RESOURCE UTILIZATION BY INDIAN FOX (*Vulpes bengalensis*) IN KUTCH, GUJARAT.

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By

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This thesis is dedicated to the most important woman in my life, my Thamma who has taught me the rules of survival in this world, who has never failed to support me even during my toughest times.

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SUMMARY

I studied the resource utilization patterns in the Indian fox (*Vulpes bengalensis*) with respect to diet in Kutch, Gujarat. Resource use and availability by foxes were compared between two habitats and between two seasons. Resource availability was quantified through transects laid in both the habitats for the different prey items: mainly mammals, birds, reptiles, arthropods and fruits. Resource availability differed in both the habitats as well as across seasons (summer and winter). Density of fruiting shrubs (particularly *Zizyphus*) and gerbil burrows were significantly different between the two habitats. Gerbil population mean obtained from different colonies trapped during the study period showed a significant relationship with the total number of burrows in the colony (R^2 =0.969). Scats collected from den sites were used to quantify resource use of the Indian fox. The minimum number of scats that can be used to estimate the annual food habits of the Indian fox in a dry arid area like Kutch is about 110 scats. Frequency of occurrence of prey species also differed across habitat and seasons. Arthropods were the most frequently occurring prey items (75% and above). They are seen to be selected more than availability within the habitat. This was indicated by the three methods used to compare use versus availability (Ivlev's Index, Bonferroni's CI, and Compositional Analysis). However the Indian fox is seen to maximize energy requirements by selecting gerbils next in the preference after arthropods being selected more than availability during most cases within the habitat.

Density of breeding units evaluated in the scrubland showed a density of 0.10/sq km. The density of breeding pairs obtained in this particular study was much higher as

compared to the ones reported earlier for Kutch (0.04-0.06/sq km) due to good rainfall in the preceding two years thereby indicating a good prey base as compared to other years.

1. INTRODUCTION

1.1. General Introduction:

The site occupancy of animals has been explained often with the availability of the environmental components necessary for life. The life requisites include food, water, cover and nesting or denning sites. Food habits of animals determine a number of life history strategies like habitat selection, movement and success of reproduction (Krebs, 1978). Home range configuration and size is the result of the habitat selection of an animal in its search for an area containing all resources it needs to reproduce and survive through the year. Habitat selection is likely to reflect the dispersion of resources and therefore it can be considered the functional link between the dispersion of food patches and home range size (Lucherini *et al*., 1995). Macdonald (1983) proposed the Resource Dispersion Hypothesis (RDH) which predicts that the dispersion of food patches determines territory size, whereas their richness limits the group size. The order Carnivora is well known for its wide dietetic characteristics. Determining the distribution of prey species within the selected habitat of a carnivore is important to understand the essential reasons behind various strategies it adopts to survive.

In the order Carnivora, the family Canidae comprises of highly adaptable members, inhabiting almost all realms. This family comprises of about 38 species categorized under 13 genera (http://www.canids.org/1990CAP/90candap.htm). Out of these 38 species, 23 species are foxes distributed in all the land masses. The foxes are the smallest amongst the canids characterized by their solitary nature (the only social unit being a pair during the breeding season) and versatility in strategies for effective survival.

They are omnivorous and opportunistic canids, being flexible in their feeding habits. They are monogamous and least social of all canids (exception being the bat eared fox in Africa which maintains a social system). The distributions of these small canids are also varied. Some foxes like the Island foxes (*Urocyon littoralis*), inhabiting the Channel Islands and the Darwin's foxes (*Pseudalopex fulvipes*) in the Chiloé Islands off the coast of Chile have a very small geographic range while the red fox spans several continents. The distributions of foxes with respect to habitat also vary ranging from deserts to ice-fields, rainforests to grassland and swamps as well as the urban jungle (Macdonald & Sillero-Zubiri, 2004). However most of the fox species are found in areas which are relatively open. Being small sized canids which are subjected to predation by other canids or carnivores, selecting relatively open places is more like a survival strategy within the habitat.

The Indian fox (*Vulpes bengalensis*) [Shaw, 1800] 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. However nowhere in its range is the Indian fox abundant (Johnsingh & Jhala, 2004). The species largely occupies semi arid, flat to undulating terrain, scrub and grassland habitats which are suitable for foraging and denning activities. The Biogeographic Zones 3 (Desert), 4 (Semi arid) and 6 (Deccan Peninsula) (Rodgers *et al*., 2000) is believed to hold relatively high numbers. As per the population status, the species is still listed in the Data Deficient category of the IUCN Red Data Book (revised 1996). The Wildlife Protection Act 1972 (as amended till 2002) lists this species in Schedule II (Part B).

The arid landscape of Kutch houses three canid species. Amongst them the Peninsular wolf (*Canis lupus pallipes*) belongs to Schedule I of WPA (1972). It also houses a considerable population of Indian foxes (*Vulpes bengalensis*) in the landscape. Unlike the wolves which have a bad reputation in the area owing to their sole subsistence on livestock as prey, foxes have a nondescript existence because of their different dietary requirements which does not involve any conflict with humans. It is one of the least studied canids in the world with scientific information being restricted to two studies by Johnsingh (1978) and Manakadan & Rahmani (2000). This study attempts to understand the relationship of the Indian fox with its surroundings with respect to a very prominent part of resource use i.e. food.

1.2. Literature Review:

Much of the literature relating to foxes comes from the red fox (*Vulpes vulpes*) which has been widely studied. Factors affecting activity, habitat use and home range of the red foxes have been studied in heterogeneous environments ranging from Mediterranean landscapes (Lucherini *et al*., 1995; Cavallini & Lovari 1991; Lovari *et al.,* 1994; Ricci *et al*., 1998) to suburban and urban jungles (Harris 1977; Harris, 1980). The availability, dispersion and the use of main food resources have been known to influence the activity patterns of red foxes. These principle food resources in turn may be guided by meteorologic factors (Cavallini & Lovari, 1991). Thus the term opportunistic has been aptly used to describe the food habits of the foxes in general. Studies on the diet of foxes have revealed a wide range of prey species starting form rodents, lagomorphs, reptiles, birds, fishes, invertebrates and fruits. They have also been reported to feed on carcasses, eggs, and urban waste. Positive correlations have been found between food abundance and consumption by the red foxes for food categories showing a clear seasonality (Ferrari & Webber, 1995).

Resource distribution in space and time has a considerable impact on survival strategies. A comparison between two habitats (one with a fluctuating food resources and one with a stable food resources) in the distribution range of the arctic foxes have revealed the divergence of strategies with respect to parental investment between the two populations. In places characterized by unpredictable food resources the arctic foxes have been known to increase their litter size (jackpot strategy) (Angerbjörn *et al*., 2004). Fox densities seem to track rodent densities. However the functional responses seem to be different among the different species and with a special mention of the habitat type. The red fox is distributed mainly in the areas of fluctuating *Microtine* vole populations. With a decrease in the vole population, prey switching has been observed (O' Mahony *et al* 1999) while a study on the San Joaquin kit foxes (*Vulpes macrotis mutica*) showed an inability to switch to abundant alternate prey during declines in the density of their preferred prey (leporids) followed by a decline in abundance of the foxes (White *et al*., 1996).

While the Arctic foxes, kit foxes, swift foxes and the Patagonian foxes have a dominance of mammalian prey in their diet, arthropods seem to dominate in the diet of some species. The bat eared foxes (*Otocyon megalotis*) found in the open grasslands of Africa are outliers not only with respect to their social organization but also with respect to their diet. They are almost completely insectivorous rarely eating mammalian prey. Harvester termites (*Hodotermes mossambicus*) and other termites of the genera

Macrotermes or *Odentotermes* are their most important food along with the dung beetles (Nel &Mackie, 1990). Similarly studies on the the Blanford's fox (*Vulpes cana*) in Ein Gedi in Israel have shown an insectivorous and a frugivorous diet. Amongst the invertebrates, beetles, grasshoppers, ants and termites were favoured with remains of vertebrates being found in 10% of the faecal samples (Geffen *et al*., 1992). A study comparing the diets of two sympatric canids, Arabic fox (*Vulpes vulpes arabica*) and the Rüppell's fox (*Vulpes rüppelli sabea*) in Mahazat as- Syed in Saudi Arabia showed the importance of small mammals and invertebrates in the diet (Lenain *et al*., 2004). Invertebrates were a major component of the diet of red foxes (introduced) in the Tanami Desert in Australia representing 31% of the prey items consumed, with the reptiles ranking in second (Paltridge, 2002). Studies on the foraging habits of red foxes in the Mediterranean beach dune system confirmed the remains of vertebrates and plants during winter while invertebrates dominated the rest of the seasons, particularly beetles (Ricci *et al*., 1998).

Seasonal fruits have also been an important part of the fox diet. Studies on the red foxes in the Mediterranean landscape have stressed the importance of juniper berries as a substantial food resource, requiring low searching and handling times (Cavallini & Lovari, 1991). Fruit diet in the Blandford's foxes includes two species of caperbush, *Capparis cartilaginea* and *Capparis spinosa*. Blanford's foxes in Pakistan are largely frugivorous, feeding on olives, melons and grapes (Roberts, 1977). A study on the South American culpeo (*Pseudalopex culpaeus*) demonstrated the increase in the BMR after an intake of mixed diet, constituted of fruits (particularly pepper fruits) and rodents (Silva *et al*., 2004). Thus fruits serve an important alternative resource in the seasons of low abundance of other prey species. Studies on other small carnivores, like the stoats (*Mustela erminea*) in Alpine habitats have demonstrated that foraging on fruits especially to integrate the daily diet after the capture of a rodent prey, was more profitable that continuing to search for other rodent prey leaving more time for behaviour related to reproductive activities (Martinoli *et al*., 2001).

The denning behaviour in foxes is an integral part of resource use with respect to habitat in which it resides. Den use again had been attributed to a number of factors such as availability of food, and water, disturbance factors and presence of conspecifics. Fox dens can be easily identified by the presence of numerous fox holes or earths. The foxes are also known to maintain several dens within their territory, of which more than one den may be used for pup rearing. Dens are located in comparatively open areas however reports of grey fox dens in old sawmill slabpiles, hollow logs and cavities under rocks indicated that the dens were in more dense cover (Nicholson *et al*., 1985). Dens used by Blanford's foxes in Israel were particularly on mountain slopes and consisted of large rock and boulder piles or screes. These foxes used only natural cavities and never dug burrows (Geffen & Macdonald, 1992). Dens were used throughout the year. Swift foxes and kit foxes have been known to use dens virtually everyday of their lives. Dens are mainly used for escaping predators, avoiding temperature extremes and excessive water loss, diurnal resting cover and for raising the young. They are also known to appropriate rodent burrows but can dig their own dens (Moehrenschlager *et al.,* 2004). The San Joaquin kit foxes have been reported to have an average of 11.8 dens each year. The number of dens being used also varied among seasons with more dens being used in the dispersal season that during pup rearing (Koopman *et al*., 1998). However in case of the fox species in which denning is known to be restricted to the breeding season, they have been known to come back to their natal dens to breed. This has been particularly recorded for Arctic foxes in Fennoscandia (Frafjord, 2003). Dens having pups have been reported to have a higher number of holes (Frafjord, 2003; Egoscue 1962).

The Indian fox (*Vulpes bengalensis*) like the other species of foxes have been reported as an omnivorous opportunistic canid. They are mostly crepuscular and nocturnal in habits, foraging usually in the dark hours. Their diet has been known to comprise of insects (grasshoppers, termites, beetles, scorpions, ants, and spiders), crustaceans, rodents including gerbils, field rats and mice, hares (*Lepus nigricollis*), birds and their eggs, ground lizards and rat snakes (*Ptyas mucosus*). Fruits consumed by the foxes included ber (*Zizyphus* spp.), neem (*Azadirachta indica*), mango (*Mangifera indica*), jamun (*Syzigium cumini*), banyan (*Ficus bengalensis*) and pods of *Cicer arietum* and *Cassia fistula*. They have also been reported to consume fruits of *Capparis*, *Acacia*, *Prosopis* and *Salvadora*. Densities of breeding pairs range to about 0.15-0.1/ sq km during periods of rodent abundance (Johnsingh & Jhala, 2004). Denning in the Indian fox (studied in the Rollapadu grasslands) is restricted to the pup rearing period (February to June). The Indian fox breeds from December to January in Kutch average litter size being two. The breeding season is heralded by re excavation of old dens or digging of new dens (Manakadan & Rahmani, 2000). Indian foxes have also been known to appropriate gerbil burrows and show great site fidelity with the natal dens being used for breeding year after year (Johnsingh, 1978).

However during the study period the foxes were observed to use dens around the month of February. The pups were seen to come out of their dens by third week of

March. Both the male and the female guarded the den intensively and hardly moved 200 m away from the den.

1.3. Objectives:

(a) To quantify the diet of the Indian fox.

(b) To quantify the seasonal abundance and the availability of the major food items within the fox habitat.

(c) To compare use versus availability of food resources.

(d) To estimate the density of breeding units within the study area.

2. STUDY AREA

2.1. Location:

Kutch district encompasses the northwestern region of Gujarat state. The total area is about 45,652 sq. km., being divided into nine talukas. The study was conducted in the scrub and grassland habitats of Abdasa taluka, in the Kutch district of Gujarat. This taluka encompasses the south western province of Kutch abutting the Gulf of Kutch and the Arabian Sea.

2.2. History:

Kutch has been detached from the mainland for the last nine hundred years. The key-factor has been the condition of the Rann. In ancient times, when the Rann was an arm of the Arabian Sea, Kutch was an island, easily to be reached from what is now Sind, and forming a kind of Adam's Bridge between Sind and Kathiawad. How long Kutch remained a true island, entirely surrounded by the sea, can only be guessed; but its function as a bridge linking Sind and the west coast of India may have lasted into the dawn of history. Some traces of the remarkable Indus Valley civilization (perhaps 2800 to 2200 BC) have been found in Kutch; and it is probably through Kutch that this civilization penetrated into Kathiawad and western India. Microlithic finds in Kutch, moreover, bear obvious analogies to those found on the mainland on either side (Williams, 1958).

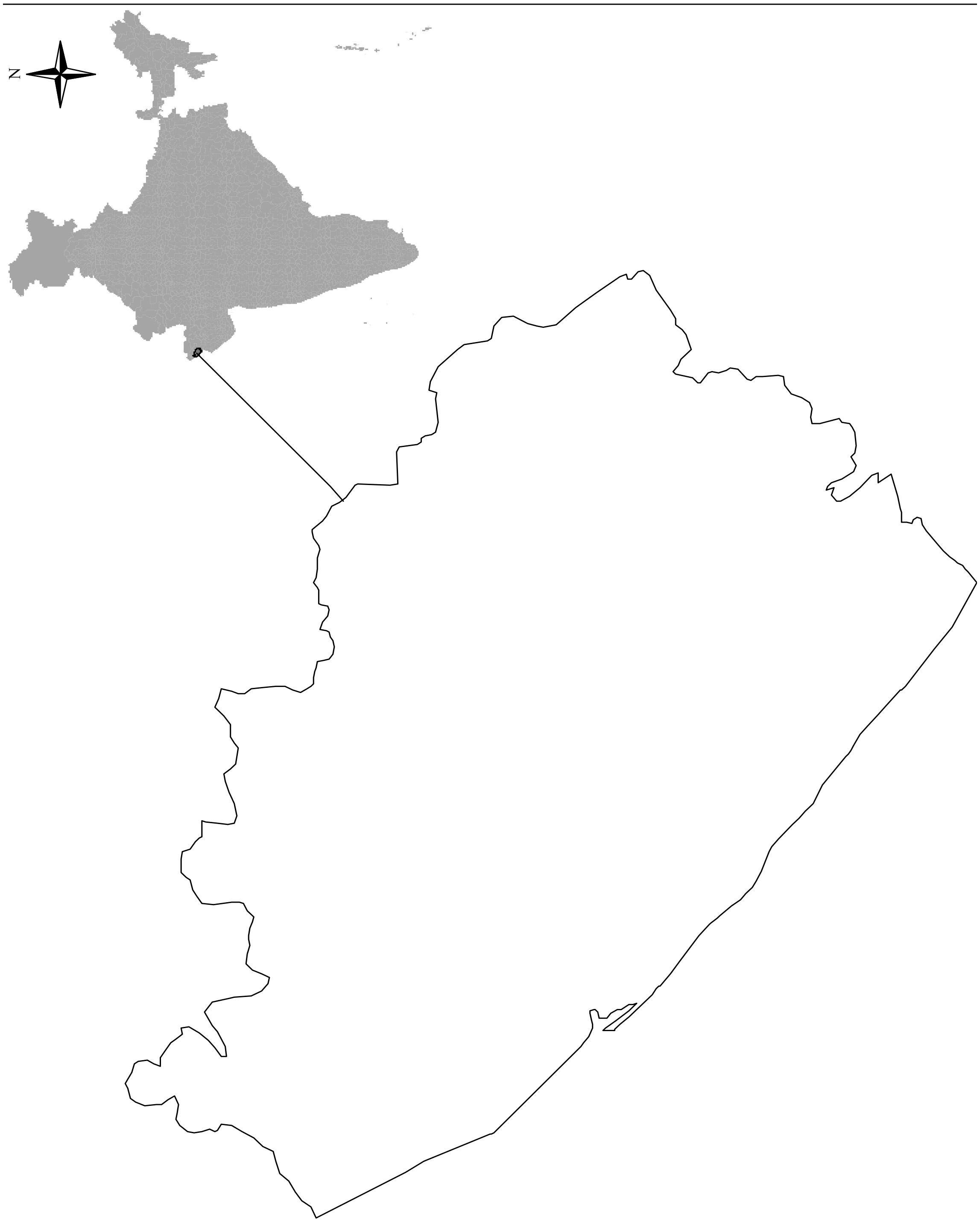


Plate 1:

Map showing the Abdasa taluka in the state of Gujarat, India. The two intensive study areas were located in this taluka.

2.3. Geology:

A major area of the state of Kutch is occupied by the Jurassic rocks, which is an attribute of the geological process of the Pleistocene age. Even during historic times the Rann of Kutch was a gulf of sea, with surrounding coast towns, a few recognizable relics of which still exist. The gulf was gradually silted up; a process aided no doubt by a slow elevation of the land (Williams, 1958).

2.4. Climate:

Since the ecological zone falls in the semi desert region, rainfall is scanty. The average annual precipitation is about 384mm with interim drought years within a decade. The Kutch district is characterized by the scanty and erratic rainfall as well as the extremes of temperatures resulting in high evapo-transpiration rates. As a result of which there are no persistent water sources. Natural water sources totally dry up leaving behind a few man-made water sources to exist during the lean periods. The area is characterized by three distinct seasons: winter, summer and monsoon. Winter usually lasts from the middle of November to the end of February, January being the coldest month (minimum average temperature being 5˚C). However as and when disturbances occur over north India during winter, cold wave conditions occur in the district. Summer starts from March and continues till late June. Kutch experiences the highest air temperature in the month of May with temperatures ranging from 40˚C-45˚C. The south west monsoons reach the coastal regions by the middle of June and by the first week of July spread to the other parts. Long term rainfall records from meteorological stations in the area indicate that the rainfall arrives in time (before 15th of July) in 65% of the years, whereas the late onset of rains occur in 35% of the years (Sinha *et al*., 1972)

2.5. Vegetation:

The vegetation in this area has been classified as Northern Tropical Thorn Forest (6B) and sub classified as Desert Thorn Forest (6B/C1) as per the classification of forest types by Champion and Seth (1968). This area lies in the Biogeographic Zone 3B (Kachch Desert) (Rodgers *et al* 2000). The area has an undulating terrain with the low hillocks being dominated by species such as *Acacia nilotica*, *Acacia senegal*, *Prosopis juliflora*, *Salvadora persica*, *Salvadora oleoides* and *Euphorbia nudiflora*. Other species of flora interspersed are *Capparis decidua*, *Balanites aegyptica*, *Commiphora wightii* and *Zizyphus nummularia.* There are also grassland areas dominated by *Cymbopogon* spp, *Chrysopogon* spp, *Aristida* spp and *Dicanthium* spp.

2.6. Fauna:

The arid landscape of Kutch also houses other species of importance some of them being listed in the Schedule I (WPA 1972). These are the Indian peninsular wolf (*Canis lupus*), Caracal (*Caracal caracal*), Desert cat (*Felis libyca ornata*), Chinkara (*Gazella gazella*), Great Indian Bustard (*Ardeotis nigriceps*), Lesser florican (*Sypheotides indica*) and Spiny tailed lizard (*Uromastix hardwiicki*). Kutch is also a place for raptors and is said to have at least a small breeding population of White–backed vultures (*Gyps bengalensis*) now a Schedule I species under the WPA (1972). Other species include Striped hyaena (*Hyaena hyaena*), Golden jackal (*Canis aureus*), Jungle cat (*Felis chaus*), Nilgai (*Boselaphus tragocamelus*) and Wild boar (*Sus srcofa*).

2.7. Intensive Study Area:

The intensive study area for studying the resource utilization in the Indian fox (*Vulpes bengalensis*) encompassed two major areas describing two different habitat types; Daun, a grassland area mainly dominated by *Cymbopogon*, *Chrysopogon* and *Dicanthium* species and Hyaena Ridge, a scrubland with an undulating terrain with species like *Acacia nilotica*, *Prosopis julifora* and *Salvadora persica*. The soil conditions in Hyeana Ridge are not conducive for the growth of grasses and it has been mention as scrubland henceforth onwards. Daun as a grassland habitat encompassed a large area (about 100sq km) and hence stress was given to a part of the area where the habitat suited the requirements of the Indian fox (*Vulpes bengalensis*) (based on secondary information). The effectively sampled area for carrying out the field work was about 21sq km for the scrubland and 30 sq km for the grassland.

The encroachment by *P. juliflora* was very prominent in Hyaena Ridge making it more dominant than the Indian gum species (*Acacia nilotica*). The seasonal river Gallo cuts through the place sometimes carving deep ridges. The river sides are characterized by dense growth of *P.juliflora*. Since the vegetation in this area is scattered, visibility is very high, sometimes being more than a kilometer.

Both these areas are not within the domain of legal protection as a result of which they are subjected to high levels of disturbance every now and then. One of the major factors of disturbance is uncontrolled grazing. Both in Daun as well as in Hyaena Ridge, there were cowherds and goatherds coming to the area from the nearby villages daily. The disturbance levels in Hyaena Ridge are comparatively higher than Daun. In my six months of stay, extraction of construction rock by quarrying was a major occupation of some of the villagers working as daily labourers for a dam which was being built close to the study area (Kuvapaddar). Poaching, extraction of gum and cutting *Prosopis* for making charcoal were some of the major disturbance factors in the study area.

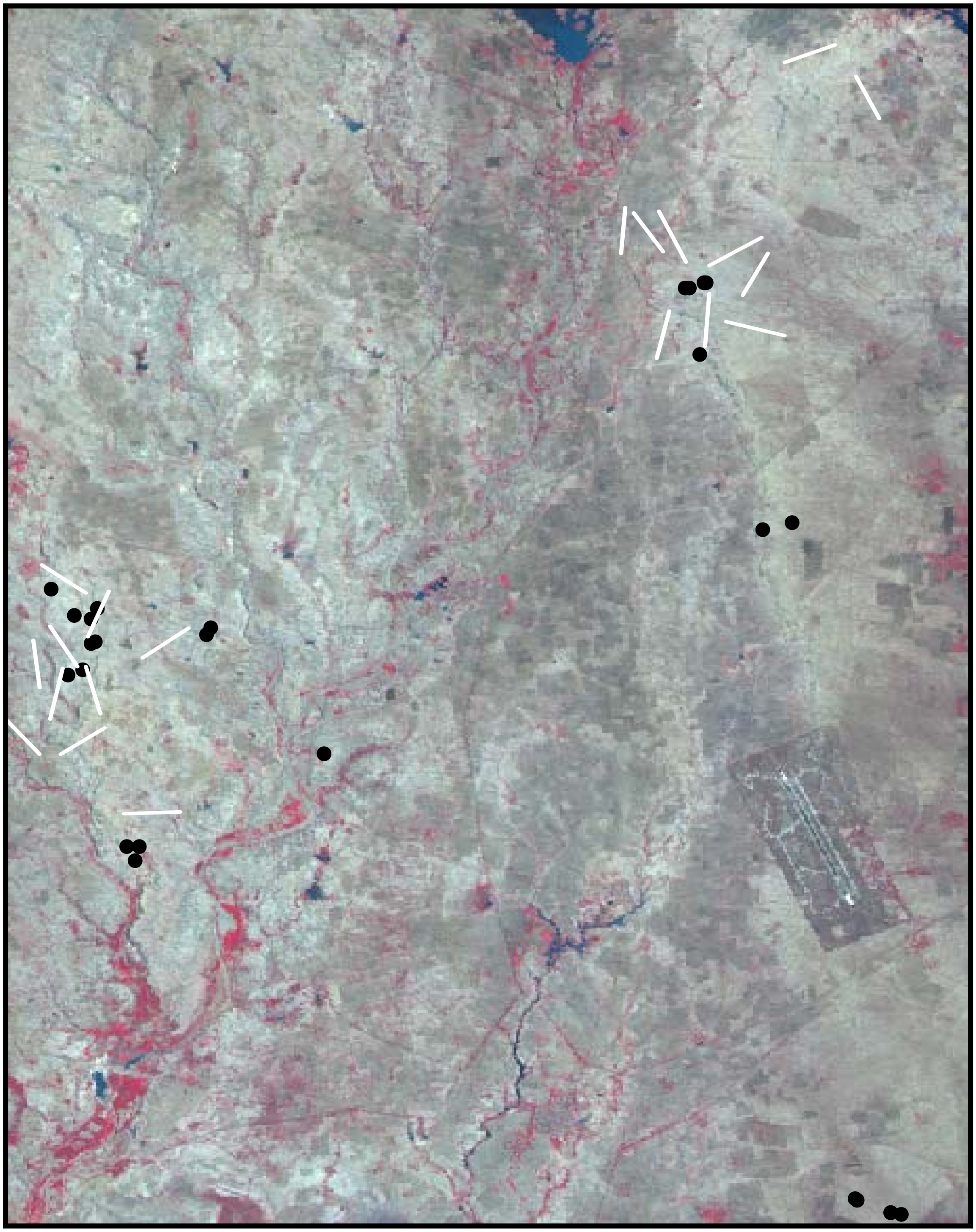
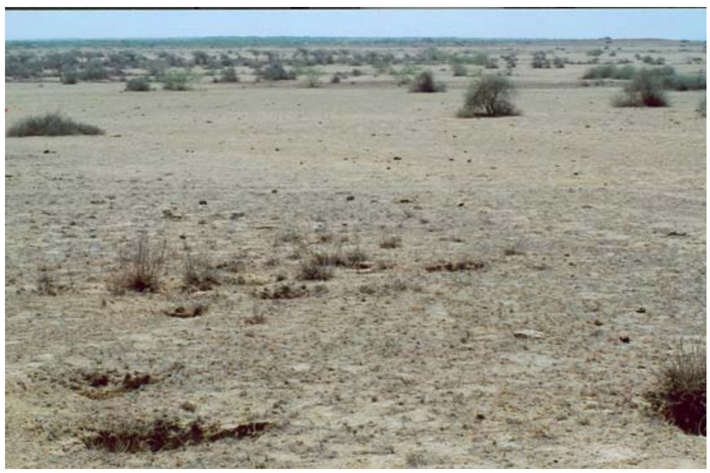


Plate 2:

IRS LISS III Georectified map of the study area showing the fox den locations and the transects marked.

Plate 3

Photograph of the scrubland habitat (Hyaena Ridge)



Photograph of the grassland habitat (Daun)

Picture of a fox den in the scrubland

3. METHODS

The study involving the resource utilization in the Indian fox (*Vulpes bengalensis*) in the arid landscape of Kutch within the scrubland and the grassland habitats, involved assessing the food availability through transects and simultaneously collecting scats from the two study areas. Food availability was assessed for the two seasons spanning the study period; winter and summer of 2005.

3.1. Reconnaissance Survey:

The reconnaissance survey was carried out from the middle of November till the first week of December (about two and half weeks). During this time fox dens were located in the two habitats. Information regarding den locations was obtained from the earlier studies done in this area by WII. This was further validated by secondary information from local shepherds and goatherds and the nomadic Rabbaris. The confirmations of dens were based on direct sightings of the animals near them, through tracks and presence of scats. The GPS locations were taken and information regarding the dens as active or passive was noted down, along with the number of holes or earths. These dens served as sites for scat sampling. About 12 dens were located in the scrubland and 8 dens in the grasslands. Information regarding movement of the animals such as using water resources near human habitation was noted. Whenever a fox was sighted, it was correlated with the presence of the nearest den site and once confirmed; observations were made during the day.

3.2. Field Sampling Methods:

3.2.1. *Sampling Food Availability*

The availability of the most probable food resources for the foxes was estimated through indices of relative abundance. The major prey items considered for quantification included mammals particularly rodents and hares, birds, reptiles, arthropods and fruits. Keeping in mind, stratified random sampling as a backbone of the sampling design, ten belt transects of length 1km (open width and fixed width = 2m) were laid in Daun (grassland) and Hyaena Ridge (scrubland) within a radius of 2 kilometers around the dens. Each transect was walked twice during the two seasons; winter (Dec to mid Feb) and summer (March to end April), once during the day for estimating abundances of diurnal probable prey species and once during the night nocturnal probable fox food. During the day, on each of these belt transects, active gerbil burrows and passive burrows were recorded within the groups as an index of rodent abundance. Similarly hare and reptile abundance (particularly spiny tailed lizards) were estimated using indirect evidences, such as pellet group counts for hares and active burrow counts for spiny tailed lizards.

Arthropod abundance (mainly Orthopterans, Coleopterans and Arachnidans) were estimated by direct counts of the number of individuals that were seen along the belt walked. Fruit availability was quantified by counting the fruiting shrubs on the belt transect. Encounters of hares, birds and reptiles were noted down along with perpendicular distances to transect.

Night walks involved looking for probable fox food within the 2m width particularly invertebrates, hares and roosting birds. However owing to the high visibility in the area, if hares were spotted away from the 2m width by means of powerful torch lights, approximate perpendicular distances were noted down with an accuracy of 0-5m. The main objectives of the night walks were to assess the abundance of relatively sessile nocturnal food items.

Small mammals like gerbils have been known to contribute significantly in the diet of foxes. To develop a relationship between number of gerbils inhabiting a colony and variables of colony size, e.g. number of burrows, length and breadth, the most abundant species in the study area, the desert gerbil (*Merriones hurrianae*) was trapped in different sized colonies using Sherman traps. For each colony the maximum length, maximum breadth, total number of burrows and the number of active burrows were recorded. A minimum of four sessions and a maximum of nine sessions of trapping were done for seven gerbil colonies. Sampling sessions were done on consecutive days (4-9 days).

Owing to the diurnal nature of the gerbil, the trapping sessions were done in the morning. The traps were camouflaged with brown paper and were placed randomly covering the extent of the colony. Since colonies covered small areas, the traps were placed to maximize trapping efficiency as the objective was to estimate the size of the rodent population in the study colony. The number of traps remained almost the same throughout the sampling sessions (13 traps). The session time ranged from 1.5 to 5 hours per day over the sampling sessions. However an average of 3 hours as session time was maintained. Peanuts were used as bait for the gerbils. Each gerbil captured was marked before being set free. Gerbils when captured were marked on their ventral side of the right hind limb by means of a permanent marker. Trapping was done in colonies of different sizes and the minimum distance between two colonies was at least 50m.

Plate 4

Gerbil burrows in a colony

Setting traps in a colony

Gerbil trapping session

3.2.2. *Sampling resource use pattern*

Scat analysis was the primary sampling strategy to assess the food resources used by the foxes. Misidentifications of scats were avoided by choosing for den sites for sampling and opportunistic sampling was avoided as much as possible. Most of the scats collected in field were dry however if scats were collected fresh they were sun dried and stored in polythene zip locks. Information about the date of collection, time and den ID was noted. Scats were collected periodically over the seasons spanning during the study period.

3.3. Analytical methods:

3.3.1. *Food availability*

3.3.1a. *Food availability from transects*

Food availability was calculated as density of prey items per hectare. Density of reptile and gerbil burrows, hare pellets, arthropods, birds, reptiles and fruiting shrubs were computed as the number/hectare. Densities were calculated for different seasons and between habitats. In case of hare sightings for which perpendicular distances were noted, density was computed manually since use of the software DISTANCE (Version 4.1) was not feasible due to considerably lower number of observations. Effective strip widths were calculated by plotting a histogram and excluding distances beyond which the detections started to fall. Similarly for the night walks, densities for the relatively sessile prey were computed manually as the number/ hectare. T test was done after a confirmation of normal distribution by the Kolmogorov Smirnov's test (See Appendix 1) to compare individual prey densities between the habitats.

3.3.1b. *Gerbil trapping*

The main purpose in trapping gerbils was to find a relationship between actual numbers and the colony size variables. Each colony was a distinct entity with a certain number of individuals. For each of the colony, individual capture histories were constructed using a standard 'X-matrix format' (Otis *et al*., 1978; Nichols, 1992), in which '1' indicated capture of a particular individual during a specific sampling occasion, while '0' indicated that the animal was not captured during that occasion. To estimate the population of gerbils for each colony, programme MARK (Cooch &White, 1995) was used. The analysis of the capture history data requires comparison between the possible capture-recapture models using a series of hypothesis tests. The closed population models are generally used for experiments covering relatively short periods of time (Pollock *et al*., 1990). Since each session for a particular colony was conducted consecutively, it was assumed that the gerbil population in a colony was demographically closed with no individuals moving out or individuals from other colonies coming in. In the analysis using programme MARK the following models were fitted and AIC criteria used to select between them:

(1) **M(o)**: capture probability is the same for all individuals not being influenced by behavioural response, time or individual heterogeneity.

(2) **M(h)**: capture probabilities are heterogeneous for each individual gerbil but not affected by trap response or time.

(3) **M(b)**: capture probabilities differ between previously caught and uncaught gerbils due to trap response behaviour or time.

(4) **M(t)**: capture probabilities are same for the gerbils but varies during the sampling only due to time specific factors.

The model selection process considered other complex models such as M(bh),incorporating behaviour and heterogeneity, M(th), incorporating time and heterogeneity, M(tb), incorporating time and behaviour (trap response) and M(tbh), incorporating a combination of all the three. The overall model selection function scores potential models between a score of 0-1, the higher score indicating a better fit of the model to the data given. The model fitting is based on the AIC (Akaike Information Criteria). The model best fitted by the software in based on the lowest AIC value. The AIC provides an objective way of determining which model among a set of models is most parsimonious based on Kullback-Leibler information on model selection (good model minimizes the loss of information) (Anderson *et al*., 2001).

Of the total seven colonies were trapped, the programme MARK estimated the number of individuals and the capture probabilities of gerbils in each colony. I regressed population size of each colony with the parameters of colony size like length, width, number of active burrows and total number of burrows using SPSS (Version 8) (See Appendix 2 &3).

3.3.2. *Scat Analysis*

3.3.2a. *Laboratory Analysis:*

Analysis of prey remains in faeces has been widely used to assess carnivore diets (Putman 1984). It is a simple nondestructive technique which has wide applicability. To estimate the diet of the Indian fox, scat analysis was done using the standard protocols for estimation (Korschgen, 1980). A total of 668 scats (including both grassland =192 and scrubland; n= 473) were collected during the study period. All the scats were transferred to paper bags from polythene zip locks and oven dried at 60˚C in the laboratory.

Since the fox scats were much smaller than other canid scats (as compared to wolves and jackals), the scats were dismembered using forceps and needle and the indigestible components such as fruit seeds, hairs, claws, scales, feathers, bones and insect chitin were separated. Identification of mammalian species was based on cuticular and medullary characteristics of hairs (Mukherjee *et al* 1994). Reference slides for cuticular and medullary patterns were prepared for all the mammals in the study area. The hairs separated were washed in xylene and slides were prepared for microscopic analysis. Whole mounts of hairs were prepared in DPX for examining medullary characteristics. Cuticular imprints of the hairs separated were made on a gelatin layer prepared on slides and observed under 10X and 45X magnifications.

3.3.2b. ***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 Indian fox, the cumulative percent frequencies of the occurrences of the different prey species were calculated for each increment of ten scats and this was plotted against the total number of scats. It is seen that as the number of scats increase the proportion of prey items stabilize at a point giving an approximate number of scats required to analyze the annual food habits. Sample size estimation was done individually for both grassland and scrubland habitats as well as for all the scats analyzed. This standardization would help optimize efforts and minimize costs for food habit studies (Jethva & Jhala, 2003).

3.3.2c. *Data Analysis:*

Foxes being versatile in their food habits have been known to have varying occurrences of different prey species in their scats. The most commonly used and easily applied method of diet analysis is the frequency of occurrences of prey types/ sample of faeces (Leopold & Krausman 1986; Corbett, 1989). The frequency of occurrence of a prey item was calculated as the number of times a specific prey item was found to occur in the fox scats expressed as a percentage. Frequency of occurrences of prey items was calculated for the fox scats collected from the two habitats spanning summer and winter. On the frequency of occurrences obtained, 95% confidence intervals were generated by 1000 bootstrap simulations. The bootstrap method is a re-sampling technique used for estimating confidence intervals and other information about the distribution of sample statistics (Marly, 1997). All bootstrap simulations to generate confidence intervals on the frequency of occurrences were done using the statistical software SIMSTAT (Version 2.5). (http://www.provalisresearch.com/simstat/simstatv.html).

3.3.3. *Food selection*

The frequency of occurrence of prey from the scats were converted to biomass consumed, by the relationship $Y= 0.0182X +0.217$ (Jethva & Jhala, 2004), where Y = Biomass consumed /scat and X= Average prey weight. This relationship was developed to compute biomass consumption from prey occurrences in wolf scats. Since no such derivation was available for small sized canids like foxes, and in the absence of any better procedure, I applied this equation to estimate biomass consumption of different prey items from frequency of occurrence in fox scats. The correction factors were derived for the mammals, birds, reptiles and arthropods. For the arthropods the average weight of an arthropod in the diet of the foxes was found by means of weighted average since four different groups of arthropods were found in the diet. For the fruits the average number of seeds obtained per scat was calculated and then multiplied by the weight and the frequency of occurrence to get the percentage biomass per scat. The use of prey in scats was expressed as percentage biomass per scat (observed values). For estimating availability of prey items, the densities obtained were converted to percentage biomass per hectare (expected values). The species considered for correlating availability to their use were: hares, rodents, spiny-tailed lizards, birds, arthropods and fruits which composed > 95% of the fox's diet.

The comparison between the estimated and the expected occurrences to conclude about the use of prey as per its availability within the habitat was done by generating mainly three different methods; Ivlev's Index (Ivlev 1961), Bonferroni's simultaneous confidence intervals (Neu *et al* 1974) and Compositional Analysis (Aebischer & Robertson 1993). The Ivlev's Electivity Index is scaled between -1(complete avoidance) to +1 (exclusive selection). 0 indicates the use of prey items in proportion to availability. This method was mainly used to measure the electivity for macroinvertebrate taxa in fish rations. It is one of the simplest methods to check for availability versus use of prey items.

The analysis described by Neu *et al* (1974) compares the observed occurrence to the expected occurrences of each category. It was mainly tested on the use and the availability of different habitat categories although it may be applicable to determine the preference or avoidance of forage species (Neu *et al* 1976).The confidence intervals are generated on the observed values and then compared with that of the expected values.

The Compositional analysis (Aebischer & Robertson 1993) can be used to compare availability versus use of prey items. However the method was initially used to compare availability versus use of habitats by animals using radio tracking data. It mainly takes into consideration the differences in the log ratios for use and availability. The categories are ranked in the highest order based on the number of positive values generated by a matrix comprising of the difference in log ratio values. The prey type which is used least but available has been used to generate the ratio of availability and use values.

3.3.4. *Den densities (number of active breeding units) in the study area*

Den groups were identified based on personal observations in field during the six months tenure and considering the general ecology of the animal. The number of breeding units / sq km was quantified by using GIS Software ArcView (Version 3.2). The GPS locations of the dens taken were plotted on the Georectified satellite (IRS LISS III) image of the study area. A 100% Minimum Convex Polygon (MCP) was drawn on these locations and a buffer was added around this MCP using Proximity Analysis by taking half of the average of the distances between the centre of activity of the dens. This buffer was added to include the area of possible use by the animal around the dens. Den density was enumerated using ArcView Extension (Animal Movement SA v 2.04 beta). The number of breeding units / sq km. was estimated for the scrubland habitat.

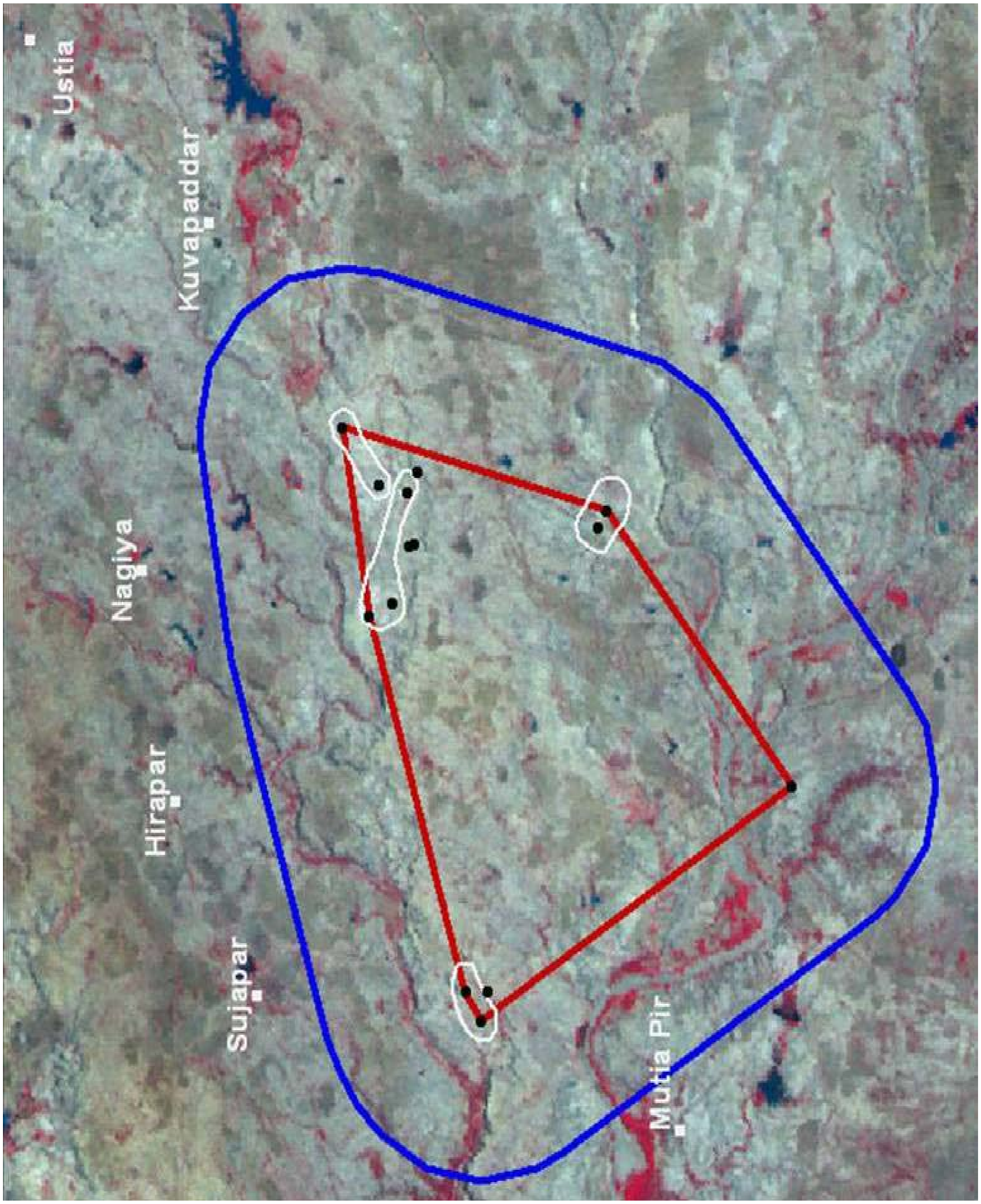


Plate 5:

Map showing the Minimum Convex Polygon (MCP) with buffer the den groups and the villages in the study area

4. RESULTS

4.1. Food availability:

4.1.1. *Density of prey from transects:*

Density of the individual prey items were compared between the two habitats using a T-test. Densities for the winter and summer were gain compared between the two habitats. The results of the T- test are given as follows and the densities which are significant at $\alpha = 0.05$ level has been highlighted.

Table 1. T-test to compare the two habitats: grassland and scrubland with respect to the variables (prey items):

Prey items	F	Sig.	t	df	Sig. (2-tailed)
(Assuming equal var)	Levene's Test		Test statistic		
STL(Spiny tailed lizard burrows)	5.80	0.02	1.66	38	0.10
GER(Gerbil burrows)	13.22	0.0008	-3.34	38	0.001
HPG (Hare pellet groups)	0.28	0.59	-1.41	38	0.16
HPT(Total hare pellets)	0.44	0.50	-1.88	38	0.06
REP(Reptiles)	0.41	0.52	-0.66	38	0.50
BIRDS	0.65	0.42	0.12	38	0.90
ARTHRO(Arthropods)	1.21	0.27	1.43	38	0.15
FRUITS (All)	44.53	4.74E-08	3.07	38	0.003
ZIZ (Only *Zizyphus*)	62.17	1.65E-10	2.84	38	0.007

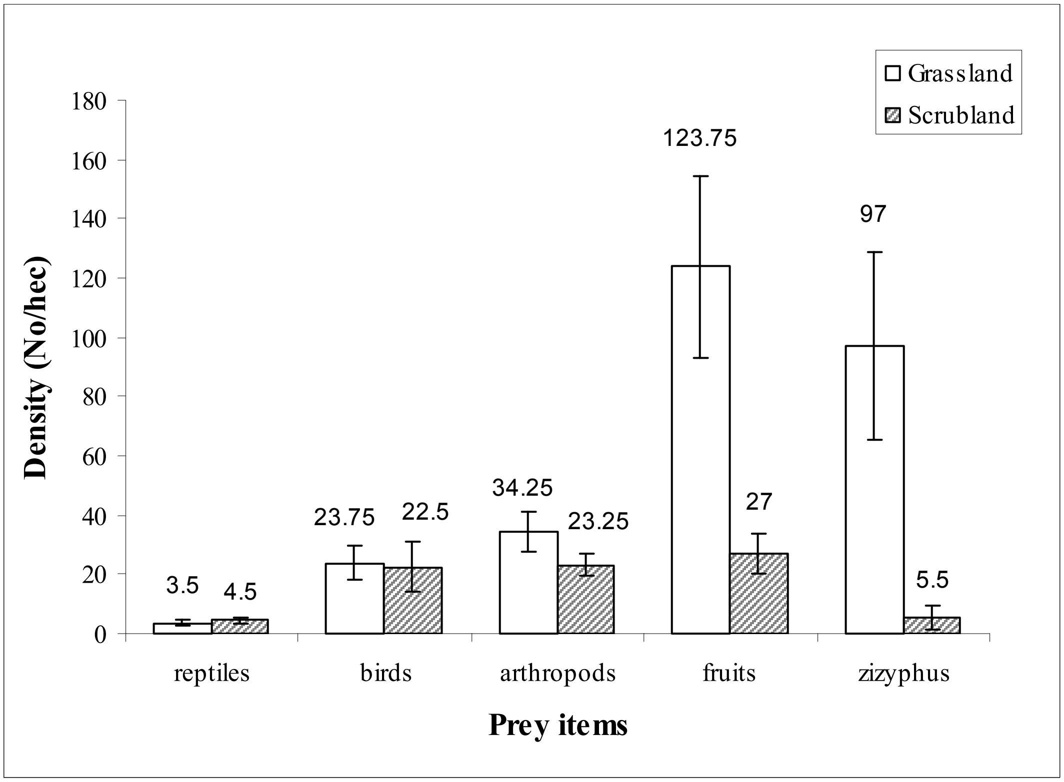


Fig.1. Graphical representation of densities of prey in the two habitats (direct sightings)

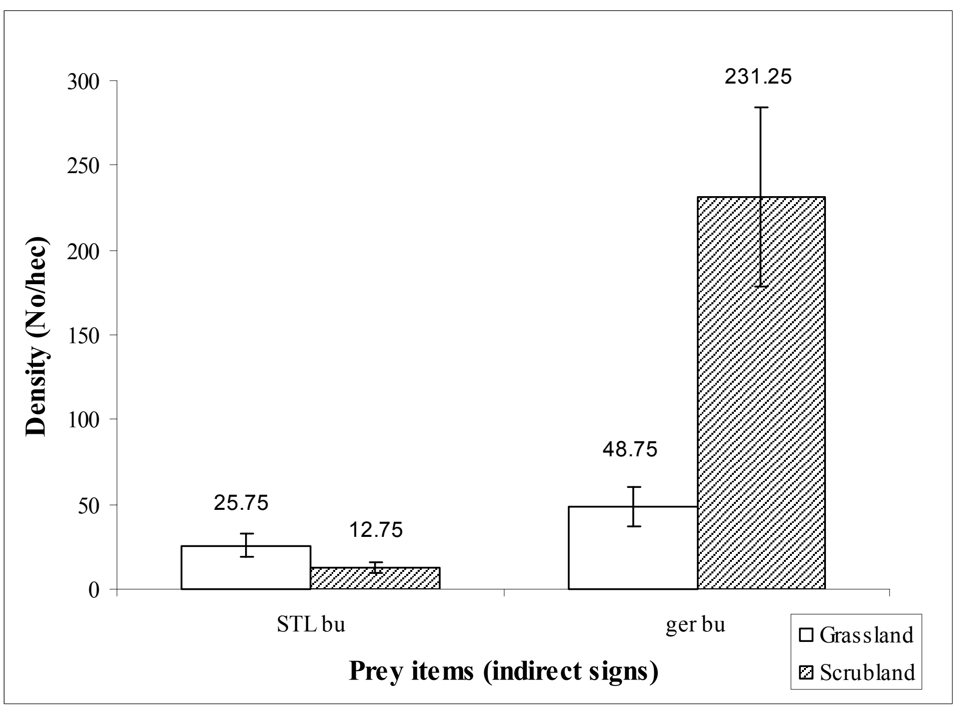


Fig.2. Graphical representation of the density of indirect indices

Table 2. T-test done to compare densities of prey for the winter season between two habitats:

Prey items	**F**	**Sig.**	**t**	**df**	**Sig. (2-tailed)**
(Assuming equal var)	Levene's Test		Test statistic		
STL(Spiny tailed lizard burrows)	0.77	0.39	1.01	18	0.32
GER(Gerbil burrows)	6.69	0.01	-2.68	18	0.015
HPG(Hare pellet groups)	5.15	0.03	-3.87	18	0.001
HPT(Total hare pellets)	6.07	0.02	-3.941	18	0.0009
REP(Reptiles)	6.72	0.01	-1.38	18	0.18
BIRDS	0.42	0.52	0.19	18	0.85
ARTHRO(Arthropods)	1.69	0.20	1.12	18	0.27
FRUITS(All)	12.65	0.002	3.77	18	0.001
ZIZ (Only *Zizyphus*)	15.58	0.0009	3.84	18	0.001

Variables significant at α= 0.05 are highlighted.

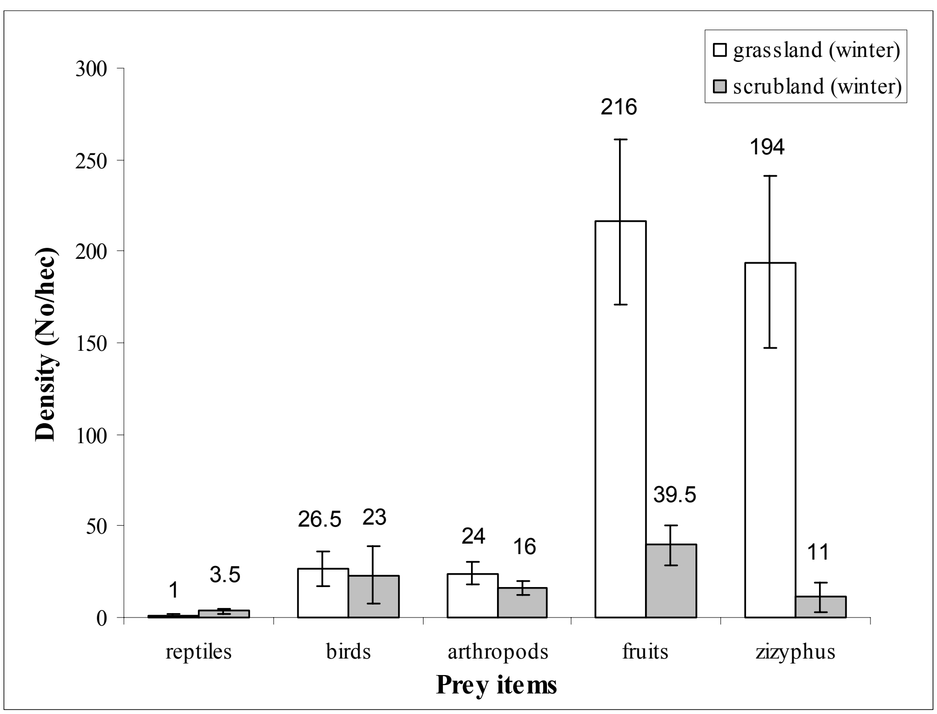


Fig.3. Comparison of prey densities in winter (direct sightings) for habitats.

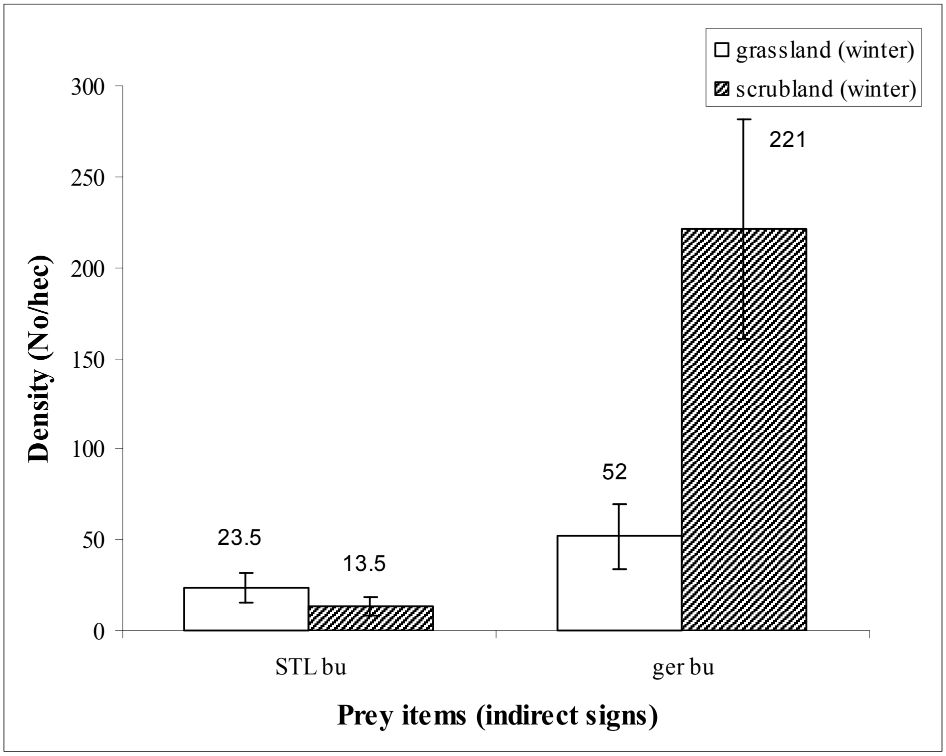


Fig. 4. Graphical representation of the winter densities of prey indices in both habitats.

Table 3. T-test done to compare densities of prey for the summer season between two habitats:

Prey items	F	Sig.	t	df	Sig. (2-tailed)
(Assuming equal var)	Levene's Test		Test statistic		
STL(Spiny tailed lizard burrows)	6.35	0.02	1.26	18	0.22
GER(Gerbil burrows)	8.16	0.01	-2.11	18	0.048
HPG(Hare pellet groups)	5.07	0.03	-0.92	18	0.36
HPT(Total hare pellets)	0.64	0.43	-1.54	18	0.14
REP(Reptiles)	0.05	0.82	0.23	18	0.81
BIRDS	0.35	0.55	-0.1	18	0.92
ARTHRO(Arthropods)	1.51	0.23	1.10	18	0.28
FRUITS (All)	0.52	0.47	1.89	18	0.07

Variables significant at $\alpha=0.05$ are highlighted

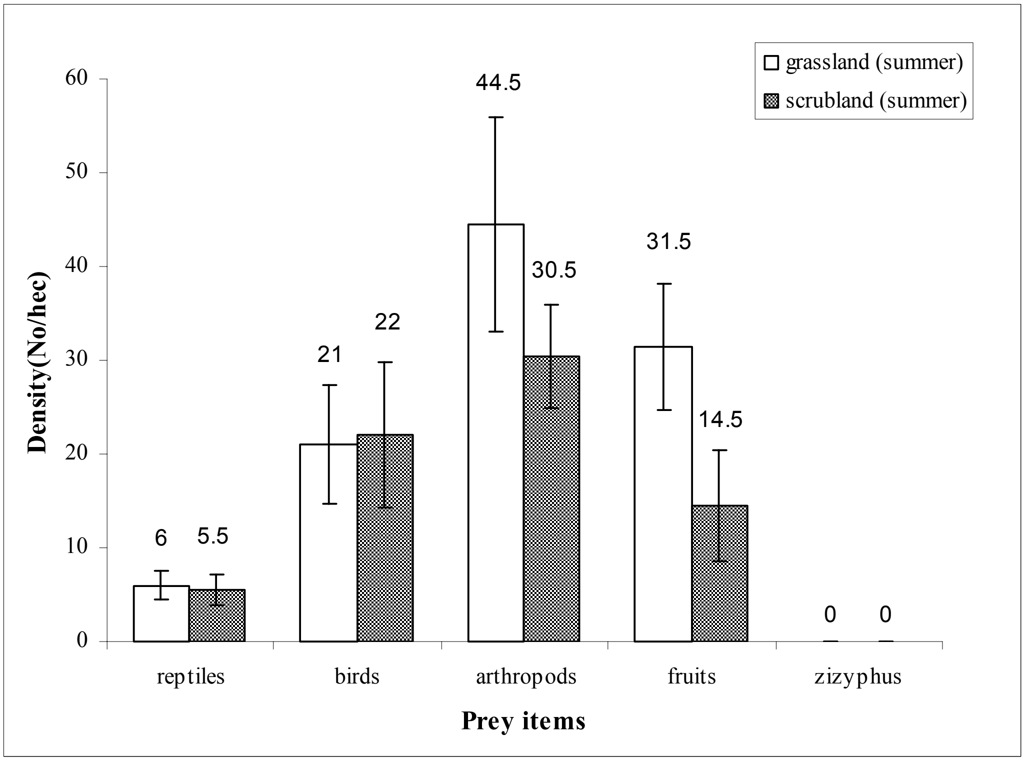


Fig.5. Comparing densities for summer in both the habitats (direct sightings).

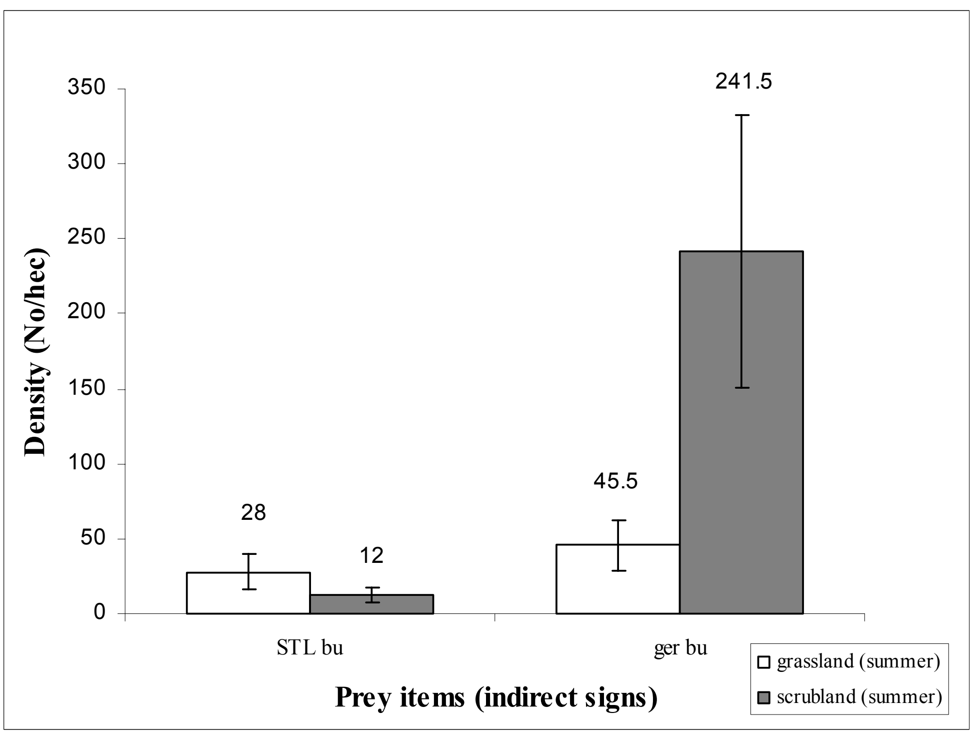


Fig.6. Comparing the densities of reptilian and mammalian burrows in summer in both the habitats.

Table 4. T-test done to compare densities of prey for the scrubland between two seasons (winter and summer):

Prey items	F	Sig.	t	df	Sig. (2-tailed)
(Assuming equal var)	Levene's Test		Test statistic		
STL(Spiny tailed lizard burrows)	0.02	0.88	0.20	18	0.83
GER(Gerbil burrows)	0.89	0.35	-0.18	18	0.85
HPG(Hare pellet groups)	58.38	4.68E-07	-2.77	18	0.01
HPT(Total hare pellets)	10.99	0.003	-3.92	18	0.001
REP(Reptiles)	0.13	0.71	-0.87	18	0.39
BIRDS	0.66	0.42	0.057	18	0.95
ARTHRO(Arthropods)	1.28	0.27	-2.18	18	0.042
FRUITS (All)	5.42	0.03	2.04	18	0.056
ZIZ (Only *Zizyphus*)	10.96	0.003	1.38	18	0.18

Variables significant at α=0.05 are highlighted.

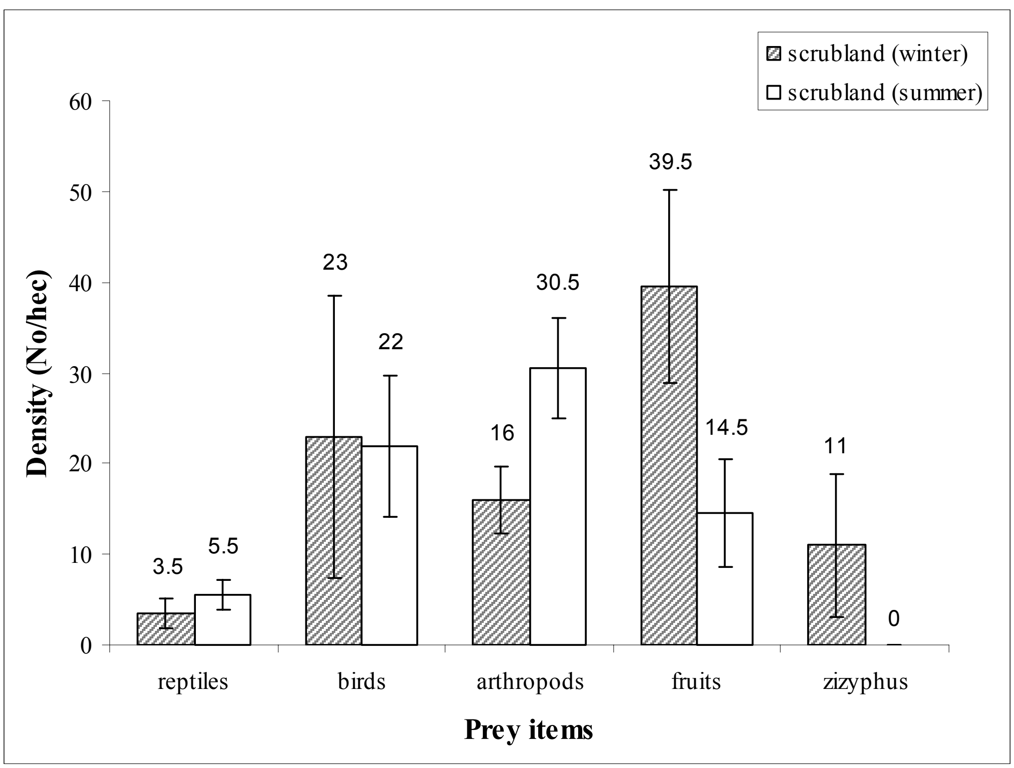


Fig.7. Comparing seasonal changes in density for the scrubland habitat.

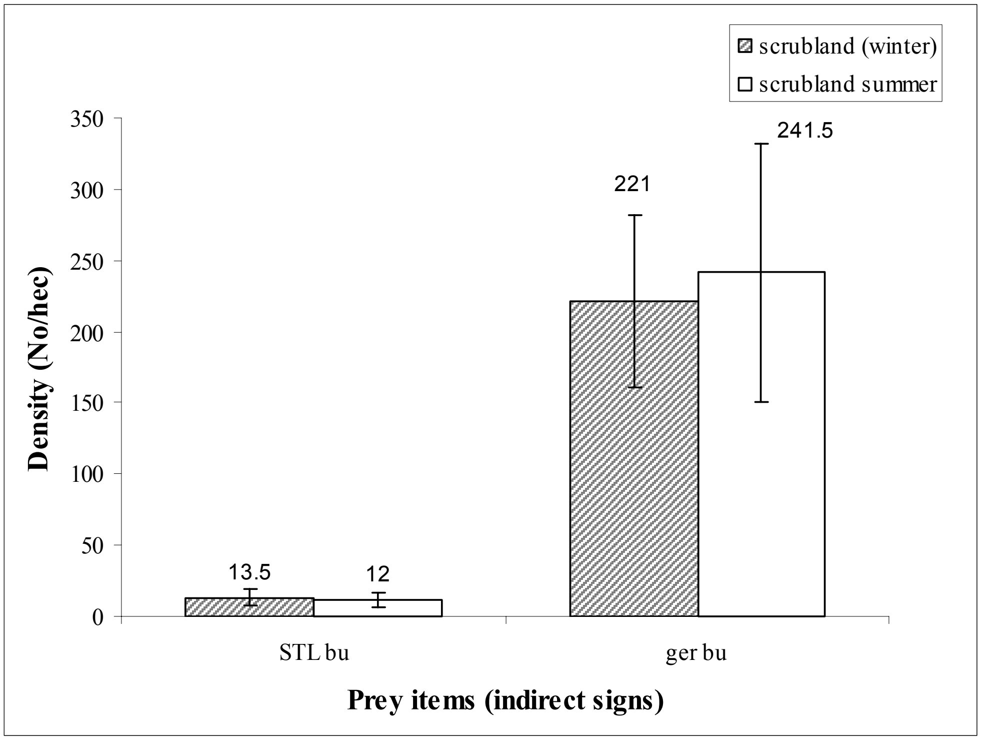


Fig.8. Comparing seasonal changes in densities for the scrubland.

Table.5. T-test done to compare densities of prey (direct sightings and indirect evidences) for the grassland between two seasons (winter and summer):

Prey items	F	Sig.	t	df	Sig. (2-tailed)
(Assuming equal var)	Levene's Test		Test statistic		
FRUITS (All)	16.34	0.0007	4.01	18	0.0008
GER(Gerbil burrows)	0.17	0.67	0.26	18	0.79
HPG (Hare pellet groups)	23.64	0.0001	-3.71	18	0.001
HPT(Total hare pellets)	16.45	0.0007	-4.36	18	0.0003
REP(Reptiles)	3.28	0.08	-3.12	18	0.005
BIRDS	0.36	0.55	0.47	18	0.64
ARTHRO (Arthropods)	1.17	0.29	-1.58	18	0.13
STL(Spiny tailed lizard burrows)	1.68	0.21	-0.31	18	0.75
ZIZ (Only *Zizyphus*)	22.42	0.0001	4.13	18	0.0006

Variables highlighted are significant at $\alpha=0.05$

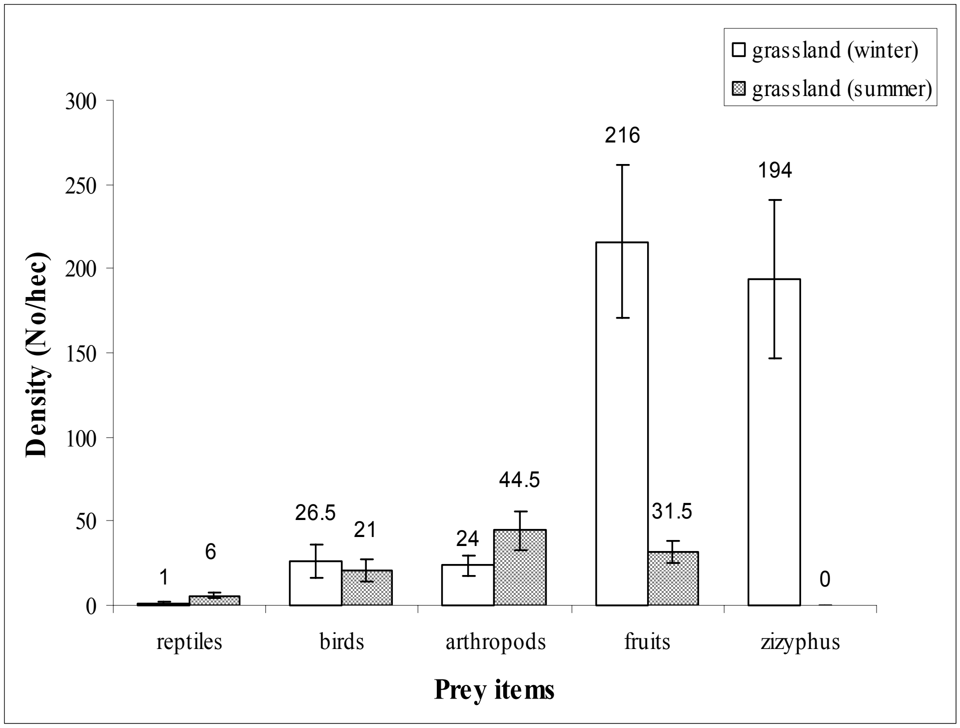


Fig.9. Comparing seasonal changes in densities of prey items in the grassland

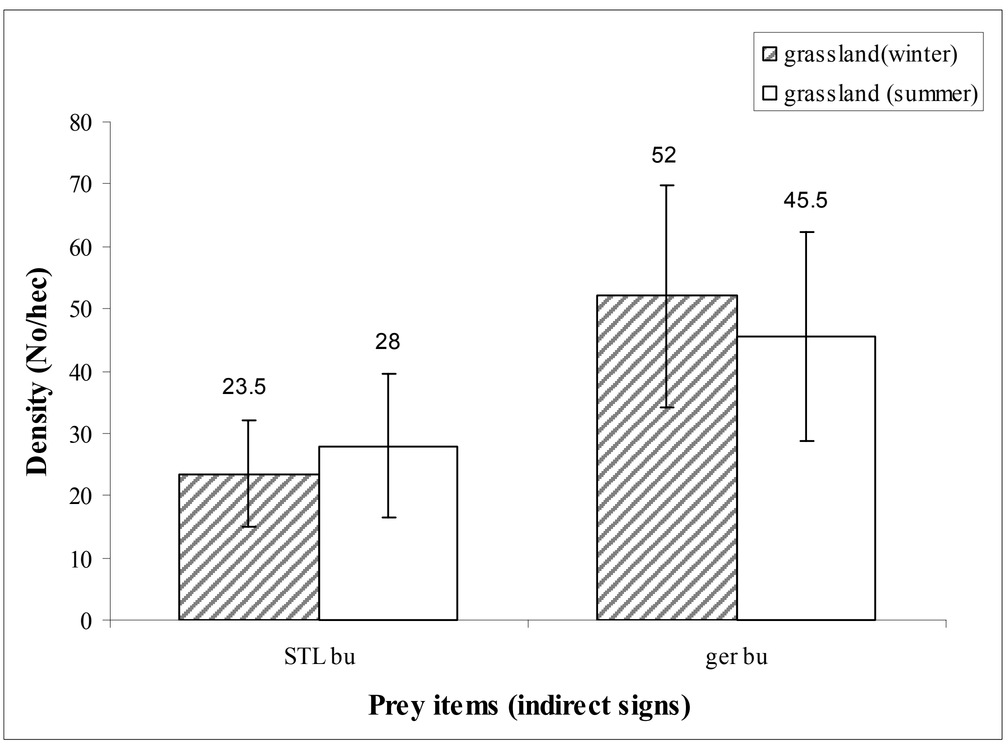


Fig.10. Comparing seasonal changes in densities for the grassland habitat.

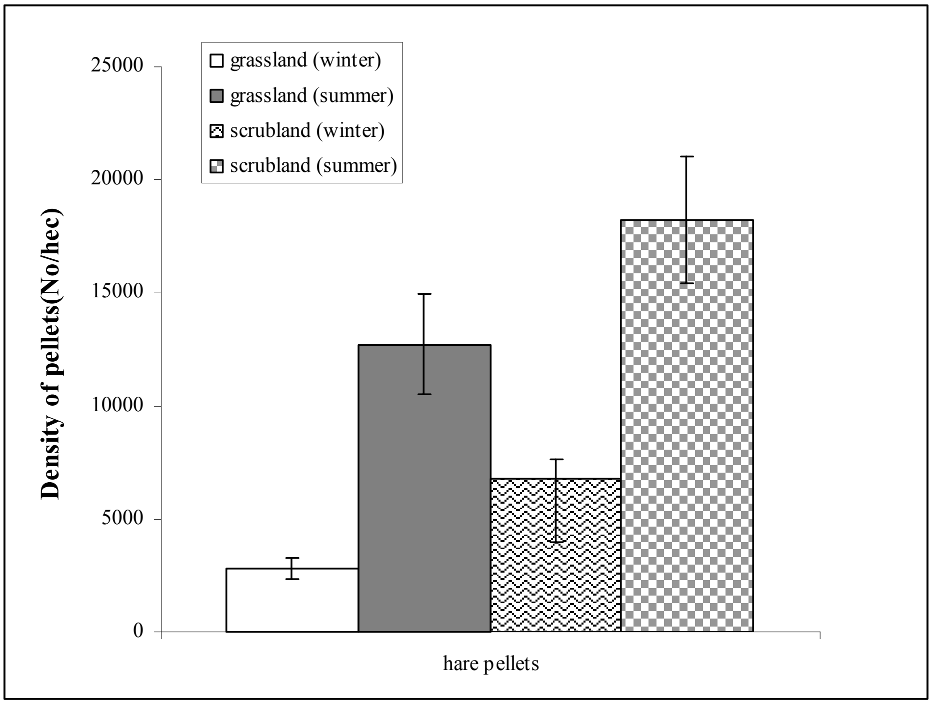


Fig.11. Hare pellet densities over seasons and habitats.

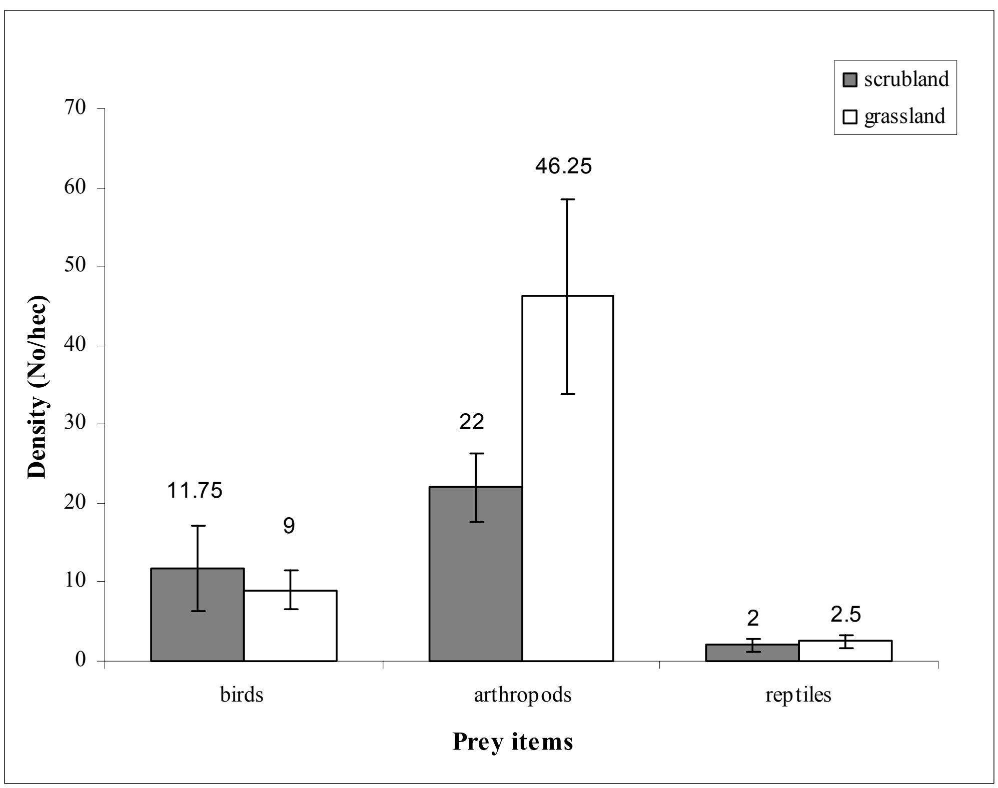


Fig. 12. Comparing prey densities from night walks in both the habitats

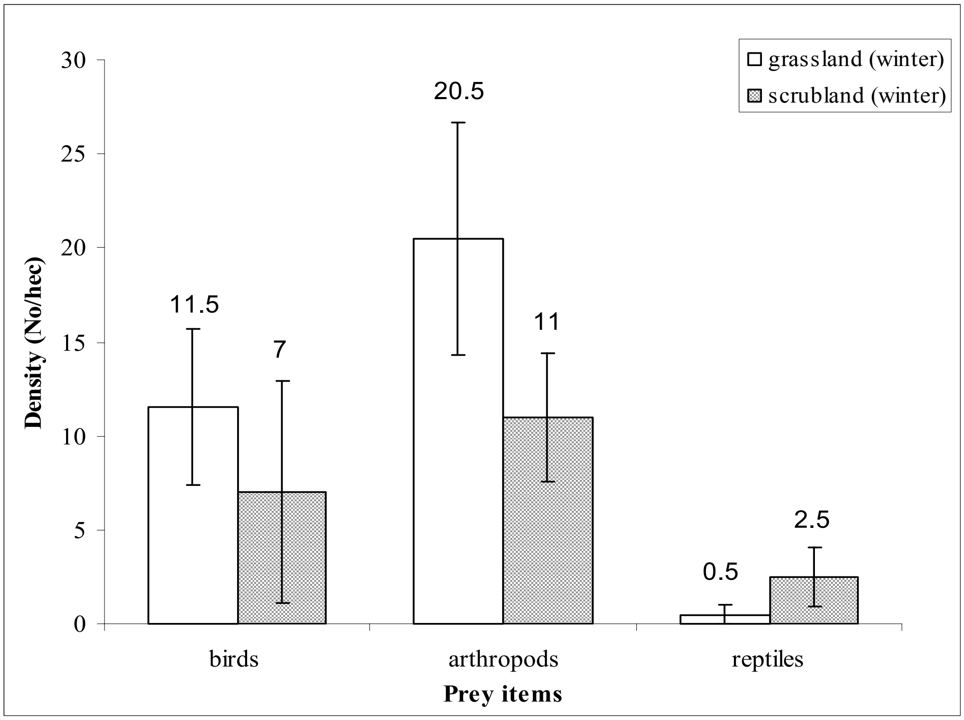


Fig.13. Prey densities in the winter for the two habitats (night)

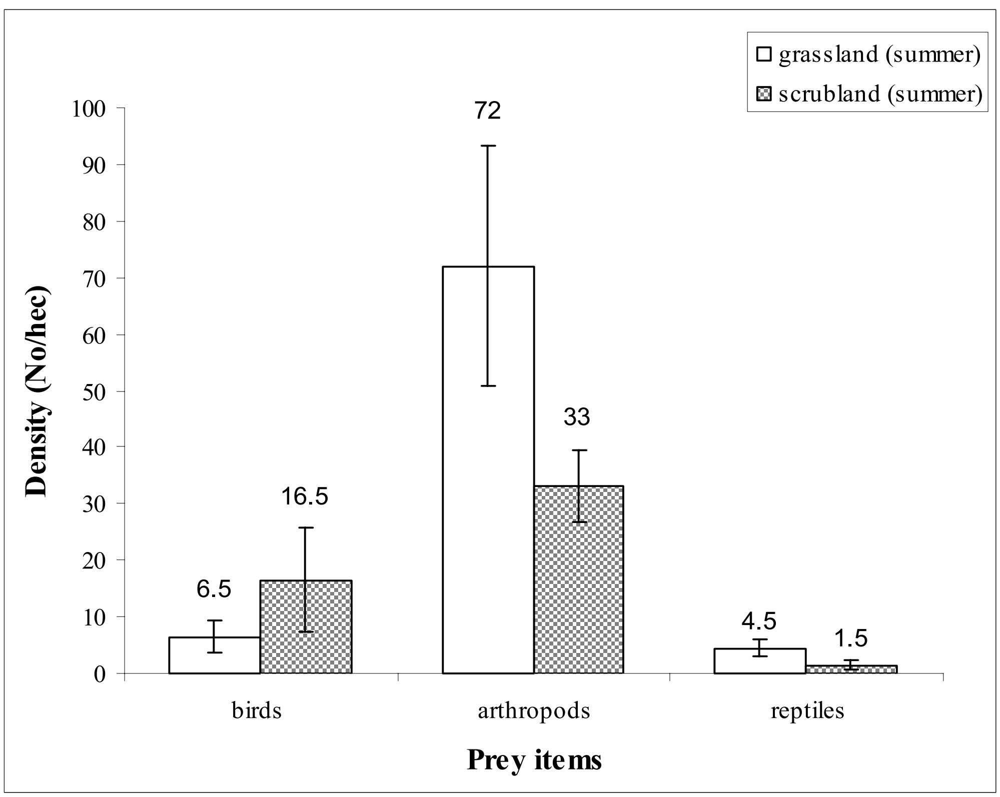


Fig.14. Prey densities in the summer for the two habitats (night).

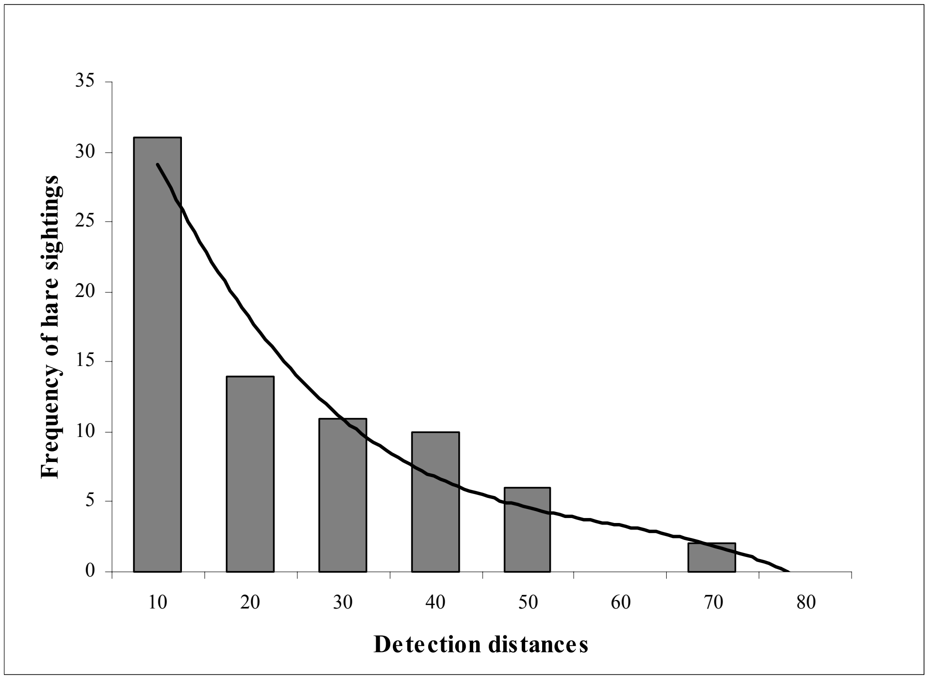


Fig.15. Calculating effective strip width for generating hare densities.
Effective strip width has been calculated as 55m (night and day data pooled)

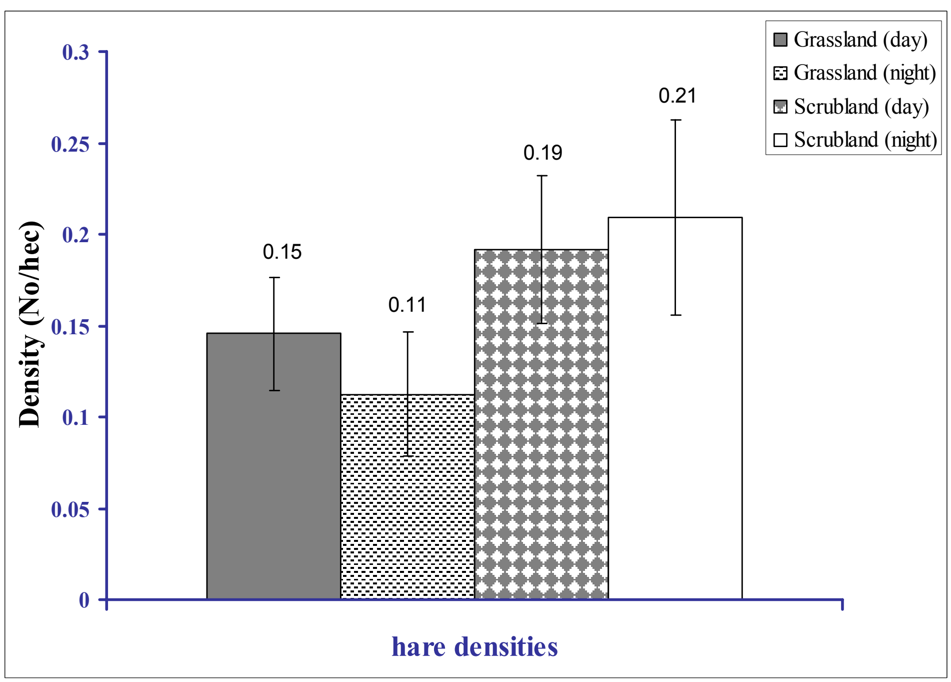


Fig.16. Hare densities shown for the two habitats for day and night.

4.1.2. *Gerbil trapping*

4.1.2a. *Estimating gerbil population in each colony*

Population estimate of the gerbils trapped in the different colonies by using MARK chose the Null Model; M(o) as the best fit model for all the colonies.

Table.6. Output of mark recapture data using MARK to estimate gerbil population in each colony.

Colony No.	Model selected	*p*-hat(prob.of capture)	N	SE	CV
1.	M(o)	0.37	15	2.26	15%
2.	M(o)	0.12	23	4.75	21%
3.	M(o)	0.12	46	7.06	15%
4.	M(o)	0.46	13	0.89	7%
5.	M(o)	0.60	8	0.30	4%
6.	M(o)	0.28	16	2.58	16%
7.	M(o)	0.29	15	1.47	10%

4.1.2b. *Correlating gerbil numbers to colony size variables*

The population estimates of the different colonies were correlated with the different colony sized variables (See Table 7 below). Results showed a significant relationship with all the variables at $\alpha = 0.05$. However the r value was the highest for the total number of burrows. Regression analysis using the population mean and the total number of burrows yielded a relationship defined by the equation:

Y (Population size) = 0.01317(±0.001) (Total number of burrows) + 0.217 (±1.673).

Table.7. Table showing correlation values of the population mean and the colony size variables

Colony Size variables	*p*	r (Correlation coefficient)	Sample size
Length	0.005	0.90	7
Breadth	0.02	0.83	7
Total burrows	0.0001	0.98	7
Active burrows	0.018	0.84	7

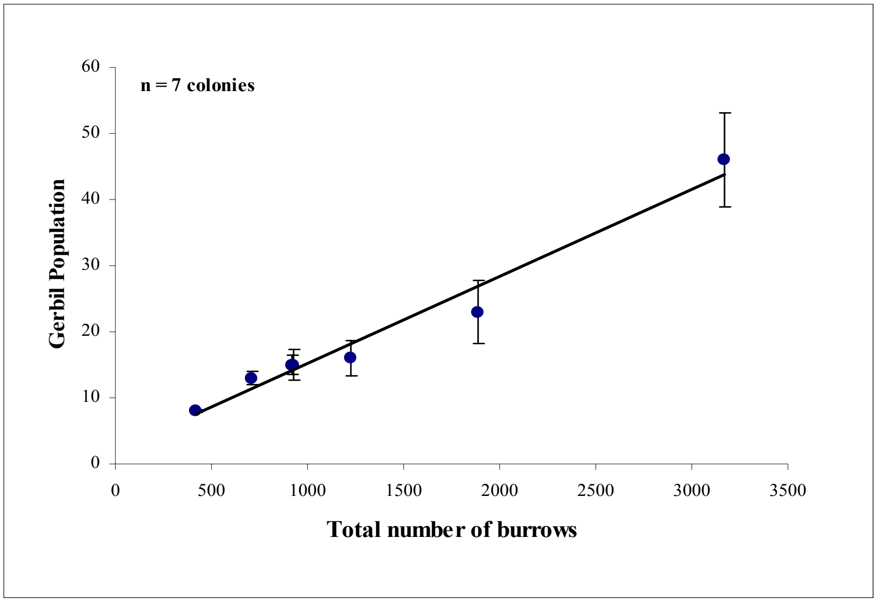


Fig. 17. Regression between the mean gerbil population and the total number of burrows (R square = 0.969). The error bars are the standard errors given with the mean.

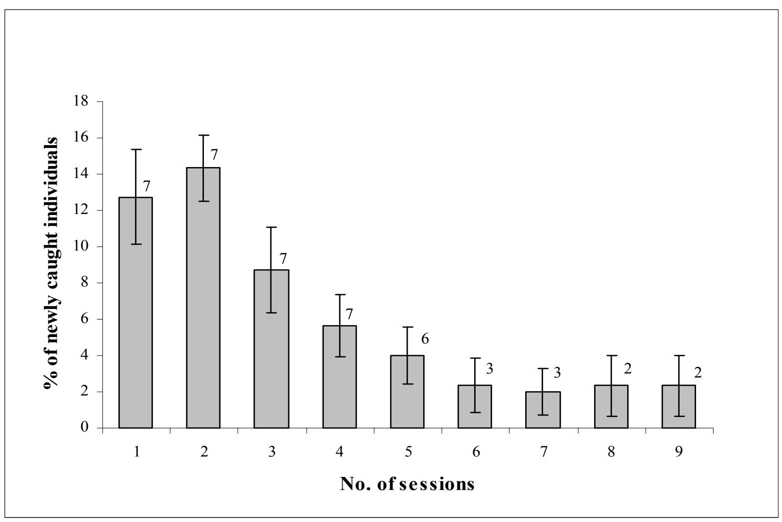


Fig.18. Percentage of newly caught individuals as the sessions increases.

Hare densities were calculated by pooling the day and the night data since no significant differences were seen in the densities computed for seasons and habitats through diurnal and nocturnal walks. Thus a common density was obtained for the area using an effective strip width of 55m (Fig.15). Density of hares was found to be 0.156 animals/ hectare. This density was used for calculating expected values (or availability) computed for food selection.

Similarly the equation (See Fig.17) depicting a relationship between the total number of burrows and the gerbil numbers was used to convert all the total burrows encountered on transects to gerbil numbers (now as numbers/ hectare). Since the study was conducted from winter to summer and it was not the breeding season of the spiny tailed lizard, it is assumed that one spiny tailed lizard burrow is equivalent to one individual. With all these assumptions, the expected values (or availability) were calculated.

4.2. Scat Analysis:

4.2.1 *Sample size estimation for minimum number of scats*

A total of 392 scats were analyzed (n=195 for grassland and n=197 for scrubland). The sample size estimation done for both the habitats shows that the cumulative frequencies of prey items stabilize at around 110 scats for both the areas Daun (grassland) (Fig. 19) and Hyaena Ridge(scrubland) (Fig. 20). The sample size estimated for all the scats (n= 392) also indicate the point of stabilization at about 100 scats (Fig. 21).

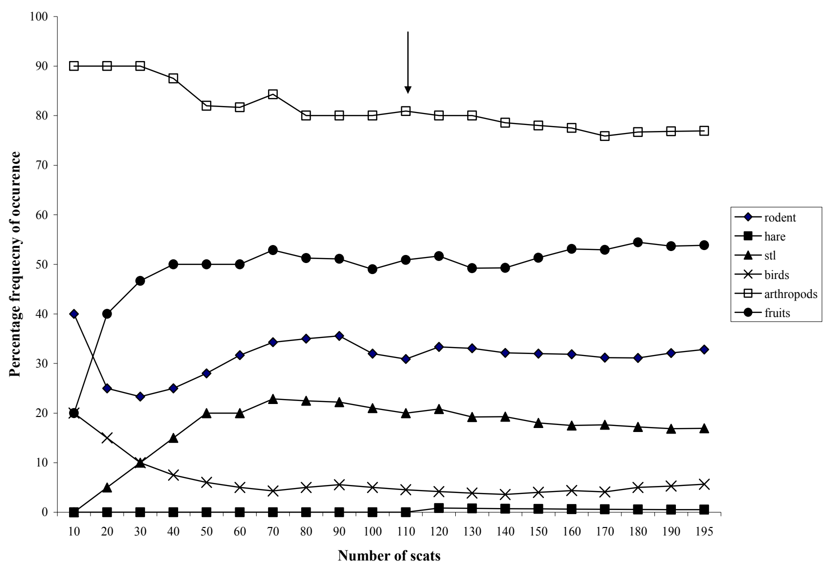


Fig. 19. Estimation of minimum number of scats that need to be analyzed to study food habits in the Indian fox (grassland). STL stands for Spiny-tailed lizards. Arrow indicate where the prey items stabilize.

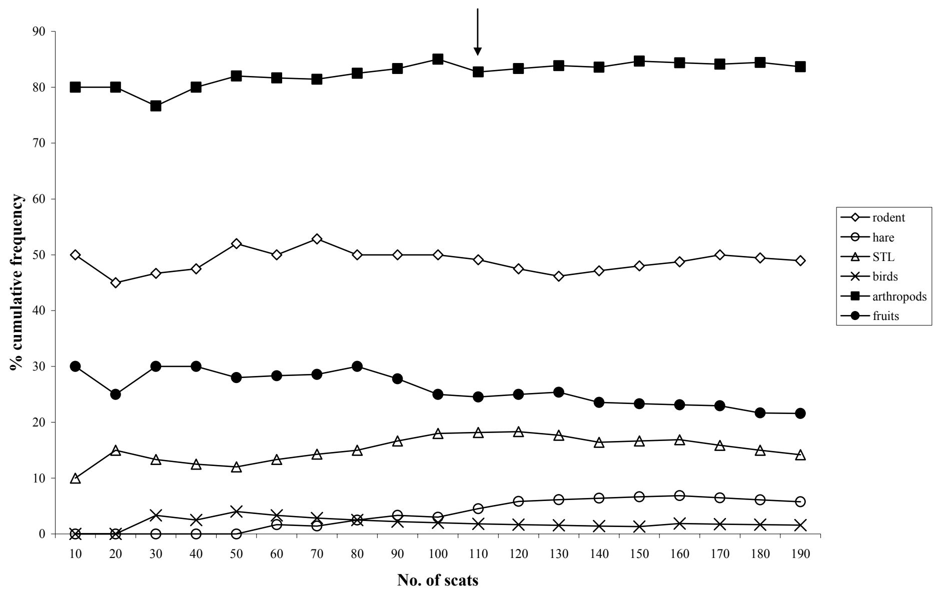


Fig. 20. Estimation of the minimum number of scats to study the food habits of the Indian fox (scrubland).Arrow indicates where the prey items stabilize.

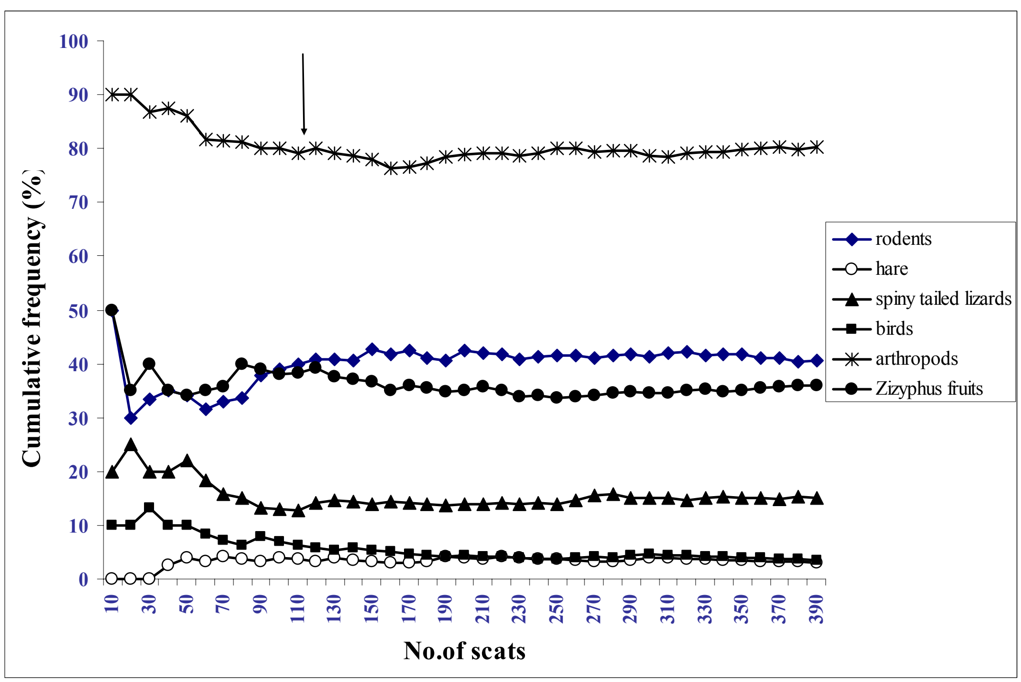


Fig.21. Estimation of the minimum number of scats to study the annual food habits of the Indian fox (n= 392). The number of scats stabilizes to about 100 scats.

Food habits of the Indian fox (*Vulpes bengalensis*) in Kutch

Table 8. The following prey items were recorded as per frequency of occurrence in all scats as well as for the two seasons.

Mammals					Birds		Reptiles		Arthropods				Fruits	
Rodents	**Hares**	**Sheep**	**Goat**	**Cattle**	**Birds**	**Eggshells**	**STL**	**Others**	**Beetles**	**Orthopterans**	**Scorpions**	**Termites**	***Zizyphus***	***Prosopis***
40.82	3.06	4.84	1.02	0.26	3.57	1.79	15.31	19.39	47.7	41.07	8.67	52.81	35.71	2.04
(All scats; n=392)														
39.61	0.65	11.69	2.6	0	1.3	0.65	22.73	19.48	43.51	48.05	9.74	50.65	55.19	2.6
(Winter scats; n= 154)														
41.6	4.62	0.42	0	0.42	5.04	2.52	10.5	19.33	50.42	36.55	7.98	54.2	23.11	1.68
(Summer scats; n=238)														

4.2.2. *Food habits of the Indian fox:*

4.2.2a. *Overall comparison between the scrubland and the grassland*

Table 8 shows the overall food habits of the Indian fox (expressed as percentage frequency of occurrence). Frequency of occurrences of the different prey items in the fox scats suggested that the arthropods comprised a major part of the diet in both the habitats (Fig.22). The error bars shown here are actually 95% CI and hence significant differences in intake of prey items were based on visual estimates. Even within the arthropods, the contribution by beetles and termites to the diet the foxes were significantly different when compared between the two habitats. Percentage occurrence of mammalian prey as a group did not change but significant differences were noted for prey categories due to the differential intake of rodents in both the habitats (Fig.24).

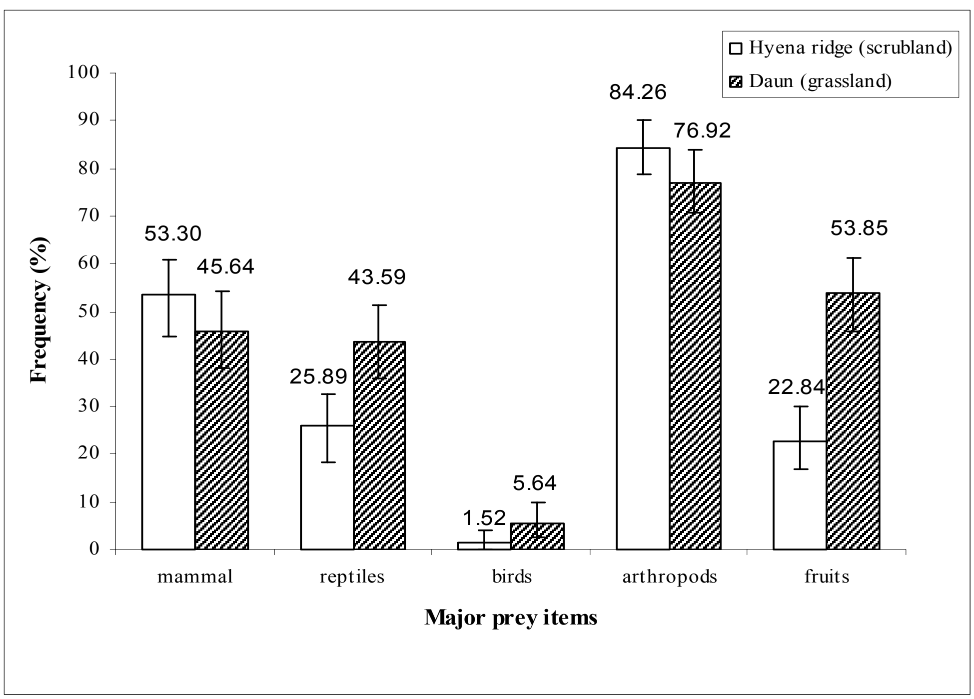


Fig. 22. Comparison of the frequency of occurrence of major prey items between two habitats. Error bars show 95% bootstrap CI (n=392).

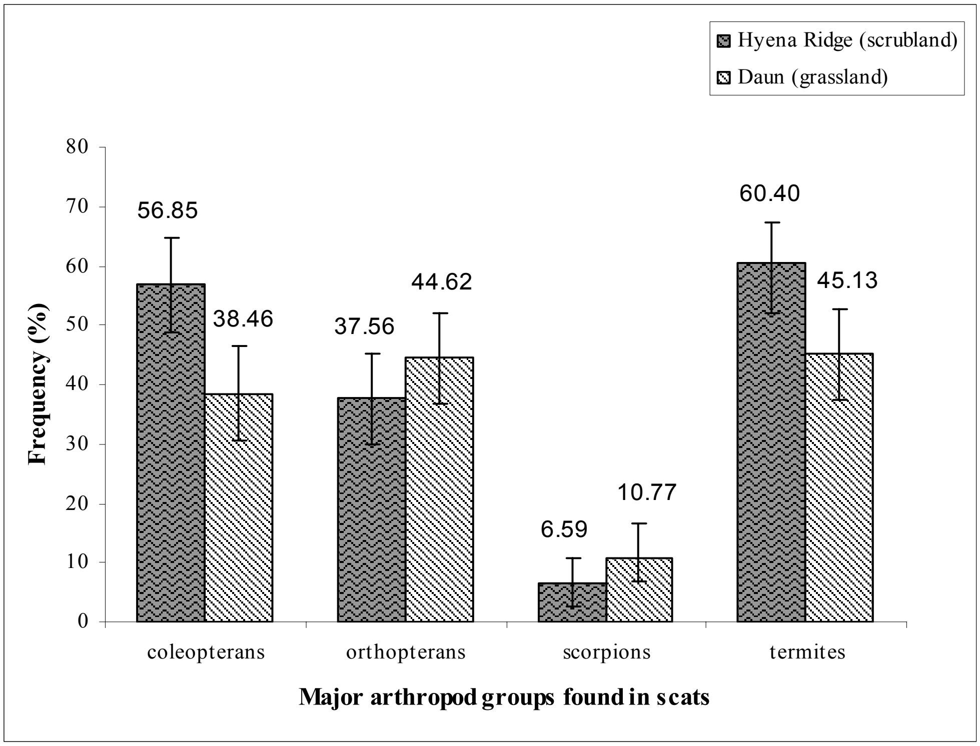


Fig.23. Comparison of major arthropod groups between the two habitats. Error bars are 95%CI (n= 392).

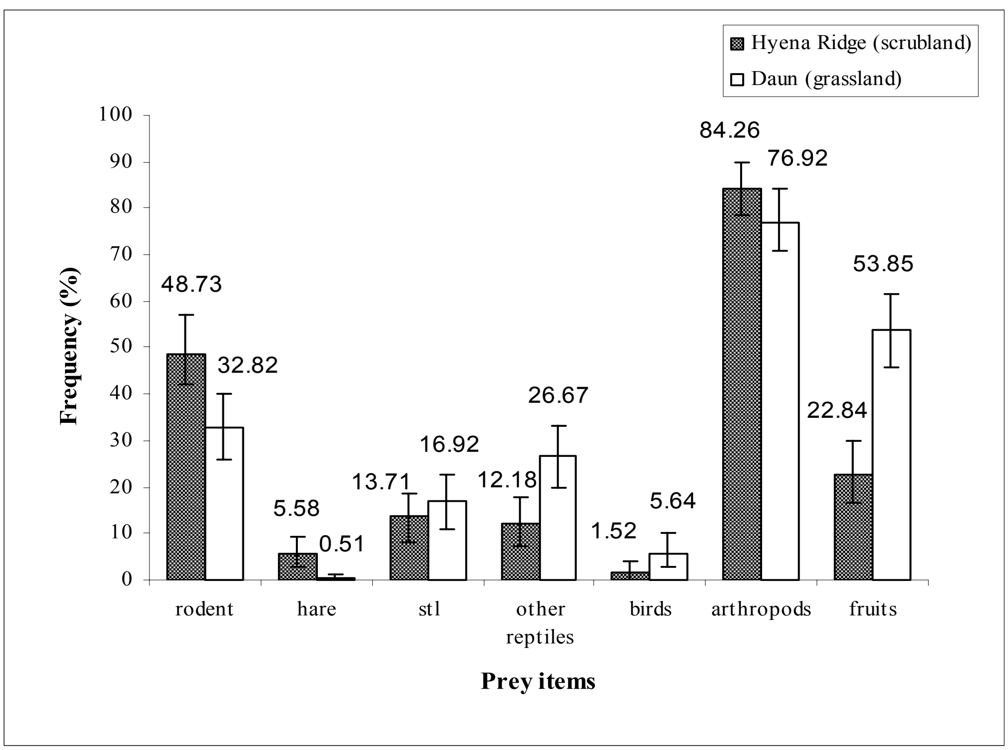


Fig. 24. Comparison of the frequency of occurrences of prey categorized between the two habitats. Error bars are 95%bootstrap CI (n=392).

4.2.2b. *Seasonal comparison between the two habitats with reference to diet*

Significant differences were seen in the winter diet between the two habitats with respect to fruits (mainly *Zizyphus*) and birds (Fig.25). Birds were not found in the winter diet of foxes in the scrubland. Similarly livestock remains of sheep and goat were found only for the grassland habitat (Fig.26). No significant differences in diets were seen for the different arthropod groups when compared for the winter (Fig.27).

Summer diet of foxes differed considerably between the habitats. Significant differences were not only evident for the major prey items (Fig. 28) but also when they were further categorized. Differences were evident for mammalian prey with the rodents being consumed enormously in the scrubland habitat. Diet also differed significantly with respect to reptiles, birds and fruits (Fig.29). Although the overall percentages of occurrence of arthropods were similar in both the habitats, significant differences were noted for coleopterans, scorpions and termite heads (Fig30).

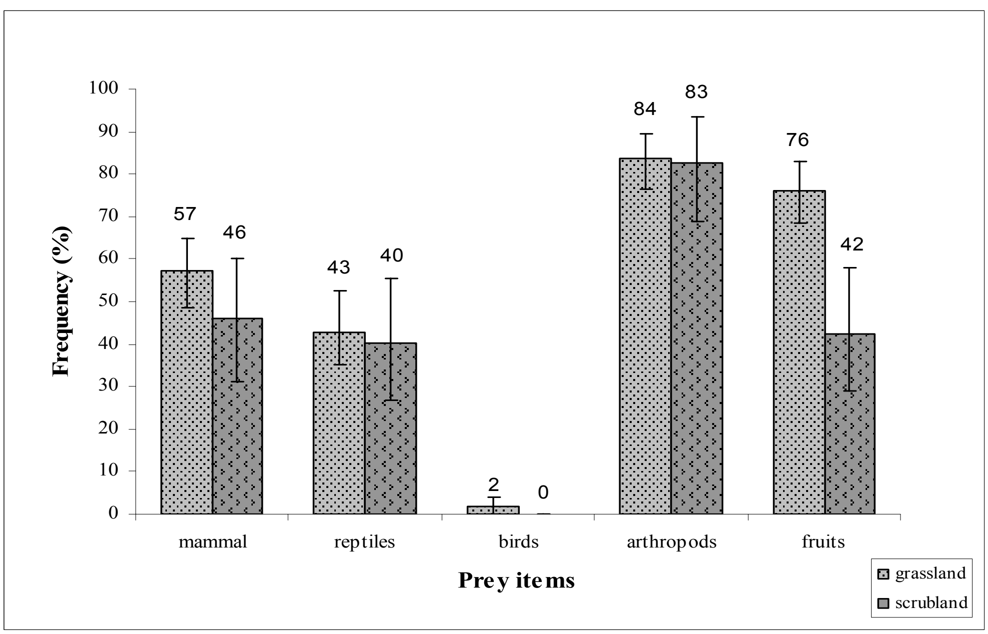


Fig.25. Comparison of frequency of occurrence of major prey items between two habitats in winter. Error bars indicate 95% bootstrap CI (n=154)

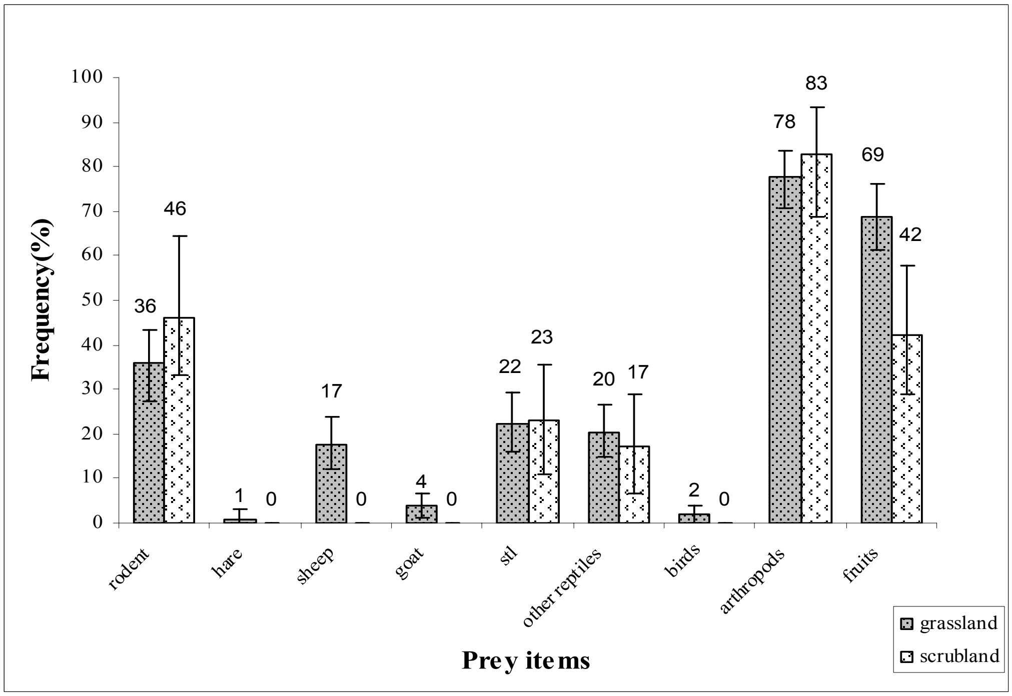


Fig.26. Comparison between the two habitats for winter (prey categorized). Error bars are 95% bootstrap CI (n= 154)

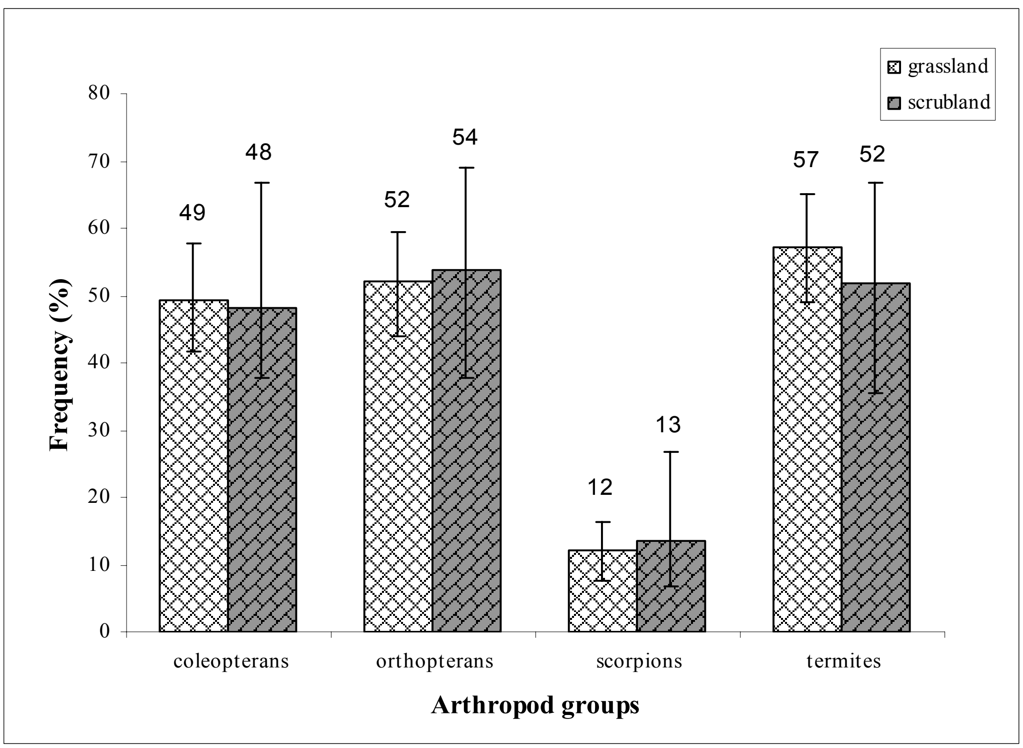


Fig.27. Comparing frequency of occurrences of the different arthropod groups for the winter between the two habitats. Error bars represent 95% bootstrap CI (n=154).

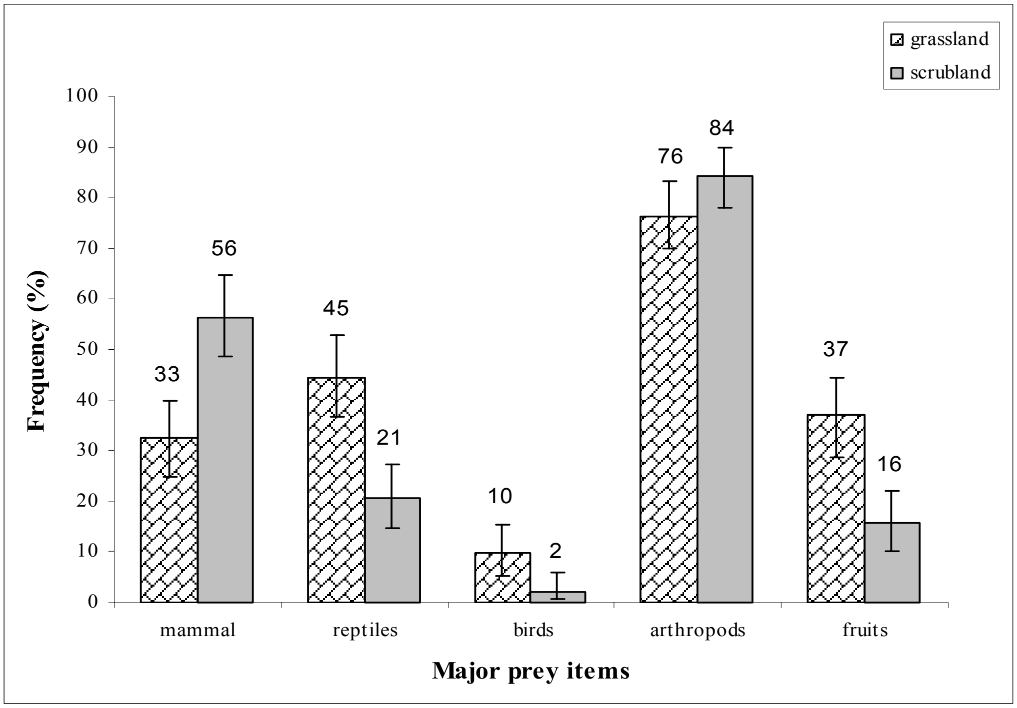


Fig.28. Frequency of occurrences of major prey items for the summer in the two habitats. Error bars are 95% bootstrap CI (n=238).

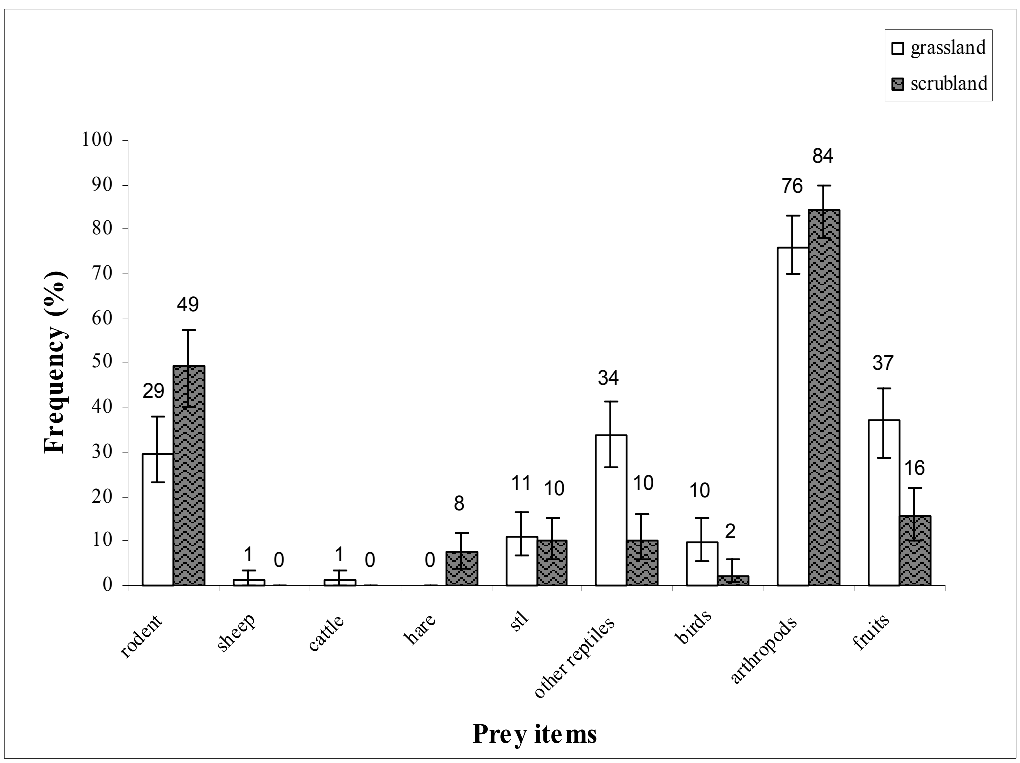


Fig.29. Frequency of occurrences of prey in the two habitats for the summer. Error bars are 95% bootstrap CI (n=238).

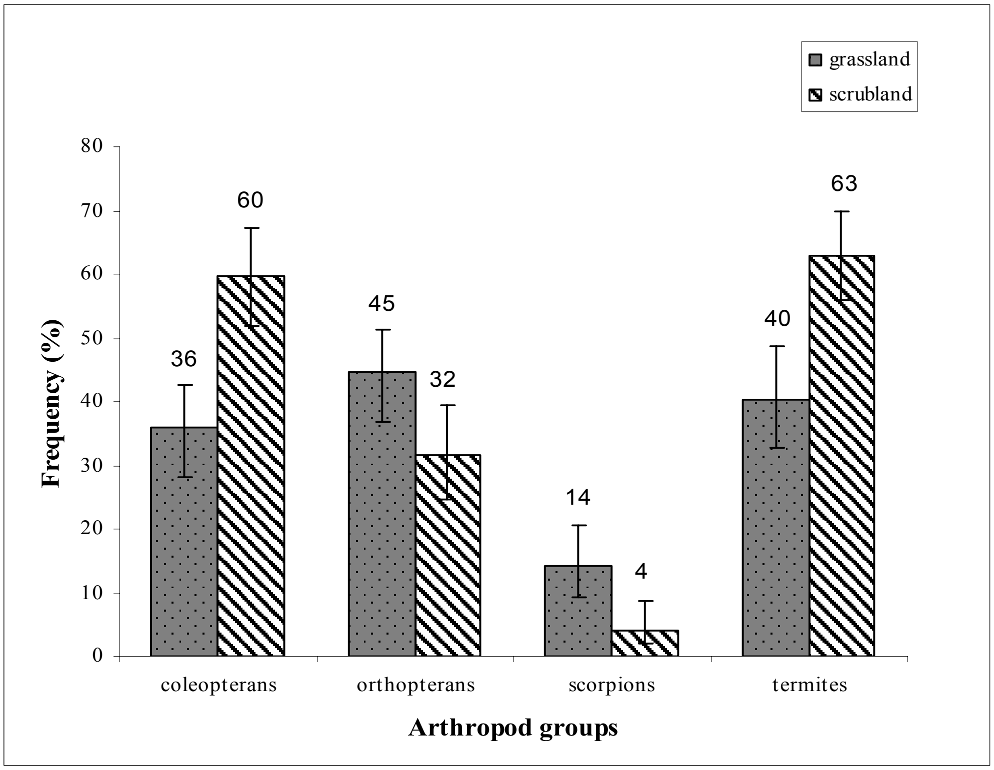


Fig.30. Frequency of occurrences of arthropod groups in summer in the two habitats. Error bars are the 95% bootstrap CI (n=238).

4.2.2c. *Comparing seasonal differences within habitats*

Even within the habitats seasonal differences in the diet of the Indian foxes were clearly visible (Fig.31 to Fig.36). While winters are scarce in food resources, summer on the other hand, is the time when food resources are more due to the onset of breeding season of many of its prey species. Seasonal differences in both the habitats thus contribute to their overall variation in time.

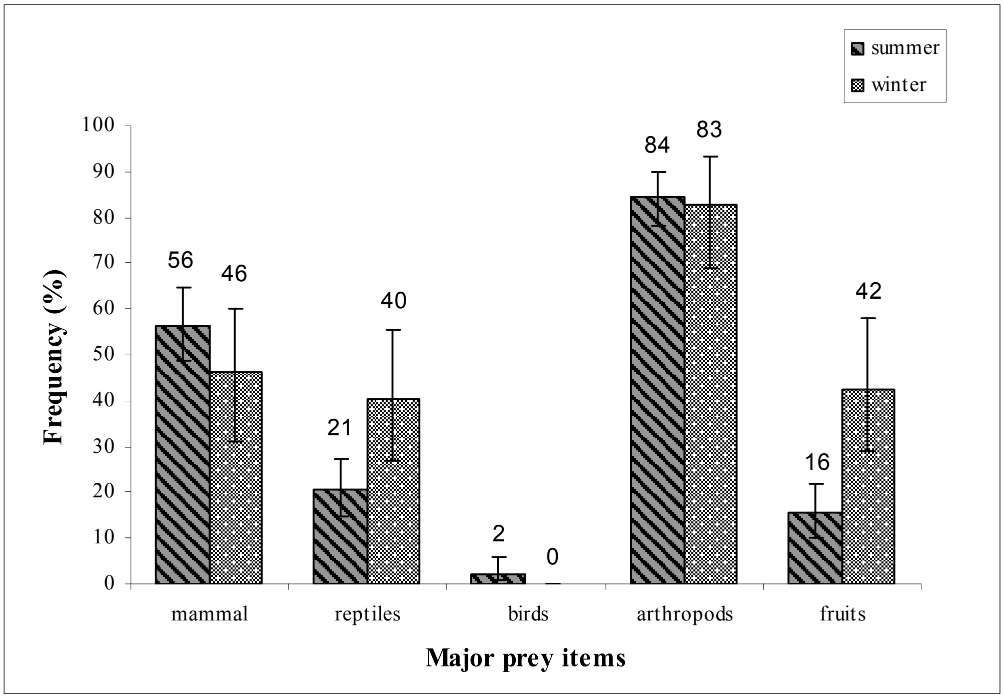


Fig.31. Seasonal differences in the frequency of occurrences of major prey species within the scrubland. Error bars are the 95% bootstrap CI (n=197).

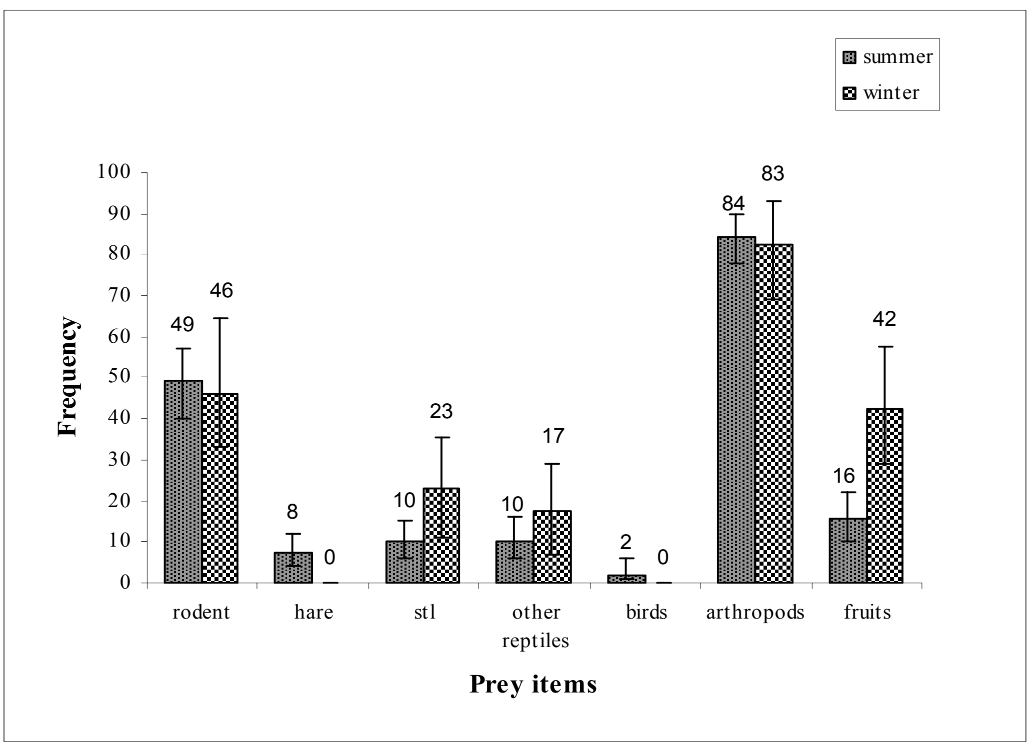


Fig.32. Seasonal differences within the scrubland when prey categorized. Error bars are 95% bootstrap CI (n=197).

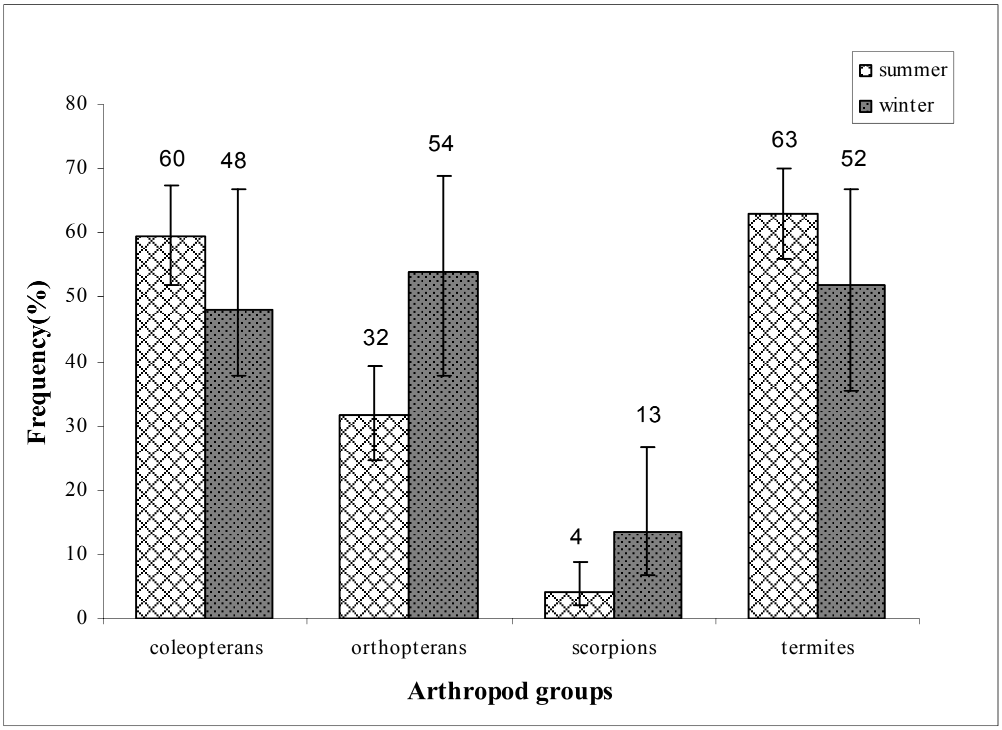


Fig.33. Seasonal differences in the contribution of different arthropod groups in the scrubland. Error bars are 95% bootstrap CI (n=197).

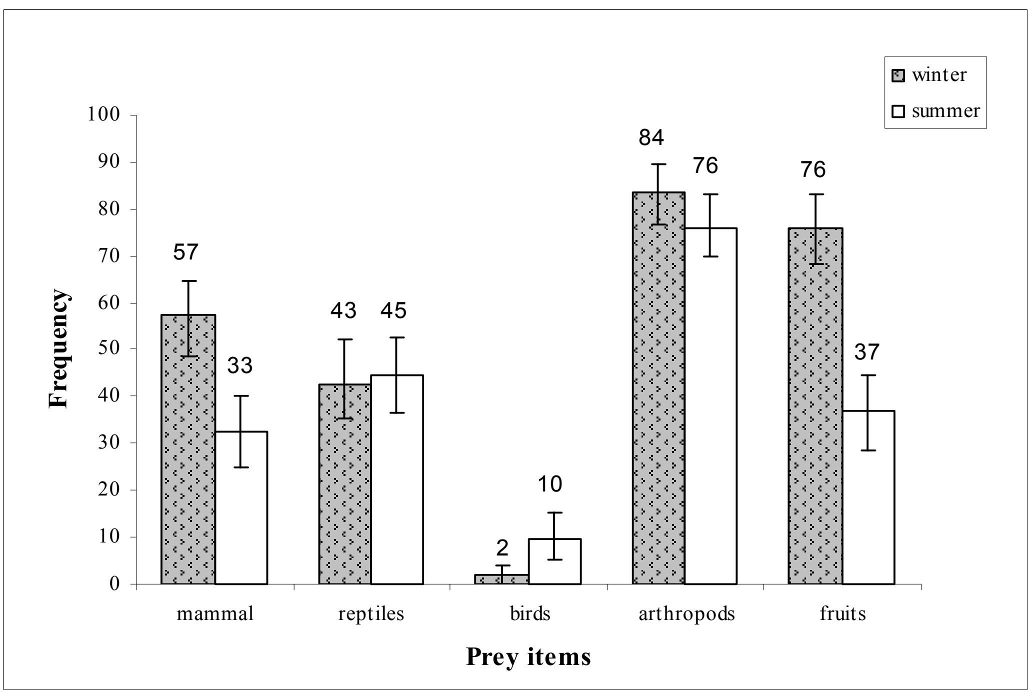


Fig.34. Seasonal differences in the major prey items within the grassland habitat. Error bars are 95% bootstrap confidence intervals (n= 195).

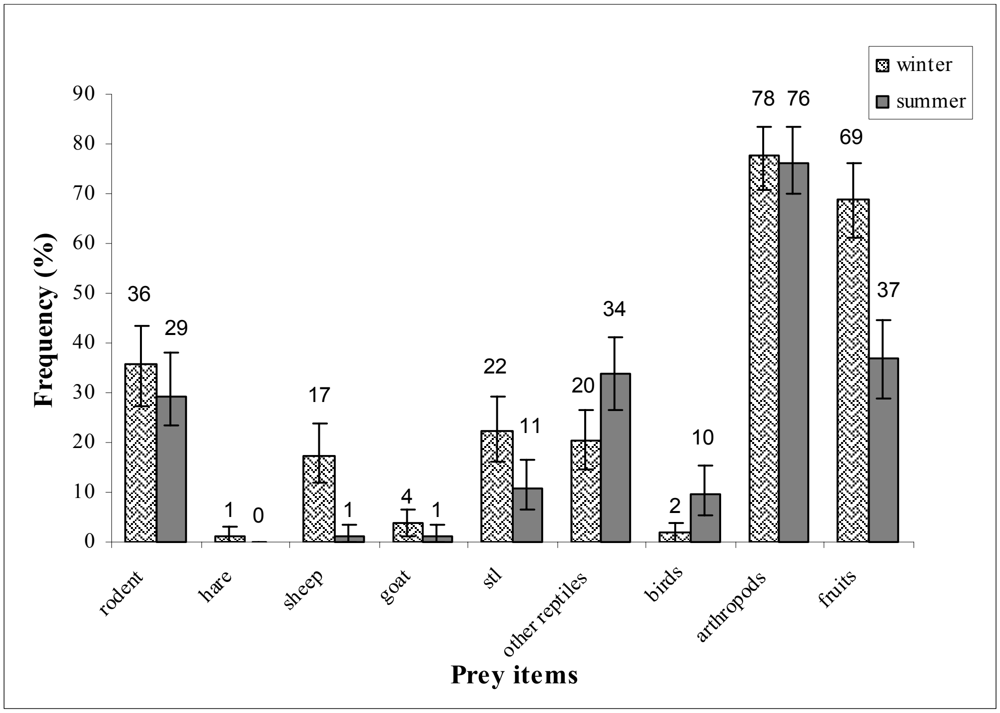


Fig.35. Seasonal differences in the prey items within the grassland habitat (prey categorized). Error bars are the 95% bootstrap confidence intervals (n=195).

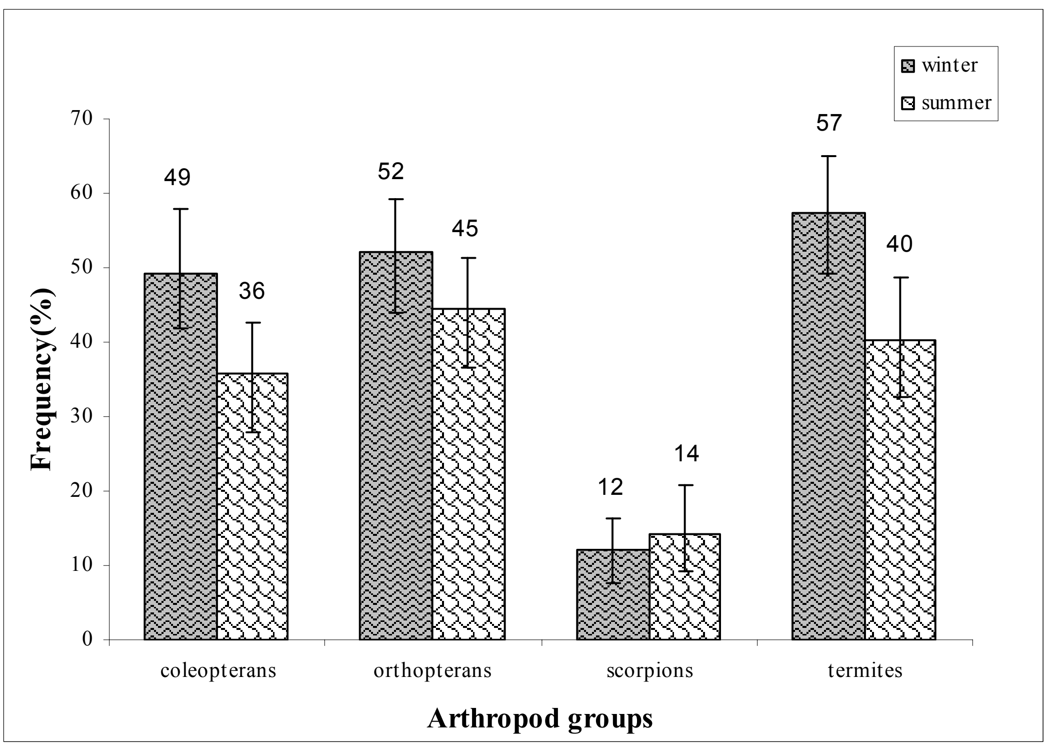


Fig.36. Seasonal differences seen in the contribution by the arthropod groups in the grassland habitat. Error bars represent 95% bootstrap confidence intervals (n=195)

4.3. Food selection:

4.3.1. *Using Ivlev's Index*

Ivlev's Index used to compare use versus availability for the different prey items in the study area showed a strong preference for arthropods. This trend was noticed when Bonferroni's CI was built on the observed values as well as for the Compositional analysis where arthropods ranked first followed by mammalian prey. The results for the three methods are given as follows:

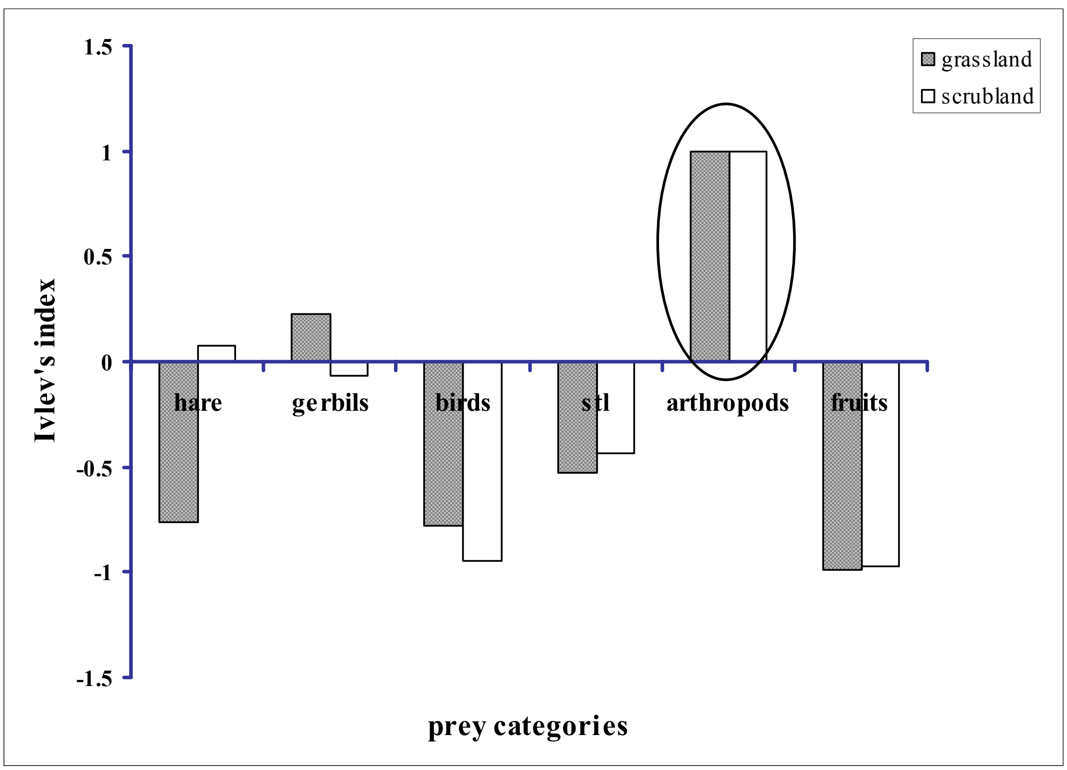


Fig 37. Graph depicting the Ivlev's Index for each of the prey items with a high preference for arthropods.

4.3.2. *Using Bonferroni's Simultaneous Confidence Intervals*

Table.9. Overall use Vs availability in the scrubland (using Bonferroni's CI)

Prey species	Expected	Observed	95% BCI on exp	Deduction
Hare	3.72	4.32	0.49 ≤ exp≤ 8.14	0 (in prop)
Rodents	37.41	32.69	23.87 ≤ exp≤ 41.52	0 (in prop)
Birds	35.11	0.97	-0.87 ≤exp ≤ 2.82	- (significant)
STL	22.52	8.79	3.47 ≤ exp≤ 14.12	- (significant)
Arthropods	0.04	53.19	43.81 ≤ exp≤ 62.57	+ (significant)
Fruits	1.19	0.01	-0.2151 ≤exp ≤ 0.25	- (significant)

Table.10. Overall use Vs availability in the grassland (using Bonferroni's CI)
:

Prey species	Expected	Observed	95% BCI on exp	Deduction
Hare	3.40	0.46	-0.82 ≤ exp≤ 1.74	- (significant)
Rodents	16.11	25.75	17.49 ≤exp ≤ 34.02	+ (significant)
Birds	33.86	4.23	0.42 ≤exp ≤ 8.03	- (significant)
STL	41.57	12.71	6.41 ≤ exp≤ 19.01	- (significant)
Arthropods	0.60	56.83	47.46 ≤ exp≤ 66.19	+ (significant)
Fruits	4.99	0.02	-0.25 ≤exp ≤ 0.29	- (significant)

Table.11. Use Vs availability in winter for the grassland habitat (using Bonferroni's CI)
:

Prey species	Expected	Observed	95% BCI on exp	Deduction
Hare	3.26	0.84	-1.54 ≤exp ≤ 3.21	- (significant)
Rodents	15.70	26.93	15.39 ≤exp ≤ 38.47	0 (in prop)
Birds	36.24	1.36	-1.65 ≤exp ≤ 4.37	- (significant)
STL	36.39	16.00	6.46 ≤ exp≤ 25.54	- (significant)
Arthropods	0.04	54.84	41.89 ≤exp ≤ 67.79	+ (significant)
Fruits	8.36	0.19	-0.34 ≤exp ≤ 0.38	- (significant)

Table.12. Use Vs availability in winter for scrubland habitat (using Bonferroni's CI)

Prey species	Expected	Observed	95% BCI on exp	Deduction
Hare	3.80	0	0 ≤ exp≤0	- (significant)
Rodents	33.36	31.62	14.59≤exp ≤ 48.64	0 (in prop)
Birds	36.66	0	0 ≤exp ≤ 0	- (significant)
STL	24.36	15.12	2.00≤ exp≤ 28.24	- (in prop)
Arthropods	0.03	53.24	34.98 ≤ exp≤71.51	+ (significant)
Fruits	1.78	0.02	-0.43 ≤exp ≤ 0.47	- (significant)

Table.13. Use Vs availability in summer for grassland habitat (using Bonferroni's CI)

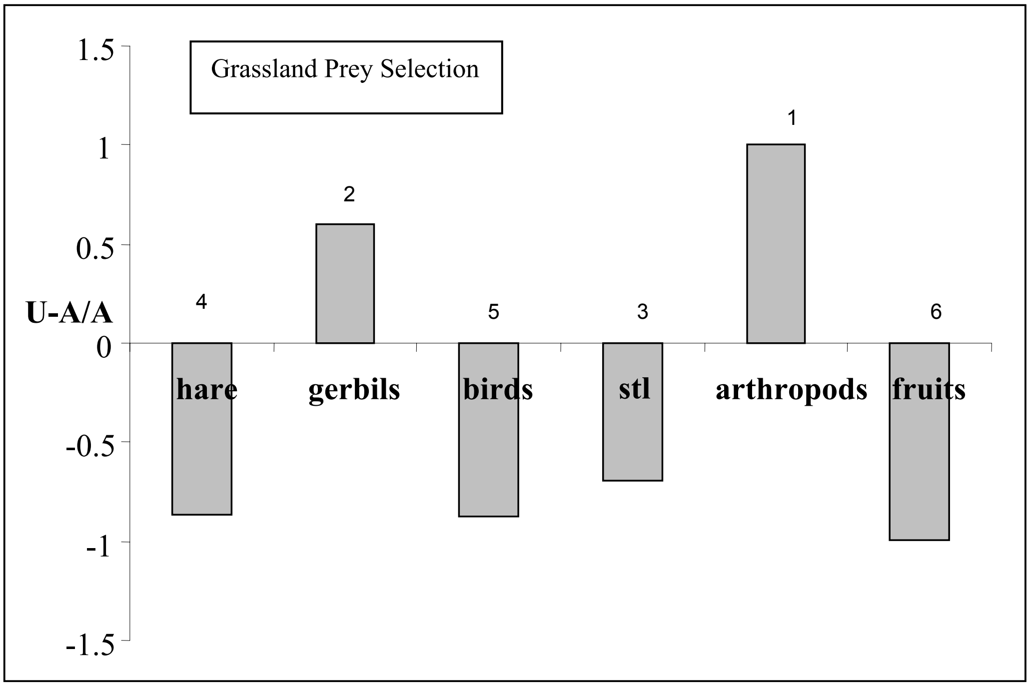
Prey species	Expected	Observed	95% BCI on exp	Deduction
Hare	3.55	0	0 ≤ exp≤0	- (significant)
Rodents	16.55	24.28	12.48≤exp ≤36.09	0 (in prop)
Birds	31.28	7.54	0.39≤exp ≤ 15.11	- (significant)
STL	47.21	8.61	0.89 ≤exp ≤ 16.33	- (significant)
Arthropods	0.07	59.33	45.81 ≤exp ≤ 72.85	+ (significant)
Fruits	1.33	0.21	-0.38 ≤exp ≤0.42	- (significant)

Table.14. Use Vs availability in summer for scrubland habitat (using Bonferroni's CI)

Prey species	Expected	Observed	95% BCI on exp	Deduction
Hare	3.94	5.83	5.76 ≤ exp≤ 5.89	+ (significant)
Rodents	36.49	33.08	32.81≤exp ≤ 33.36	- (significant)
Birds	36.37	1.31	1.29 ≤exp ≤ 1.33	- (significant)
STL	22.46	6.59	6.51 ≤exp ≤ 6.67	- (significant)
Arthropods	0.58	53.17	52.86 ≤exp ≤ 53.48	+ (significant)
Fruits	0.67	0.014	0.014≤exp ≤ 0.015	- (significant)

4.3.3. *Using Compositional Analysis*

The results for the Compositional analysis are given as:



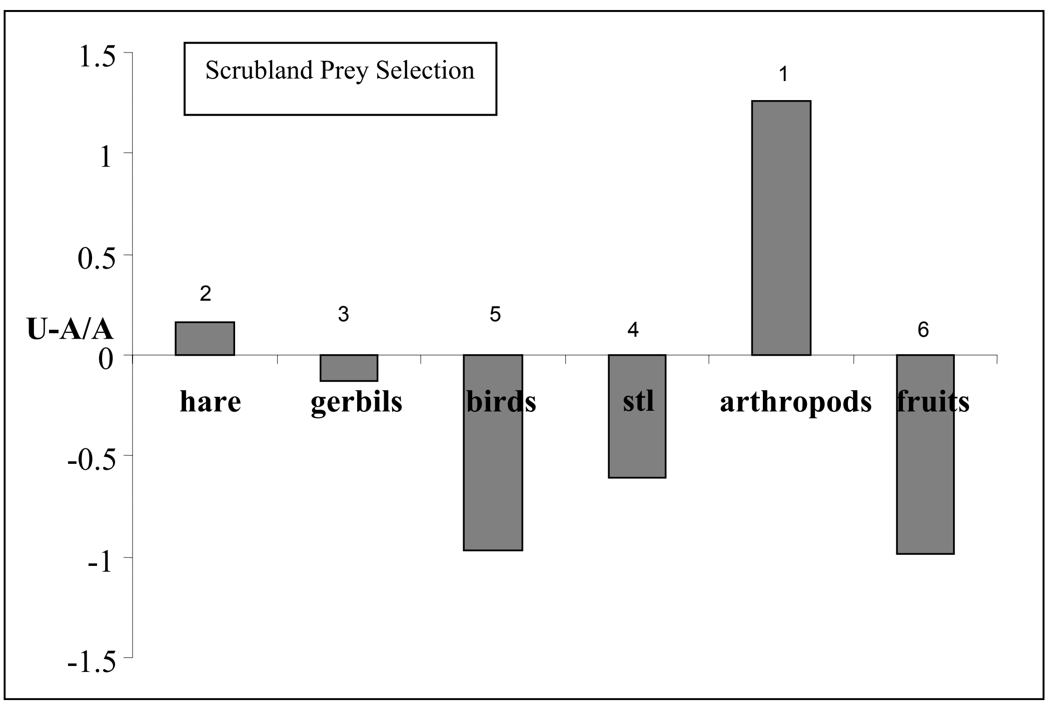


Fig.38. Compositional Analysis showing the ranks of different prey items in both the habitats.

4.4. Density of breeding units in the scrubland:

The total number of breeding units in Hyaena Ridge (scrubland) observed in the six months of field work was 5. A single breeding unit may have more than one den. Out of the five breeding pairs, four pairs were known to have at least two dens sites. The buffer computed by taking the average of the minimum distances between dens was 1.57 km. The total area (MCP + Buffer) was 49.08 sq.km (See Plate 3). Thus the density of breeding units in the scrubland was found to be 0.10/ sq km. The minimum distances of fox dens from human habitation has been calculated to be about 2.9 km or an approximate of 3km away from human habitation.

5. DISCUSSION

5.1. Food habits of the Indian fox and comparing it with use and availability:

5.1.1. *Prey availability:*

The objective behind the study, as mentioned before was to evaluate resource uses within two habitats particularly in relation to the diet of the Indian fox. Studies on the red foxes in the Mediterranean landscape have shown that the diet of the fox was correlated to the availability of the most important food resources which again is connected to meteorological factors (Cavallini & Lovari 1991). Coming to the Indian scenario, the two habitats studied are distinct and do differ in the availability of certain prey species. A difference in the density of gerbil burrows is clearly reflected when the two habitats are compared ($P<0.05$) with the scrubland having a much higher density of gerbil burrows. Densities of hare pellets in general showed a marked difference between scrubland than the grassland (higher in scrubland than grassland) but not significant statistically. Density of fruiting shrubs and particularly density of *Zizyphus* fruiting shrubs showed up to be significantly different for the two habitats ($P<0.05$) (Fig.1 & Fig.2) the grassland showing higher densities as compared to the scrubland.

More than the overall differences between the two habitats, it is the seasonal differences which make a deeper impact thereby changing availability within and between the habitats. Winters showed higher fruit availability both in terms of overall fruiting shrub density as well as *Zizyphus* fruiting shrub densities ($P<0.05$). Fruit availability in summer for the two habitats showed a marked difference, though not significant at $\alpha=0.05$ level. Summer heralded the fruiting season of *Prosopis juliflora* which were encountered more in the grasslands. For the summer season, density of *Zizyphus* fruiting shrubs in both the areas was zero since no fruiting shrubs were encountered on transect. This clearly indicates the seasonal availability of *Zizyphus* fruits within the habitats. Density of *Zizyphus* fruiting shrubs in the scrubland was not significant when compared between seasons since the overall density during winter was very low with no encounter of *Zizyphus* fruits in summer. But the density of overall fruiting shrubs showed differences within habitats for the two seasons ($P=0.05$) (See Fig.7). Comparing within grassland for summer and winter, both overall fruiting shrub density and *Zizyphus* fruiting shrub densities appeared to be significant ($P<0.05$) (See Fig.9).

Overall densities of arthropods in both the habitats were not shown to be significant but seasonal changes were noticed in both the habitats. Particularly in the scrubland there was a boom in arthropod density in the summer as compared to winter thereby causing a significant change ($P<0.05$) (Fig. 7). However arthropod densities were seen to be considerably more for the grassland than the scrubland. This is also evident when night densities were compared between the two habitats for the same seasons however no significant differences in the arthropod densities were noted for the night when compared between the two (See Fig. 12, 13 & 14).

Seasonal density of reptiles was significantly different for the grassland ($P<0.05$), whereas no marked differences between habitats were noticed. Seasonal densities for the two habitats were also not considerably different. This is because, in both the habitats, the reptile densities share a common trend; they are less in winter but more during summer which is a natural phenomenon since they come out of hibernation. No evidence of significance in the density of reptiles was found to be found through night walks in both the areas. No significant differences in the density of birds were evident when compared between the two habitats and between seasons either through diurnal walks or through nocturnal walks. Densities of hare pellets in general were very high due to their persistence within the habitat. Due to the arid conditions, pellets stay for a longer time within the environment. In general, winters showed low density of hare pellets while summers showed high density in both the areas (Fig.11).

5.1.2. ***Prey use:***

Percentage occurrences of the different prey items found in the fox scats suggested that arthropods occurred most in the diets of the Indian fox in both the habitats (>75%)(See Fig.22). Within the arthropods, disparity was seen with respect to consumption of beetles (57% in scrubland; 38% in grassland) and termites (60% in scrubland; 45% in grassland). Mammalian prey contributed to 53% occurrence in the diet in scrubland, and 46% in the grassland showing no significant differences. However when categorized, significant differences were observed with regards to consumption of rodents and hares. The diet in the scrubland habitat has a significant preponderance of rodents constituting 49% as compared to 33% for the grassland habitat. Hares seem to be a less important prey for the foxes in the study area. They were found mostly in the pup scats collected from the scrubland and contributed to only 6% of the diet particularly during summer. This is because it coincides with the reproductive period of the hares and therefore hare young are most likely to be more vulnerable to fox predation than adults. Hares contributed not even 1% (0.5%) to the diet of the foxes inhabiting the grassland habitat. Instead other categories like sheep, goat and cattle contributed 13% of the diet (believed to be scavenged) (See Fig. 24). Overall contribution by reptiles and fruits to the diet was significant between the two habitats. Among the reptiles, it is important to know that the contribution by reptiles other than spiny tailed lizards was making all the difference in the diet of the fox in the two habitats (See Fig.24).

Significant differences were seen the winter diet between two habitats with respect to fruits (mainly *Zizyphus*) and birds. Birds were not found in the winter diet of foxes in the scrubland. *Zizyphus* fruits were found to be consumed more in grassland (69%) than scrubland (42%). Mammalian prey other than rodents contributed to the diet which was not found in the scats collected from scrubland. These were mainly livestock which the foxes would have scavenged (See Fig.26). Occurrence of hare was noted only in the grassland (0.97%). No significant differences in the consumption of arthropods, reptiles and rodents were noticed. However there was a general trend of the rodents and arthropods being taken more in the scrubland as compared to grassland.

Summer diet of foxes differed considerably between the habitats. Significant differences were seen in the occurrence of mammalian prey, reptiles, birds and fruits (See Fig.28). Clear differences were observed in the consumption of rodents in the two habitats (49% for scrubland and 29% for scrubland) (See Fig.29). Other reptiles contributed significantly more in the diet of foxes in the grassland as compared to scrubland. Birds were consumed more in grassland as compared to scrubland (in general) (See Fig.29). Fruit consumption was higher in grassland than in scrubland in summer. Although there were no significant differences in the overall occurrence of arthropods as a whole in summer (84% in scrubland; 76% in grassland) disparity occurred in their composition. Beetles (60%) and termites (63%) dominated the scrubland scats as compared to the grassland (36% for beetles and 40% for termites). However scorpions dominated more in the grassland (14%) than in the scrubland (4%) (See Fig.30).

Seasonal differences within the habitats were also clearly visible in the diet of the Indian foxes. Overall reptilian intake was reduced in summer in the scrubland as compared to winter. Spiny tailed lizards were found to more in the winter scats than in the summer scats (See Fig.32). A plausible explanation for this can be the fact that the foxes can dig the lizards out when they are hibernating and inactive. Hare and birds dominated in the summer diet. Among the arthropods, there was a greater prevalence of orthopterans in the winter (54%) as compared to summer (32%). Scorpions were more in the winter diet (14%) than in the summer (4%) again stressing on the fact that digging them out was easier in winter. The foxes heavily utilized seasonal fruits in both the habitats indicating the importance of *Zizyphus* fruits winter. The diet of foxes in grassland showed clear differences in the intake of spiny tailed lizards when compared between the two seasons, occurrence being more in winter (22%) than summer (11%). Other reptiles contributed more in summer as compare to winter in the grassland (See Fig.35). Overall mammalian prey intake differed significantly between winter and summer, although the occurrence of rodents did not change significantly. This was because of the diverse mammalian prey intake in winter: sheep, goat (scavenged), rodents and hare.

Thus although the Indian fox has a wide variety of prey taken as food, prey items like hares and birds seemed to contribute much less as compared to arthropods. The diet of the Indian fox was greatly dominated by the arthropods. Amongst them termites were extensively consumed followed by beetles, grasshopper and scorpions. The occurrence of scorpions was much lower as compared to other arthropod groups. The fact that arthropods contributed largely to the diet of the Indian fox can be probably attributed to the fact that the chance of encounter is very high. Moreover they are useful prey items in the desert as they have a higher proportion of water per unit nitrogen and a proportion of fat per gram of body mass than vertebrates (Konecny 1987). This is true for the termites that have a high percentage of fat and occur in high percentage in the fox scats. Arthropod densities are also known to vary with temperature. The differences in the intake of certain groups of arthropods can be distinctly seen for the summer when their densities are higher. Seasonal fruits, like *Zizyphus* berries were important resources particularly during the time when other prey species were not found in abundance. Rodents also contributed to their diet, and were an important part of the diet of fox pups during weaning. The high frequency of occurrence of mammalian diet, particularly rodents probably explains the fact that the foxes maximize energy requirements by taking high energy mammalian prey. Although energy calculations revealed that the felids obtain a higher amount of metabolizable energy (ME) from rodents than canids (Mukherjee *et al* 2004).

5.1.3. *Use versus Availability:*

In order to find how the resource utilization patterns occured in the Indian fox with respect to food the study quantified the potential food items (rodents, hares, birds, reptiles, arthropods and fruits) and also determined the food habits from field collected scats. It is expected that resources such as food would be used in relation to their availability. However the availability of food resources is subjected to various other factors. Since in the study area there was a marked difference in seasons in terms of temperature a difference in food availability could be affected, thereby changing resource usage patterns. Resource use is also guided by many other factors such as weather, competitors and prey behaviour but, primarily driven by the physiological requirements of the animal. Availability of seasonal food resources are of great importance to small bodied animals like foxes since they substitute for prey which are less abundant during the lean seasons and reduce the searching and handling time and optimizing foraging.

Resource use was compared with availability in both the habitats by comparing the observed values (use; from scat data) with the expected values (availability; quantified in the habitat). Ivlev's Index showed the arthropods being particularly selected in the diet of the foxes, with gerbils being selected more particularly in the grassland and hares being selected in the scrubland (See Fig.36). The Bonferroni's CI was calculated to compare availability versus use patterns not only across habitats but also for the same seasons in both the habitats. An overall comparison showed how the arthropods were being selected more than available in both the habitats (See Table 9 & 10). This was followed by mammalian prey with the rodents being taken more than availability in the grassland while in proportion within the scrubland. Hares were taken much less that what was available within the grassland habitat, however were taken in proportion within the scrubland. Arthropods seem to dominate in all the seasons. Gerbils also follow the arthropods being an important part of the diet of the fox. Although spiny tailed lizard remains have been found in 15% of the scats overall (See Table 1). However there are larger numbers of spiny tailed lizard remains in the winter scats. During this time, the use of these lizards as food has been found to be in proportion to availability within the scrubland habitat (See Table 12). Since the actual availability of fruits was not quantified in the form of fallen fruits, it was difficult to account for the fact that the fruits were being consumed more or in proportion to availability in winter. Considering availability in terms of fruiting shrubs, consumption is much below than proportion present. The fruits like *Zizyphus* are clumped resources which are present in high densities only for a short period of time and their consumption as per availability is less.

Compositional analysis done for the different prey items to check for their use versus availability patterns show a very similar trend as seen for both Ivlev's Index as well as for the Bonferroni's CI. Arthropods rank first followed by mammalian prey which is hares for the scrubland and gerbils for the grassland (See Fig 37).

Amongst the arthropods as mentioned earlier the termites contributed the most followed by beetles. However the sampling techniques for quantifying arthropods could not actually quantify termites during sampling. Thus the use of arthropods as prey items being taken more than availability can be an artifact of the data since it could not take into consideration the presence of termites during sampling. Thus the estimates of densities for arthropods obtained through both day and night walks does not have termites as a part as per other groups which were quantified.

5.2. Den densities in the study area:

The density of breeding units calculated for the scrubland was 0.10/ sq km or approximately 0.16/sq km. In Kutch, the reported densities of breeding pairs were found to be around 0.04-0.06/sq km (Johnsingh & Jhala 2004). The density of breeding pairs obtained in this particular study was much higher as compared to the ones reported earlier, probably due to the good rainfall in the preceding two years, thereby indicating that perhaps the prey base was comparatively better as compared to other years. Probably because of this, the area was able to support a fairly high density of breeding pairs.

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* Not quoted from original document

Appendix 1

Results of Kolmogorov- Smirnov's Test to check for normality of data:

		STL	GEB	HPT	REP	BIRDS	ARTHRO	FRUITS	ZIZ
N		40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Normal Parameters	Mean	19.25	140.00	10131.88	4.00	23.13	28.75	75.38	51.25
	Std. Deviation	25.31	193.65	8190.61	4.70	31.88	24.49	109.84	110.54
Most Extreme Differences	Absolute	0.27	0.23	0.15	0.28	0.23	0.25	0.30	0.43
	Positive	0.27	0.20	0.15	0.28	0.19	0.25	0.30	0.43
	Negative	-0.22	-0.23	-0.12	-0.20	-0.23	-0.12	-0.25	-0.32
Kolmogorov-Smirnov Z		1.69	1.49	0.96	1.76	1.48	1.58	1.91	2.71
Asymp. Sig. (2-tailed)		0.01	0.02	0.32	0.00	0.02	0.01	0.00	0.00

a Test distribution is Normal.

b Calculated from data.

Appendix 2

Results of the SPSS output for Regression analysis done for gerbil mean population with the total number of burrows:

Gerbil Numbers Vs Total number of Burrows:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.984	.969	.962	2.4271

a Predictors: (Constant), TB

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	912.260	1	912.260	154.861	.000
	Residual	29.454	5	5.891		
	Total	941.714	6			

a Predictors: (Constant), TB
b Dependent Variable: POP

Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	2.019	1.673		1.207	.281
	TB	1.317E-02	.001	.984	12.444	.000

a Dependent Variable: POP

Residuals Statistics

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	7.5381	43.7609	19.4286	12.3306	7
Residual	-3.9008	2.2391	2.030E-15	2.2156	7
Std. Predicted Value	-.964	1.973	.000	1.000	7
Std. Residual	-1.607	.923	.000	.913	7

a Dependent Variable: POP

Appendix 3

SPSS Results of the Pearson's Correlation between Gerbil population mean and the different Colony size variables:

Correlations

		POP	LENGTH	BREADTH	TB	AB
POP	Pearson Correlation	1.000	.903	.826	.984	.839
	Sig. (2-tailed)	.	.005	.022	.000	.018
	N	7	7	7	7	7
LENGTH	Pearson Correlation	.903	1.000	.838	.918	.822
	Sig. (2-tailed)	.005	.	.018	.004	.023
	N	7	7	7	7	7
BREADTH	Pearson Correlation	.826	.838	1.000	.905	.990
	Sig. (2-tailed)	.022	.018	.	.005	.000
	N	7	7	7	7	7
TB	Pearson Correlation	.984	.918	.905	1.000	.918
	Sig. (2-tailed)	.000	.004	.005	.	.003
	N	7	7	7	7	7
AB	Pearson Correlation	.839	.822	.990	.918	1.000
	Sig. (2-tailed)	.018	.023	.000	.003	.
	N	7	7	7	7	7

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).