COMPARATIVE FOOD HABITS OF FOUR SYMPATRIC CARNIVORES (WOLF, FOX, HYENA AND JACKAL) IN KUTCH

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COMPARATIVE FOOD HABITS OF FOUR SYMPATRIC CARNIVORES (WOLF, FOX, HYENA AND JACKAL) IN KUTCH

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By

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Abstract

Four species of sympatric predators, wolf(*Canis lupus pallipes*), fox(*Vulpes bengalensis*) , hyena(*Hyaena hyaena*) and jackal(*Canis aureus*) inhabit Kutch. The aim of the present study was to determine their food habits and overlaps in their trophic niche. The food habits were determined by scat analysis. Scat samples were collected from Abdasa taluka of Kutch during December, 2005- Ferbruary, 2006 and prey remains were analysed to species on taxa. The wolf primarily subsisted on goat and sheep. The fox and the jackal had a diverse diet consisting of mammals, birds, insects and fruits. The hyena mostly ate cattle and dogs. The most wide trophic niche belonged to the fox, (Levins' index, B= 8.667) followed by jackal (B= 5.518) and hyena (B= 4.06). The amount of diet overlap was greatest between wolf and hyena, (Pianka's index of overlap, O= 0.487) followed by fox and jackal (O= 0.285). The least overlap was observed between fox and hyena (0.055) these findings permit a better understanding of the ecological separation of the four species that enables their coexistence.

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1. Introduction

The study of diet can help us understand the role of a species in the energy flow and nutrient cycle of an ecosystem. It also sets a foundation for the understanding of foraging behavior, population dynamics, habitat use and social organization of a species (Mills, 1992). The study of diet in carnivores is particularly important, because they are often at the end of a food chain and may play an important role in affecting the distribution and abundance of other species (Shun-An-Chuang and Ling Lee, 1987). Studies on food habits have provided valuable information about an animals' life history (Korschgen, 1986). Based on the utilization of the food resources available, an animal can be termed either as a generalist or as a specialist. A generalist uses a wide spectrum of available food resources while a specialist restricts itself in using only a few resources (Krebs, 1998).

Carnivore diet studies have a tendency to be biased towards studying food habits of large carnivores, which dominate the food chain. However, the lesser carnivores, which are often overlooked, are very important organisms in the functioning of an ecosystem. The four species under present study, the wolf, the jackal, the fox and striped hyena are sympatric predators surviving in the same area and utilizing the same set of food resources available to them. Three of them belong to the family **Canidae** and can be termed as sympatric canids and the fourth one, the striped hyena belongs under the family **Hyaenidae**.

The present study aims at analyzing the diets of each of the four species and at determining their trophic niche width and niche overlaps. The niche width thus calculated will represent the extent to which each predator utilizes the food resources available. The study also aims at determining the trophic niche overlaps among the four sympatric predators, which will help in understanding the dynamics of their association and the possibility of interspecific competition.

The arid landscape of Kutch houses three canid species, the fox, jackal and the peninsular wolf, which belongs to schedule I of WPA (1972).All four species are found in the present study area, Abdasa Taluka of Kutch.

The endangered Indian wolf *(Canis lupus pallipes*) primarily inhabits human dominated agro-pastoral landscapes and avoids forested areas. The majority of their population is found outside protected areas (Jethva and Jhala, 2002). Within Indian limits, the wolf is distributed throughout Tibet, Ladakh and parts of Kashmir, extending into the dry desert zone and dry open planes of peninsular India (Prater, 1971).

Wolves in most of their range primarily subsist on domestic livestock (Shahi, 1982; Jhala 1993; Kumar, 2000) and come into direct conflict with man. Throughout their range, wolves face severe persecution from man. In Kutch, their population is about 200-300, stronghold being Abdasa, Nakhatrana and Bhachau Talukas (Jhala, 2002). They also feed on rodents and blackbucks, which is the staple prey in other areas of Gujrat (Jethva and Jhala, 2002).

The Indian fox (*Vulpes bengalensis*) is endemic to the Indian subcontinent. The species has a relatively wide distribution varying from the foothills of the Himalayas in Nepal to the southern tip of the Indian subcontinent (Home, 2005). However, nowhere in its range is the fox abundant (Johnsingh and Jhala, 2004). The fox's diet has been known to comprise of insects (grasshoppers, termites, beetles, scorpions, ants etc.), rodents including gerbils, field rats and mice, hares, birds and their eggs. Fruits consumed by the fox include ber, neem, mango, jamun (Home, 2005). Positive correlations have been found between food abundance and consumption by the foxes for food categories showing a clear seasonality (Ferrari and Wabber, 1995).

Striped hyenas (*Hyaena hyaena*) are typically associated with semi-arid and dry deciduous forests and avoid regions of extreme cold and rainfall (Jhala 2002). Kutch's population of striped hyenas stands at a decent 500-800. They perform an important ecological function by feeding on the large bones of carcasses. In Kutch, hyenas primarily feed on cattle, but also prey on village dogs and occasionally goats, sheep, porcupine and chinkara (Jhala, 2002). It is truly a strange carnivore about which little is known apart from the common notion that they are efficient scavengers.

The jackal (*Canis aureus*) is a widely adaptable creature, which is distributed throughout India, southwestern Asia and Sri Lanka (Prater, 1971). They live in almost any environment, in humid forest country, or in dry open planes or desert (Prater, 1971). They provide good sanitary services in and around human neighborhoods where they have been known to subsist entirely on human wastes (MacDonald. 1979). However, they are capable of hunting down prey which may consist of poultry birds, lambs, kids, sickened goats and sheep. In areas where ber trees grow, jackals are known to collect and feed on the fallen fruits (Prater, 1971).

The four sympatric species of carnivores described above have been surviving in arid landscape of Kutch since time immemorial. They are well adapted predators which play an important role in the functioning of the ecosystem. To what extent do their diets overlap has not been studied in detail. This is an important area of research because it might provide valuable information or set the foundation for further studies on possible interspecific competition. Also as the dry arid area of Kutch holds limited wild prey and mostly domestic livestock, the study of diet can indicate possible sources of human-animal conflict. So, the present study attempts to quantify the diets of each carnivore and to what extent does it share its food resources with other sympatric carnivores.

2. Objectives

The objectives of the present study are given below:

- To determine the individual food habits of the four species, wolf, fox, hyena and the jackal.

- To quantify the trophic niche width of each predator.

- To determine the overlaps in trophic niche among the four sympatric species.

3. Literature review

3.1 Review of literature on scat analysis to study food habits

Mammalian scats may be regarded as primary or supplemental source of information. There exists a correlation between food eaten and residual evidence in scats (Scott, 1941). Ecological estimates which can be obtained from faecal analysis include population estimation (Bennet *et al*, 1940), population age and sex structure, habitat use(Bever, 1955; Rogers et al, 1958; Loudon, 1979), range use (Kruuk, 1978).But scat analysis has the widest application in food habit studies. The food items found present in the scats are expressed as frequency of occurrence, which when used with volume or weight expressed as a percentage of the sample, can indicate food preferences and habits (Korschgen, 1980).

The main advantage of using scat analysis in dietary studies is the readily available nature of the material and the technique's simplicity. (Putman, 1984) There are two basic methods of faecal analysis.(Reynolds and Aebischer ,1991) One method involves separating the microscopic and macroscopic remains by a .5 mm mesh. The different classes of remains are separated by hand, dried and the data regarding the relative proportion is used with weight or volume to quantify diet. (Lockie, 1959; Burrows, 1968; Richards, 1977) The other method involves placing faeces in nylon strainer bags and washing mechanically, which results in the loss of microscopic remains. The macroscopic remains are separated, dried and weighed for each prey class(Johnson and Hansen, 1979; Johnson, 1981).

Both the methods described suffer from some value limiting problems. (Reynolds and Ae bischer, 1991) these problems arise from the following factors-

- Unequal representation of bird remains in micro and macroscopic components of scats compared to mammals.
- Error involved in assuming that the estimates of consumption of each prey species is independent.
- Disparity in results using different conversion factors between the dry weight of remains and fresh weight of food ingested.
- Inclusion of non-food items in diet composition.

- Unquantifiable food items.
- Determination of the proper of scat sample to be analyzed to minimize errors involved in sampling procedure.

To minimize the errors involved in quantifying diets using scat analysis as mentioned above, Reynolds and Aebischer, 1991 suggest proper planning and collection of scat samples, maintaining hygiene and safety during analysis. Proper and careful lab procedures are a priority which involves drying and weighing scat samples, separation of macro and microscopic fragments, proper conversion of raw data and calculation of fresh weight. As regarding the required sample size, they suggest simulations like Monte Carlo simulations to estimate the mean and the 95% percentile range of proportions of different food items. To estimate the sampling errors, bootstrap simulation, a computer-based randomization technique (Efron and Tibshirani, 1986) is recommended. This technique measures the 95% confidence limits of the proportion of each food item in the diet, the limits of which range measure the random sampling errors.

3.2 Food habits of foxes

The fox is generally considered to be a generalist, particularly as regards to its food habits (Englund, 1965, Amores, 1975). which implies that it utilizes a wide variety of food resources. In order to understand why different proportions of fruits, invertebrates and vertebrates are found in fox's diet, the first factor to be taken into consideration is the availability of those resources. (Calisti *et al*, 1999)

Much of the studies on the food habits of foxes have been done on Red foxes (*Vulpes vulpes*). Harris, 1981, examined 571 fox stomachs in Greater London and found a wide array of food items in their diet. The adult foxes had 24% non food items in their diet and 13% coarse grasses. Bird remains were found in a large proportion of the stomachs, especially in

case of cubs. A Diversity of food items including earthworms,(12.2%) fruits and vegetables, (7.6%) and scavenged meat and bone (24.1%) were observed in the fox's diet.
Other studies on the food habits of red foxes in Britain also show a wide variety of food items in their diet (Jensen and Sequeira, 1978; Brosset, 1975.).

On the study of predation of the red fox on the water vole in western Switzerland, 1213 scats were analyzed. Scavenged prey like cattle, roe deer dominated the diet.(62.3%) Invertebrates and birds were present in smaller percentages (10.3% and 2.5% respectively) and their consumption was highly seasonal. Miscellaneous items like grasses, earth, and straw comprised 19.3% of the diet (Weber and Aubry, 1992).

Calisti *et al*, 1999 studied the food habit of red fox in Maremma national park, central Italy. A total of 325 Scats were analysed and it was found that plants made up the bulk of the diet. (65%) In particular, Juniper, seeds of stone pine and Blackberries were had high frequency of occurrence. Plants were followed up by insects, represented by Orthoptera and Coleoptera. 20% of the dietary volume was comprised of vertebrates, which consisted mainly of micro mammals and scavenged carcasses. Birds were present in their diet, but in a lower percentage value.
Micro mammals including rodents were also found to be the chief food item (35%) in the study of the diet of the red fox in south western Hungary during winter and spring by J.Lanszki and M.Heltai, 2002. Among other mammals, members of the family Cervidae were present. Invertebrates were present in 15% of the scats, followed by remains of birds.

The Indian fox (*Vulpes bengalensis*) is distributed throughout the Indian Subcontinent ,from the foothills of the Himalayas to cape Comorin. (Prater, 1971). Their diet is known to consist of insects like grasshoppers, beetles, termites, rodents, hare, birds and their eggs, lizards and snakes. They also feed on fruits like Ber, Neem, and Mango. (Home, 2005)

Chandrima Home studied the feeding habits of the Indian fox in Kutch, including the present study area. A total of 392 scats were collected for both winter and summer seasons and analyzed. In the scats, among the mammalian prey items present, rodents were the predominant food items. (40.82%), followed by sheep, goat, cattle and goat.

Among the invertebrates, termites were present in 52.8% of the scats, followed by beetles. (47.7%) Birds comprised about 4% of the diet. Among the reptilian remains, spiny tailed lizards (*Uromastyx sp*) had a high frequency of occurrence. (Home, 2005)

3.3 Food habits of golden jackals

The golden jackal (*Canis aureus*) is an opportunistic forager and not persistent hunter (Giannatos, 2004). It is a widely adaptable creature which lives in almost every environment (Prater, 1971). They provide good sanitary services in and around human neighbourhoods where they are known to subsist almost totally on human waste (MacDonald, 1979). They are, however, not totally averse on hunting and their prey may consist of poultry birds, sickened lambs and goats and sheep. In areas where Ber (*Zizyphus mauritiana*) trees grow, jackals are known to collect and feed on the fallen fruits (Prater, 1971).

Studies on the food habits of the golden jackal have mostly been conducted in western countries and are an area which needs further research.

Lanszki and Heltai, 2002 studied the food habits of the golden jackal in south western Hungary. The results showed that carrion and rodents were the chief food items present in their diet. Rodents comprised 43% of the diet based on the frequency of occurrence data. Ungulate remains were present in 24% of the scats and wild boar also comprised 41.1% of the scats.

In comparison, birds, reptiles and amphibians did not occur in substantial proportions.

In an ecological study of the golden jackal in Bangladesh, it was found that carrion was the most frequently observed food items which occurred in 45% of the animals examined. There was little evidence of jackals consuming urban and rural human waste in the study. The general diet was varied and depended primarily on the availability of the food types. (Poche, Evans, Sultana *et al*, 1987)

Livestock was found to be an important part of jackal's diet in the study on the cattle predation in golden heights in Jordan. Livestock predation was found to be a rather common occurrence, and thus cattle represented one of the main prey species of the area (Yum-Tov, Ashkenazi and Viner, 2005).

In Greece, scats collected as a part of the ecological study of the golden jackal showed that the main prey items present were rodents and Lagomorphs like hare. Insects like ants and termites also contributed significantly to the diet (Giannatos, 2004).

In the Indian subcontinent, studies on the food habits of the golden jackal have shown it to have a diverse diet consisting of mammals, birds and vegetable matter. Schaller studied the the food habits in Kanha and found more than 80% of the diet comprising of mammals, reptiles and fruits(Kotwal *et al*, 1991, Y. Jhala, pers.obs). A similar study in Bharatpur found 60% occurrence of rodents, birds and fruits (Sankar, 1998). Mukherjee studied the food habits of the golden jackal in Sariska Tiger reserve, rajasthan. Her study showed the animals having a diet comprised mainly of mammals, (45% occurrence, of which 36% was rodents) vegetable matter (20%), and birds (19%) (Mukherjee, 1998).

3.4 Review of the literature on the food habits of striped hyena

The striped hyena is one of the strangest predatory mammals around. Built neither for speed, nor for direct attack on prey animals, it is mainly a scavenger by nature.

However, it does not feed wholly on carrion. Sheep and Goats are occasionally hunted and stray dogs are quite often carried off (Prater, 1971).

The food habits of striped hyenas were studied in Logatham, northern Kenya. By Leaky *et al*, 1999, it was found that there were a high proportion of livestock, dog and human remains in the diet, which indicated that the hyenas predated on small livestock.

Studies on the food habits of the striped hyena have been very few, especially in the Indian subcontinent.

Food habits of the striped hyena were studied in the Sariska tiger reserve, Rajasthan. 26 scats were collected and analyzed. Remains of cheetal were found in 35% of the scats analyzed. Among the other mammalian prey items found, cattle, nilgai and rufous-tailed hare were present. Fruits of ber (*Zizyphus sp*) were also present along with the remains of an unidentified bird (Sankar and Jethva, 2001).

3.5. Food habit of grey wolves

The grey wolf(*Canis lupus*), has been a much maligned creature since a very long time. Wrongful persecution across several countries has led to its decline in population. In India, the grey wolf is distributed throughout Tibet, Ladakh, parts of Kashmir, extending into the dry open plains of peninsular India. Wolves in most of their range primarily subsist on domestic livestock, which has led to its severe persecution (Shahi, 1982; Jhala, 1993; Kumar, 2000).

The studies on the food habits of the grey wolf have been quite extensively carried out in western countries. In northern Wisconsin, Thompson found 97% occurrence of white-tailed deer (*Odocoileus virginiaus*) in 425 analyzed scats. Remains of lagomorphs and rodents were found in 9% of the scats (Thompson, 1952).

Cowan studied the food habit of wolves in the Canadian national parks in rocky mountains and found an annual occurrence of 80% ungulates and 18% rodents in the die. (Cowan, 1944).
In an extensive study on the food habit of wolves in Thelon Game sanctuary and Bishop-Beniah lake area in Alaska, E.Kuyt analyzed 595 scats and found that caribou was the

main prey item (38%) Rodent remains were found in 10.5-15.9 percent of the scats, followed by birds (Kuyt, 1987).

Wild and domestic ungulates were also found to be the staple diet of wolves in Abruzzo national park in central Italy in a study by Patalano and Lovari (Patalano and Lovari, 1993)

In another study in three different ecosystems in central and northern Italy, Capitani *et al,* 2004, studied the diet of the gray wolf by scat analysis. They analyzed 194, 355, 118 scats from the three study sites and found that Cervids were the main prey items in two of the three ecosystems studied. Wild boar predominated as the chief prey in Pratomago. Remains of Bovids and livestock also had good frequency of occurrences.

Food habits of arctic wolves studied by analyzing 461 scats collected from two study areas in northern and eastern Greenland. Remains of musk-ox had the highest frequency of occurrence.(79.4%) It was followed up by Lemmings and by snow shoe hare(Marquard-Peterson, 1998).

Studies on the food habits of the gray wolf, *Canis lupus pallipes* in the Indian subcontinent have also shown ungulates to be the main prey items consumed, depending on availability(Jethva and Jhala, 2004).

In the study on predation on blackbuck by wolves in the Velvadar National Park, it was found that that blackbuck was the main prey item (88% of the biomass consumed). Other mammalian prey included hare (Jhala, 1993).

Jhala and Jethva also studied the foraging ecology of Indian wolves in Bhal region oh western Gujarat. They collected and analysed 1246 scats and the results showed blackbuck to be the main prey item. (55.5%) Other mammalian prey items found included cattle (25.7%) and rodents (Jethva and Jhala, 2004).

3.6 Trophic niche overlap among sympatric predators

Niche overlap refers to the utilization of the same resource types by two or more species resource consumers (Abrams, 1980). The most common resources measured in order to calculate overlap are food and space (Krebs, 1980). The trophic niche of an organism represents its utilization of the food resources available. Differences between sympatric species in the use of trophic niche have been frequently used to describe and explain community structure (Jaksic, Schlatter and Yamez, 1980). by measuring the trophic niche of an organism, we can find out whether it is a generalist and utilizes a wide spectrum of resources or a specialist using only a few resources (Krebs, 1980). Niche overlap also serves as a foundation for discussing competition (Hurlbert, 1978).

Studies on trophic niche overlap among sympatric species involve analyzing their diet by faecal analysis or other methods and quantification of the index of overlap as described Levins, 1968 and Pianka, 1972.

Padial *et al* studied the food habits and diet overlaps among the red fox and the stone marten in Sierra Nevada national park in southern Spain. Scat analysis was carried out with 856 scats collected from two habitat types, mesic and xeric. The results showed a high overall trophic niche overlap in the mesic habitat while the xeric habitat represented an annually moderate overlap. The stone marten's diet consisted of mainly small mammals while the fox based its diet on carrion, small mammals and lagomorphs(Padial, Avila and Gil-Sanchez, 2002).

The feeding habits of the golden jackal and red fox were studied in south western Hungary by Lanszki and Heltai. In the two study areas, Small mammals and ungulate carcasses were predominant in the diet of golden jackal. Likewise, small mammals and birds were the chief components of the fox's diet. The trophic niche overlap was determined at 60-77% based on the frequency of occurrence data, which signified a considerable amount of diet overlap(Lanszki and Heltai, 2002).

Diet overlaps of more than two sympatric predators were studied in Cerrato biome of Central Brazil. Food habits and diet overlaps of maned wolves (*Chrysocyon brachyurus*), crab-eating foxes, (*Ceradocyon thous*) and hoary foxes(*Lycalopex vetulus*) were studied by faecal analysis. Diet overlap between maned wolf and the crab-eating fox was greatest than others (Juarez and Marinho-Filho, 2002).

Diet overlap between the wolf and the red fox was determined in the Abruzzo national park in central Italy. Scats were collected and analyzed and it was found that wild and domestic ungulates were the chief prey items found in the wolf's diet. The chief remains present in fox scats consisted of rodents. On the whole, the diets overlapped little as the wolf and the fox seemed to have preyed on animals of different body sizes. The wolf's diet consisted of much larger species than the fox's (Patalano and Lovari, 1993).

Diet overlap studies have also been conducted in Asian countries. In the Fushan forest of northern Taiwan, food habits of three sympatric predators, the lesser oriental civet, the crab eating mongoose and the ferret-badger were studied. The civet's diet mainly consisted of mammals and insects. The mongoose had a considerable amount of birds, reptiles and crustaceans in its diet. The ferret-badger mainly fed on invertebrates including insects and Oligochaetes. The degree of diet overlap was the greatest between the civet and the ferret-badger, followed by the civet and the mongoose (An Chuang and LingLee, 1997).

4. Study area:

Location: Kutch district encompasses the north western region of Gujarat state. It has a total area of 45,652 sq. km. The district is divided into nine talukas. The present study was conducted in the scrub and grassland habitats of Abdasa taluka, in the Kutch district of Gujarat. The taluka is located in the south western province of Kutch, abutting the Gulf of Kutch and the Arabian sea.

History: Kutch has remained detached from the mainland for the last nine hundred years. In ancient times, when the Rann was an arm of the Arabian sea, Kutch was more like an island, linking Sind and Kathiawad. Traces of remarkable Indus valley civilization have been found in Kutch. There is a definite possibility that this civilization penetrated into Kathiawad and western India through Kutch.

Climate: Being a semi-desert region, Kutch has a scanty rainfall. The average annual rainfall is about 384 mm, with drought years occurring in a decade. There are three distinct seasons in the region, summer, winter and monsoon. January is the coldest month, with average minimum temperature being 5 degree Celsius. The highest air temperature is recorded in the month of May, with the temperatures ranging from 40 to 45 degree Celsius. The south west monsoon reaches the coastal areas by the middle of June and spreads to other parts by by the first week of July.

Vegetation: the vegetation in the area has been classified as northern tropical thorn forest and sub classified as Desert thorn forest.(6B/ C1) as per the classification of India’s forest types by Champion and Seth(1968) The area is comprised of undulating terrain with low hillocks dominated by species such as *Acacia nilotica*, *Acacia Senegal*, *Prosopis juliflora*, *Salvadora sp*., etc. Other species in the area include *Zizyphus* sp., *Commiphora* sp. Etc. There are grassland areas dominated by species such as *Cymbopogon* sp., *Chrysopogon* sp.etc.

Fauna: Kutch houses many important species, some of which have been included in the Schedule I of Wildlife Protection Act, 1972. Apart from the peninsular wolf, other important species include jackal, Indian fox, striped hyena, caracal, desert cat, chinkara, nilgai, wild boar, spiny tailed lizard, great Indian bustard, lesser florican, etc. It also presumably holds a small breeding population of endangered white-backed vultures.

5. Materials and methods

Food habits of the four sympatric carnivores were studied using scat analysis. This method was preferred because of the following reasons:

- Post ingestion sampling is the most common technique for analyzing food habits of vertebrates (Korschgen, 1980).
- Scats can be collected without interfering with the target species (Korschgen 1980).
- Faecal material and pellets from predators require minimal preparation (Korschgen, 1980).
- Much of the material in carnivore faeces or regurgitations may be identified macroscopically or from bone shapes and structures, from tooth patterns or from hair or feather patterns (Day, 1966; Yalden, 1977; Debrot *et al*. 1982).

5.1. Collection of materials:

The scat samples of the four species under study, the wolf, the jackal, the hyena and the fox were collected from Abdasa Taluka of Kutch during December 2005 to February 2006. the scats were distinguished on a species level with the help of diameter, size, shape, odour, colour and the numbers of scats collected for each species are as follows:

- Wolf – 85
- Fox – 91
- Hyena – 74
- Jackal – 90

The scats were stored in polythene zip locks and the locality was noted. The scat samples were brought to the laboratory for further analysis.

5.2 Laboratory methods:

5.2.1 Preparation of material:

All scat samples collected were oven dried at 60^0 C for 48 hours. The scats were then broken apart by hand and the macroscopic and microscopic components were separated. Hairs were teased apart using forceps and stored separately and all other macroscopic remains like bone fragments, skull, mandible, feathers, scales, seeds and other plant materials were categorized and stored.

5.2.2 Identification of food items:

The macroscopic remains like bones, claws, skin, hooves, mandible, quills and vegetable materials were examined to identify the prey remains (Grobler and Wilson, 1972). But since this method was not conclusive, hair remains in scat samples were microscopically examined (Mukherjee *et al*. 1994).

5.2.3 Preparation of slides:

The hairs collected from the scats were soaked in xylene overnight for washing away dirt and removing medullary pigments. The hairs were then dried and mounted on microscopic slides for microscopic examination for identification of prey species.

5.2.4 Reference sample slide preparation:

Reference hair samples of wild and domestic prey living in the study area were collected from the reference collection of Wildlife Institute of India. The hairs were soaked in xylene overnight and reference slides for cuticular and medullary pattern were made using the following techniques:

5.2.5 Slides for studying cuticular patterns:

Gelatin solution was prepared by mixing gelatin powder in boiling water and a few grains of methylene blue were added into it. A thin smear of this solution was applied on a clean microscopic slide. Clean, dry hairs were placed on the slide, some with the lower shaft region overhanging and some with the tip overhanging the edge of the slide and allowed to dry (Oli, 1993). The hairs were then gently removed by holding individual hair with the help of fine forceps and scale replica was studied under microscope.

5.2.6 Slides for studying medullary patterns:

Clean, individual hairs were placed on clean microscopic slides, mounted with DPX and microscopically studied.

Photographs of reference hairs were taken to provide additional reference material apart from the slides themselves.

5.2.7 Identification of prey species:

The method for making sample slides was similar to that of reference slides (Mukherjee *et al*. 1983). The slides were studied under microscope for examining cuticular and medullary patterns. The characteristics studied were scale margins, inter-scale distance, medulla thickness, medulla type and arrangement of medullary pigments. The hairs were identified by comparing with reference samples...

5.3 Analytical methods:

5.3.1. Sample size estimation:

To determine the minimum number of scats that needs to be analyzed to have an accurate estimate of the food habits of the species under study, the cumulative percent frequencies of the occurrences of the different prey species were calculated for each increment of five scats and this was plotted against the total number of scats analyzed. It is seen as the number of scats increase, the proportions of prey items stabilize at a point giving an approximate number of scats required to analyze the food habits of the species under study. Sample size estimation was done individually for each species. This standardization would help optimize efforts and minimize costs for food habit studies (Jethva and Jhala, 2003).

5.3.2. Data Analysis:

The commonly used and widely applied method of diet analysis is the frequency of occurrences of prey types per sample of faeces (Leopold and Krausmen, 1986; Corbet, 1989). The frequency of occurrence of a prey item was calculated as the number of times a specific prey item was found to occur, expressed as a percentage. The frequency of occurrences of different prey species found were plotted graphically for each predator, thus giving a visual representation of the different prey items found in the diet.

To estimate the variation in diet, computer based Bootstrap simulation; a sub sampling technique based on randomization (Efron and Tibshirani, 1986) was used. The Bootstrap method is a resampling technique used for confidence intervals and other information about the distribution of sample statistics (Marly, 1987). This technique generates the 95% confidence limits of the proportion of each food item in the diet, the limits of which range measure the random sampling errors (Reynolds and AeBischer, 1981). The confidence limits thus found for each prey species were plotted on the graphs showing frequencies of occurrences. Bootstrap simulation was carried out using SIMSTAT software. (Version 2.5). (http: // www.provalisresearch.com/simstat/simstatv.html)

Niche width and niche overlaps between the four species under study were calculated using appropriate indexes provided by Levins (1968) and Pianka (1972)

5.3.3. Calculation of niche width

Niche widths were calculated using the index provided by Levins (1968)

$$B = \frac{1}{\sum P_i^2}$$

Where, B= Levins' measure of niche width

P= Fraction of items in diet those are of Food category i

Or, $$B = \frac{Y}{\sum N_i^2}$$

Where, Y= total no. of individuals sampled

N_i= no. of individuals found in or using resource state i

Here, N_i= Number of scats where a particular a particular prey species is present

Y= Total number of scats where prey species are present

The niche widths thus calculated for each species were standardized on a scale from 0 to 1 by calculating Levins' measure of standardized niche breadth. (Levins, 1968)

$$\hat{B} = \frac{B-1}{N-1}$$

Where, $\hat{B}$ = Levins' measure of standardized Niche breadth

B= Levin's measure of niche breadth

N= No. of food items

5.3.4 Calculation of niche overlaps:

Niche overlaps among the four sympatric predators were calculated using Pianka's index of niche overlap. (1972)

$$O_{jk} = \frac{\sum (Pij.\ P_{ik})}{\sum P_{ij}^2 .\ \sum P_{ik}^2}$$

Where, O_{jk}= Pianka's measure of niche overlap between species j and k

P_{ij}= Proportion resource i is of the total resources used by species j

P_{ik}= Proportion resource k is of the total resources used by species k

To find out the proportions of the each of the food items found in the diet with the total number of food items found, % of occurrence of each food item was calculated for each carnivore. (Pianka. 1972)

The resultant dietary niche overlaps among the four carnivores is tabulated below:

Niche overlap is measured on a scale of 0 to 1, thus an overlap of 1 represents total diet overlap.

5.3.5. Determination of diversity of diet

The percentage of occurrence of each prey type was also calculated apart from frequency of occurrence to determine the diversities observed in the diets of the four predators. To achieve this, % of occurrence data was used to enumerate Shannon-Wiener index of diversity. The species having a more varied diet will obviously have a greater index. The more specialized species will have a smaller index compared to the generalist ones.(Krebs, 1998)

$$\overline{H} = -\sum P_i \log P_i$$

Where, $\overline{H}$= Shannon Wiener index of diversity.

P_i= Proportion of food item i in the diet (%)

5.3.6. Computation of biomass consumption

The frequency of occurrence data was used to calculate the % of biomass consumption of each prey species by the predators.

The frequency of occurrence data were converted into estimated biomass consumption with the help of the equation provided by Jhala and Jethva, 2004, Floyd *et al*, 1978 and Ackerman *et al*, 1984 . This equation estimates the amount of biomass consumed per collectible scat with the following relation:

$$\mathbf{Y = 0.0148X + 0.135}$$

Where, **Y**= biomass consumed per collectible scat

X= average body weight of prey

Now, by multiplying Y with N or the occurrence of that prey species in total scat, the estimation of consumption of that species was achieved. The resultant biomass consumptions in terms of kilograms were summed for all the prey items, which represented the total consumption of biomass by that carnivore. The individual consumption amounts were then expressed as a percentage of the total consumption, thus giving the % consumption of biomass of each prey species.

6. A Results and findings: Identification features of reference material

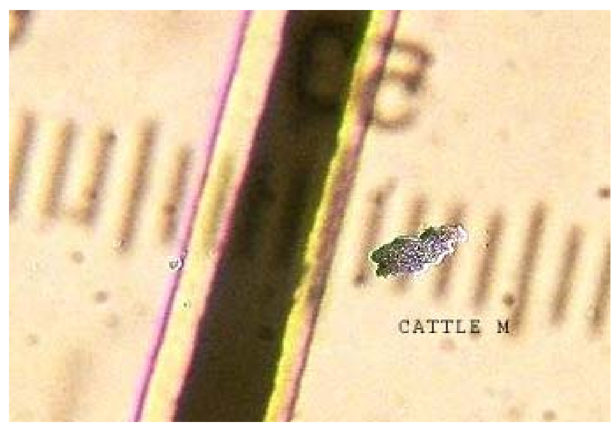
6. A.1 Cow (*Bos indicus*)

A. Medulla characteristics- Dimensions(mm)
- Hair thickness (M) - 0.07± 0.17
- Medulla thickness (T)- 0.03± 0.2
- M/T- 0.48

B. Medulla type- Simple

C. Cuticular characteristics**-**

Hair portion	Scale patters	Scale margin	Distance between scales
Medial	Irregular wave	Rippled	Near



- Comment- The cuticular scale patterns could be confused with goat, but the inter scale gap and the medulla are wider ,which distinguishes the two.

6. A.2 Goat (*Capra hircees*)

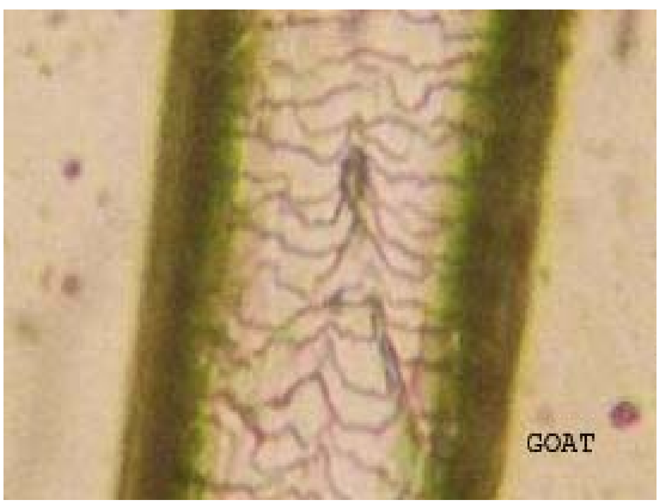
A. Medulla characteristics- (dimensions-mm)

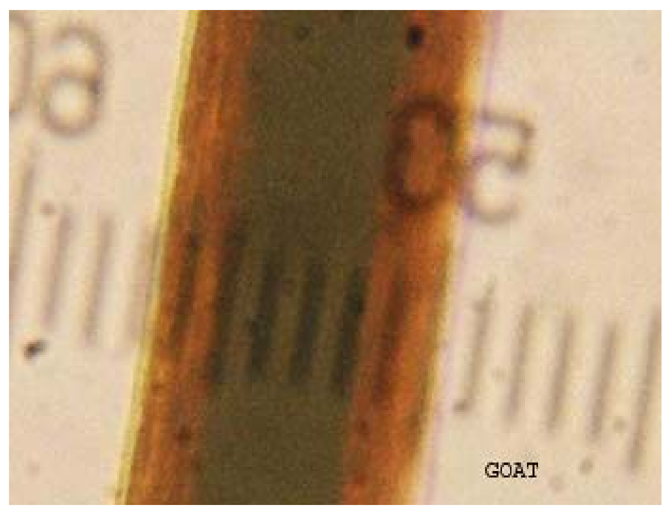
- Hair thickness(M)- 0.09±0.2
- Medulla thickness(T)- 0.03±o.14
- M/T- 0.35

B. Medulla type- Simple

C .Cuticular characteristics-

Hair portion	**Scale patterns**	**Scale margin**	**Distance between scale**
Medial	Irregular wave	Rippled	Near





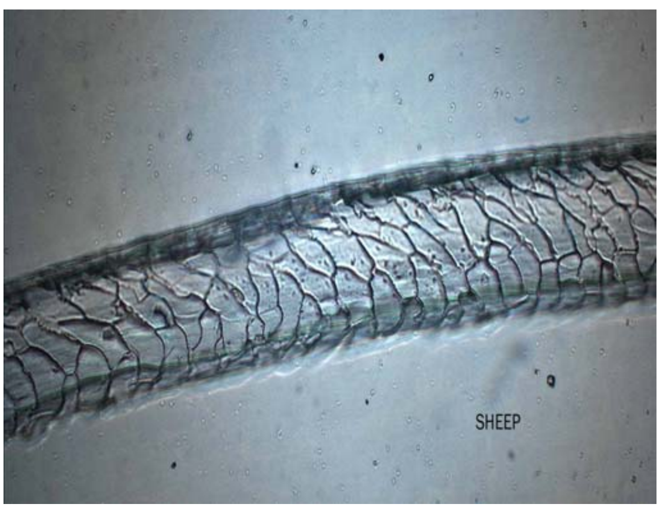
6. A.3 Sheep (*Ovies aries*)

A. Medulla characteristics-(dimension-mm)
   - Hair thickness(M)- 0.07± 0.3
   - Medulla thickness(T)- 0.033± 0.4
   - M/T- 0.47

B. Medulla type- Fragmental

C. Cuticular characteristics-

Hair portion	Scale patterns	Scale margins	Distance between scales
Medial	Broad petal	Smooth	Distant



- The fragmented nature of the medulla is the most distinguishing feature in sheep. The medulla may be broken up in places.

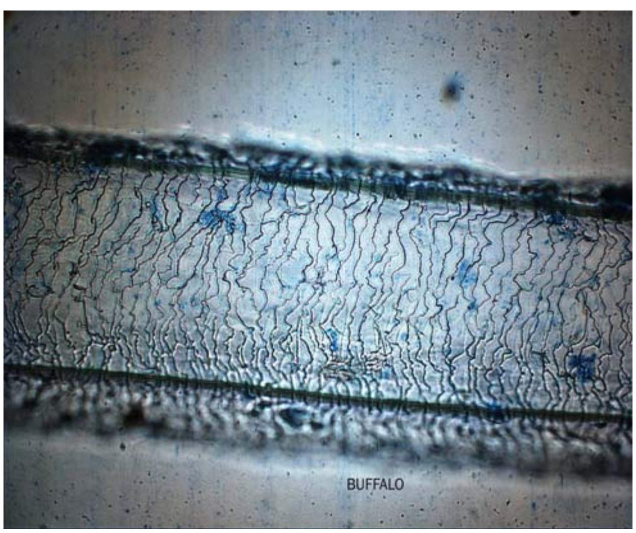
6. A.4 Buffalo (*Bubalus bubalis*)

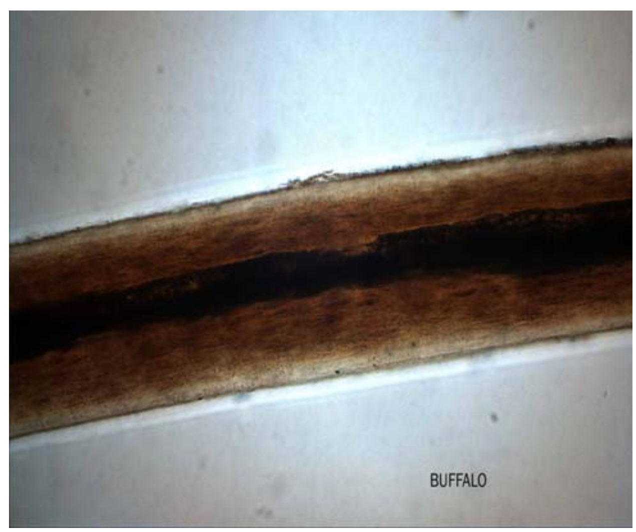
A. Medulla characteristics-(Dimension-mm)
   - Hair thickness(M)- 0.12± 0.2
   - Medulla thickness(T)- 0.03± 0.25
   - M/T- 0.25

B. Medulla type- Interrupted and simple

C. Cuticular characteristics-

Hair portion	**Scale patterns**	**Scale margin**	**Distance between scales**
Medial	Irregular wave	Rippled	Near





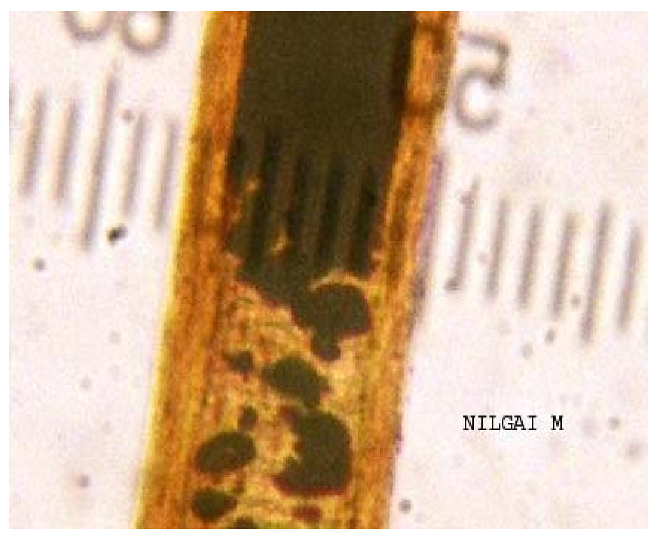
6. A.5 Nilgai (*Boselaphus tragocamelus*)

A. Medulla characteristics-(dimensions-mm)
   - Hair thickness- 0.083± 0.32
   - Medulla thickness- 0.055± 0.114
   - M/T- 0.65

B. Medulla type- Simple

C. Cuticular characteristics

Hair portion	**Scale pattern**	**Scale margin**	**Distance between scales**
Medial	Irregular	Crenate	Near



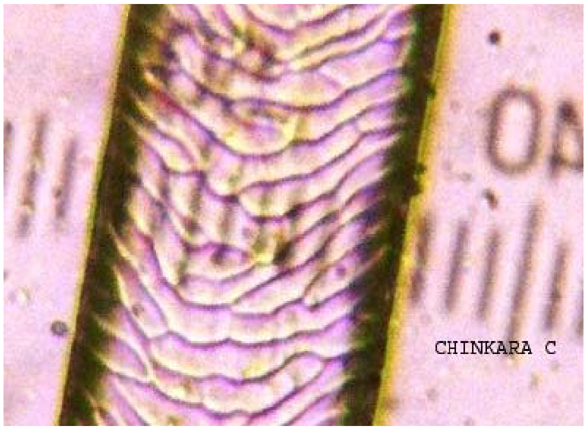
6. A.6 Chinkara (*Gazella bennetti*)

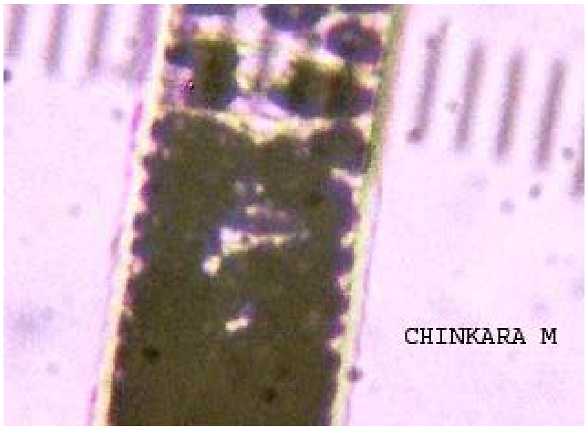
A. Medulla characteristics-(dimensions-mm)
   - Hair thickness(M)- 0.083± 0.32
   - Medulla thickness(T)- 0.055± 0.114
   - M/T- 0.65

B. Medulla type- Simple

C. Cuticular characteristics-

Hair portion	Scale pattern	Scale margin	Distance between scales
Medial	Irregular	Crenate	Near





- Comments- The crenate scale margins are a distinctive feature.

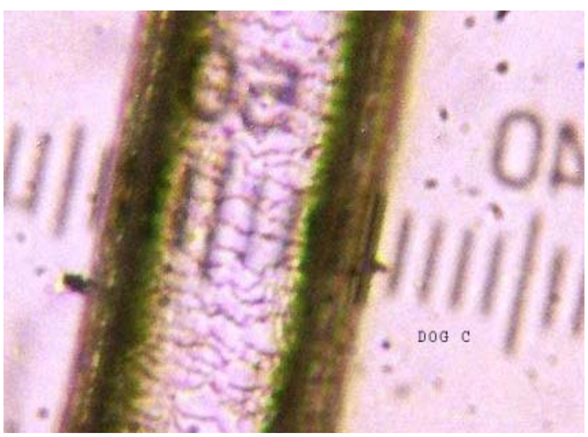
6. A.7 Dog (*Canis familiaris*)

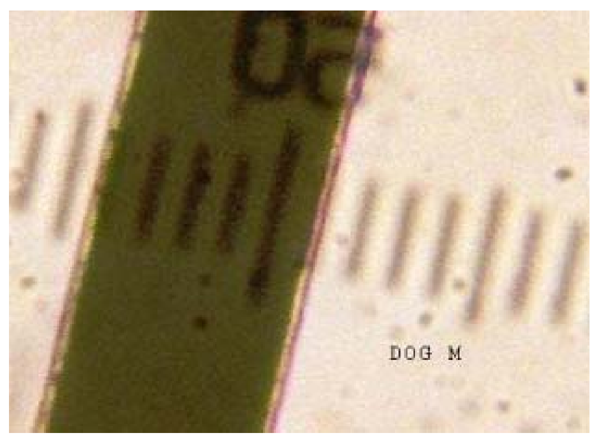
A. Medulla characteristics- (dimensions-mm)
Hair thickness(M)- 0.09± 0.1
Medulla thickness(T)- 0.05± 0.0
M/T- 0.5

B. Medulla type- Simple

C. Cuticular characteristics-

Hair portion	**Scale patterns**	**Scale margin**	**Distance between scale**
Medial	Irregular wave	Rippled	Near





- Comments- the rippled scale margins distinguish it from cow.

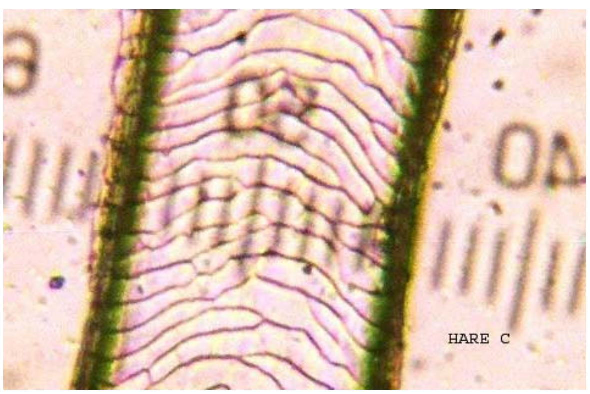
6. A.8 Rufous tailed hare (*Lepus nigricolis)*

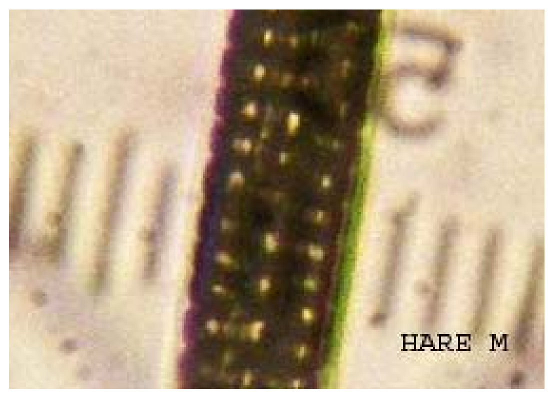
A. Medullary characteristics- (dimensions-mm)
    - Hair thickness(M)- Not determined
    - Medullary thickness(T)- Not determined
    - M/T- Not determined

B. Medulla type- Simple

C. Cuticular characteristics- Crenate

Hair portion	Scale pattern	Scale margin	Distance between scales
Medial	regular	Smooth	Near





- Comments- the medulla patterns are very distinctive, the pigments being arranged like corn in more than two strips.

6. A.9 Rodent (Rattus sp)

A. Medulla characteristics- (Dimensions-mm)
    - Hair thickness- 0.065 ± 0.1
    - Medulla thickness- 0.05± 0.1
    - M/T- 0.8

B. Medulla type- Multiserial ladder

C. Cuticular characteristics-

Hair portion	Scale Pattern	Scale margin	Distance between Scale
Medial	Regular wave	Smooth	Near

- Comments- the medulla patterns can be confused with hare. The distinguishing feature is that the medulla pigments in case of hare are arranged in distinct strips which number in more than two. Whereas in rodents the pigments do not show distinct separate strips.

6. **Results and findings**

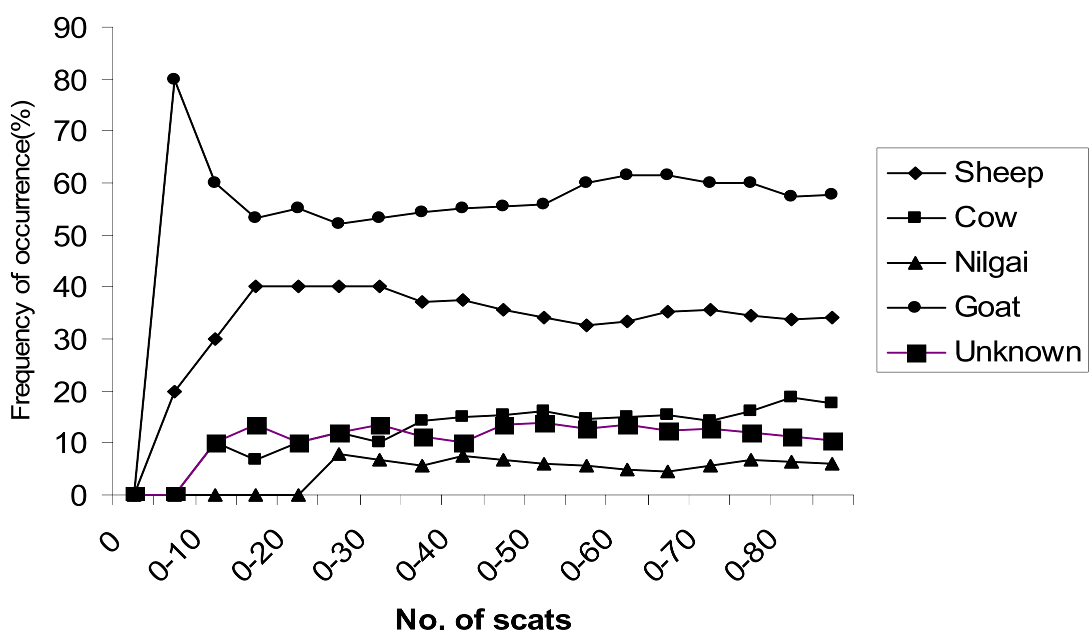
6.1 Individual food habits

6.1.1 The Indian wolf (Canis *lupus pallipes*)

Proportionate contribution of different prey items stabilized after analysis of 70 scats, showing adequacy of scat samples analysed for an accurate estimate of food habits of wolves (Fig 1)

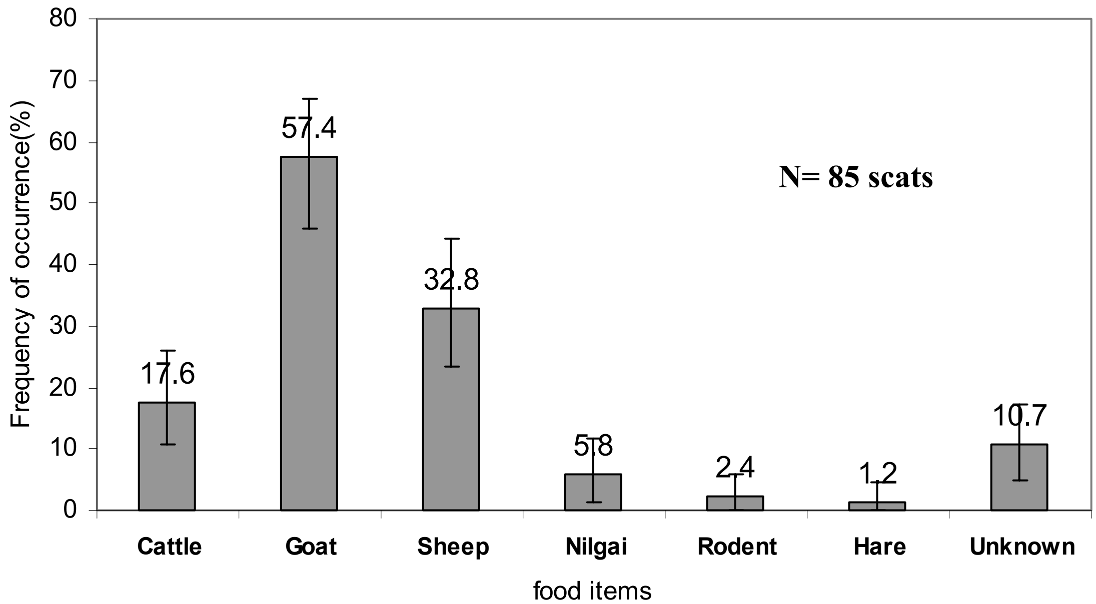
A total of 85 wolf scats were analyzed. The results show goat to be the major prey item. Its remains were found in 57.4% of the scats. Goat was followed by sheep which had a frequency of occurrence of 32.8%. Cow remains were found in 17.6% occasions. The wolf also fed on nilgai (5.8%), rodents (2.4%) and hare (1.2%). All mammalian remains not identified through microscopic examination were grouped as unknown mammals, which had a frequency of 10.7 %(Fig 2)

Fig 1: sample size estimation for the no. of scats required to be analysed for accurate food habits study in Abdasa, Kutch.



The confidence limits thus generated by Bootstrap resampling were plotted on the graphs showing frequencies of occurrences.

Figure 2: Food habits of wolves in Abdasa Kutch as depicted by frequency of occurrence of prey remains in scats.



6.1.2 Food habit of Indian fox (*Vulpes bengalensis*)

Proportionate contribution of different prey items stabilized after analysis of about 80-85 scats, showing adequacy of scat samples analysed for an accurate estimate of food habits of fox (Fig 3)

The number of scats analyzed of Indian fox was 91. The results show the fox to have a diverse diet consisting of mammals, birds, reptiles and plant matter. Among mammalian prey items, rodents were the predominant prey (34.1%). Remains of hares had a frequency of occurrence of 13.2%. Goats were also found in the diet; however, remains of its carcasses had a frequency of occurrence of only 4.7%. Feathers of birds eaten had been found on 35.9% of the occasions, which was considerably high. Scales and bones of reptiles were found in 15.2% of the scats. Among insects, termites had the highest frequency of occurrence(27.8%) Termites were followed by ants(22.9%), beetles(10.9%), scorpion(5.5%). Remains of unidentified insects were found in 36.3% of the scats

Plant matter had a frequency of occurrence of 27.8%.The cumulative frequency of occurrence (%) of prey remains stabilized at around 80-85 scats, thus showing adequacy of sample

Figure 3: sample size estimation for the no. of scats required to be analysed for accurate food habits study in Abdasa, Kutch.

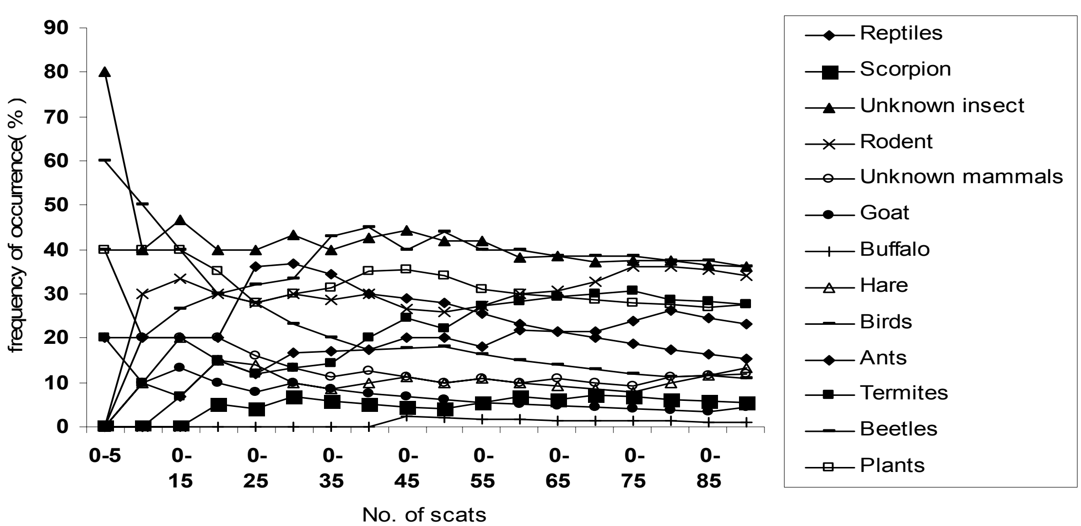
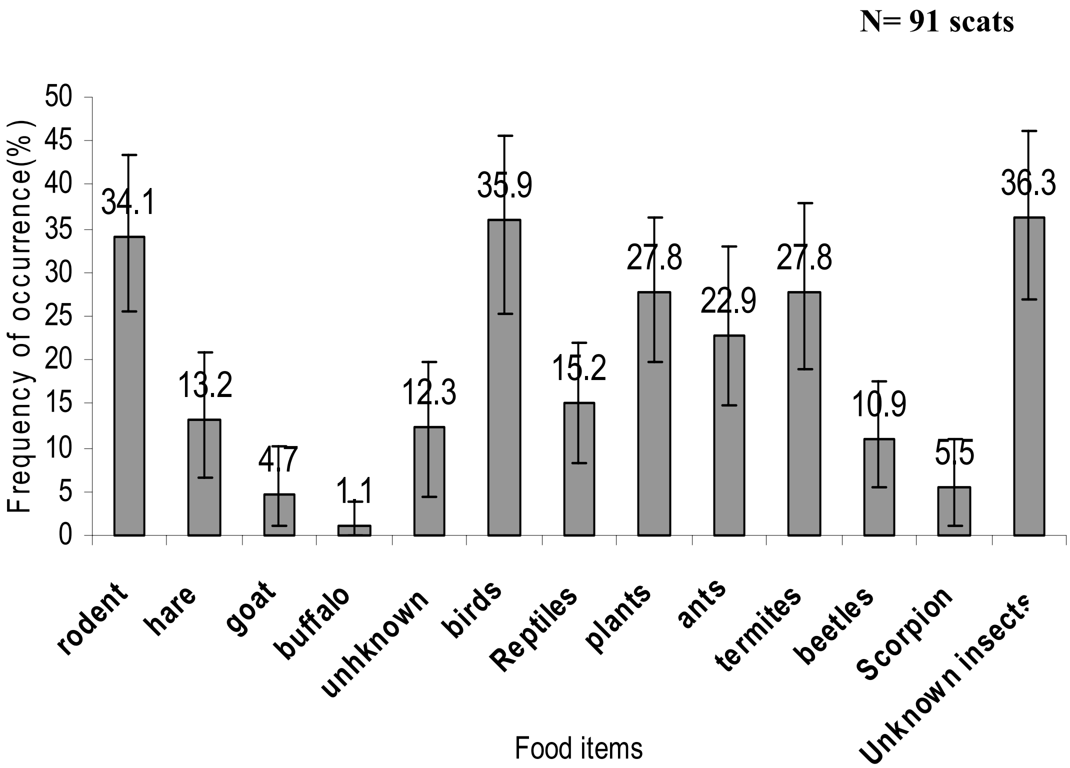


Figure 4: Food habits of foxes in Abdasa Kutch as depicted by frequency of occurrence of prey remains in scats.



6.1.3 Food habits of golden jackal(*Canis aureus*)

Proportionate contribution of different prey items stabilized after analysis of about 75-80 scats, showing adequacy of scat samples analysed for an accurate estimate of food habits of jackal (Fig 5)

In total, 90 scats of golden jackal were analyzed to determine its food habits. The results show it to have a diverse diet like fox. Among the mammalian prey, remains of buffalo carcasses had the highest frequency of occurrence (26.7%) Buffalo was followed by Cow, which was found in 15.4% of the scats. Remains of sheep were found in 5.4% of the occasions. Other mammalian prey included rodent (6.7%). Remains of unidentified mammalian prey were found in 7.8% of the scats. Feathers of birds had a frequency of occurrence of 3.2%.

Among insects, termites had the highest frequency of occurrence (4.4%).Remains of ants were found in 3.4% of the scats. Unknown insects were found in 6.7% of the occasions. Among plant matter, seeds and whole fruits of Zizyphus mauritiana clearly predominated. Its remains were found in 52% of the scats. Unidentified plants had a frequency of occurrence of 24.4%. The cumulative frequency of occurrence (%) of prey remains stabilized at around 75-80 scats (Fig 5), showing adequacy of sample size

Figure 5: sample size estimation for the no. of scats required to be analysed for accurate food habits study in Abdasa, Kutch

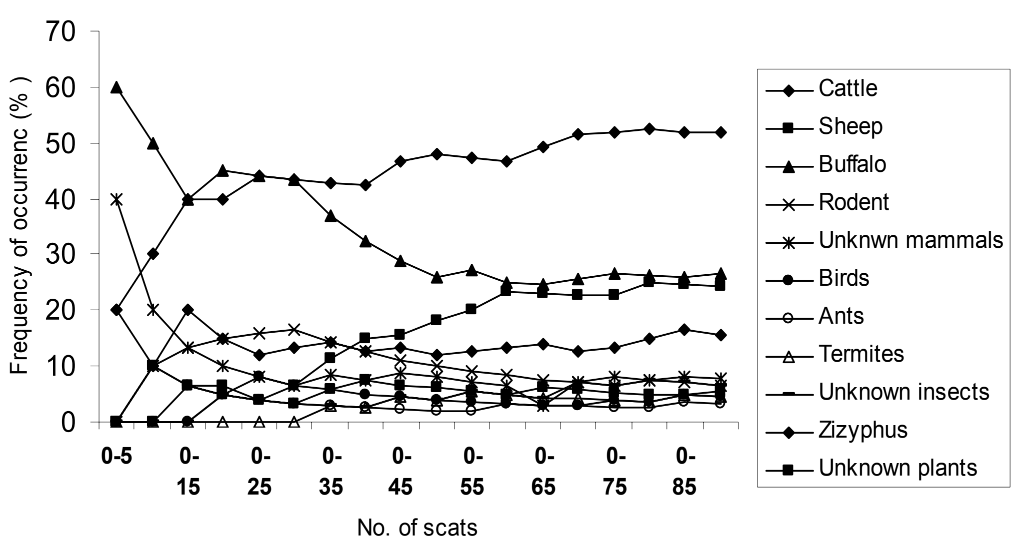
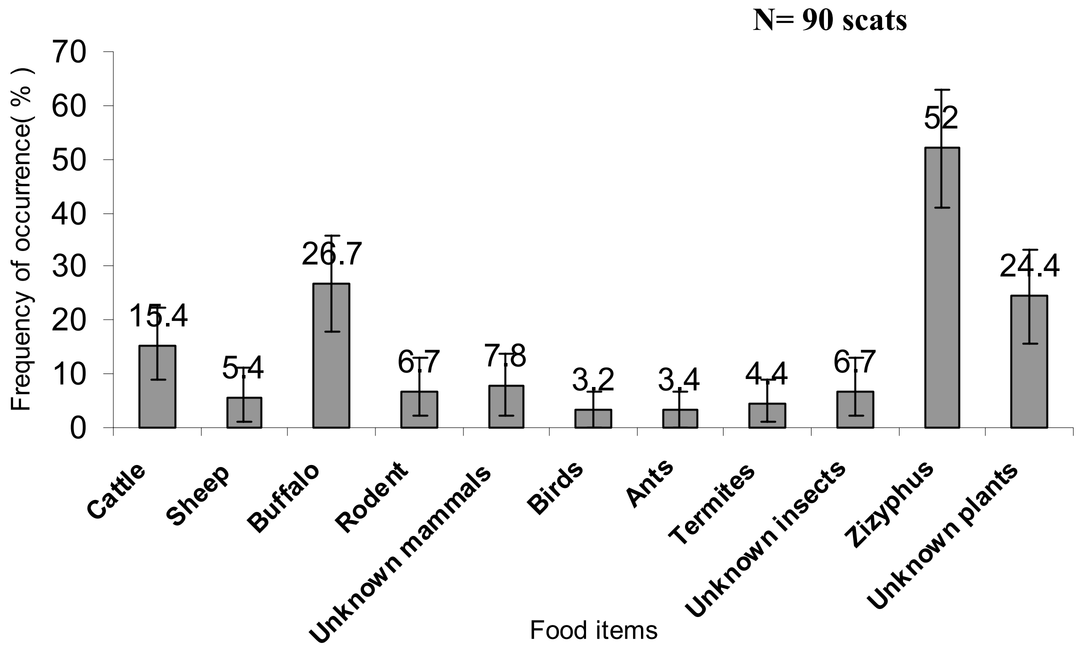


Figure 6: Food habits of jackals in Abdasa Kutch as depicted by frequency of occurrence of prey remains in scats.



6.1.4 Food habits of the striped hyena(*Hyaena hyaena*)

Proportionate contribution of different prey items stabilized after analysis of about 75-80 scats, showing adequacy of scat samples analysed for an accurate estimate of food habits of hyena (Fig 7)

The number of scats analyzed in order to determine the food habits of striped hyena were 74. The results show Cow to be the chief prey item; its remains were found in 36.5% of the scats. Next to Cow, dog had the highest frequency of occurrence(28.1%) The other prey species included sheep(12.2%), goat(14.8%) buffalo (6.7%). The hyena also fed on hare carcasses, remains of which were found in 4.3% of the scats

Figure 7: sample size estimation for the no. of scats required to be analysed for accurate food habits study in Abdasa, Kutch

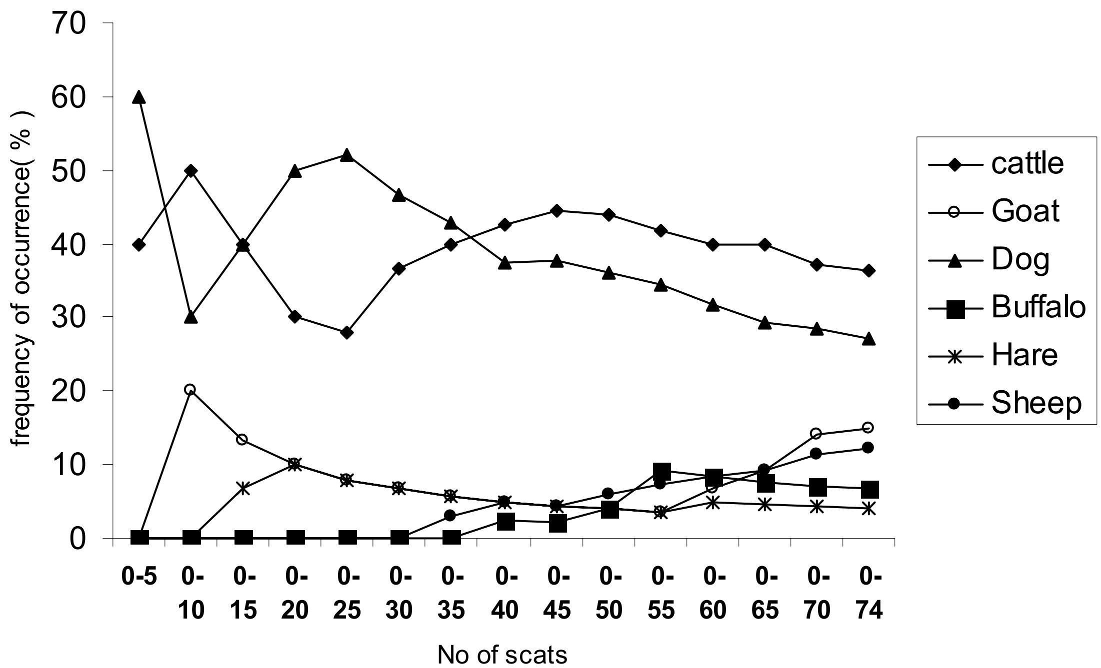
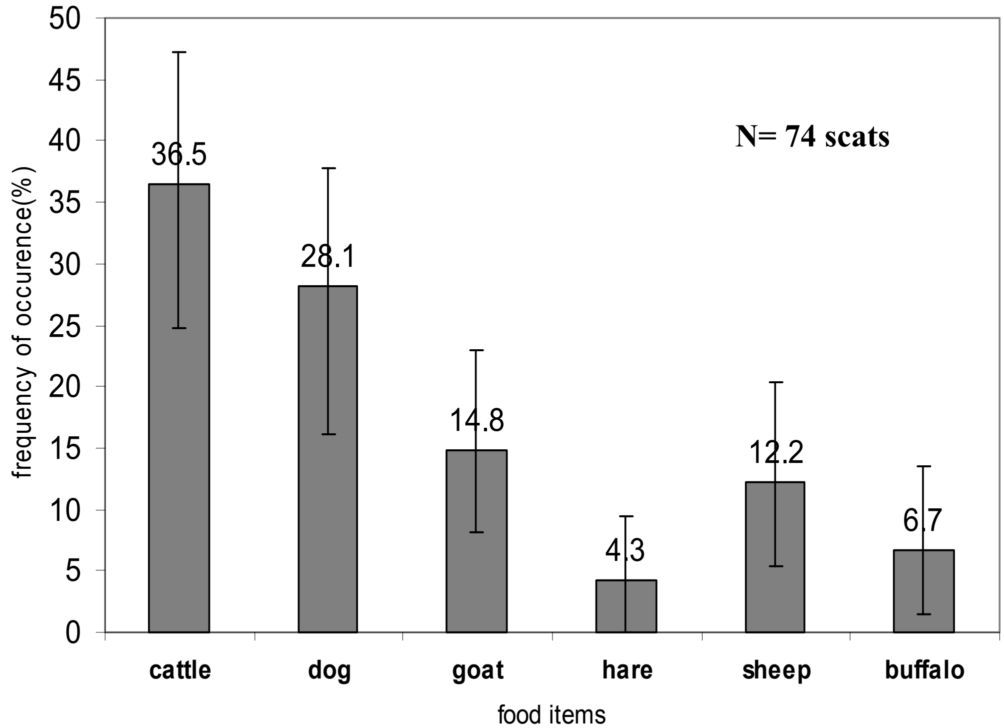


Figure 8: Food habits of hyena in Abdasa Kutch as depicted by frequency of occurrence of prey remains in scats.



6.1.5 Niche width and niche overlaps

The fox has the maximum niche breadth among the four carnivores, followed by jackal in terms of Levins' measure of niche breadth, though in terms of Levins' measure of standardized niche breadth, the hyena has a wider trophic niche. The narrowest trophic niche among the four sympatric predators belongs to the Indian wolf. (Table 1)

Table 1: Diet niche breadths (using Levins' index) of the four species.

Species	Hyena	Wolf	Jackal	Fox
Levins' measure of niche breadth	4.060	3.374	5.518	8.667
Levins' measure of standardized niche breadth	0.612	0.395	0.451	0.630

.

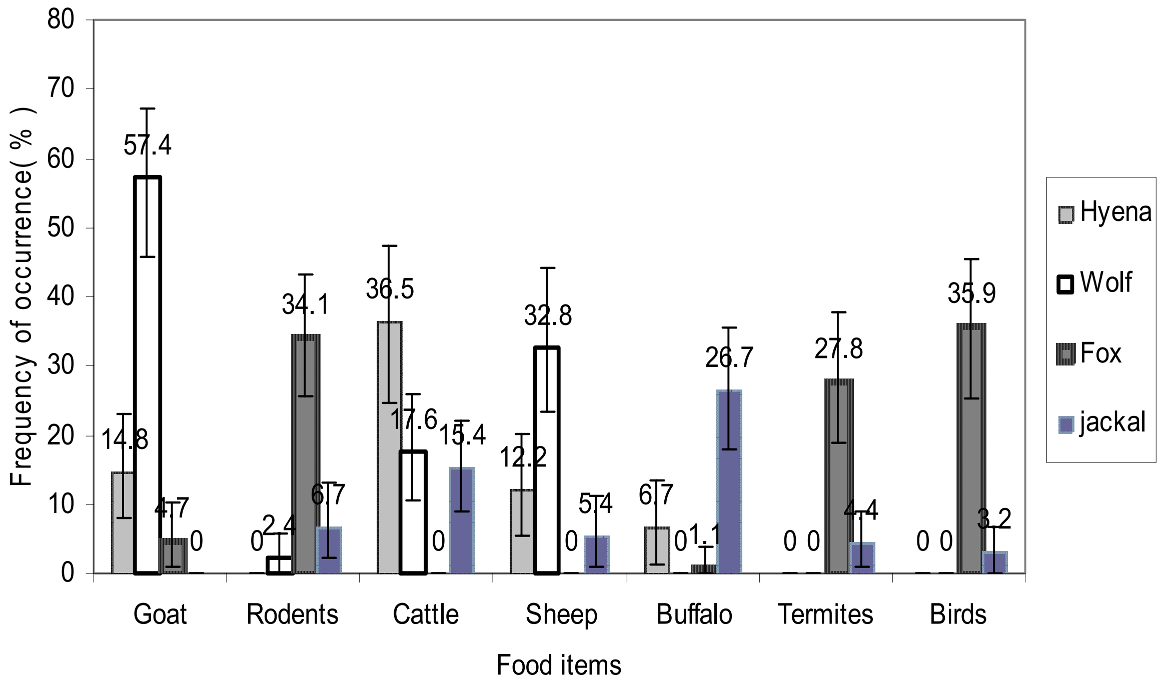
The maximum amount of diet overlap exists between the hyena and the wolf.(Table 2) Diet overlap between the fox and the jackal is next in terms of amount of overlap. The overlap between jackal and hyena is also considerable in amount. The least amount of overlap exists between the fox and the wolf.

Table 2: Trophic niche overlap (Using Pianka's index, 1973) between the four sympatric carnivores in Abdasa, Kutch

Species	**Hyena**	**Wolf**	**Jackal**	**Fox**
Hyena	1.000	0.487	0.235	0.055
Wolf	0.487	1.000	0.113	0.106
Jackal	0.235	0.113	1.000	0.285
Fox	0.055	0.106	0.285	1.000

The overlaps in the confidence limits of a common food item between the two predators signifies relative importance in diet of that food item and possibility of competition

Figure 9: Frequency of occurrence (%) of the major common food types in the diet of the four carnivores. The error bars represent 95% confidence limits generated by Bootstrap re-sampling.



6.1.6 Determination of diversity of diet.

The % of occurrences of each food type found in the diet of the predators was used to estimate the Shannon- Wiener Diversity Index.. The result for each predator is given below. (Table 3:)

Species	Shannon-Wiener diversity index
Hyena	0.747
Wolf	0.570
Jackal	0.859
Fox	0.878

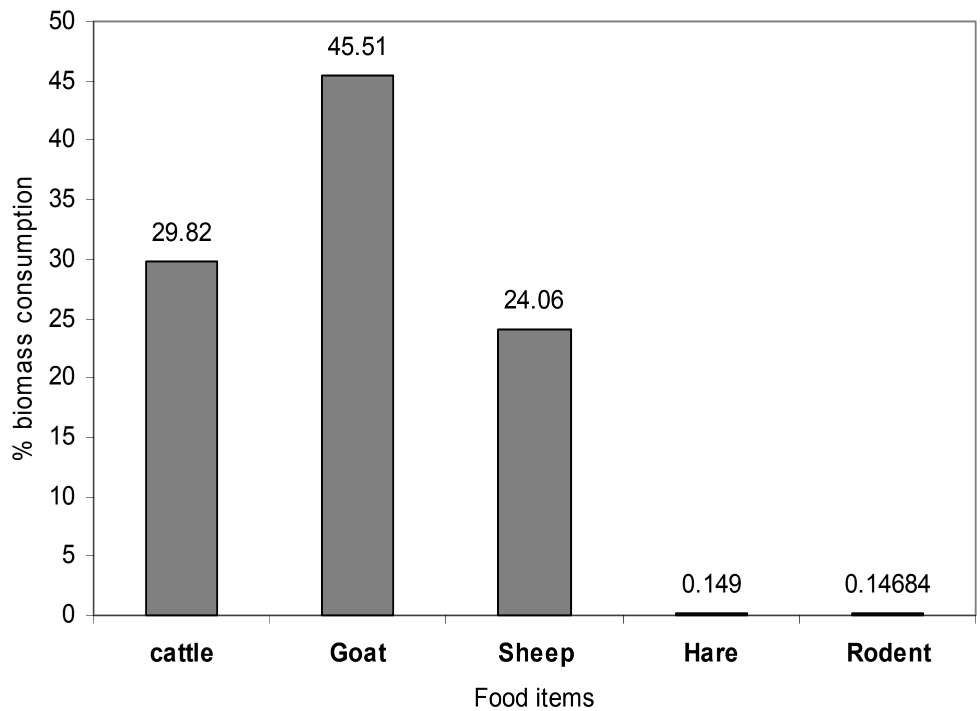
The results show the fox to have the most diverse diet consisting of ungulate remains, micro mammals, birds and reptiles. Next to fox, the golden jackal has the the most diversity among the food items taken. The most specialized diet belongs to the Indian wolf, mainly comprising of goats and sheep, hence the least diversity.

6.1.7 Computation of biomass consumed.

Wolf

Goat is the major prey item in the diet of the Indian wolf, as far as the percentage of biomass consumption is concerned (45.51%). Next to goat, cattle was the source of maximum biomass consumed (29.82%), followed by sheep (24.06%). Among the other mammalian prey, rodents (0.14684%) and hares (0.149%) comprised very little biomass in the diet.

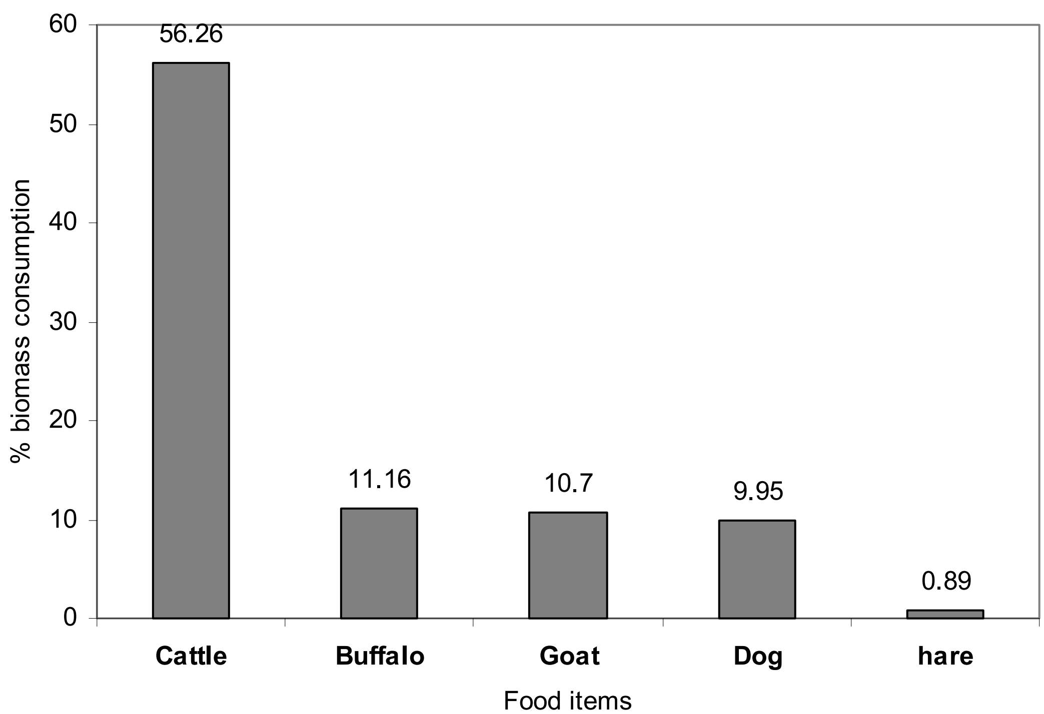
Figure 10: % of biomass consumption of major mammalian preys by the wolf in Abdasa, Kutch.



6.1.7.1 Hyena

Cattle had the maximum amount of biomass consumption in the diet of the hyena (56.26%). Other ungulate preys like goats (10.7%) and buffalo (11.16%) were significant sources of biomass consumption. Dogs had a biomass consumption of 9.95%, despite their high frequency of occurrence, which might be explained by incorporating pup's weights in to the formula for biomass consumption as they are particularly favoured by the hyena.

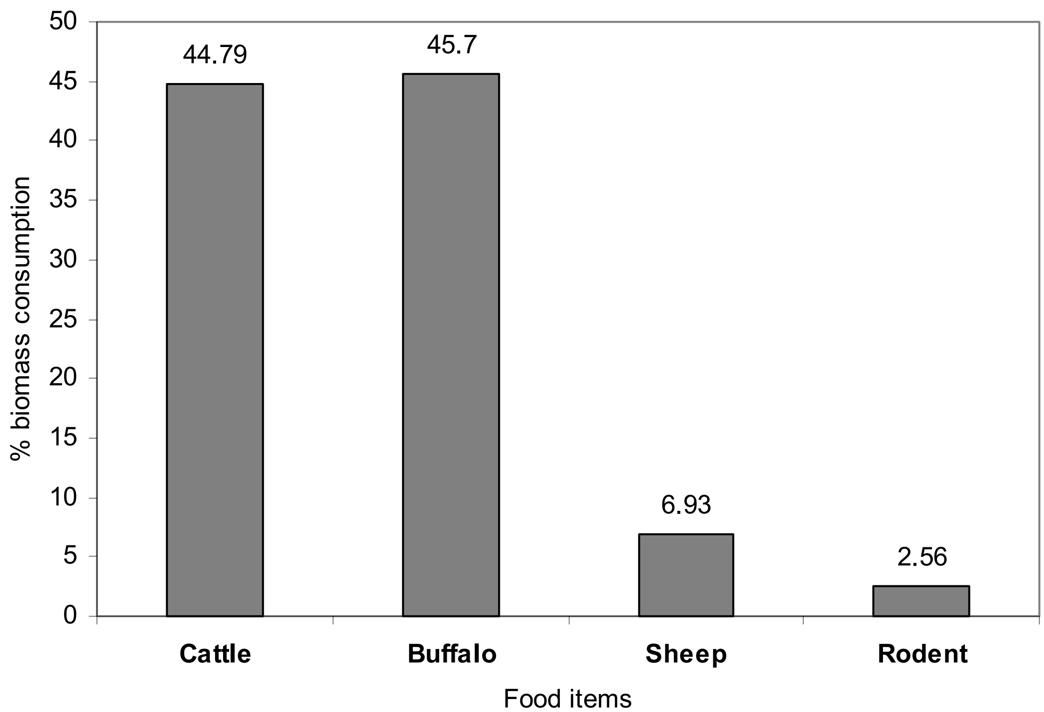
Figure 11: % of biomass consumption of major mammalian preys by the hyena in Abdasa, Kutch.



6.1.7.2 Jackal

Cattle and buffalo had almost identical percentage of biomass consumption in the diet of the golden jackal (44.79% and 45.70%, respectively.), thus showing the predator to have a preference for scavenging on the remains both the species. Other major mammalian preys included sheep (6.93%) and rodents (2.56%).

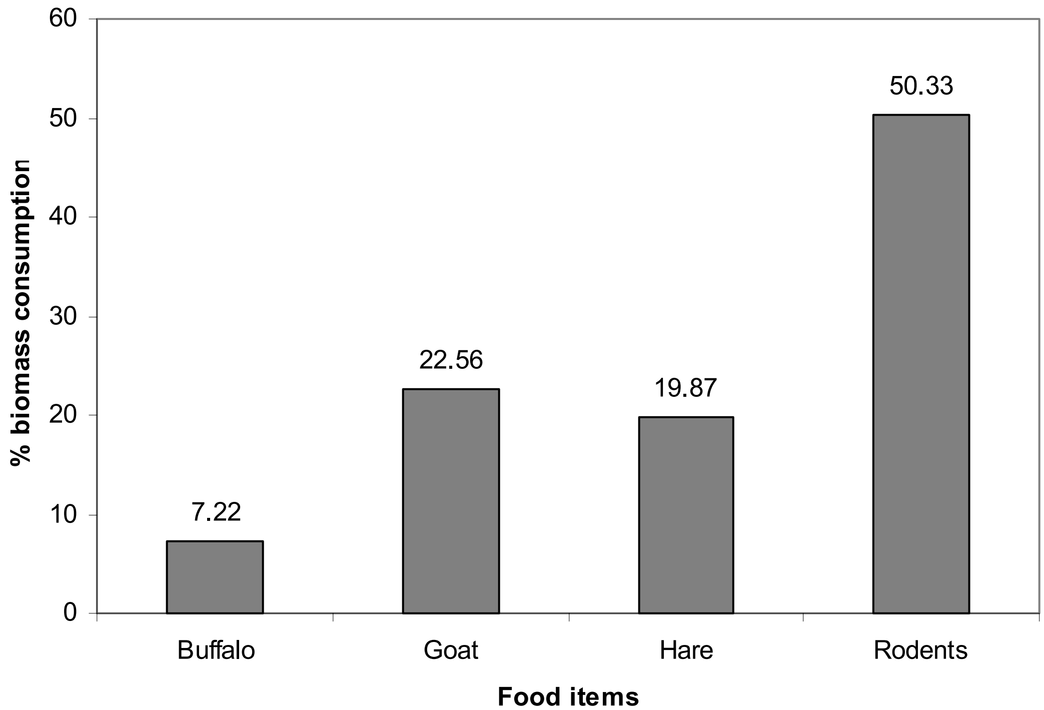
Figure 12: % of biomass consumption of major mammalian preys by the jackal in Abdasa, Kutch.



6.1.7.3 Fox

Micro mammals like rodents were the chief sources of biomass consumption (50.33%) among the other major preys, goats were calculated to have a consumption rate of 22.9%. lagomorphs like hares also had good . the other large ungulate prey consisted of buffalo, which had a % of biomass consumption of 7.22

Figure 13: % of biomass consumption of major mammalian preys by the fox in Abdasa, Kutch.



7. Discussion

Of the four sympatric carnivores whose food habits were analyzed, the Indian fox had the most diverse diet. Among mammalian prey, it fed on rodents (34.1%) like gerbils and rats and Lagomorphs like hare (13.2%). Being fleet footed, it had the ability to chase down these fast footed preys. It also scavenged on carcasses of goats (4.7%), buffalo (1.1%). However, the % of scavenged ungulates was small compared to other food items. It had a high % of bird's feathers in the scats (35.9%), which may indicate that it preyed upon ground nesting birds like sand grouses and partridges found in the study area and also scavenged on bird carcasses.

Foxes living in arid areas have been known to feed (Home, 2005) on ants and termites more than other species of insects. The results corroborate this notion by showing termites to have the highest frequency of occurrence (%) among insect remains (27.8%). Ants (22.9%), beetles (10.9%) also had sufficient frequencies of occurrences. Body fragments of insects which could not be identified were found in 36.3% of the scats, which is quite high. Scales and bones of reptiles were found on 15.2% occasions. So the results indicate the fox to be a rather generalist which feeds on small mammals, birds and insects. The trophic niche width, calculated using Levins' index (1968), was the highest among four sympatric carnivores. (8.667)

Next to fox, jackal had the highest trophic niche width (5.518). It also had a diverse diet consisting of mammals, birds, fruits and insects. The % of ungulate carcasses was greater in jackal than in fox's. Buffalo remains had the highest frequency of occurrence (26.7%), followed by cow (15.4%) and sheep (5.4%). This may indicate that the jackals frequented village outskirts and dumping grounds quite regularly. The frequency of occurrence of rodents (6.7%) was quite small than fox and surprisingly, no evidence of hares was found the diet. The proportion of birds and insects was also smaller than fox with termites having the highest frequency (4.4%). In plant remains, *Zizyphus* seeds and whole undigested fruits had the highest frequency of occurrence of any food item (52%). This fact confirms the observation by Prater (1971) that jackals have been known to collect around fruiting *Zizyphus* trees and to feed on the fallen fruits. Unknown plant remains were found in 24.4% of the scats. Findings of a similar nature were achieved by Mukherjee in Sariska Tiger Reserve., Rajasthan. Scat analysis revealed presence of Mammals (45%), vegetable matter (20%) and birds (19%) in the diet of the golden jackal. (Mukherjee, 1998). Studies on the food habits in Kanha by Schaller revealed over 80% of the diet consisting of rodents, reptiles and fruits (Jhala and Moelhman). The high preference on Zizyphus fruits found in the present study reveals their high dependence on these fruits in fruiting areas (Kotwal, et al, 1991, Y. Jhala. Pers. Obs.)

Surprisingly, the striped hyena had a wider trophic niche width (4.060) than the wolf, which might be explained by the nature of the index itself. Though the hyena fed on a limited number of preys, it utilized that limited prey base quite efficiently. Remains of cow and dog were closely matched in terms of frequency of occurrence (36.5% and 28.2%, respectively) and there were a number of times where a single scat contained remains of both the species. Likewise, remains of goats (14.8 %) and sheep (12.2%) were quite substantial. Another interesting find is the occurrence of hare in 4.3% of the scats. This fact might indicate that the hyena scavenged on the carcasses of these Lagomorphs. These high frequencies of occurrences and a limited number of preys may have resulted in the large niche breadth.

The presence of dogs in the diet may indicate that apart from scavenging on its remains, hyenas in the present study area might have preyed on some animals, specially pups. In fact, hyenas in the study area have been seen to enter village outskirts to hunt dog pups (Jhala, 2002).

The results show the Indian peninsular wolf to have a diet mainly consisting of domestic livestock. Goats were the major prey item, remains of which were found in 57.4% of the scats. Next to goat, sheep had the highest frequency of occurrence
(32.8%). Other major prey items included cow (17.6%), nilgai (5.8%), and rodent

(2.4%) and hare (1.2%). Remains of unidentified mammals were found in 10.7% of the scats. This relatively high preference on goat, sheep and cow in the diet may have resulted in the relatively narrow trophic niche width (3.374) of the Indian wolf.

The wolf's diet, as determined by the present study, again indicates possible sources of human- animal conflict with the high amount of possible predation on domestic livestock.

The niche overlaps were calculated using Pianka's index (1972). The results show that the maximum amount of diet overlap exists between the wolf and the hyena (0.487). This might be explained with the high occurrence of domestic livestock (cow, goat, and sheep) in the diets of both the species. Niche overlap between fox and jackal was next in terms of amount of overlap (0.285). Both the species were seen to have a diverse diet including mammals, birds, insects (ants, termites, etc) and plant material. In case of mammalian prey, both the species preyed on rodents, but the jackal had greater proportion of large ungulates in its diet. This observation in the diet of the jackal may be the cause of considerable amount of diet overlap between it and the hyena (0.235). Niche overlaps between fox and wolf and jackal and wolf were quite similar (0.106 and 0.113, respectively).

The least amount of diet overlap was found to exist between fox and hyena. This might be the result of high frequency of occurrence of large ungulate prey in the hyena's diet, compared to occurrences of mostly small mammals and insects, birds in the diet of fox.
To determine the sharing of food items and possible source of competition, the frequency of occurrence of the major common food items were plotted, which showed possible overlap and similar importance in the diet in terms of cattle between wolf and hyena, no other major sharing of resources was seen.

Overall, the four sympatric species of carnivores were seen to utilize the available food resources quite efficiently.

By comparing the results of the present study with past studies, it can be seen that the major food items comprising the diets of these sympatric carnivores primarily depend on the habitat and availability of prey. Calisti *et al* studied the food habits of the red fox(*Vulpes vulpes*) in the primarily mountainous habitat of Maremma National Park in central Italy. Their findings showed plants like Juniper and Pine to be the chief components of the fox's diet.(Calisti *et al*, 1999) Likewise, plant remains were found in 27.8% of the scats analysed, a substantial proportion of the diet. Next to plants, insects like Orthopterans and Coleoptreans and micro mammals like rodents made up the bulk of the diet. The findings of the present study also show the fox to have a high preference in diet of insects like termites and ants and rodents.

In a very relevant study by Home, 2005, the food habits of the Indian fox were determined in Abdasa taluka of Kutch, the present study area. Her findings showed that rodents were the major mammalian prey items (40.7%) in the diet. The present study also emphasized the importance of rodents (Found in 34.1% of the scats) in the diet of the Indian fox. Among insect prey, her study showed termites to have the highest frequency of occurrence (52%), followed by beetles. The presence of these two insects was also found in substantial quantities in the diet. She found bird remains in 4% of the scats; however, the present study found quite a high proportion of bird remains (35.9%). This disparity might be explained with the seasonal variation in the food habits as the scats were collected during winter. She found a high frequency of spiny-tailed lizards *(Uromastyx sp*) in the scats. The frequency of reptiles found in the present study was also substantial (15.2%), however, they could not be identified on a species level due to the nature of the remains and due to time constrains. On the whole, the results were quite similar.

The diet of the Indian wolf in the Subcontinent mainly consistins of domestic livestock.(Shahi, 1982; Jhala, 1993; and Jethva, 2000). The studies on its food habits have shown ungulates to be the main prey items. (Jhala, 1993; Jethva and ajhala, 2004). In their studies, ungulates like blackbucks and chinkaras were the main wild prey items found in the diet. However, both these species being absent from the present study area, the majority of mammalian remains consisted of domestic livestock like goats and sheeps. This confirms the observation by Jhala (2002) that the diet of the wolf in the present study area mainly consists of sheeps and goats.

Other studies on the food habits of wolves in the subcontinent have also shown wild and domestic ungulates to be the chief prey items found in the diet. Wild species like chinkara and blackbuck being absent and with easy availability of goats and other livestock, the relatively high proportion of these species in the diet can be explained in terms of prey abundance.

Fruits, birds, insects, ungulate carcasses have been associated with the diet of the golden jackal. In a study on its food habits in south western Hungary, it was found ungulate carcasses were in 24.7% of the scats analyzed. Rodents had the highest frequency among mammalian prey, 43%. In relation, frequency of birds, reptiles and fruits in the diet was less (Lanszki and Heltai, 2002). The present study found *Zizyphus* fruits in 52% of the scats analysed, thus confirming the observation that jackals collect around fruiting Ber trees to feed on the fallen fruits(Prater, 1971) The frequency of occurrence of rodents was less than fox's diet. This might be explained with the possible breeding activities during the collection period which meant that maximum energy was conserved for finding dens and other activities associated with breeding. Remains of buffalo carcasses occupied the highest frequency of occurrence (26.7 %), followed by cattle remains. Thus, the results showed the golden jackal to primarily scavenge on large ungulate carcasses, conforming to the results from studies in other areas.

The amount of overlap in trophic niche among the sympatric predators determined the level of resource sharing between the species. Studies on niche overlap in other regions. The niche overlap of red fox and golden jackal in south western Hungary was studied by Lanszki and Heltai. Their results showed a high amount of diet overlap (60-77%) between the diets of the two species. (Lanszki and Heltai, 2002) In the present study too, the overlap (Pianka's index of overlap, O= 0.285) between jackal and fox was only

second to that between wolf and hyena. This considerable amount of overlap was due to both the species having a diverse diet consisting of mammals, fruits, birds and insects.
Diet overlap between wolf and red fox was determined in Abruzzo National Park in central Italy. Like the present study, they found mostly remains of wild and domestic ungulates in the wolf's diet. The chief mammalian prey in fox's diet consisted of rodents. With these findings, the researchers calculated the amount of overlaps in diet between the two species. On the whole, the diets overlapped little as both the animals were seen to have preyed on different-sized preys(Patalano and Lovari, 1991). In the present study also, the index of overlap was only 0.106, which signified little overlap.

The percentage of occurrence data of each predator was used to determine the diversities in their diet. Shannon- Wiener index of diversity was used to enumerate the differences. The results showed the Indian fox to have the most diverse diet consisting of mammals, birds, insects, fruits. It was seen to have a rather generalistic approach in food acquiring. The most restricted diet of the four belonged to the Indian wolf (0.0570). It had a high preference in diet of sheep and goats to some extent, cattle. These large ungulate preys made up the bulk of the diet of the Indian wolf, hence the least amount of diversity.

The frequency of occurrence data was also used to estimate the percentage of biomass consumption of each prey species. The frequency of occurrence data were converted into amount of biomass consumed per collectible scat and multiplied with the the frequencies of occurrences of each prey and expressed as a percentage to give the % of biomass consumption. The results depicted the hyena to mainly scavenge or prey on cattle, a species represented by 56.26% of the total biomass consumed. Goat and sheep had closely matched consumption percentages, followed by dog. Though the frequency of occurrence of dogs was quite high (N-20), its consumption was under-represented in terms of biomass. This occurrence might be explained with the weight classes applied for dog, which mainly consisted of pup weights. This was deliberately done because hyenas were seen to hunt dog pups in the present study area (Jhala, 2002).

Domestic livestock like goat, sheep and cattle provided the maximum amount of biomass in the diet of the Indian wolf. Goat had the maximum % of biomass consumption with 45.51%. Remains of hares and rodents were fund in very small percentages of the total biomass consumed.

The golden jackal had almost equal % of biomass consumption of cattle and buffalo and these two species made up the bulk of the biomass consumed.

Unlike jackal, the fox had smaller mammals comprising the bulk of the biomass consumption. Rodents had the maximum percentage (50.33%), followed by goats.

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