck and chinkara. This is evident from the fact that while the antelope study area Dhawa-Doli is located within the limits of this closed area, the nilgai study area Janwar-Doli falls outside these limits (map. 1).

1. LOCATION AND DESCRIPTION OF THE STUDY AREAS:

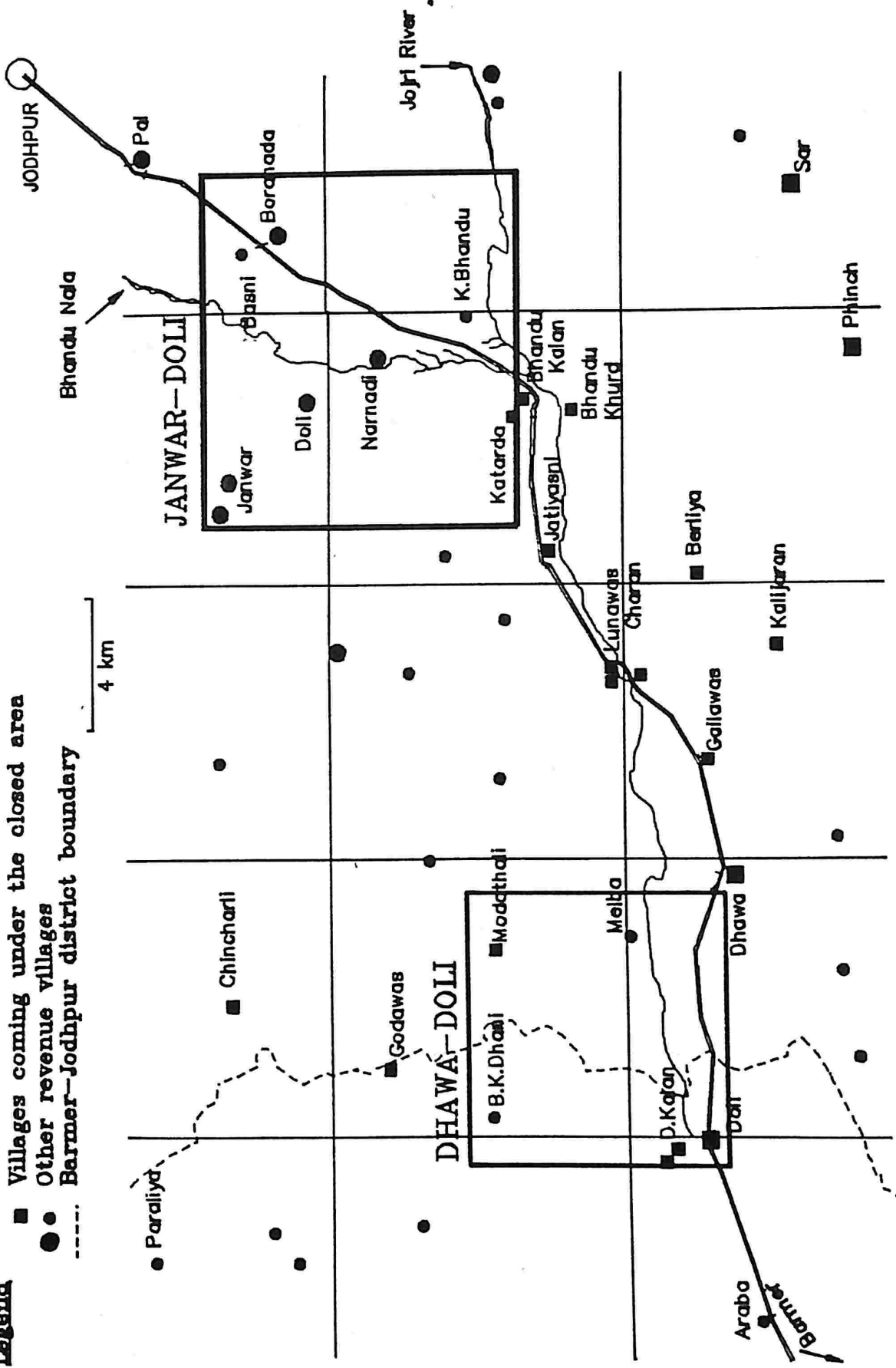
DHAWA-DOLI, STUDY AREA FOR BLACKBUCK AND CHINKARA :

The western study area Dhawa-Doli ($26^{\circ} 03' N$ to $26^{\circ} 08' N$ and $72^{\circ} 39' E$ to $72^{\circ} 44' E$) is situated 41 km to the southwest of Jodhpur (see Map.2a). It is located to the north of the Jodhpur-Barmer highway with an area of 57.8 sq.km. consisting of 2 main villages (Doli and Melba) and four minor villages (Modathali,

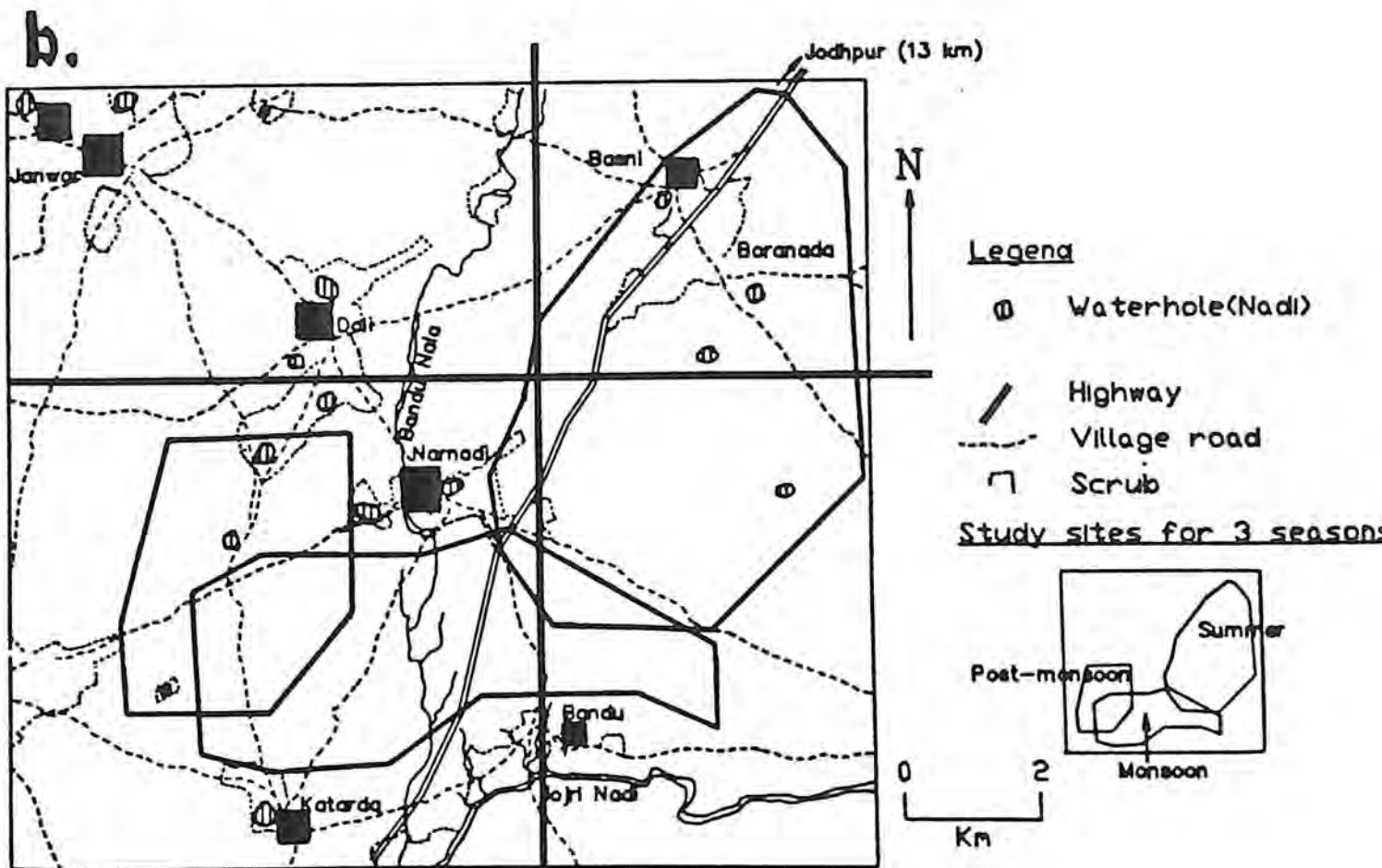
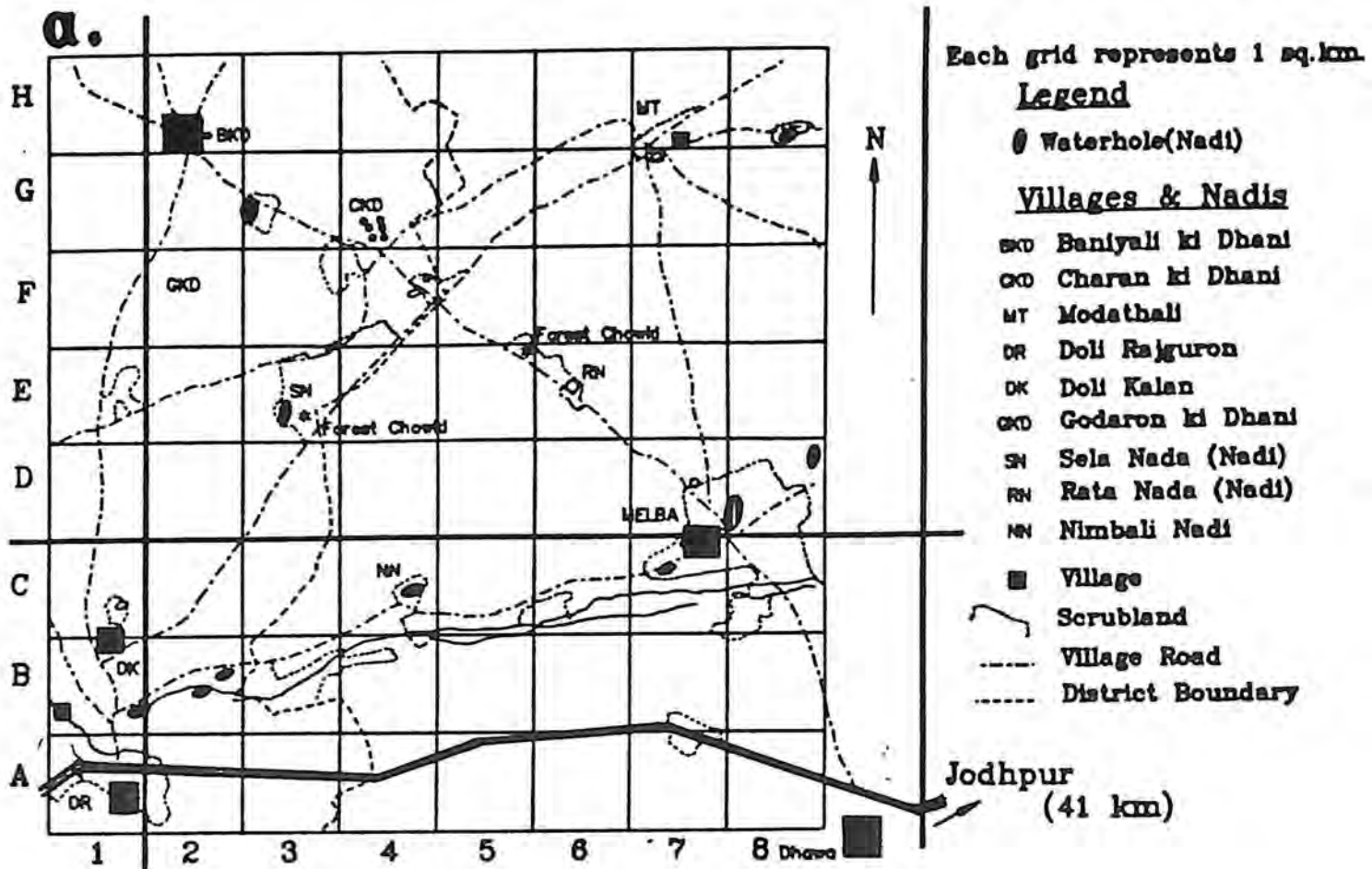
Legend

- Villages coming under the closed area
- Other revenue villages
- - - - Barmer-Jodhpur district boundary

4 km



MAP 1..... LOCATION OF THE TWO STUDY AREAS



MAP : 2.

(a) STUDY AREA FOR CHINKARA AND BLACKBUCK : DHAWA-DOLI

(b) STUDY AREA FOR NILGAI : JANWAR-DOLI

Charan ki Dhani, Godaron ki Dhani and & Baniyali ki Dhani). Approximately only 10 % of the area remain as scrubland and the remaining area is cultivable. The Barmer-Jodhpur district boundary bisects the study area into western and eastern halves, Doli coming under the Barmer district administration and Melba coming under the Jodhpur district administration. The Jojri river which runs through the Nilgai study area all along the highway, enters the antelope study area and ends in a Nadi (waterhole) close to Doli.

JANWAR-DOLI, STUDY AREA FOR NILGAI :

Janwar-Doli ($26^{\circ} 07' N$ to $26^{\circ} 12' N$ and $73^{\circ} 51'$ to $73^{\circ} 57' E$) is situated 15 km to the southwest of Jodhpur and 15km to the east of the antelope study area (see map.2b). The Bandu nulla (of Golasni river) which runs through the area joins the Jojri river near Bandu village. Out of the 110 sq km total area, only 41 sq.km was involved in the study since preliminary detailed vegetation and animal distribution survey was not done. As in Dhawa-Doli, approximately only 10 % of the area was dense or open scrubs, the remainder being cultivable lands. Boranada, Janwar, Doli, Narnadi, Katarda, Karda-Bandu and Basni are villages in the study area.

2. CLIMATE

Both the study areas fall under the subdesertic zone (Gupta, 1976) which includes areas with an annual rainfall between 200 to

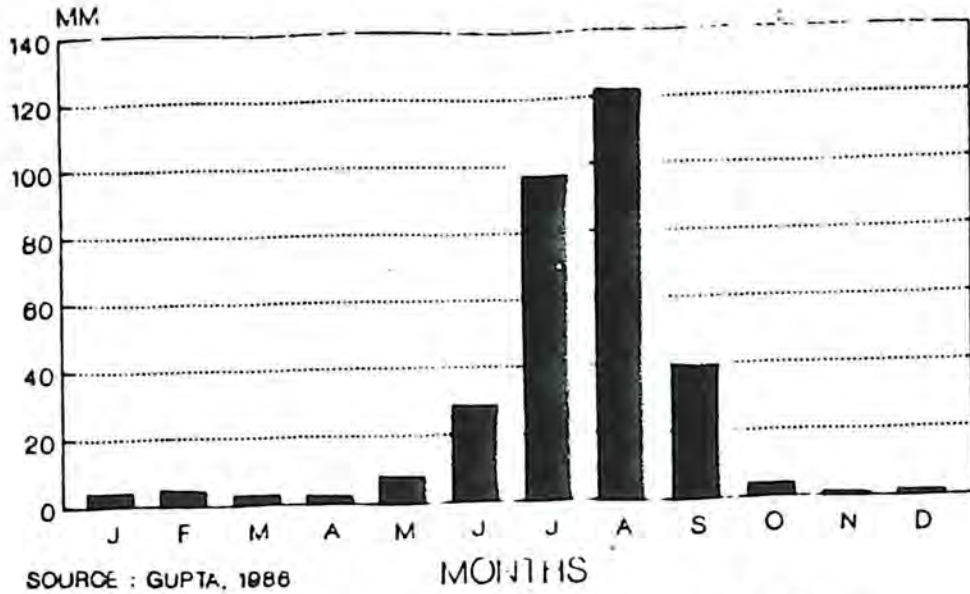
400 mm. The rainfall is very erratic, as happened this year, occurring mainly from the end of June to August end, with sporadic heavy showers in between. The bulk of the rainfall was recorded in July and August. Since no rain-gauge was available for the study, data was collected based on the intensity and duration of precipitation. This was later converted into values by rating the intensity and duration so as to compare the mean weekly rainfall of Jodhpur (fig. 1) The rainfall pattern between these two areas look quite similar, except that Dhawa-Doli received an early heavy showers in June, and Jodhpur received a record of more than 6 & 8 mm more than Dhawa-Doli during the last 2 weeks of August.

Temperature during the hot summer reached upto 46° C. The monthly mean minimum and mean maximum temperatures for the six month study period is available for Jodhpur (see table. 1).

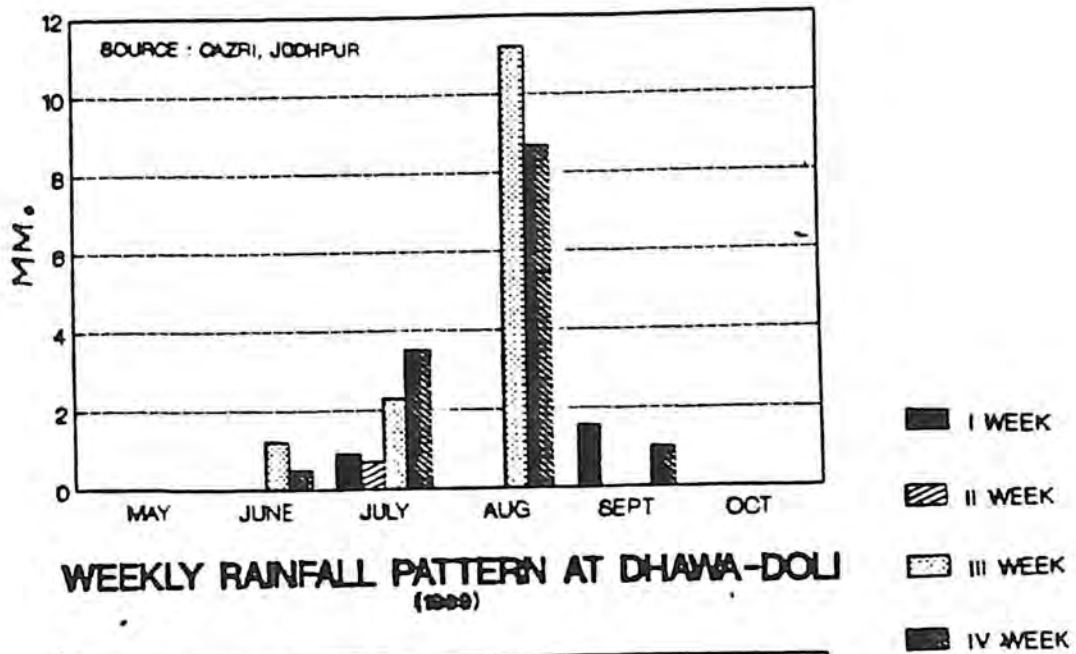
Table : 1. Monthly mean maximum and minimum temperatures for Jodhpur

MONTHS	MEAN MIN	MEAN MAX.
MAY	26.7	42.3
JUNE	27.9	39.3
JULY	26.7	36.6
AUGUST	25.6	34.9
SEPTEMBER	23.7	35.6
OCTOBER	20.6	37.3

MONTHLY RAINFALL PATTERN OF JODHPUR



WEEKLY MEAN RAINFALL AT JODHPUR ('89)



WEEKLY RAINFALL PATTERN AT DHAWA-DOLI (1989)

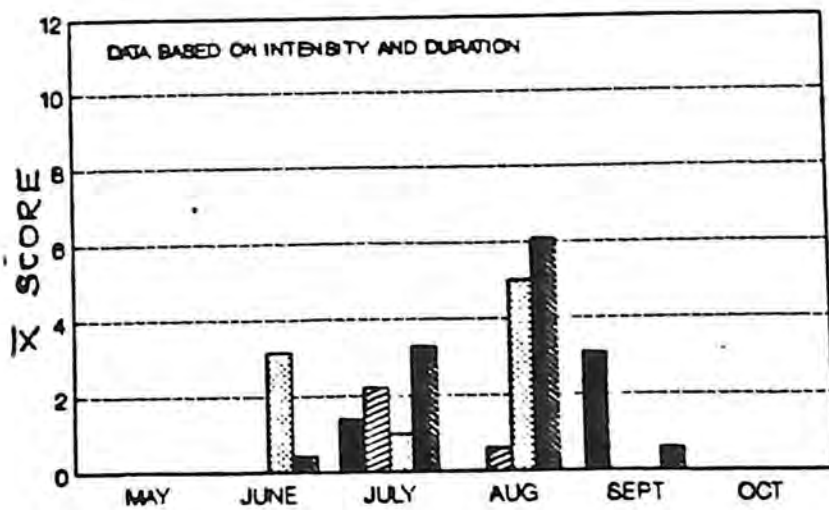


Figure. 1. (a) Annual rainfall pattern for Jodhpur
 (b) Weekly mean rainfall for Jodhpur ('89)
 (c) Weekly rainfall pattern at Dhawa-Doli

3. VEGETATION

Champion and Seth (1968), regarded the vegetation of these areas as Zizyphus scrubs (DS 1) under the sub-group Northern Thorn Forest, owing to the intense biotic pressure on this thorn forest belt.

Of the three series of aridland vegetation (Calligonum series : Prosopis-Salvadora-Capparis-Zizyphus : Acacia-Capparis) formation recognized by the French Institute, the 'Prosopis-Salvadora-Capparia-Zizyphus' series is the one recognized in the these study areas (Puri et al., 1983). Further sub-divisions of this series was based on physiognomy of the vegetation. The subdivision : Scattered shrubs and trees, in cultivated areas seem to fit well for these two study areas.

While this type of vegetation sub-division was based on physiognomy, more detailed studies by Gupta (1976) was based on dominant and sub-dominant species. Under their classification of Sub-desertic zone, out of the 8 plant communities they distinguished, the two following associations were recognized in the study areas.

a) Prosopis-Capparis-Zizyphus

and b) Prosopis-Salvadora

(iv) The report by the Integrated Resource Survey Programme of CAZRI, Jodhpur, identified 14 Major Land Resource Units (MLRU). According to this, MLRU numbers of 1,2,3 & 4 have been assigned to describe the geomorphic features, soil types, water resources and natural vegetation of these two study areas (CAZRI, 1982).

4. PEOPLE :

The two study areas are dominated by a community called Bishnois, who protect wildlife with religious reverence. But for this Bishnois, the blackbuck might have disappeared from the desert scene (Prakash, 1988). Prakash also reports that the Bishnois provide water and grains to the animals during drought and engage people to look after them in remote areas. In Dhawa-Doli, almost every Bishnoi hut located around the inhabitation of the antelopes invariably had an earthen pot with water during summer. Chinkara have been observed to approach these mini-water sources in the late hours of the day. However, the Bishnois were not seen to provide grain or employ people to look after them. The forest department resorted to artificial feeding (a mixture composed of mainly Zizyphus nummularia) for one of the three herds of blackbuck during late summer. Other communities are Patels, Rajputs and Devasis. The main occupation of Devasis is animal husbandry. Bishnois do not keep goats and sheep as they are regarded 'unclean' because of their dioestrous reproductive habits.

5. LIVESTOCK AND WILDLIFE :

These study areas are one of the rare examples where people, livestock and wildlife coexist in an environment where resources are overused by domestic livestock. In spite of the competition for resources, the desert wild ungulates have survived largely because of the Bishnois who have protected them.

Apart from blackbuck, chinkara and nilgai, wild animals commonly seen in these areas are the desert fox (Vulpus vulpus griffithi), desert monitor (Varanus griseus), Kakinto (Agama agilis), grey partridge (Francolinus pondicerianus) and a number of columbiformes. The wolf (Canis lupus) which was earlier seen and photographed (by Krishnan in 1985) at Dhawa-Doli study area seem to be extinct now. Before the turn of this century, there were large herds of blackbuck in 1930 in the Western Rajasthan but their population has dwindled in recent years and they now survive only in pockets and most of them have been protected (Prakash, 1988).

Prakash (1988) reports that there were about 3000 blackbuck at Dhawa-Doli closed area. This information, eventhough it possibly includes the nearest population of blackbuck at Phinch (approximately 20 km from Dhawa), seems to be an exaggeration considering the present population of around 160 blackbuck at Dhawa-Doli alone. The density of chinkara is greater than that of blackbuck at Dhawa-Doli (table 2).

According to the 1987 livestock census for Dhawa and Doli villages, sheep and goats accounted for about 70 % of the total livestock population. This census data was converted into density per sq.km. in order to compare with the density of chinkara, blackbuck and nilgai (see table. 2).

Though cattle, buffalo and camel are resident populations, a sizable proportion of the caprids, particularly sheep are taken

to the neighbouring state Haryana for grazing. The actual proportion of livestock which migrate are not available. They return from Haryana only during monsoon.

TABLE : 2 Comparison of livestock and wildlife density

Note: Livestock data based on 1987 census by revenue department (density calculated for 80 sq.km)
Wildlife data based on census carried out during the study (total number for 57.8 sq. km.)

SPECIES	TOTAL	DENSITY PER per sq.km.
1) SHEEP	4,469	55.9
2) GOAT	3,764	47
3) CATTLE	2,042	25.5
4) BUFFALO	1,543	19.3
5) CAMEL	160	2.0
6) DONKEY	36	0.5
7) CHINKARA	421	7.3
8) BLACKBUCK	approx.160	2.7
8) NILGAI	approx. 33	< 1

It is evident from the table that wildlife has a minor role in overgrazing and overbrowsing. Considering the number of livestock in proportion to wildlife, their food habits were also studied in order to understand their role in food resource partitioning.

CHAPTER.III.

METHODS

More emphasis was given to the Dhawa-Doli study area than Janwar-Doli in studying vegetation since two of the three species (chinkara and blackbuck) inhabited Dhawa-Doli. Though chinkara were occasionally sighted in Janwar-Doli, they were not studied for their food habits.

1.FIELD METHODS

Field methods were designed to quantify the proportion of time animals spend feeding on different plant species and the forage available to them during that period of time.

An initial vegetation survey at Dhawa-Doli was carried out by walking along 1 km North-South grid lines to determine the species composition, abundance and distribution of both plants and antelopes. Spatial distribution of chinkara and blackbuck during summer was recorded by mapping the sightings during the vegetation transects to select the study sites.

1-1.STUDY SITES :

Within the 57.8 square kilometre Dhawa-Doli study area, three study sites were identified in the beginning to represent the different vegetation types. The selection of these study sites within the vegetation types was based on the distribution of blackbuck. Food habit studies were done as far as possible in the

same site every season (Summer-SUM, Premonsoon -PMO, Monsoon-MON and Postmonsoon-POM) but three new study sites were later added according to the movement pattern of blackbuck. The table given below (table. 3) shows the availability of data in the six study sites of Dhawa-Doli.

Table : 3. Study sites selected at Dhawa-Doli and the availability of data in different seasons.

STUDY SITES	SEASONS							
	SUMMER		PREMONSOON		MONSOON		POSTMONSOON	
	BB	CH	BB	CH	BB	CH	BB	CH
1) MODATHALI		✓				✓		✓
2) SELANADA					✓	✓	✓	✓
3) RATANADA	✓		✓	✓	✓	✓	✓	✓
4) MELBA NORTH					✓		✓	
5) MELBA SOUTH			✓					
6) NIMBALI NADI	✓	✓		✓		✓	✓	✓

LEGEND
 CH Chinkara
 BB Blackbuck
 ✓ Data present

The location of these sites in the study area is shown in Chapter IV when the results of food habits are discussed.

The selection of such study sites for the three seasons at Janwar-Doli (no data during premonsoon) was based on where nilgai

were seen and observed first. In summer, foraging activities of nilgai coincided with the proximity of crop fields with irrigated crops. One such area was Boranada, which was the study site for summer. As crops came up everywhere, these study sites changed for monsoon and post-monsoon. The location of these sites are shown in map 2-b (see Chapter II). The same area was visited again in successive days until a reasonably good number of feeding observations were obtained.

1-2. FOOD HABIT STUDIES

To quantify the proportion of time animals spent feeding on different species of plants, scan sampling- a technique described by Altman (1974) was followed. The activities of randomly selected individuals in a group were recorded using a 8 X 40 binocular, following them for 13 hours from 6.00 AM to 7.00 PM. A two days scan per study site was considered ideal, but whenever the number of feeding observations were less than 100, an extra day was spent to get a record of more than 100 feeding observations.

Other activities classified were scanning, walking, running, standing, lying, social interactions & other activities. These were recorded once in every five minutes according to age and sex classes (Adult male, Adult female, Subadult male & Subadult female and young). Scan sampling was preferred over other methods of quantifying observations not only because the ungulates tolerated human presence (the fleeing distance varied from 50 to 200 metres depending on the species and locality) but also as it

gave more feeding observations per scan than by recording the time spent by an individual animal on every plant species in a day. Feeding individuals were observed for the plant species, the plant part eaten (leaf, shoot, pod, fruit, flower etc.) and the feeding height from the ground level in centimetres. Whenever the plant species eaten could not be recognized from the scanning distance, the feeding locations were noted and later inspected to see which plant was consumed. This need for 'feeding-site' confirmation increased towards monsoon and postmonsoon when annual plant species dominated the ground flora, as these could not be identified from a distance. Related data collected included date, time, zone, site, cloud cover, wind speed, occurrence of rain, foraging vegetation type (open scrub, cultivated field and uncultivated field) and also resting locations (whether resting under shade or in the open). The proportion of time spent in the different habitat subunits (cultivated fields, uncultivated fields and openscrubs) in monsoon and postmonsoon was considered to represent the utilization of any habitat subunit.

Night scan during moonlit nights to determine crop raiding activities was done for nilgai only in summer when most individuals of the area visited the few crop-fields. They were not disturbed when spot-light was used. Even when disturbed on rare occasions, they returned as there were no adjacent cropfields to move into. However, during monsoon and postmonsoon, night scan had to be discontinued because all the three

ungulates got easily disturbed. In monsoon, feeding data on Nilgai was obtained in day time by following their tracks in the fields and elsewhere.

1-3. FORAGE AVAILABILITY :

Forage available to animals was determined by recording percentage ground cover within the reach of the ungulates when they are quadrupedal (less than 1.25 metres for blackbuck, less than 1.0 metre for chinkara and less than 2.5 metres for nilgai). Circular plots of 10 and 20 metre radius were laid at regular intervals along fixed line transects to quantify availability and tree density in localities wherever they were observed feeding. The percent ground cover was quantified in various cover-class intervals of $\leq 0.5\%$, >0.5 to 1% , >1 to 5% , >5 to 10% , >10 to 15% and so on.

The proportion of forbs, grass and sedges (annuals only) available to the animals at every feeding site was quantified during premonsoon, monsoon and postmonsoon by using a 0.5×0.5 metre square or 62 centimetre diameter circular quadrats and recording the percentage frequency of occurrence of F:G:S (FORBS:GRASS:SEDGES). This was later compared with the proportion of these annuals utilized by chinkara and blackbuck. The same method was used to obtain the percentage frequency of occurrence of individual species of herbaceous monocots and dicots.

2. ANALYTICAL METHODS

Data obtained from the field was analysed for

- i) the principal and preferred food items of different species of ungulates and the seasonal variation in utilization - for dietary separation,
- ii) dietary overlap and diversity - as measures of extent of competition among these wild and domestic ungulates,
- & iii) significant correlations (a) between availability and utilization b) between food habits of a species between sites and (c) between two species of ungulates in the same site..... using SPCOVAR.BASIC computer programme for Spearman's Rank Correlation Coefficient test. A non parametric test was preferred since variables like forage availability was obtained by ranking the percentage cover classes.

2-1. FOOD HABITS ANALYSIS :

Percent frequency of time spent feeding on individual plant species was assumed to represent the proportion of those species in the diet at any given period of time. This was calculated from the total number of feeding observations at a study site. The unknown feeding observations, which increased from 1-4 % in summer to 6-13 % in monsoon and post-monsoon were omitted to have a meaningful comparison of any two sets of food habits data. Forage types recognized for analysis were :

- i) Different species of browse. Species that were rare in the environment were clumped into a separate category as 'other browse spp.'
- ii) Grass

- iii) Sedges
- iv) Perennial forbs
- v) Annual forbs
- vi) Fruits and flowers
- vii) Pods
- viii) Coppice shoots
- ix) Cereal crop (bajra)
- x) Pulse crops (mung, guar, moth)
- xi) Oil crop (til)
- xii) Cucumber crops
- xiii) Litter

Coppice shoots of different shrub species was included as a forage class in monsoon as it formed one of the principal food types for animals, particularly chinkara. The tender moisture laden shoots were coppice regrowths sprouting after being cut by people before ploughing the agricultural fields (e.g. Zizyphus nummularia).

2-2. FOOD AVAILABILITY ANALYSIS :

Availability of forage at any particular period of time was determined by assigning ranks for the percentage cover classes as follows

% cover classes	Ranks
<=0.5	1
>0.5 to 1	2
> 1 to 5	3
> 5 to 10	4
>10 to 15	5 etc. etc.

(i) A Cover Index (CI*) was calculated using the formula

$$CI^* \text{ (for cover)} = \frac{\sum r_i}{N}$$

where r_i is the sum of ranks of the species in different sample plots

N is the total number of sample plots

(ii) Relative availability RA of forage was then calculated using the formula

$$\% \text{ RA} = \frac{\sum r_i}{\sum_i R_i} \times 100$$

where r_i is the sum of ranks of the i th species in all sample plots

R_i is the sum of ranks of all species in all sample plots

(iii) Seasonal trend in availability of annuals (forbs, grass and sedges - F:G:S ratio) for chinkara and blackbuck was obtained by calculating the percentage frequency of occurrence of these annuals. Corresponding seasonal variation in utilization by chinkara and blackbuck was obtained from their dietary composition.

2-3. STATISTICAL ANALYSIS :

Statistical analysis included analysis of dietary preference, dietary overlap, diet diversity and correlation tests between availability and utilization, between food habits of two species and between food habits of the same species at different sites.

(i) Several authors have proposed different electivity indices and statistical tests to compare availability and utilization for evaluating resource preference (Ilvev, 1961 ; Jacobs, 1974 ; Vanderploeg and Scavia, 1979b (in Lwchowicz, 1982) ; Johnson, 1980) and several authors have critically reviewed these indices (Cock, 1978 ; Johnson, 1980 ; Lechowicz, 1982). Lechowicz (1982) made a comparative graphical study of linearity and symmetry of the values of these indices. He suggested that Vanderploeg & Scavia's Electivity Index is the single though not the perfect electivity index. To make a meaningful comparison of food preference in different study sites, this electivity index was used. This index ranges from -1.....0.....+1, a value below 0 indicating avoidance, values above 0 indicating preference and a 0 value indicating random feeding.

The index is arrived at, using the formula,

$$\text{Electivity Index } E_i^* = \frac{(W_i - 1/n)}{(W_i + 1/n)}$$

where : W_i is the Electivity Coefficient, an earlier version of the formula by the same authors

$$\text{Electivity Coefficient } W_i = \frac{R_i / P_i}{\sum_i R_i / P_i}$$

where : R_i is the percentage of a species in the diet
 P_i is the percentage of that species available to the animal.

(ii) Ecologists have developed various indices that measure the degree of overlap between two sets of variables and most of them are based on relative usage of resources without taking into account corresponding relative availabilities (Ludwig and Reynolds, 1988). It cannot also be assumed that resources are equally available in the environment. Moreover, what is available may not be of interest to the consumer. Considering these limitations, the measure of overlap developed by Petraitis (1979) is used here which is based on the likelihood that the resource utilization by one species is identical to that of another. His overlap measure, by taking into account the resource breadth of the two species concerned, gives two values of indices - one value for overlap of species 1 into 2 and the other value for overlap of species 2 into 1. This specific dietary overlap between various species of this study was calculated using the computer programme SPOVRLAP.BASIC which involves the formula

$$S O (1,2) = e^{E_{1,2}}$$

(Specific overlap of
species 1 into 2)

$$\text{where } E_{1,2} = \sum_j^r (P_{1j} \ln P_{2j}) - \sum_j^r (P_{1j} \ln P_{1j})$$

and $S O (2,1) = e^{E_{2,1}}$

(Specific overlap
of spp. 2 into 1)

$$\text{where } E_{2,1} = \sum_j^r (P_{2j} \ln P_{1j}) - \sum_j^r (P_{2j} \ln P_{2j})$$

where P_1, P_2 are proportions of the i th component in species 1 and species 2

r is the number of resource types

j represents the j th resource.

The Index (SO) ranges from 0 to 1, lower values indicating a lesser degree of overlap and a higher value meaning a higher degree of overlap. The limitation in interpreting the result of this value is overcome here in this study because the values are compared for seven species of ungulates (camel, nilgai, cattle, blackbuck, goat, sheep and chinkara).

(iii) Since diet diversity involves both the total number of food species and their relative abundance, diversity indices were considered to be a determinant factor in this resource partitioning study. The units of various diversity indices used in ecological studies differ greatly, making comparisons difficult and confusing which adds to the interpretation problem (Ludwig and Reynolds, 1988). The Shannon Index (H') has been used here, the value ranging from 0 to 1. This value increases as the number of species increase and as the relative abundance among species become even. The diversity indices were computed using the computer programme SPDIVERS.BASIC which is based on the formula

$$H' = - \sum_{i=1}^s \left[\left(\frac{n_i}{n} \right) \ln \left(\frac{n_i}{n} \right) \right]$$

where n_i is the abundance of the i th food resource
in the sample

n is the total abundance of all food
components in the sample.

s is the number of species in the sample.

(iv) The covariation in abundance between availability and utilization, between food habits of two species at a given place and between food habits of the same species in different sites were assessed by ranking the percentage frequencies of dietary components and computing the non parametric test of Spearman's Rank Correlation Coefficient (R_s). This was done to test

- a. if two species agreed significantly in percentage time spent feeding on individual plant species in the same site.
- b. if there is any significant correlation in percentage time spent on individual dietary component at different study sites by the same species.
- c. if there is any significant correlation between percentage available food plants and percentage of these components in the diet of any given species.

CHAPTER. IV. RESULTS

This chapter comprises of five sections dealing with the following results.

Section A with the vegetation of the study areas.

Section B deals with the comparative food habits of the wild ungulates.

Section C with the similarity between diets of wild and domestic ungulates

Section Dwith the seasonal dietary preference, overlap and diversity.

Section Ewith the Spatial aspects of food resource partitioning.

Section - 1. VEGETATION

Very little of the vegetation in Dhawa-Doli and Janwar-Doli areas can be considered 'natural' as most sites have been subjected to cultivation by man. This has resulted in changed community structure and composition, particularly in the ground flora. The presence of exotic tree species like Prosopis juliflora around villages and Acacia tortillis plantations further support the role of man altering the native vegetation.

1-1. TREES, SHRUBS AND PERENNIAL HERBS

The dominant tree species is Prosopis cineraria associating with

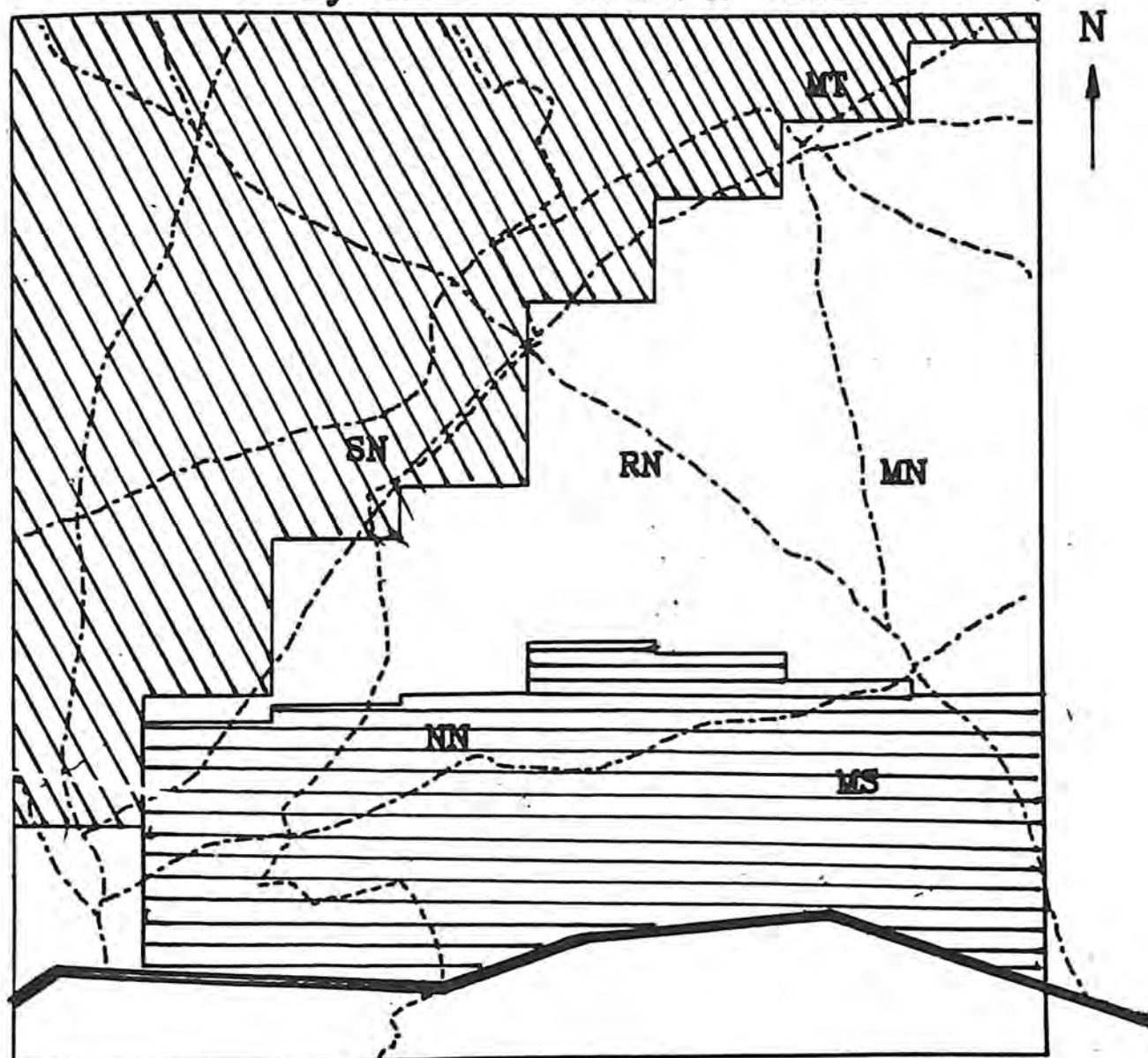
Salvadora oleoides, Maytenus emarginata, Acacia nilotica, Capparis decidua, Tecomella undulata etc. Zizyphus nummularia, one of the major species in the shrub level, was reduced to clump form in summer due to cutting and overbrowsing. Another species with a similar growth form, Crotalaria burhia which dominated in the dunes, was browsed throughout the study period. From this it is clear that the present day vegetation largely corresponds to the landuse pattern apart from the landforms.

From the initial vegetation survey at Dhawa-Doli based on distribution of dominant and sub-dominant trees in the 57.8 square kilometer area, the following vegetation zones were recognized.

VEGETATION ZONES	MAJOR TREE SPECIES
I. The North-Western Maytenus Zone (MZ)	<u>Prosopis cineraria</u> & <u>Maytenus emarginata</u>
2. The Middle Prosopis Zone (PZ)	<u>Prosopis cineraria</u>
3. The Southern Salvadora Zone (SZ)	<u>Prosopis cineraria</u> & <u>Salvadora oleoides</u>

These three vegetation zones differed not only in vegetation composition but also in geomorphic and edaphic features. The Maytenus zone was more dunal than other vegetation zones. The Prosopis zone was a flat plain with hardpan soil. Dunes were rare. The Salvadora zone was the river belt of Jojri river and hence more shallower. The soil here possibly has a high moisture retention capacity as small pools of stagnant water was seen even in postmonsoon.

Study Area : DHAWA-DOLI



- MAYTENUS ZONE
- PROSOPIS ZONE
- SALVADORA ZONE

Name of Study Sites

- MT Modathali
- SN Sela Nada
- RN Rata Nada
- MN Melba North
- NN Nimbali Nadi
- MS Melba South

Map. 3 : The three vegetation zones and the six study sites involved in Dhawa-Doli.

Maytenus Zone constituted 41 % (24 sq.km) of the area. Prosopis Zone constituted 33 % (19 sq.km) of the area. Salvadora Zone constituted 26% (14.8 ,,) of the area.

The difference in tree density and shrub cover index is shown in table 4. Apart from these three vegetation zones of Dhawa-Doli, also shown in the table are that of Boranada (Nilgai study site in summer) and a fenced crop field where biotic pressure on plants by domestic herbivores was less.

For tree density, the irrigated crop field had 29 trees per hectare, followed by the *Salvadora* zone with 12.6 trees per hectare and the least in the *Prosopis* zone with only 1.4 trees per hectare. The *Prosopis* trees in the irrigated crop fields were not lopped and thus had more pods below their canopy (in summer) than trees outside these irrigated fields.

Apart from tree layer, the three zones differed in perennial shrub and herb composition. The cover values of seven important species of shrubs and herbs (*Prosopis cineraria*, *Crotalaria burhia*, *Capparis decidua*, *Zizyphus nummularia*, *Fagonia cretica*, *Aerva persica* and *Tephrosia purpurea*) showed how these three zones differed (table : 4). The cover indices of these species show that *C. burhia* and *A. persica* dominated the Maytenus zone. One of the rare species in this zone, apart from those in the scrublands, was *C. decidua*. The characteristic species of the middle *Prosopis* zone was *T. purpurea*, even though *F. cretica* and *C. burhia* were more in terms of ground cover. In the *Salvadora* zone, the overall ground cover was less than that of other vegetation zones. Except for *P. cineraria* and *C. burhia*, all other species had a cover index of less than 1 (an Index of 1 is equal to < 0.5 % ground cover).

TABLE : 4. The difference in tree density and cover index values for the seven important species of perennials.

COMMUNITY	SPECIES	VEGETATION ZONES			BORA NADA	CROP FIELD
		MZ	PZ	SZ		
(summer)						
A. TREE SPECIES (Density per hect.)	<u>P. cineraria</u>	7.9	2.2	7.6	8.5	10.6
	<u>A. nilotica</u>	+	0.2	1.2	+	1.5
	<u>A. torillis</u>	A	0.1	A	A	3.5
	<u>T. undulata</u>	+	+	0.2	0.4	5.5
	<u>S. oleoides</u>	+	+	3.6	A	A
	<u>M. emarginata</u>	1.3	+	+	+	+
Other species: <u>Prosopis juliflora</u> , <u>Salvadora persica</u> , <u>Balanites aegyptiaca</u> , <u>Cordia myxa</u> , <u>Azherdirecta indica</u> and <u>Zizyphus nummularia</u> are other trees species rarely seen. (Total density = 1.2')						
B. Perennial shrubs herbs. (cover index)	<u>P. cineraria</u>	1.6	1.6	1.1	0.4	Only 0.15 was the CI for all these species combined. Crops and green herbaceous dicots & monocots were predominant.
	<u>C. burhia</u>	4.9	2.5	1.0	0.8	
	<u>C. decidua</u>	+	0.7	0.7	0.7	
	<u>Z. nummularia</u>	1.2	1.8	0.5	0.8	
	<u>F. cretica</u>	0.6	3.3	0.8	0.6	
	<u>A. persica</u>	1.1	+	0.1	+	
<u>T. purpurea</u>	0.1	1.6	0.2	1.0		
Legend		Cover Index			% cover	
+ present		1	=	< 0.5	%	
		2	=	> 0.5	to 1 %	
		3	=	> 1.0	to 5 %	
A absent		4	=	> 5.0	to 10%	

1-2. HERBACEOUS MONOCOTS AND DICOTS :

In summer, dry Aristida spp was the most abundant grass at Boranada (of Janwar-Doli) and in the Maytenus zone of Dhawa-Doli. It was rare or almost absent in the other zones. This possibly reflects the similar sandy type of soil in the two sites. Both these sites have been classified under the same Major Land Resource unit (MLRU) (refer section 3 in Chapter II).

After early monsoon showers in the month of June, Sedges (Cyperus rotundus) dominated among the annuals. In the following months - July, August and September - forbs and grasses were the dominant annuals. The trend in relative abundance of forbs, grass and sedges is shown in fig :2 a. Grass dominated for a brief period in monsoon, but forbs dominated others during the months of September and October. Twenty species of grass and two species of sedges were recorded at Dhawa-Doli. The species common in different vegetation zones are listed below.

- (i) Cenchrus biflorus, Brachiaria ramosa and Aristida mutabilis at Narnadi (monsoon study site for Nilgai).
- (ii) Cenchrus biflorus and Aristida spp. in the Maytenus zone at Dhawa Doli.
- (iii) Eragrostis ciliaris, Tragus biflorus and Dactyloctenium spp. in the Prosopis zone.
- (iv) Cenchrus biflorus, Dactyloctenium spp in the Salvadoria zone.

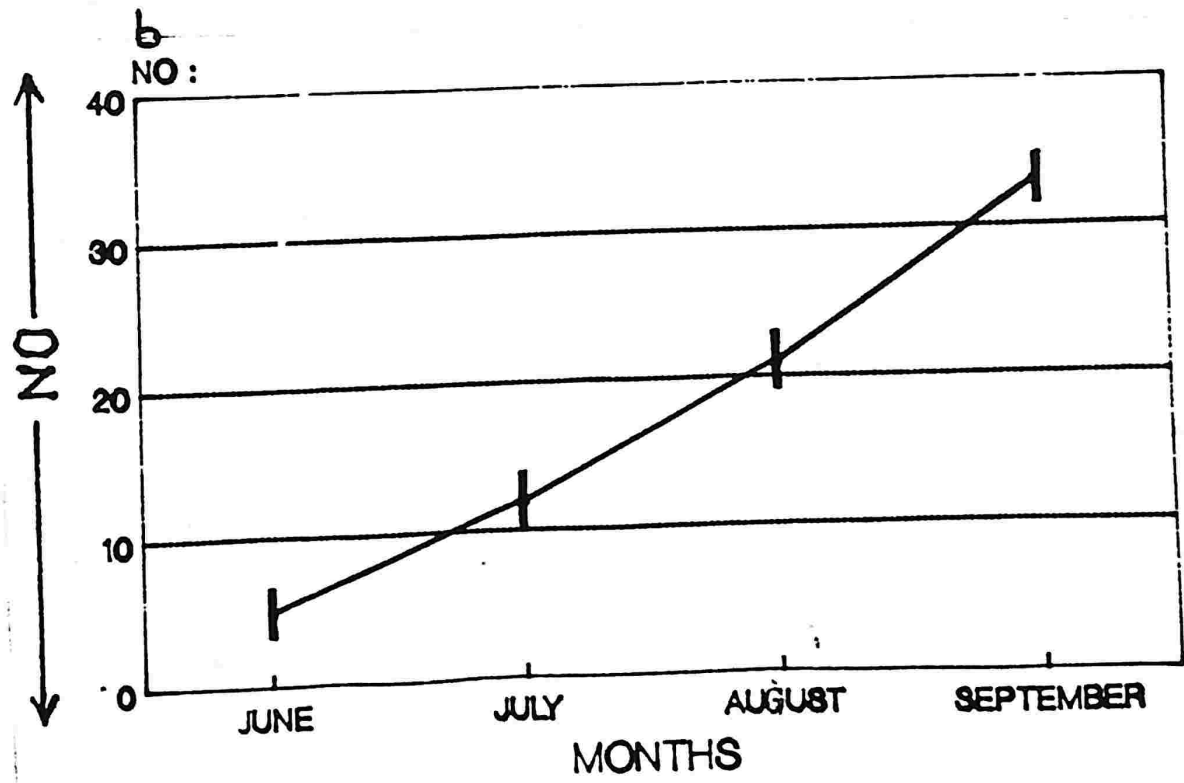
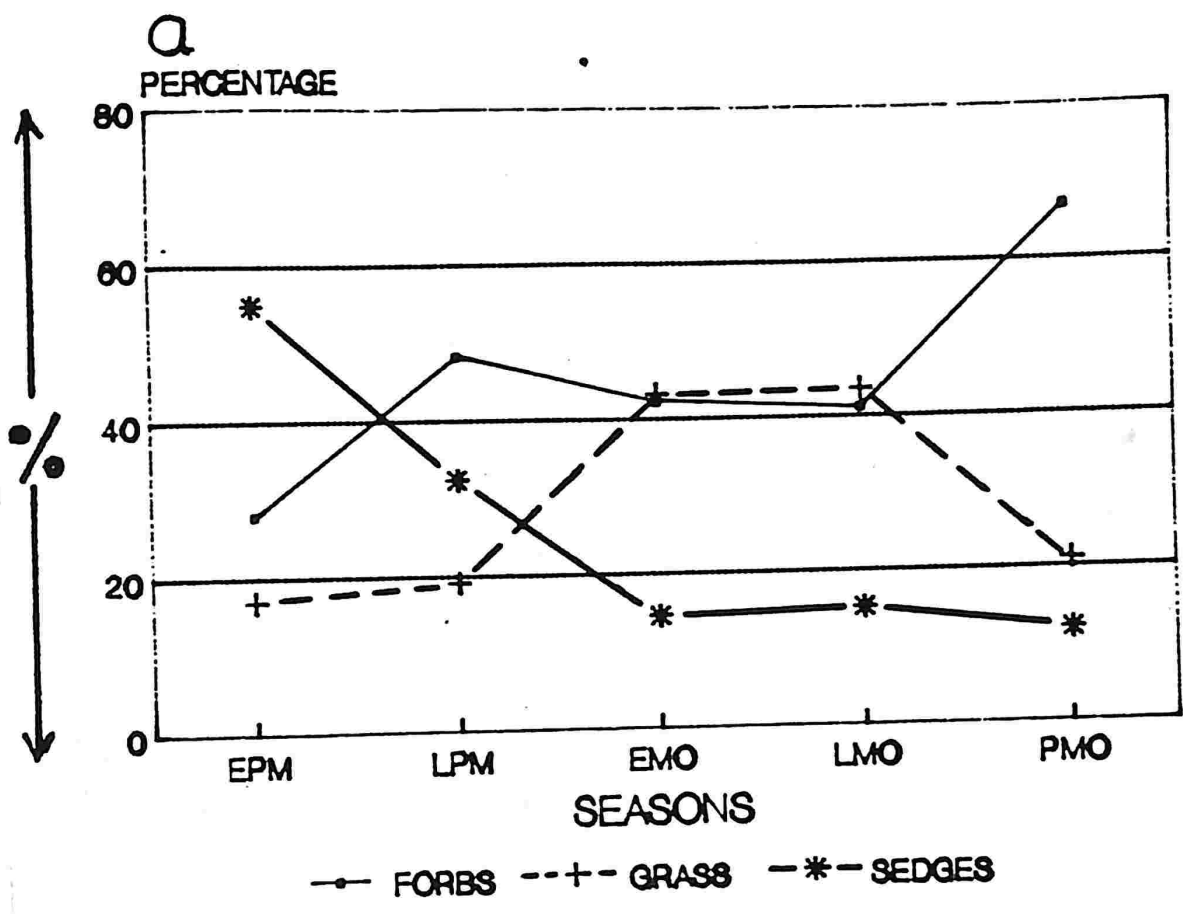


FIG : 2. The figure 'a' (above) shows the seasonal pattern in proportion of availability of annuals. The figure 'b' (below) shows the cumulative number of annual dicot species recorded during the course of 4 months.

Legend
 EPM-Early premonsoon
 LPM-Late premonsoon
 EMO-Early monsoon
 POM-Post monsoon

Among the two species of sedges, Cyperus rotundus was distributed throughout in all the study sites. The other genus Fimbristylis spp. was characteristic of the Maytenus zone. Other grass species, apart from the common ones were....

Eleusine indicum, E. indica & E. compressa

Dactyloctenium indicum & D. aegypticum

Cenchrus setigerus & C. ciliaris

Eragrostis poaoides & E. tenella

Panicum turgidum

Digitaria marginata and

Lasiurus indicus

As monsoon progressed from June onwards to September, new species of forbs appeared. The cumulative number of species of annual dicots recorded during the course of four months (June to September) is shown in figure 2 b. The time between emergence and flowering was very brief, possibly an adaptation to this environment of erratic rainfall. The seasonal availability of major forage types based on the phenology is shown in figure 3 a.

The percentage frequency of occurrence of 20 common species of annual dicots and 8 common species of monocots in six different locations at Dhawa-Doli is shown in table 5. Though there is a general agreement among the monocot composition, all the six different locations showed a marked difference in overall species composition. Because of this difference from one field to another within a study site, availability data on individual forb species to determine preference could not be collected for most of the study sites.

Table.5. Percentage frequency of occurrence of dicots & monocots

SPECIES	1	2	3	4	5	6
MONOCOTS						
<u>Aristida mutabilis</u>	35	0	2	2.5	50	3.6
<u>Tragus biflorus</u>	1.5	32.3	96	1.3	2.5	0
<u>Eragrostis ciliaris</u>	0.5	5.4	8	57	67.5	73.2
<u>Eragrostis (other sp)</u>	9.5	15.4	30	32.9	32.5	16.1
<u>Dactyloctenium spp.</u>	6	27.7	0	11.4	7.5	1.8
<u>Cenchrus spp.</u>	70	0	0	11.4	10	3.6
<u>Brachiaria spp.</u>	3	0	0	1.3	2.5	1.8
<u>Cyperus spp.</u>	31	5.4	0	5.1	10	0
DICOTS						
<u>Boerhavia diffusa</u>	3.5	29.3	4	2.5	2.5	0
<u>Borreria hispida</u>	20	0	0	0	0	0
<u>Convolvulus arvensis</u>	0	0	0	12.7	0	3.6
<u>C. microphyllus</u>	27	8.5	12	78.5	52.5	28.6
<u>Corchorus depressus</u>	0	70.8	90	26.6	27.5	8.9
<u>C. tridens</u>	55.5	2.3	6	53.2	82.5	73.2
<u>Cleome viscosa</u>	2.5	0.8	24	29.1	32.5	85.7
<u>Digera muricata</u>	5.5	8.5	2	60.8	30	64.3
<u>Euphorbia granulata</u>	25.5	29.2	88	51.9	52.5	71.4
<u>Farsetia hamiltonii</u>	26	7.7	8	24.1	35	35.7
<u>Gisekia pharnaceoides</u>	3	3.1	0	8.9	0	3.6
<u>Heliotropium subulatum</u>	3	0	0	5.1	15	3.6
<u>H. strigosum</u>	12	38.5	76	16.5	27.5	14.3
<u>Indigofera cordifolia</u>	87	33.1	58	7.6	70	12.5
<u>I. anabaptista</u>	66	16.2	38	19	50	14.3
<u>I. linifolia</u>	11	0.8	0	0	0	0
<u>Oldenlandia aspera</u>	1	0	0	13.9	0	21.4
<u>Phyllanthus niruri</u>	21.5	0	4	64.6	32.5	93
<u>Pulicaria angustifolia</u>	2.5	0.8	6	21.5	22.5	50
<u>Tribulus terrestris</u>	7	0.8	0	0	2.5	0

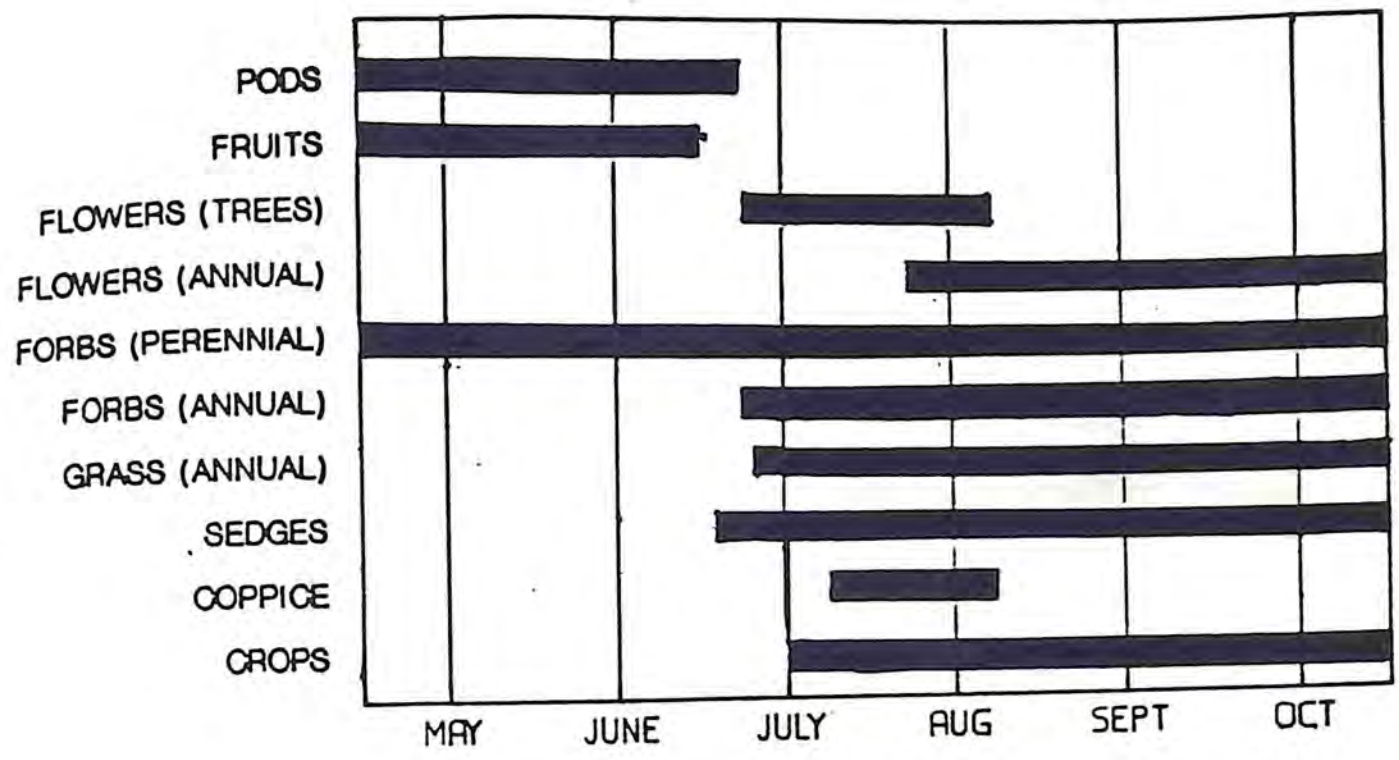


Figure. 3.a. Seasonal availability of major forage types at Dhawa-Doli.

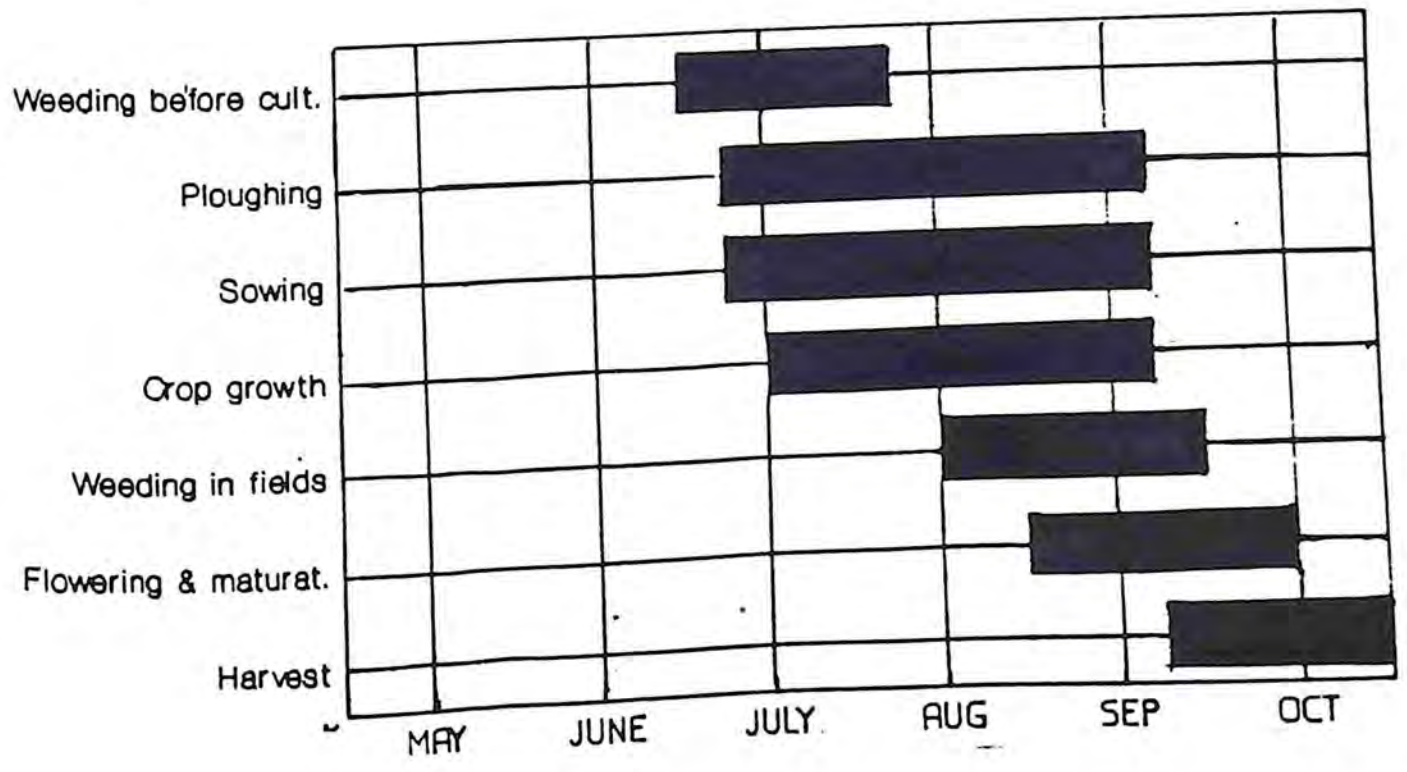


Figure. 3.b. Calendar showing the major agricultural practices at Dhawa-Doli.

1-3.EFFECT OF AGRICULTURAL AND ANIMAL HUSBANDRY PRACTICES IN ALTERING THE VEGETATION COMPOSITION

From wildlife point of view, some of the yearly agricultural practices of farmers and shepherds alter the resource availability in different seasons.

i) SUMMER

One of the main important plants of economic importance to people is Khejri (Prosopis cineraria), a leguminous tree, often described as the King tree of Rajasthan because of its value as fodder (called 'loong') for livestock. In places where rosopis cineraria shrubs are rare, these trees are lopped to satisfy the fodder demands of goats, sheep and cattle.

This lopping possibly considerably decreases the productivity of pods in late summer as it forms an important part of the diet of wild ungulates. Also blackbuck and chinkara have been seen feeding on the leaves of lopped trees. Both green and mature pods were collected by people as food for them, which might further reduce the availability of pods for wildlife. Pods are also sought after by domestic ungulates.

Throughout summer, people collected Salvadora oleoides fruits (both fallen fruits as well as directly from trees) as food for them as well for goats and sheep. Like fallen pods, these fruits were also sought after by livestock.

ii) PREMONSOON

The first good showers towards the end of June mark the beginning of agricultural operations. Fig. 3 b shows the major agricultural practices of people at Dhawa-Doli during the study period. Shrubs like P. cineraria, C. decidua, C. burhia, B.aegyptiaca and even Z.nummularia are removed before ploughing. Only those shrubs with a woody stem are left. Removal of these important food plants alter the availability to wild ungulates, forcing them to feed on alternative food resources (see Section 2 for detail). The coppice shoots of such cut plants form an important forage type for chinkara in monsoon.

iii) MONSOON

Vegetation composition inside and outside openscrubs differed markedly. Opposed to the hard ground surface in the scrublands, the soil outside is loose and soft as it is subjected to ploughing every year. In terms of species diversity, cultivable lands supported more species than openscrubs. Species like Tephrosia purpurea and Aerva pseudotomentosa, which are generally considered of low forage value (only camels prefer T.purpurea) dominated the scrublands. C. burhia, an important food plant during summer, was almost absent in the scrubs. P. cineraria, an important browse plant for chinkara, nilgai and domestic ungulates in summer, was rare in the scrublands.

iv) POST-MONSOON

Harvest of crops like Pennisetum, Sesamum, Vigna etc result in a

sudden change in the overall availability to animals, during which time species like nilgai switch over to the crop residues of the family Cucurbitaceae.

v) WINTER

During November and December, Z. nummularia shrubs are cut before the leaves fall and are stored for summer use. The effect of this sudden depletion of these shrubs on the food habits of these ungulates needs to be studied. However, in peak summer (May to June), only the clump-forms of Z. nummularia (those that coppice after being cut in November and December) bear leaves whereas all these shrub-forms become deciduous, possibly towards the end of winter.

SECTION : 2. DIETARY COMPOSITION OF WILD UNGULATES

This section deals with the dietary composition of wild ungulates in different seasons (summer, premonsoon, monsoon and postmonsoon). The study sites involved in different seasons is shown diagrammatically in the season-wise description of food habits. The seasonal trend in utilization of annuals in response to corresponding availability is dealt separately at the end of this section. Diet selectivity, dietary overlap, and diversity will be dealt separately in section 3.

The preference values for different dietary items are given in table 6. Throughout the study (in all feeding sites), there was no significant correlation between blackbuck and chinkara in percentage time spent feeding on different plant species.

2-(1). FOOD HABITS BY FORAGE TYPES :

SUMMER

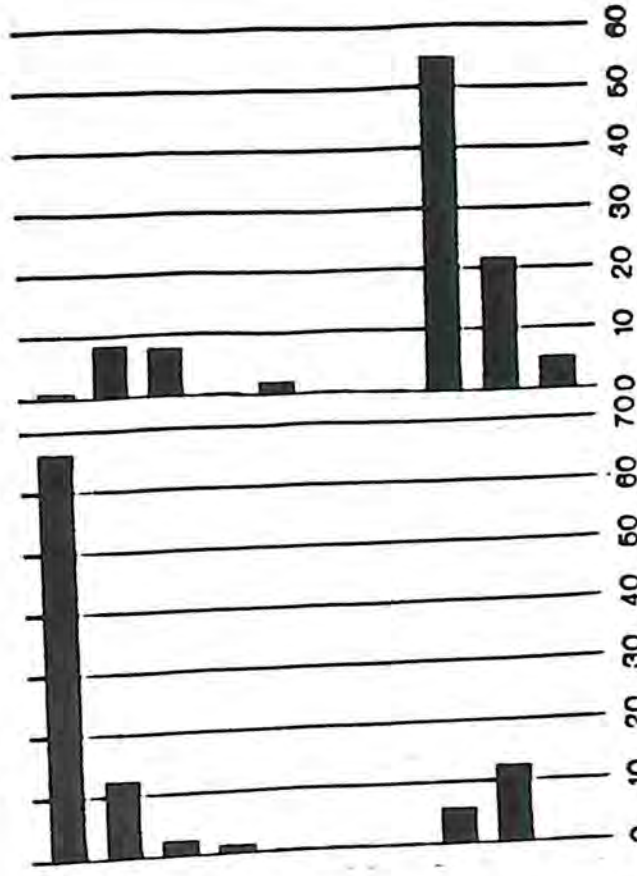
The dietary composition of chinkara and blackbuck is given in fig. 4. Given the same availability in the *Salvadora* zone (site : Nimbali nadi), blackbuck and chinkara preferred different dietary components. While blackbuck highly preferred the fruits of *Salvadora oleoides* and pods of *Prosopis cineraria*, chinkara preferred also browse.

In the absence of *Salvadora* fruits, chinkara in the *Maytenus* zone preferred browse. Among the different species of browse, chinkara



BLACKBUCK

ZONE : SZ
SITE : NN

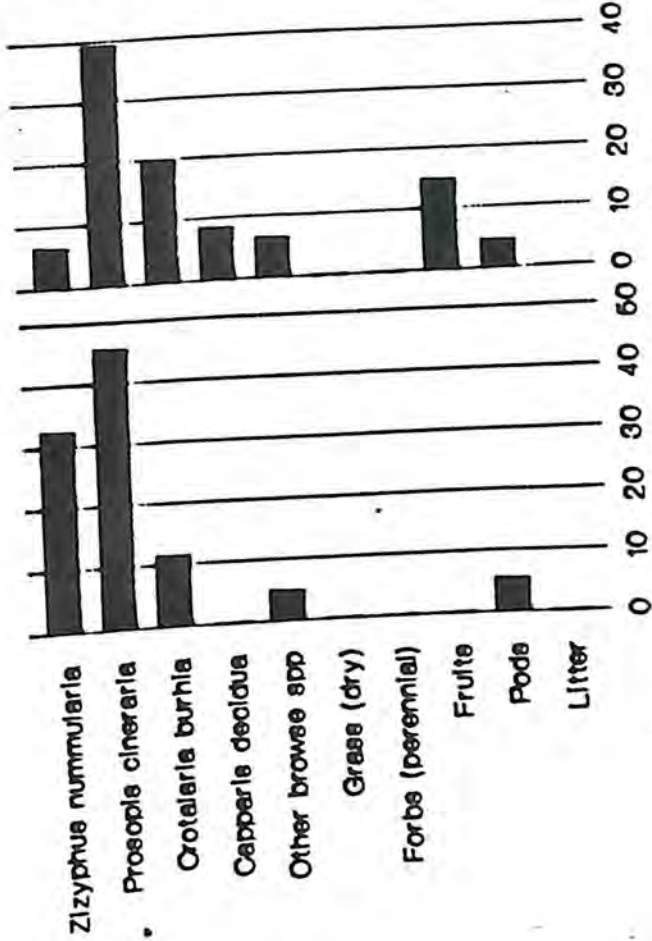


% UTILIZATION



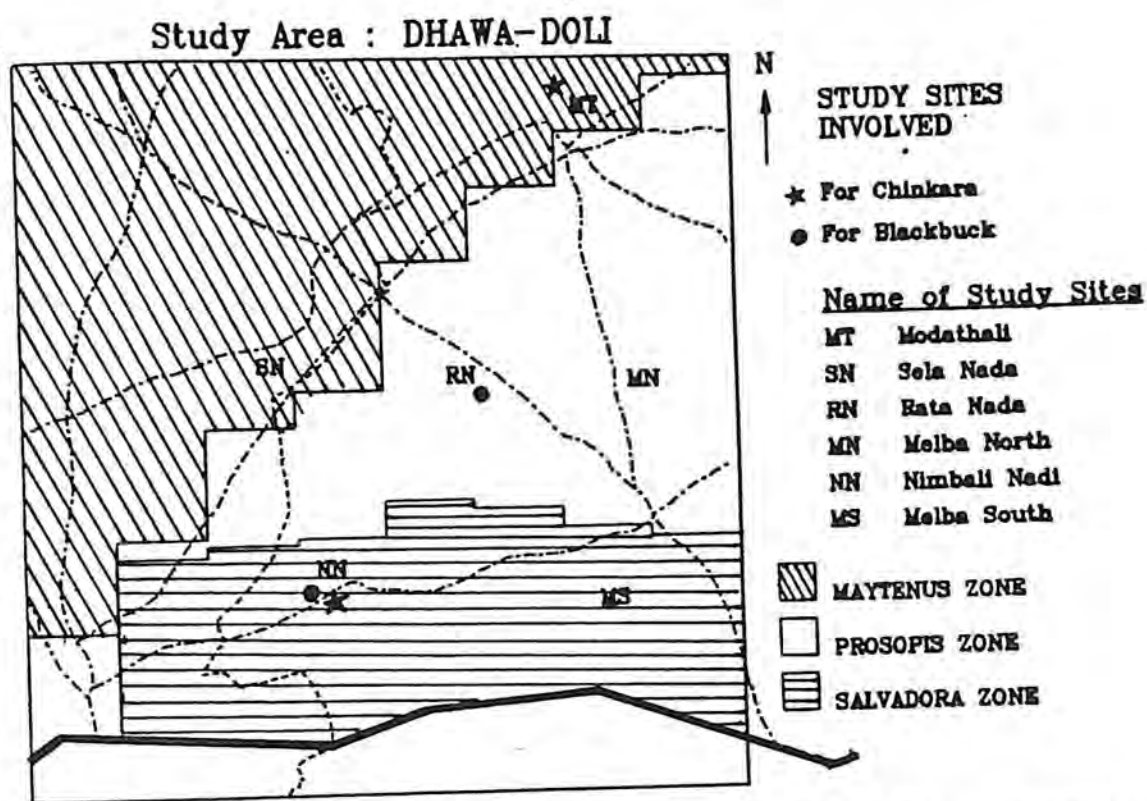
CHINKARA

ZONE : MZ
SITE : MT



% UTILIZATION

Figure. 4. Dietary composition of chinkara and blackbuck in summer in two different study sites at Dhawa-Doli.



did not show any preference for Capparis decidua shoots and Salvadora oleoides leaves.

In contrast to blackbuck inhabiting the Salvadora zone, those in Prosopis zone, preferred browse (leaves of Zizyphus nummularia). Apart from this species, fallen pods of P. cineraria and fallen fruits of C. decidua were also preferred.

While chinkara preferred both Z. nummularia and P. cineraria leaves, blackbuck generally avoided P. cineraria leaves. Blackbuck consumed more pods than chinkara (12 to 20 % for blackbuck and 3-5 % for chinkara). Both the ungulates avoided perennial forbs like Tephrosia purpurea, Fagonia cretica, Aerva persica and A. pseudotomentosa.

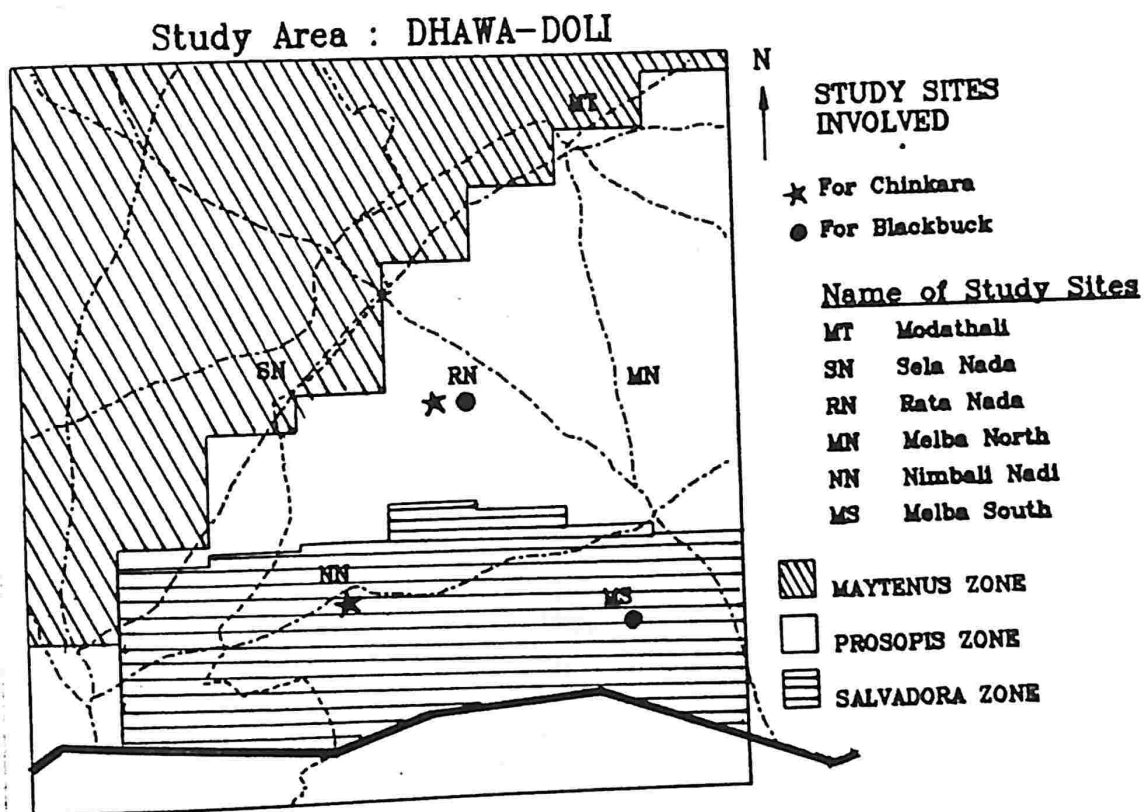
Unlike blackbuck and chinkara, nilgai in summer at Janwar-Doli (site : Boranada) avoided the clump form of Z. nummularia. They highly preferred the pods and leaves of P. cineraria (see fig.6). Calotropis procera, at this study site was not heavily used by domestic ungulates unlike in Dhawa-Doli, possibly because of a low browsing pressure. Nilgai also showed a preference for the leaves of this species. Though blackbuck and chinkara were also observed to feed on this species, preference could not be calculated because of low availability and utilization.

Nilgai visited irrigated crops possibly every night. Two complete night observations of their feeding behaviour revealed that they preferred to visit crop-fields which had pods below the canopies of unlopped P. cineraria trees. They spent 80 % of their activity time at night (night scans done from 7.00 PM to 6.00 AM) scanning and feeding under these trees for pods. Apart from pods, they also consumed stored onions and succulent forbs and grass.

PREMONSOON :

This season is a brief period (last week of June to II week of July) when there were no pods and fruits. Annuals (dominated by sedges) had begun to sprout during the premonsoon showers. During this brief transition period, both chinkara and blackbuck preferred sedges and A. nilotica flowers. This was the season when chinkara showed a preference for any monocot species. Data from the Salvador zone during this season on both the species was obtained from different sites (Nimbali nadi & Melba south

respectively. see adjoining figure). This was because, of the two herds of blackbuck inhabiting the Salvadora zone, the Doli group (the group studied in summer) had moved north for better feeding patches. So the Melba group was studied to represent the Salvadora zone.



In the Prosopis zone, both the species consumed Z. nummularia leaves which constituted about 60-67 % of their dietary item. However, they differed in the use of other dietary components. (see fig. 5). Because of early showers at the Eastern belt of the Salvadora zone, 82% of the diet of Melba blackbuck was composed of annuals. They showed a high preference for sedges which alone constituted 58 % . Chinkara in the Western belt of this zone (site : NN) preferred all the browse species except C. decidua



BLACKBUCK



CHINKARA

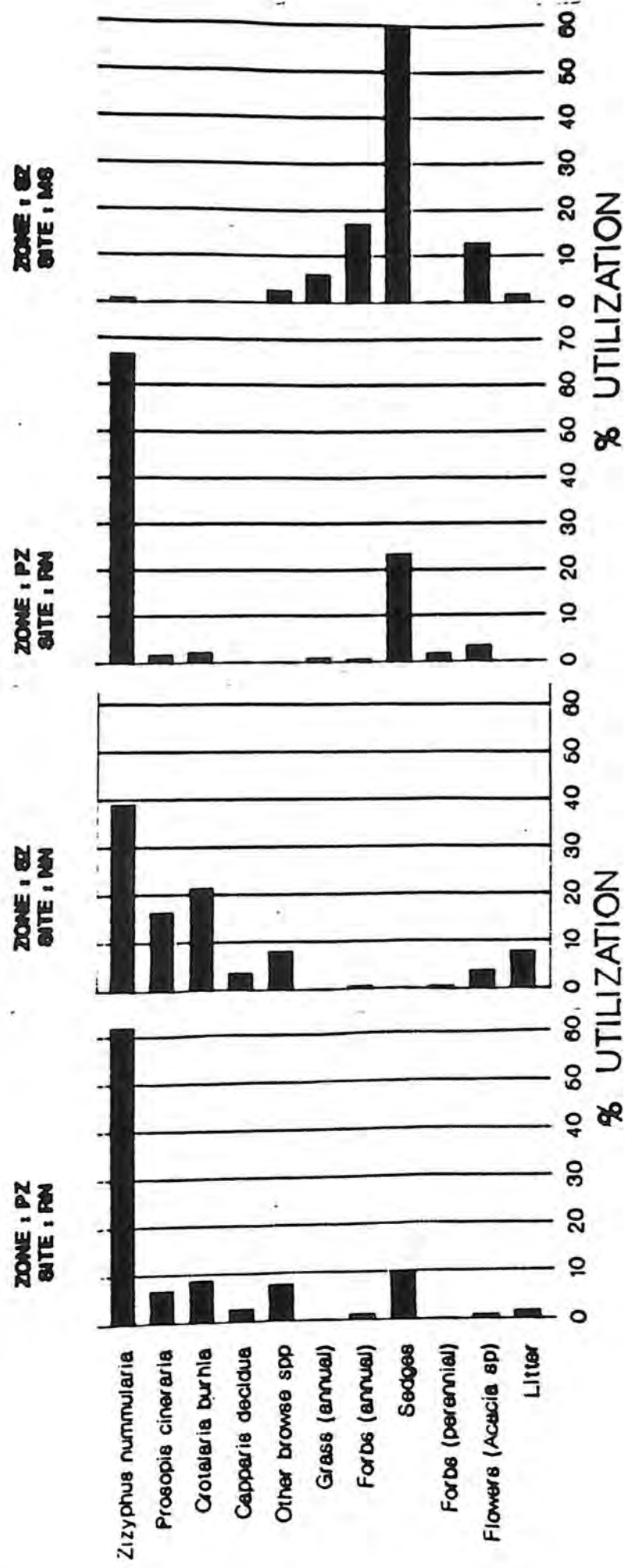


Figure. 5. Dietary composition of chinkara and blackbuck in premonsoon. Two study sites are compared here.

NILGAI

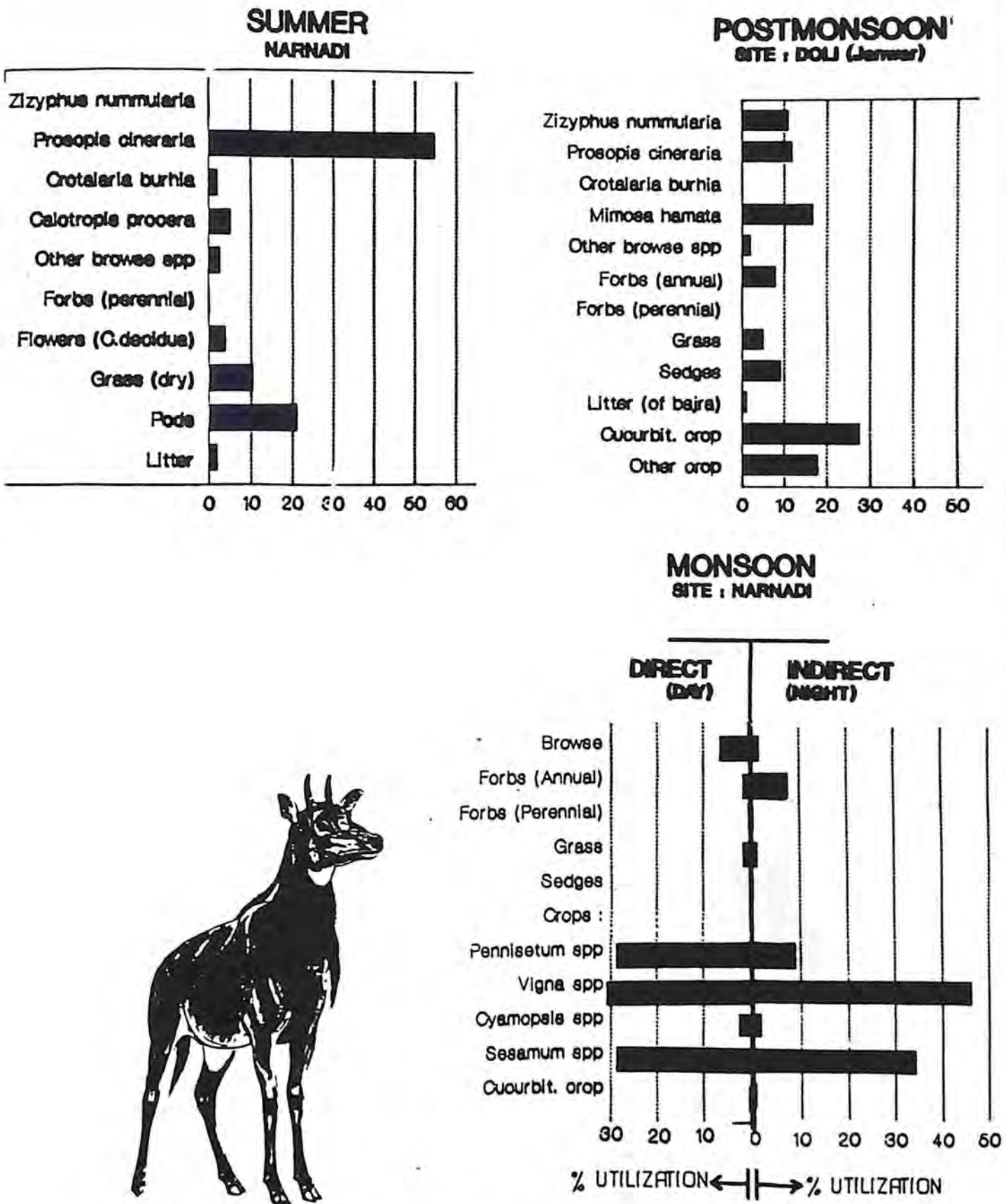
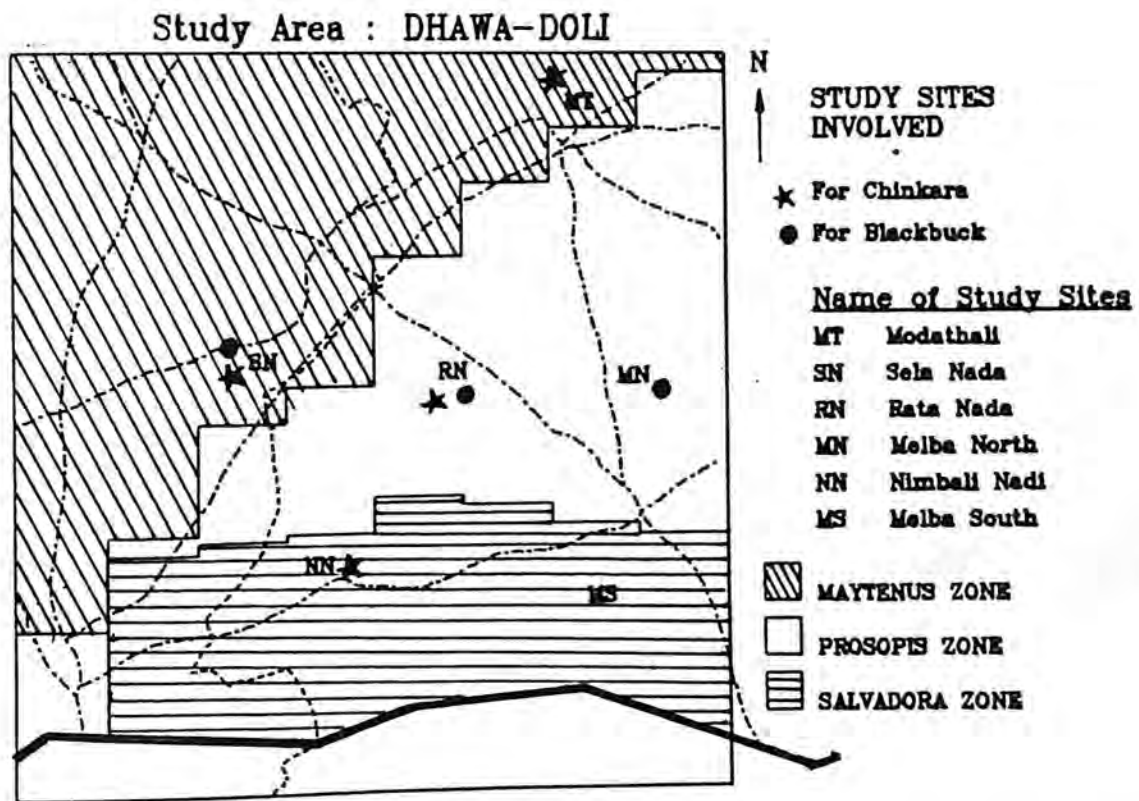


Figure. 6. Dietary composition of nilgai during summer, monsoon and postmonsoon from three different study sites at Janwar-Doli. Monsoon figure compares day and night feeding differences.

and S. oleoides.

MONSOON

As there was a shift in the home range of blackbuck in monsoon, new study sites (Selanada & Melba North) were included (see adjoining figure). Monsoon was the period when monocots formed the principal dietary item of blackbuck. (40 % to 73 %),



depending on the study site. (fig. 7). They preferred the annuals- sedges, grass & forbs- in this order. The difference in availability of forage types between sites is reflected in their dietary composition. Z. nummularia still continued to form an important diet of blackbuck inhabiting the two study sites in the Prosopis zone, where rainfall was inadequate for the sprout of annuals.



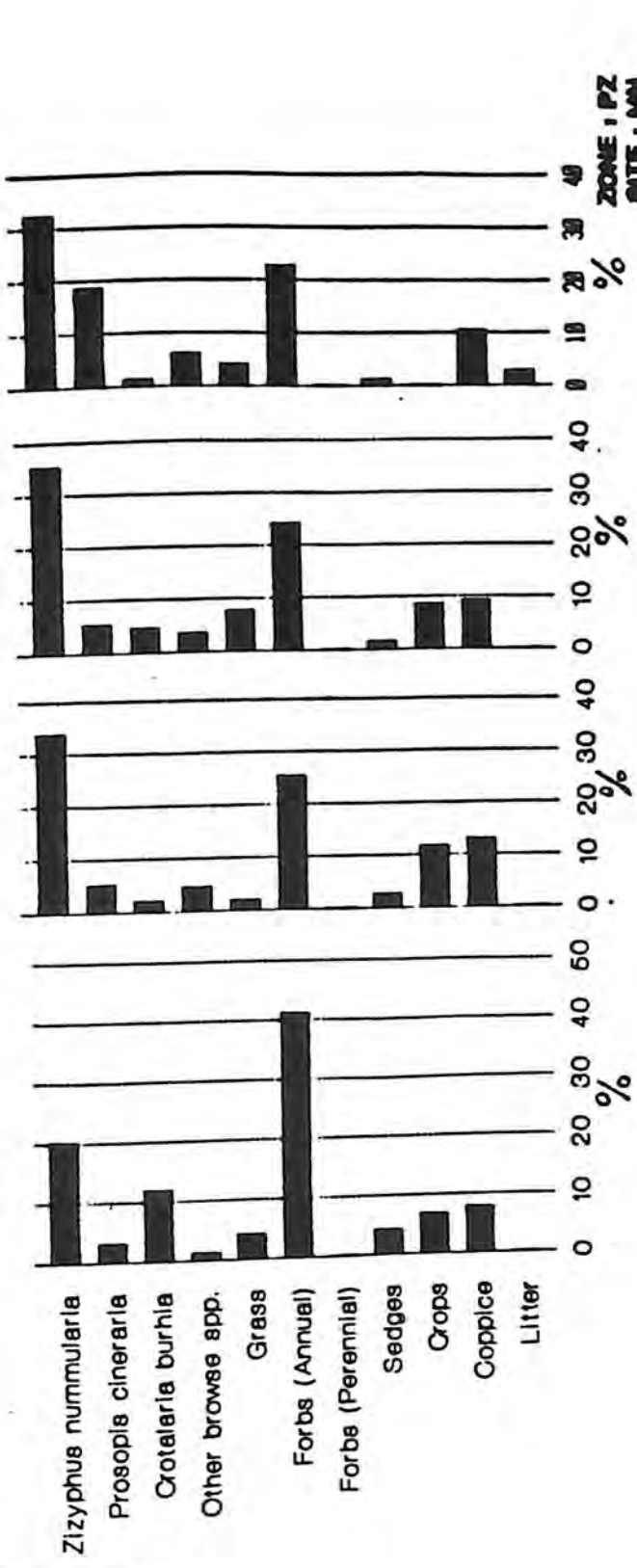
CHINKARA

ZONE : MZ
SITE : MT

ZONE : PZ
SITE : RN

ZONE : MZ
SITE : SN

ZONE : SZ
SITE : NN



BLACKBUCK

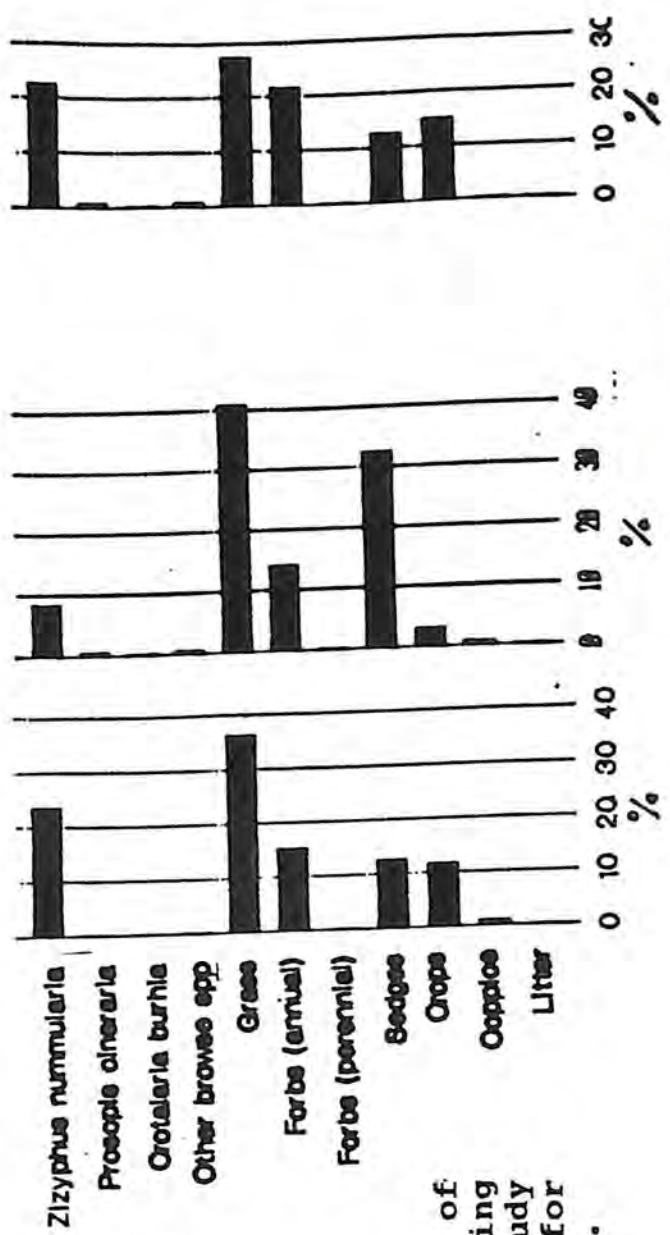


Figure. 7. Dietary composition of chinkara and blackbuck during monsoon at Dhawa-Doli. Four study sites are compared here for chinkara and three for blackbuck.

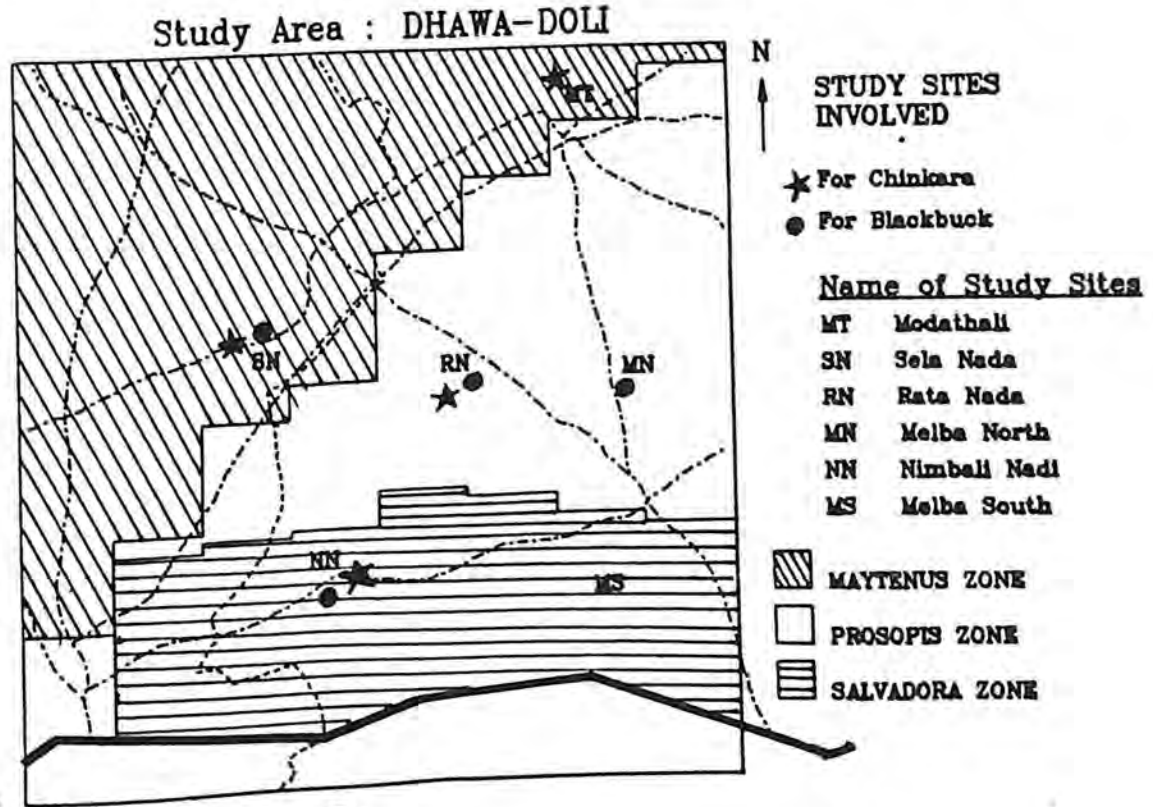
Unlike blackbuck, chinkara preferred Z. nummularia, annual forbs and coppice shoots in all the study sites irrespective of difference in availability. They avoided monocots. P. cineraria, a species preferred in summer, was avoided in three of the four sites (fig. 7). The possible reason for the preference of this species in the Salvadoria zone (site : Nimbali nadi) would be due to inadequate rainfall in this belt, thereby forcing the ungulates to continue preferring this species. The proportion of crops in the diets of chinkara and blackbuck varied from one study site to another depending on the amount of disturbance and proportion of land used for cultivation.

Food habits data obtained on a resident male nilgai at Dhawa-Doli, was inadequate to mention here about their feeding habits. Data on nilgai obtained during monsoon from Janwar-Doli (site : Narnadi) is not comparable here with that of the antelopes in Dhawa-Doli because of the difference in crop growth stage and the percent area cultivated. While only the northern half (Maytenus zone and parts of Prosopis zone) had crops in monsoon at Dhawa-Doli, about 90 % of the whole of Janwar-Doli had cultivated fields. Their dietary composition obtained by both direct and indirect methods is shown in fig. 6. These two dietary compositions were significantly correlated ($p < 0.05$: $R_s = 0.810$: $n = 9$). The data obtained indirectly is assumed to represent the nocturnal food habits of nilgai. 89 % of their diet was composed of crops and they avoided browse & grass. They took more browse in the day hours and more forbs than browse in the night. Among crops, they highly preferred Sesamum indicum (Til) and also

Vigna radiata (Mung). They showed a preference for Pennisetum typhoides (Bajra) during day time but avoided this cereal crop at night. This might be because, in the day hours, their opportunities for selection was less because of the disturbance and they consumed the more abundantly available bajra. They avoided the leaves of Cucurbitaceous crops.

POSTMONSOON

Crops appeared in the Salvadoria zone after the late monsoon rain towards the end of August. Bajra was the major crop in the northern half of Dhawa-Doli and Guar (Cyamopsis tetragonaloba) was the major crop in the Salvadoria zone. The phenology of forbs and grass in this season is characterised by flowering of most of these species (refer Fig. 3 a).



Chinkara avoided C. burhia shoots and preferred its flowers during this season and its contribution to the overall dietary composition varied between sites (see fig. 8) according to availability. (12 % in MT, 2.7 % in SN and 0.5 % in RN). Z. nummularia and forbs were the principal and other preferred food items.

Blackbuck preferred both the monocots and dicots of the herb layer. Unlike chinkara, they avoided browse and consumed more crops. Blackbuck showed a preference for bajra, while chinkara did not. Both the antelopes preferred the pulse and Cucurbitaceous crops. Overall, the proportion of crops consumed in postmonsoon increased for both chinkara and blackbuck as more land was brought under cultivation. However, blackbuck took more crops than chinkara in all the study sites.

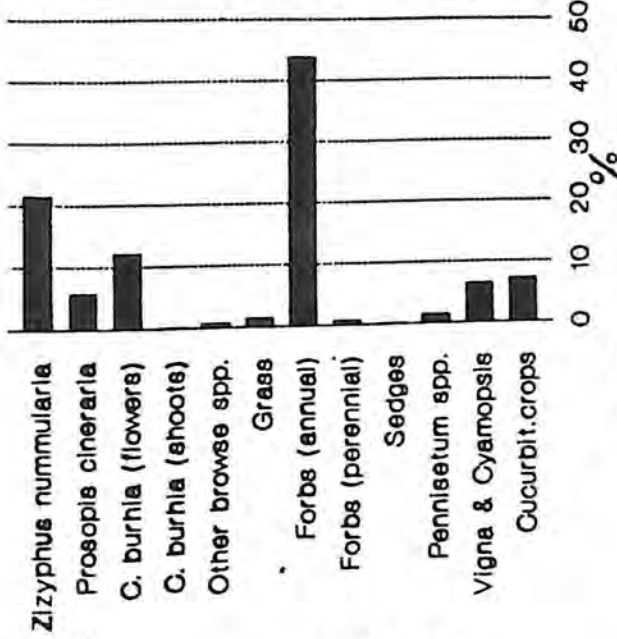
The post-monsoon data on nilgai food habits was collected when harvesting was almost over. The diet of nilgai during this season is shown in fig. 6. They consumed a mixture of browse and crop residues at Janwar-Doli. Among browse, they preferred leaves of P. cineraria and Mimosa hamata. Among the standing crop residues, they still showed a preference for Sesamum indicum (Til) eventhough the preference index came down to 0.11 from 0.67 (table 6). Unlike in Monsoon, they took only the leaves and avoided the stem portion bearing the Sesame oil seeds. Cucurbitaceous crops (Cucumis spp and Citrullus spp) which were avoided by nilgai in monsoon, was highly preferred during this season. Both the leaves and fruits of these cucumber crops were eaten.

POSTMONSOON

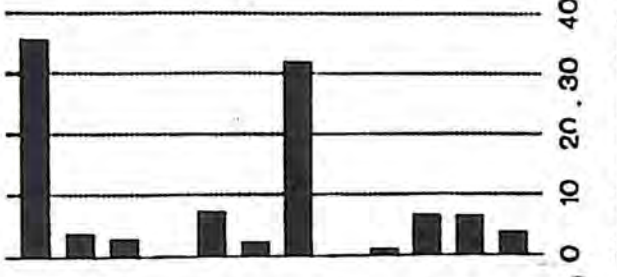


CHINKARA

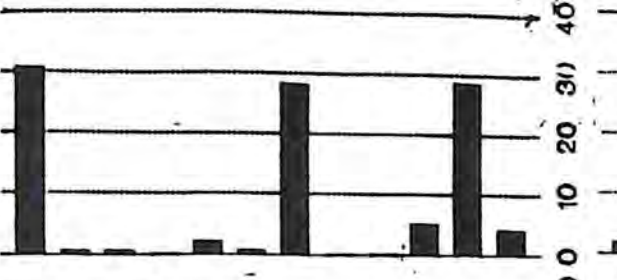
ZONE : MZ
SITE : MT



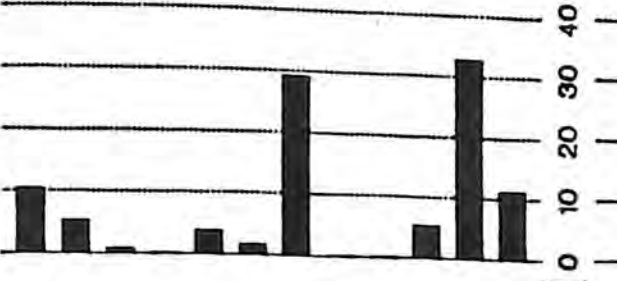
ZONE : MZ
SITE : SN



ZONE : PZ
SITE : FN



ZONE : SZ
SITE : NN



BLACKBUCK

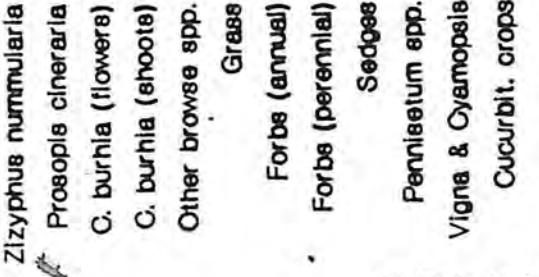


Figure. 8. Dietary composition of chinkara and blackbuck during postmonsoon at Dhawa-Doli. Four study sites are compared here for chinkara and two sites for blackbuck.

Table. 6 The mean Vanderploeg and Scavia's Electivity Indices for dietary components of chinkara (CH), blackbuck (BB) and nilgai (NG).

PLANT SPECIES	SUMMER			PREMONSOON			MONSOON			POSTMONSOON		
	CH	BB	NG	CH	BB	NG	CH	BB	NG	CH	BB	NG
1) <u>Z. nummularia</u>	0.3	0.02	-1	0.5	-0.2	-1	0.4	-0.01	-	0.4	-0.7	-0.4
2) <u>P. cineraria</u>	0.4	-0.3	0.5	-0.1	-0.9	-	0.01	-0.9	-	-0.2	-1	0.3
3) <u>C. burhia</u>	-0.2	-0.7	-0.8	0.01	-0.9	-	-0.3	-1	-0.9	-1	-1	-
4) <u>M. hamata</u>	--	--	--	--	--	--	--	--	--	--	--	0.4
5) <u>C. decidua</u>	-0.1	-0.8	-0.9	-0.5	-1	-	NOT PREFERRED					
6) <u>S. oleoides</u>	-0.3	-0.8	-	-0.3	-1	-	-0.6	-1	-	-	-	-
7) Other browse	0.1	-1	-0.8	0.2	-0.8	-	-0.2	-0.9	-	-0.3	-1	-0.9
8) Grass	-	-	-0.7	-1	-0.3	-	-0.3	0.6	-0.9	-0.9	0.2	-0.8
9) Sedges	-	-	-	-0.2	0.7	-	-0.3	0.6	-1	-0.9	0.3	-1
10) Forbs(peren.)	-1	-1	-1	-1	-1	-1	-1	-1	-1	-0.1	-1	-1
11) Forbs (ann.)	-	-	-	-0.6	-0.4	-	0.4	0.1	-0.6	0.06	0.2	-0.6
12) Coppice shoots	-	-	-	-	-	-	0.4	-0.7	-	-	-	-
13) Pods	0.3	0.6	0.4	-	-	-	-	-	-	-	-	-
14) Fruits & flow.	0.3	0.5	0.1	0.2	0.6	-	-	-	-	0.5	-1	-
15) Crops (all spp)	-	-	-	-	-	-	-0.05	-0.1	-	-	-	-0.1
16) Cereal crop	-	-	-	-	-	-	-	-	-0.3	-0.3	0.3	-
17) Pulse crop	-	-	-	-	-	-	-	-	-0.1	0.1	0.2	-
18) Oil crop (Til)	-	-	-	-	-	-	-	-	0.7	*	*	0.1
19) Cucumber crops	-	-	-	-	-	-	-	-	-1	0.3	0.2	0.7

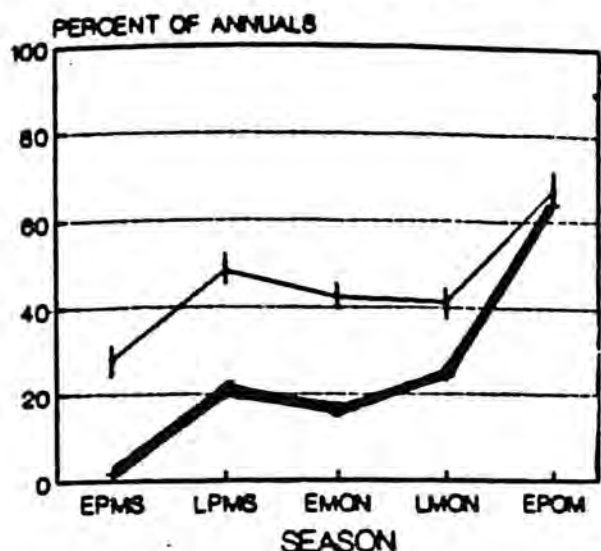
2-2. UTILIZATION OF ANNUALS

The sprout of annuals during premonsoon showers in the form of sedges, forbs and grass brought about a marked change in the composition of ground flora. Species like chinkara and blackbuck, unlike the livestock, responded to this change in availability, feeding initially with what was available among these annuals. But when the species richness, diversity, and phenology changed during the course of this study, these animals responded differently to the seasonal trend in proportion of forbs, grass and sedges.

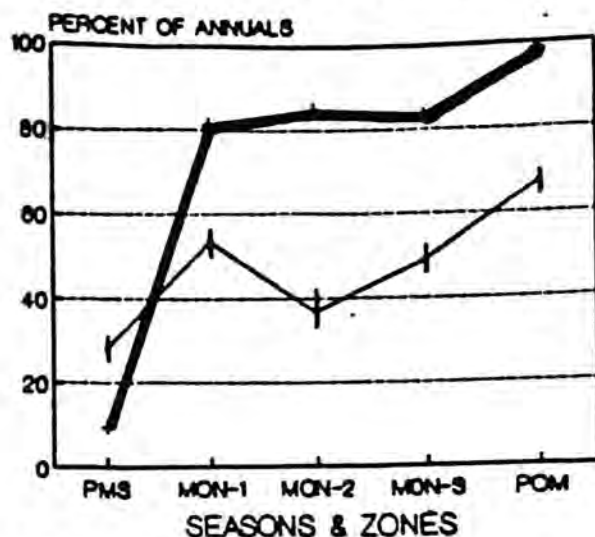
Chinkara preferred sedges during premonsoon, so also was blackbuck. However, once monsoon intensified in July, they responded differently to the trend in proportional availability of these annuals. This is illustrated in fig. 9b. Though all the three (forbs, grass and sedges) utilization curves of blackbuck respond to the trend in availability, they always preferred sedges (Cyperus rotundus), the utilization curve always being above the availability curve. On the contrary, chinkara avoided sedges after an initial preference in premonsoon.

Blackbuck showed a preference for forbs in monsoon and postmonsoon when all perennial species of plants were also included in availability for calculating preference. However, their proportional utilization of forbs was always below the availability curve, suggesting a preference for monocots than dicots. Chinkara preferred forbs (except in premonsoon), their

**(a) BLACKBUCK
(I) FORBS**



**(b) CHINKARA
(I) FORBS**

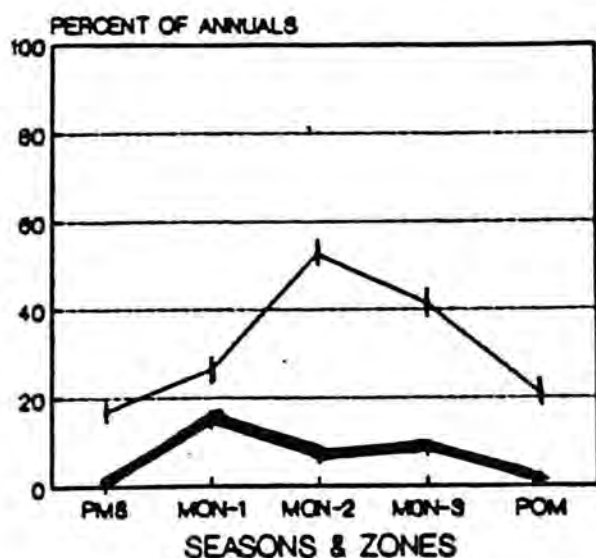
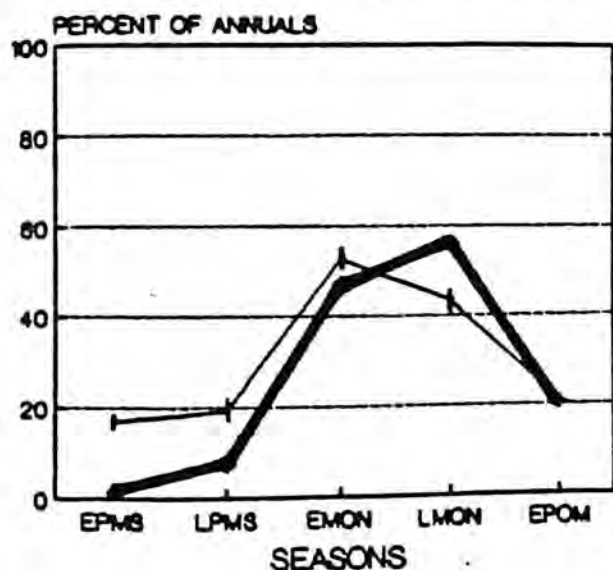


—+— AVAILABILITY

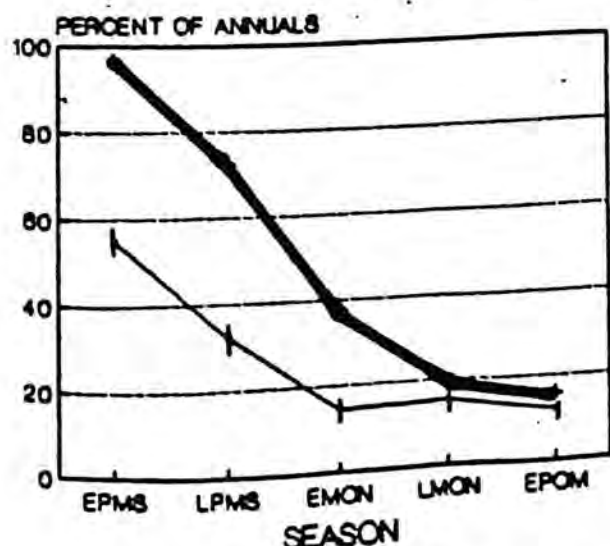
(II) GRASS

— UTILIZATION

(II) GRASS



(III) SEDGES



(III) SEDGES

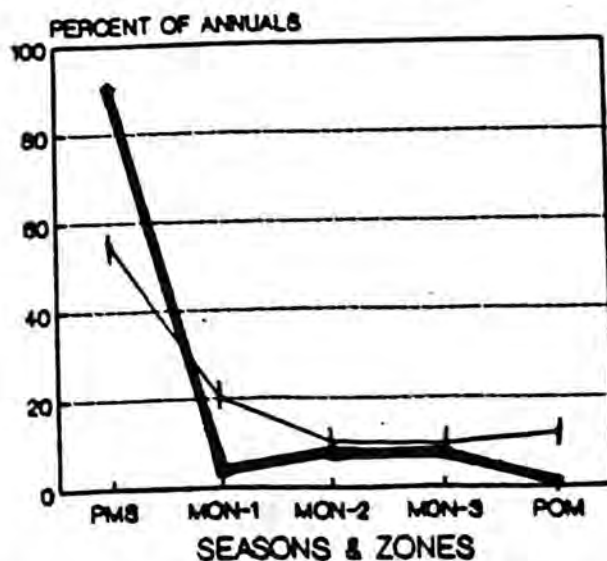


Figure. 9. Seasonal trend in utilization of annuals in response to availability. EPMS-Early PreMonsoon, LPM-Late premonsoon, EMO-Early monsoon, LMO-Late monsoon & POM-Postmonsoon. MON.1,2,3 indicate study sites in monsoon.

utilization curve remaining constant in spite of fluctuations in availability.

While blackbuck showed an intermediate response to grasses, the utilization curve being very close to the availability curve (fig. 9a), chinkara avoided grass throughout the period.

SECTION 3. SIMILARITY BETWEEN DIETS OF WILD AND DOMESTIC UNGULATES

Diet similarity between domestic and wild ungulates depended upon the type of animal (grazer or browser). Based on the feeding habits of these seven species of ungulates, competition was expected to be more between species with similar feeding habits. All possible competitors for chinkara, blackbuck and nilgai are dealt below.

No quantified data is available on food habits of domestic ungulates for summer as the decision to include them in the study was taken only towards the end of summer. However, field observations in summer showed that all species of domestic ungulates utilized the pods of P. cineraria and fruits of S. oleoides. Only fallen pods were taken as those on the trees were beyond even the reach of camels. However, camels took Salvadora fruits only directly from the tree and were not observed feeding on the fallen fruits.

In the following paragraphs, food habits of chinkara is compared with that of goats and camels, blackbuck with sheep & cattle, and nilgai with camel & cattle. For blackbuck and chinkara, two sets of data are compared. One is the premonsoon data when there were no crops and feeding sites were common. The other one is that on food habits, obtained from common grazing lands (scrublands) where both domestic and wild ungulates utilized the food resources.

Aspects like dietary overlap between wild and domestic ungulates is dealt separately in section 4. Spatial aspects of food resource partitioning (eg. feeding height) is dealt separately in section 5.

3-1. CHINKARA Vs GOATS & CAMELS

In premonsoon, chinkara differed from goat and camel in the proportion of browse species eaten eventhough it used the same species (table : 7a). While chinkara avoided C. decidua and S. oleoides, goats and camels used them in greater proportions. The clump form of Z. nummularia was rarely used by camels and goats preferred to browse on the shrub form when both forms were available. Chinkara fed randomly without showing any preference for any form. Both camels and goats used P. cineraria in greater proportions than chinkara.

In monsoon and postmonsoon, dietary composition of chinkara and goats were similar in terms of principal plant species (table. 7b). Camels differed from goats, and chinkara in particular

Table: 7.a Species composition of browse in the diet of chinkara (CH), goat (GO) and camel (CM) in premonsoon.

SPECIES	PROSOPIS ZONE			SALVADORA ZONE		
	CH	GO	CM	CH	GO	CM
1) <u>P. cineraria</u>	6.6	67.2	40.9	16.3	13.1	37
2) <u>Z. nummularia</u>	62	20	18	39	14	1.8
3) <u>C. decidua</u>	2.5	13	19	3.4	34.9	14.8
4) <u>S. oleoides</u>	0	0	0.5	2.3	20.8	39.8
5) Forbs (Peren)	0	0	17.7	0	0	2.8
N =	197	202	181	263	389	108

Table. 7.b. Species composition of browse in the diet of chinkara (CH), goats (GO) and camel (CM) in scrubland (Selanada dense scrub)

SPECIES	MONSOON			POSTMONSOON		
	CH	GO	CM	CH	GO	CM
1) <u>Z. nummularia</u>	85	85	27.7	67	46	22.7
2) <u>P. cineraria</u>	0	0.2	7.2	0	0	8.5
3) <u>M. emarginata</u>	4.1	7.9	17.5	4.6	2.9	16.1
4) <u>C. decidua</u>	4.1	3.5	21.7	2.3	0.2	14.8
5) Other browse	0	0.8	4.2	0	5	9.8
6) Forbs (annual)	6.1	1.8	0	23.3	40	23
N =	49	393	166	50	385	317

because of accessibility to browse plants like P. cineraria, M. emarginata and S. oleoides. The result given here may not hold true for all common grazing lands, as most of the scrublands did not have a wide species of food plants as in the openscrub intensively studied here.

3-2. BLACKBUCK Vs SHEEP & CATTLE

Very few sheep (often 1 to 3 in a herd of 50 to 70 goats) were seen during summer and premonsoon, suggesting that majority of them are migratory. When the remaining sheep returned in monsoon, the competition for food resources occurred only at scrublands. Cattle were stall fed in summer, premonsoon and in some parts of the study area even in monsoon.

The dietary composition of these three ungulates observed in a scrubland is shown in table 8. Sheep took more browse than blackbuck in monsoon and both avoided the dry grass (Tragus biflorus) and preferred to feed on succulent green forbs in post monsoon. Feeding on the fringes of the scrubland, cattle consumed 82 % grass (almost entirely on Dactyloctenium spp.), thus differing greatly with the dietary composition of blackbuck even within a common grazing land.

3-3. NILGAI Vs CATTLE & CAMEL

Food habits of these three species in postmonsoon is compared here. Other species like sheep and goats were still restricted to scrublands as harvest was still continuing at Janwar-Doli.

Table 8. Dietary composition of blackbuck (BB), sheep (SH) and cattle (CT) in scrubland. (Selanada openscrub)

PLANT TYPES	MONSOON			POSTMONSOON		
	BB	SH	CT	BB	SH	CT
1) Browse	4.0	25	x	5	0.7	0
2) Grass	71	52	x	34	16	84
3) Sedges	13	9	x	0	1.4	1
4) Forbs	12	14	x	61	81.7	15
N =	49	43		43	137	110

Table 9. Dietary composition of nilgai (NG), camel (CM) and cattle (CT) in postmonsoon at Janwar-Doli.

PLANT TYPES	NG	CM	CT
1) Browse	41	58	0.6
2) Grass	5	2	30.4
3) Sedges	0	0	3.5
4) Cucurbitaceous crops	27	4	5
5) Bajra crop litter	1	3	41.5
6) Other crops	18	4	2
7) Forbs	8	29	17
N =	102	51	171

Nilgai were highly selective (no significant correlation between availability and utilization $R_s = -0.16$, $n=12$) and took mostly browse, like camels. While cattle preferred the dry bajra litter (P. typhoides), nilgai highly preferred the green cucurbitaceous crop residues.

Though both camels and nilgai consumed 58 and 41 % browse respectively, they differed in species composition (see table. 9). While camels took a number of browse species, particularly Clerodendrum phlamoides, nilgai preferred to browse on M. hamata and P. cineraria.

SECTION 4. DIET SELECTIVITY, DIETARY OVERLAP AND DIET DIVERSITY

4-1. DIET SELECTIVITY

(i) Seasonal pattern in diet selectivity.

If utilization was not proportional to availability, then the species was considered to be selective. Using Spearman's Rank Correlation Coefficient tests, availability and utilization data was correlated for statistical significance to determine selectivity. Table 10 shows the correlation values for all the three species of wild ungulates. Significantly correlated values were assumed to represent that feeding was at random and there was no significant selection against availability.

Nilgai was highly selective than chinkara and blackbuck, as their utilization showed a negative correlation with availability.

Table : 10. Spearman's rank correlation coefficient values between availability and utilization.

SEASONS	VEGETATION ZONES						
	MAYTENUS		PROSOPIS		SALVADORA		NILGAI
	CH	BB	CH	BB	CH	BB	
SUMMER	0.771*	-	-	0.089	0.694*	0.167	-0.381
PREMONSOON	-	-	0.647*	0.144	0.271	0.250	-
MONSOON	0.624	0.359	0.480	0.540	0.751*	-	0.243
POSTMONSOON	0.502	-	0.827*	0.571	-	-	-0.159

* Significant $p < 0.05$

Table : 11 Spearman's rank correlation coefficient (R_s) values for comparison of food habits of different study sites.

	CHINKARA			BLACKBUCK		
	ZONES	STUDY SITES	R_s	ZONES	STUDY SITES	R_s
SUM	SZ & MZ	NN & MT	0.540	PZ & SZ	RN & NN	-0.090
PHO	SZ & PZ	NN & RN	0.544	SZ & PZ	MS & RN	0.290
MON	MZ	SN & MT	0.796**	PZ	NN & RN	0.868**
	MZ & PZ	MT & RN	0.655 *	PZ & MZ	SN & RN	0.862**
	MZ & SZ	MT & NN	0.480	PZ & NN	SN & NN	0.800 *
	MZ & PZ	SN & RN	0.857**			
	MZ & SZ	SN & NN	0.677 *			
	PZ & SZ	RN & NN	0.731 *			
POM	MZ	SN & MT	0.256	PZ & SZ	RN & NN	0.339
	MZ & PZ	MT & RN	0.332			
	MZ & SZ	MT & NN	0.448			
	MZ & PZ	SN & RN	0.824**			
	MZ & SZ	SN & NN	0.499			
	PZ & SZ	RN & NN	0.775 *			

* $P < 0.05$

** $P < 0.01$

Chinkara was the least selective of all the three species as its utilization significantly correlated with availability atleast in one study site in every season. Blackbuck were intermediate in selectivity as none of their utilization values were negatively correlated unlike nilgai in summer and postmonsoon. Broadly, there was no seasonal trend in selectivity.

(ii) Spatial aspects of selectivity

Food habits of chinkara and blackbuck obtained from different study sites in a season was compared by correlating the percentage time spent on different plant species between one site and another. This was done to see if there is any significant agreement in selectivity, spatially. As data on nilgai was obtained from only one study site per season, this test could not be done for nilgai. The correlation values are shown in table. 11.

There was no significant agreement in percentage time spent on different food plants between zones in summer and postmonsoon for both blackbuck and chinkara. Eventhough there was no significant agreement between sites during these seasons for chinkara, the correlation values ($R_s = 0.540$ & $R_s = 0.544$, $n=11$) suggest that they agreed more in proportion of time spent on food plants than blackbuck ($R_s = 0.09$ & $R_s = 0.29$, $n=11$).

In monsoon, there was significant correlation ($p < 0.05$ & $p < 0.01$) between study sites for both chinkara and blackbuck. Only two sites, the nothernmost (MT) and southernmost (NN) study

sites, did not show a significant correlation for chinkara. The magnitude of difference in species composition of availability between these two study sites was greater and thereby determining the utilization.

In postmonsoon, most of the sites did not agree significantly in percentage time spent feeding on different plant species. The reason can be attributed to the different crop species being cultivated. While the major crop in the northern half of Dhawa-Doli was bajra, in the southern part it was guar (C. tetragonaloba)

4-2. DIETARY OVERLAP

During monsoon, when a wide diversity of plant species are available as forage, chinkara and blackbuck tend to be browsers and grazers respectively. As goats and sheep had no access to cultivated fields in monsoon and postmonsoon, they relied on natural vegetation than wild ungulates. The divergence of feeding strategies (grazing and browsing), resulted in a low dietary overlap between the ungulates in most of the sites during the course of the study. The Specific Overlap values between and within wild and domestic ungulates are shown in table 12. For easy understanding, instead of actual values, the values are expressed in overlap classes as follows :

Values between 0 & 0.2 are designated as 1+ (very low overlap)

Values > 0.2 to 0.4 are designated as 2+ (low overlap)

Values > 0.4 to 0.6 are designated as 3+ (moderate overlap)

Values > 0.6 to 1.0 are designated as 4+ (high overlap)

Given in tables 12 (12a to 12 g) are two Specific Overlap values for the same two species (eg. One value for overlap of blackbuck into chinkara and the other for overlap of chinkara into blackbuck). The difference in the two values are based on the dietary breadth of two species concerned.

Dietary overlap was greatest during premonsoon in Prosopis zone for blackbuck into chinkara (3+). Both species consumed 60 to 65 percent of Z. nummularia. As chinkara took also a number of browse species, the likelihood of its utilization curve being drawn from that of blackbuck was less (1+). Table 12 b shows low overlap between wild and domestic ungulates as they differed in dietary proportion for different dietary components (dealt in the previous section 3). No data was collected on nilgai during this period.

During monsoon, overlap was more (3+) between sheep and blackbuck, than for chinkara with any other species. Dietary overlap of chinkara into other species of ungulates was very low (1+) (table 12.c). Chinkara, by feeding on a wide range of dietary components in monsoon (eg. B. aegyptiaca, C. porcera, T. undulata, flowers and leaves of A. nilotica, Coppice shoots etc.) showed a low overlap with others.

All species showed a low dietary overlap in postmonsoon (see table 12.d) at Dhawa-Doli and also for nilgai with cattle and camel (table 12.e).

TABLE : 12 a & b. Mean scores for different dietary overlap values.

Overlap values	< 0.2	.....1+.....	very low overlap
Overlap values	>0.2 to 0.4	.....2+.....	low overlap
Overlap values	>0.4 to 0.6	.....3+.....	moderate overlap
Overlap values	>0.6	.....4+.....	high overlap

TABLE. 12 a.

SUMMER

	BLACKBUCK	CHINKARA
CHINKARA	1+	-
BLACKBUCK	-	1+

TABLE. 12 b,

PREMONSOON

Overlap of	CHINKARA	GOAT	BLACKBUCK	CAMEL
Chinkara into	-	1+	1+	1+
Goat into	2+	-	1+	2+
Blackbuck into	3+	1+	-	1+
Camel into	1+	3+	1+	-

Table : 12, c and d. Mean scores for dietary overlap values for monsoon and postmonsoon. Overlap values among domestic ungulates is not shown.

Table. 12 c. MONSOON

OVERLAP OF	CHINKARA	GOAT	BLACKBUCK	SHEEP	CAMEL	CATTLE
Chinkara	-	1+	1+	1+	1+	1+
Goat	2+	-	1+			
Blackbuck	2+	1+		1+	1+	*
Sheep	2+		3+			
Camel	2+		1+			
Cattle	1+		*			

* Grazing lands not in common

Table. 12 d. POSTMONSOON

Overlap of	CHINKARA	GOAT	BLACKBUCK	SHEEP	CAMEL	CATTLE
Chinkara	-	1+	1+	1+	1+	1+
Goat	2+	-	1+			
Blackbuck	2+	1+	-		1+	1+
Sheep	1+			-		
Camel	1+		1+			
Cattle	1+	1+				

Tables 12 e & f . Mean scores for dietary overlap values in common grazing lands (scrubland)

Table : e. MONSOON

Overlap of	CHINKARA	GOAT	BLACKBUCK	SHEEP	CAMEL
CHINKARA	-	4+	1+	1+	2+
GOAT	4+	-	1+		
BLACKBUCK	1+	1+	-	4+	1+
SHEEP	1+		1+	-	
CAMEL	1+		1+		

Table : f. POSTMONSOON

Overlap of	CHINKARA	GOAT	BLACKBUCK	SHEEP	CAMEL	CATTLE
Chinkara	-	3+	1+	1+	3+	1+
Goat	2+	-	1+			
Blackbuck	1+	2+	-	4+	1+	2+
Sheep	1+		4+			
Camel	1+		1+			
Cattle	1+		3+			

Table : 12.g. Dietary overlap scores for nilgai at Janwar-Doli during postmonsoon

Overlap of	NILGAI	CAMEL	CATTLE
Nilgai	-	1+	1+
Camel	1+	-	
Cattle	1+		-

All species of ungulates used common grazing lands (scrublands). When dietary composition in these scrublands alone is considered for all species, overlap was moderate to high (3+ & 4+) for species with similar feeding habits (between chinkara & goat....and....between blackbuck and sheep) in both monsoon and postmonsoon (table 12f & 12g).

4-3. DIET DIVERSITY

Diversity indices (H') for the diets of all the three wild ungulates was calculated to determine their dietary breadths. The values are compared with diversity values of availability in the following table 13. Diet diversity remained always below diversity of available vegetation. Throughout the study period,

Table : 13. Mean species diversity of availability and utilization for chinkara, blackbuck & nilgai during the three seasons.

SPECIES	SUMMER		PREMONSOON		MONSOON		POSTMONSOON	
	AV	UT	AV	UT	AV	UT	AV	UT
CHINKARA	2.0	1.5	2.1	1.6	2.2	1.7	2.1	1.6
BLACKBUCK	2.0	1.2	2.1	1.1	2.2	1.4	2.2	1.5
NILGAI	1.9	1.3	-	-	2.2	1.5	2.1	2.0

the mean diet diversity of chinkara was higher than that of blackbuck. An increase in species diversity of available vegetation resulted in a corresponding increase in the diet

diversity of all the three species of ungulates. Diversity value for nilgai in postmonsoon (after harvest) was the highest among all the species.

SECTION : 5. SPATIAL ASPECTS OF FOOD RESOURCE

PARTITIONING

This section has three components dealing with the results of seasonal change in habitat preference, selection of different habitat sub-units (cultivated fields, uncultivated fields and scrublands) and feeding height.

5-1. SEASONAL DIFFERENCE IN HABITAT UTILIZATION

While blackbuck and nilgai exhibited a seasonal pattern of habitat utilization, chinkara did not. Nilgai was spatially separated from blackbuck and chinkara in summer as they were restricted to villages which had irrigated fields.

At Dhawa-Doli, chinkara did not show any shift in habitat utilization in response to temporal and spatial variability in food availability after the premonsoon showers like blackbuck. They however only increased their foraging range in monsoon in sites where there was insufficient rainfall to encourage cultivation. Food habits of chinkara in Salvadoria zone during monsoon shows that their foraging range increased in order to obtain annual forbs. They spent 47 % of their day time activity in the northern grid (grid : D . see map 2a) as opposed to only

4.5 % in the same grid in summer. 31 % of the diet of chinkara in grid. D was forbs as opposed to only 3.6 % in grid. C.

Blackbuck showed a more flexible seasonal variation in home range. All the three herds of blackbuck at Dhawa-Doli (Doli, Melba & Ratanada herds) showed a shift in habitat use, towards the end of premonsoon. The sprout of annuals after the early showers substantially influenced the movement of blackbuck. This was evident in the Salvadora zone where the two herds of blackbuck responded differently to the spatial availability of annuals. While the Doli herd showed a shift in habitat use by moving northwards (from site : NN to site : SN), the Melba group initially did not. The eastern belt of salvadora zone received an earlier showers which encouraged better growth of annual plants. Food habits of this group of blackbuck in premonsoon reveal that 82 % of their dietary items were composed of annual plants.

5-2. SELECTION OF HABITAT SUB-UNITS

Not every part of the 90 % available land (remaining 10 % is scrublands) is cultivated. Some portions of the cultivable land is left uncultivated for livestock grazing. This is also dependent on the amount of rainfall received during monsoon.

Results show that chinkara showed a random utilization of these habitat subunits. The proportion of time spent on these different habitat subunits in monsoon and postmonsoon was in proportion to availability. Blackbuck were not randomly dispersed over the habitat subunits available to them. Blackbuck tend to avoid crop

fields and scrublands, and used uncultivated fields predominantly. Eventhough they spent less time in crop fields in propotion to availability, they took more crops than chinkara, both in monsoon and postmonsoon. Dietary analysis of plant species utilized in cropfield reveal that the chance of consuming crops is more for a blackbuck than chinkara. In postmonsoon, 63 % of the diet of blackbuck in a cropfield was crops and 41 % for chinkara.

Nilgai fed almost exclusively on crops (96 %) from cropfields. Data on utilization of these habitat components for nilgai at Janwar-Doli is inadequate to determine preference. However, observations on diurnal movement pattern between habitat subunits on a resident nilgai at Dhawa-Doli suggests that they avoided areas with crop fields during day time and moved at night into sites which had crops. Similar observations on blackbuck have been made in monsoon, when the lower half of the study area had no crops, and they moved towards north into areas with cropfields. Unlike nilgai and blackbuck, chinkara did not show any long distance movement in monsoon or in any other season.

As domestic ungulates were denied access to cultivated fields in monsoon and postmonsoon, they were spatially separated from wild ungulates and overlap in habitat subunits occured only at scrublands and uncultivated fields.

5-3. FEEDING HEIGHT OF UNGULATES

(i) MEAN FEEDING HEIGHT :

Seasonal trend in mean feeding of the seven species of ungulates in the study are shown in fig. 10. Shown also are the 95 % confidence limits for the mean.

Mean feeding height for camel was above that of all other species. The mean for nilgai was intermediate between goats and camels as they took more browse. Eventhough the figure shows an overlap in confidence intervals for nilgai and goats, their dietary compositions were different. Nilgai data was obtained from cropfiels where 90 % of their food items were crops.

Growth of annual plants in monsoon resulted in abundant forage. All ungulate species utilized these fresh growth of annuals. This resulted in a decrease in mean feeding height of only domestic ungulates. As chinkara and blackbuck utilized growing crops, their mean feeding height increased from that of monsoon. Throughout the study, the mean feeding height of chinkara was above that of blackbuck.

During monsoon, there was a greater overlap in the mean feeding height for chinkara, blackbuck, cattle and sheep. This was the period when both blackbuck and chinkara were restricted to natural food plants (annual forbs and monocots). Overlap in mean feeding height was more between sheep and cattle as they were restricted to scrublands and uncultivated fields for grazing.

(ii). STRATIFICATION OF FORAGING HEIGHT

As mean feeding height failed to give any meaningful interpretation in determining spatial aspect of food resource utilization, vertical feeding plane was stratified into the following classes :

Stratum	1	for near ground level	.....	0 to 10 cm
Stratum	2	}Quadrupedal zone for }goats, sheep, chinkara }blackbuck	.....	11 to 50 cm
Stratum	3		.....	51 to 100 cm
Stratum	4	for goats (when bipedal) nilgai & camel	.....	101 to 150 cm
Stratum	5	for nilgai and camel	.....	151 to 250 cm
Stratum	6	where only camel can reach.....		> 250 cm

Figure 11 shows the histogram relating the percentage frequency of feeding observations with feeding height class-intervals for the seven species of ungulates. While the pattern of mean feeding height was largely determined by feeding behaviour (grazer or browser) and the height to which the animals can reach, the histograms highlight the following points which were not revealed in the pattern showing the mean feeding height .

a. All the three species of wild ungulates used ground level (0 to 10 cm) in summer. While blackbuck heavily used the ground layer (for Salvadora fruits and Prosopis pods), chinkara and blackbuck utilized different species of browse within their reach.

- b. Sheep differed from blackbuck in premonsoon in the utilization of stratum two (11 to 50 cm.) as they took more browse in this quadrupedal zone (eg. P. cineraria). Sheep showed a similar pattern with blackbuck in monsoon as both species took primarily annuals- grass, sedges and forbs. In postmonsoon, as blackbuck consumed crops, their difference in use of stratum was evident from their use of the second strata.
- c. Goats used all the feeding strata within their reach unlike chinkara. They also differed from chinkara in the use of bipedal stratum (100 to 150 cm.). Only two bipedal feeding observations were recorded on chinkara during the six months study. Both the observations have been during summer.
- d. It was only during postmonsoon that blackbuck and chinkara showed similarity in use of strata 1 and 2 as both species took annuals and crops.
- e. In monsoon, nilgai rarely used the ground level stratum as 85 percent of its diet was composed of crops.
- f. Nilgai used the two quadrupedal strata (11-50 and 51 to 100 cm height classes) increasingly in postmonsoon than in summer as the study sites had no Z. nummularia & M. hamata shrubs in summer.
- g. In postmonsoon, though camel showed an overlap with nilgai, they differed in their use of different strata. While stratum 6 was beyond the reach of nilgai, stratum 3 was rarely used by camel.

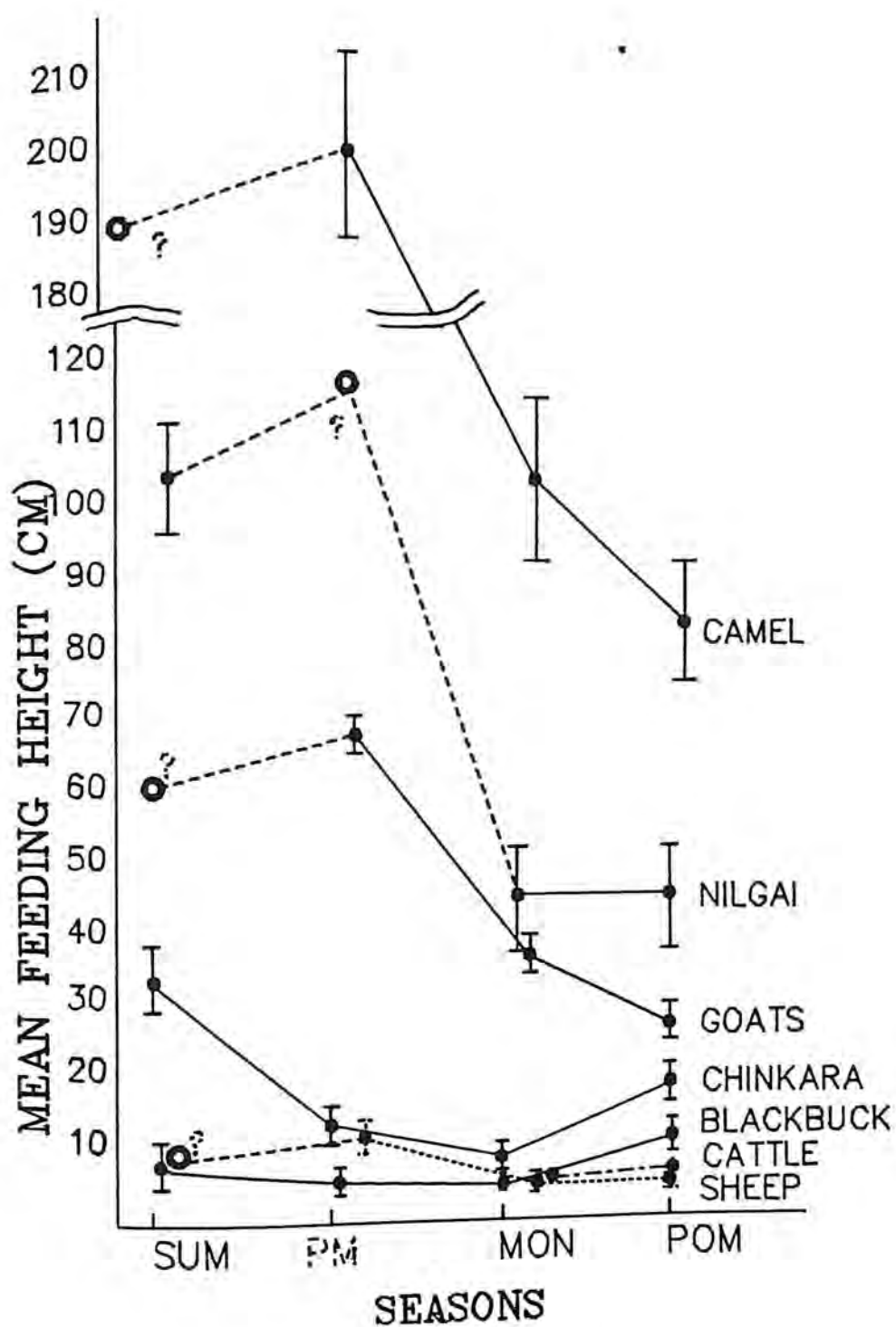
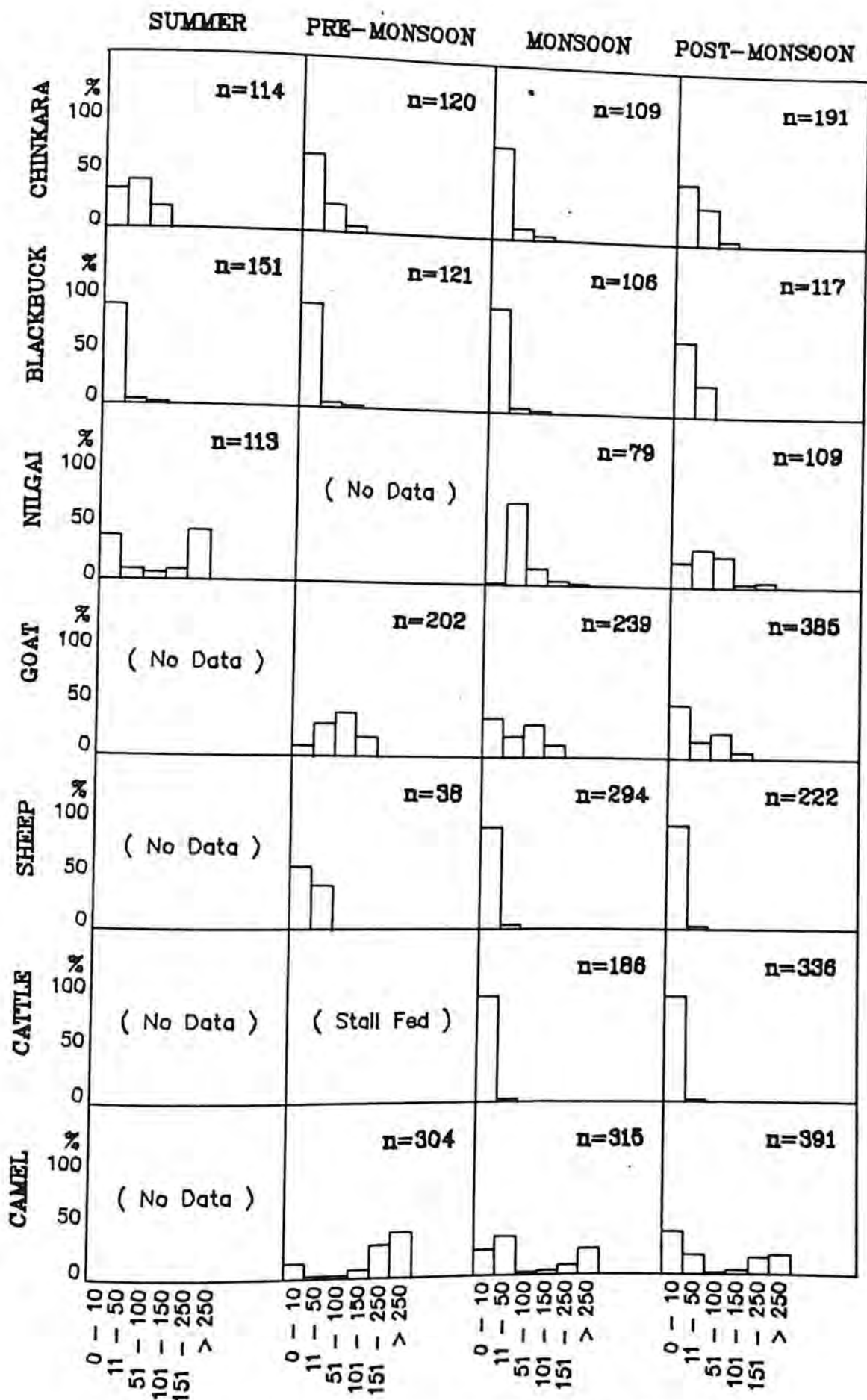


Fig. 10 Mean feeding height of seven species of ungulates - with 95% confidence interval for mean.

Note : ? mark shows expected approx. values.



FEEDING HEIGHT CLASSES (IN C.M.)

Fig. 11. Histograms relating percentage frequency and class intervals for feeding heights for chinkara, Blackbuck, Nilgai, Goat, Sheep, Cattle and Camel for the four seasons.

CHAPTER .V. DISCUSSION

1. THEORETICAL ASPECTS OF RESOURCE PARTITIONING AND COMPETITION :

Biologists often recognize three patterns of food resource partitioning, namely dietary, spatial and temporal separations. Temporal aspects of resource partitioning are not considered in this discussion since temporal aspects (like amplitude and period of graze rest cycle, i.e. number of feeding bouts) would only avoid direct confrontation between inter-specifics and they still would utilize the same food resource types provided feeding locations were similar. Dietary and spatial aspects are discussed here as possible modes of food resource partitioning. Arid environments are characterised by marked fluctuations of resource abundance. Due to erratic rainfall and brief eruption of forage, consumers that are opportunists appear to be able to persist in such environments (Jarman & Sinclair, 1979).

The degree of opportunism may be an alternative answer to the question of resource partitioning. Species which utilize a wide variety of food items randomly in proportion to availability with little evidence of preference are here termed opportunistic feeders. So the discussion in the following sections of this chapter will also be addressed to evaluate the relative levels of opportunism between chinkara, blackbuck and nilgai.

Sympatric populations of ungulates may use the same species of plant types and yet they may not be in direct competition for it if the availability is abundant and possibly surplus. However,

competition would occur when availability is limited. Several authors have reported about the problem in arriving at the level of competition between sympatric species. Overlap was a common index to measure the degree of similarity between resource utilization of two species. However, equating dietary overlap with competition can be misleading (Colwell & Futuyma, 1971). Overlap need not necessarily lead to competition unless resources are in short supply (Pianka 1976). In other words, if two species have to avoid competition they should exhibit a non-overlapping pattern of resource use. If so, an extensive overlap might actually refer to a reduced competition. A greater overlap can be expected when resources are abundant only when both species concerned have similar dietary preferences.

The results of this study do not provide any direct evidence of competition but dietary overlap results indicate that there is considerable potential for "exploitation" competition between them when resources are limited in summer and premonsoon. If dietary overlap is a determinant of the extent of competition between wild and domestic ungulates, then it occurred at scrublands between species with similar feeding habits (grazer or browser). Despite these diet similarities in scrublands, the major forces that shape resource partitioning between domestic and wild ungulates are people.

The informations collected during this study gave five major points of interest. These are elaborated following a summary of relationship between seasonal changes in resource availability and utilization.

2. RELATION BETWEEN SEASONS, RESOURCES AND FEEDING HABITS

i) Summer.

This season was characterised by absence of annual plants, availability of pods, fruits and several species of perennial shrubs and trees. Nilgai and blackbuck showed a high preference for pods unlike chinkara which also consumed a wide variety of food plants in addition to pods. Summer being a season of resource scarcity, one would expect animals to eat according to availability. Chinkara responded to this by consuming plants according to availability. Nilgai was spatially separated in summer as they were restricted to villages with cropfields. They consumed largely browse, apart from pods and showed a preference for C. procera leaves and C. decidua flowers.

There was no significant correlation in the food habits of chinkara and blackbuck between vegetation zones. As the opportunity for selection was less, chinkara utilized species like C. decidua and C. procera which were usually avoided during monsoon and postmonsoon. No data on domestic ungulates is available for this period. However, they have been observed competing with blackbuck, chinkara and nilgai for pods and fruits of P. cineraria and S. oleoides respectively.

ii). Premonsoon.

This brief period was characterised by absence of pods and fruits

and an initial sprout of annuals. Blackbuck highly preferred sedges eventhough it continued to feed on Z. nummularia leaves. A. nilotica flowers contributed to the diets of chinkara and blackbuck during this season. Dietary composition of domestic ungulates differed in species composition. They rarely used the emerging annual plants and showed a broad selection of food items.

iii). Monsoon.

Towards the end of premonsoon, blackbuck responded to the temporal and spatial availability of annuals. As the *Salvadora* zone remained dry due to inadequate rainfall, blackbuck responded according to the rainfall patchiness, by moving into *Prosopis* and *Maytenus* zones for better feeding patches. As crops were limited to the northern half of the study area, interspecific divergence of feeding strategies (grazing and browsing) resulted in a low dietary overlap between chinkara and blackbuck. Blackbuck utilized a sizable proportion of monocots in their diet during this season. They preferred all the three forage types - sedges, grass and forbs - in this order. In study sites where growth of annuals were less due to inadequate rainfall, they continued to show a dependence on Z. nummularia. Dietary resource partitioning was evident between blackbuck and chinkara during this season. Chinkara avoided grass and sedges unlike blackbuck. Nilgai at Janwar-Doli consumed mostly crops. Several authors have reported the damage inflicted to crops by nilgai (Roberts 1977; Dinerstein 1979; Ghosh et al. 1987; Schultz 1987) but no

quantified information is available so far on the proportion of crops in their diets. Most of the literatures give only the list of crops eaten and the term "preference" has been loosely used for denoting a positive selection. Nilgai at Janwar-Doli preferred Sesamum indicum and Vigna radiata.

iv). Postmonsoon.

During postmonsoon, chinkara preferred certain plant parts (e.g. C. burhia flowers instead of its shoots and leaves) and both blackbuck and chinkara preferred to take pods of leguminous crops. An increase in species diversity of available vegetation resulted in a corresponding increase in diet diversity for all the three species of wild ungulates. Consumption of crops increased for both blackbuck and chinkara. Blackbuck consumed more crops than chinkara and showed a preference for bajra. Both ungulates showed a preference for leguminous and cucurbitaceous crops.

Most of the cultivated fields were harvested at Janwar-Doli during this period. Eventhough nilgai, cattle and camel used the same harvested fields (interspersed with few uncultivated fields), their dietary composition was different. Cattle were the least selective of the three as they preferred dry bajra crop residues unlike camel and nilgai. While nilgai highly preferred leaves and fruits of cucurbitaceous crops, camel utilized a combination of browse and forbs.

During postmonsoon, three distinct habitat subunits were recognized. Broadly, there was no strong difference in habitat subunit selection between chinkara and blackbuck, eventhough blackbuck tend to avoid cultivated fields during the day. This seems to depend on the amount of disturbance which varied from one study site to another.

DIETARY AND SPATIAL ASPECTS OF FOOD RESOURCE PARTITIONING

From the results on seasonal differences in feeding habits and selection of habitat subunits, following five points of interest became evident:

- 1) Food habits of all the three species of wild ungulates fluctuated according to availability. The dimension in utilization was more pronounced in the case of blackbuck and nilgai than in chinkara which differed from other ungulates by continuing to utilize the same food resource (e.g. Z. nummularia) in all the seasons. Utilization of a wide variety of plants according to seasonal availability are possible adaptive strategies for these ungulates to survive in an environment with marked fluctuations in resource abundance.
- 2) During periods of resource scarcity (summer), blackbuck and nilgai unlike chinkara showed a greater variation in diet and habitat utilization. In periods of continued resource overutilization (as in premonsoon), blackbuck showed a shift in homerange.

- 3) In monsoon and postmonsoon, opportunities for selection was greater and food habits of the same species at different sites resembled more than that was in other seasons. Food items would generally increase as resource availability decreases (Shoener, 1974; Pianka, 1976). However, diversity of available food types determined the variety of opportunities for diet diversification for consumers like chinkara, blackbuck and nilgai. Feeding strategies reveal that nilgai and blackbuck were selective in their food habits and chinkara the least selective among the three, in periods of resource abundance.
- 4) As domestic ungulates were herded, they had less time for selection of food types unlike wild ungulates. Their feeding habits were largely determined by the locality where they were taken for feeding. Competition for food resources between wild and domestic ungulates was less during crop season as livestock were restricted to scrublands and uncultivated fields for grazing. Such a spatial separation of habitat subunits was not evident among wild ungulates. Accessibility to crop fields for chinkara, blackbuck and nilgai in monsoon and postmonsoon unlike domestic ungulates, gave them a wider opportunity for selection. Competition in scrublands between domestic and wild ungulates occurred between species with similar feeding habits (grazer and browser). Food habits of sheep resembled that of blackbuck and chinkara that of goats.

5) Both wild and domestic ungulates differed in their utilization of vertical foraging planes as a result of their size and reachability. This is needed for their coexistence in this arid environment. Both chinkara and blackbuck showed a similar seasonal trend in mean feeding height, but the mean for chinkara was always more than that of blackbuck as chinkara also utilized browse in crop season. The pattern of utilization of different feeding strata was more similar among grazers (sheep, blackbuck, cattle) as all species grazed within a height of less than ten centimetres. However, browsers differed in their use of foraging strata according to their accessibility to different browse species.

CHAPTER .VI CONCLUSIONS

Though chinkara and nilgai are browsers, they differed in utilization of food resources in all the seasons and also in habitat utilization in summer.

Though blackbuck are primarily grazers, they included a greater proportion of dicots in their diets (which varied seasonally) than the proportion of monocots in the diet of chinkara or nilgai. This is possibly a reflection of dicot - monocot ratio which was always biased towards dicots. Moreover, most of the monocots were annuals and occurred for only a brief period of time.

Feeding strategies reveal that nilgai and blackbuck are very selective in their food habits. Chinkara is the least selective among the three when opportunity for selection is greater in periods of resource abundance.

Food habits of domestic ungulates are largely determined by their foraging localities. They differed from wild ungulates in resource utilization. Dietary separation was evident in periods of resource scarcity (summer and premonsoon), when feeding locations were common and spatial segregation was evident in periods of resource abundance (monsoon & post-monsoon) where domestic ungulates had no access to one of three habitat sub-units.

While feeding in common grazing lands (scrublands), dietary overlap was greatest between species with similar feeding habits (grazer or browser). Diet of goat showed a greater overlap with that of chinkara and diet of sheep showed a greater overlap with that of blackbuck. Blackbuck differed from cattle in early monsoon because of its ability to graze on short grass, and cattle differed from blackbuck in postmonsoon in its ability to utilize mature coarse grass.

Both wild and domestic ungulates differed in utilization of vertical foraging plane. Classification of their foraging stratum reveal that they differed in using different strata within a season and also between seasons.

This study suggests that dietary differences between blackbuck, chinkara and nilgai are more important than spatial differences, in food resource partitioning.

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