HABITAT USE BY SYMPATRIC SMALL CARNIVORES IN SARISKA TIGER RESERVE, RAJASTHAN, INDIA.

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I have great pleasure in forwarding the thesis of Shomita Mukherjee, titled "*Habitat use by sympatric small carnivores in Sariska tiger reserve, Rajasthan, India*" for acceptance for the degree of **Doctor of Philosophy** in **Wildlife Science**. The thesis embodies original findings and interpretation of facts. This research was carried out by Ms. Mukherjee under my supervision, and has not been submitted in part or full to any other University / Institution for the award of any degree.

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SUMMARY

The present study on three sympatric carnivores, two felids: jungle cat (*Felis chaus*), and caracal (*Caracal caracal*) and one canid, the golden jackal (*Canis aureus*) aimed at studying their spatio - temporal use of food resources. The hypothesis are as follows :

1) Jungle cat is relatively more eclectic in the kind of habitat it inhabits than the jackal.
2) The felids are mostly nocturnal whereas the jackal is both diurnal and nocturnal (cathemeral).
3) Diet of the three carnivores differs between seasons.
4) Small mammals (<1 kg. body weight) form the major diet of the felids and are taken in proportion to their abundance.
5) Jungle cat and caracal are dietary specialists relative to the jackal.

The study was conducted in Sariska Tiger Reserve (STR) which is located between 74^0 17' to 76^0 34'N and 25^0 5' to 27^0 33' E. STR encompassing an area of 800 km^2 has three core areas of which core 1, with an area of 273.8 km^2 forms the proposed National Park. This area functioned as the study site and the intensive study area was approximately 30 km^2. STR is characterised by rugged terrain, valleys and plateaux with an altitudinal variation from 540 m. to 777 m.

After an initial reconnaissance and vegetation characterisation, various habitat categories (open scrub, dense scrub, grassland, hill forests and mosaic) were identified. Further sampling of vegetation (grass and number of bushes) was done in order to relate these habitats to disturbance and the abundance of predators and prey. Grass was sampled for various parameters such as height, percent cover (ocular), and percent green grass. This was done in 10m. radius plots set in a random systematic manner in the various habitats:. Grass height was highest in the grassland area (winter = 111 cm ± 7.8 ; summer 75 cm. ± 7.3) (± SE) followed by dense scrub (winter = 25 cm. ± 3.17 ; summer

= 53 cm. ± 12.6), hill forest (summer = 53 cm. ± 12.6). Open scrub and mosaic had grass height less than 5 cm. in winter and summer. The above ground grass cover (percent) in winter was similar in open scrub, dense scrub and grassland (53% - 63%) and was significantly higher than in mosaic (27% ± 6.5) In summer above ground grass cover was highest in grassland (53% ± 4.04) followed by dense scrub (38% ± 7.42), open scrub (29% ± 4.27), mosaic (24.5% ± 7.36) and hill forest (4.3% ± 3.05). Disturbance from domestic livestock quantified through track counts, showed open scrub and mosaic to be the most disturbed habitats during both seasons.

Quantifying prey and predators was based on indirect and direct methods. Track counts (expressed as percentages) on track plots spaced 500 m. apart along dirt tracks in each habitat, were used as indirect evidence of habitat use by predators and prey. Encounter rates and time of sightings of predators were obtained by vehicle drive counts and on one km. foot transects through various habitats. Sightings of ground birds and hare on these transects were used for obtaining encounter rates of these prey. Sherman - live traps were used for capturing murid rodents in order to obtain estimates of relative abundance in the various habitats during summer and winter (n = 9,500 trap nights).

Overall visitation rates for jackal were higher than for jungle cat in all habitats except the dense scrub. Track counts showed that in winter, jackal used open scrub (winter = 32.2% ± 5.5) and mosaic (winter = 22.8% ± 4.0) significantly more than other habitats which had visitation rates between 0.4 and 10.3%. Hill forest had a very low visitation rate (0.4 ± 0.48) and was significantly lower than all habitats. In summer mosaic and hill forest could not be monitored and there was no significant difference in visitation rate by jackal in the remaining habitats (4.0% - 13.5%). Jungle cat showed greater use of dense scrub in winter (20.4% ± 4.0) than all other habitats which had visitation rates ranging from 3.0% to 8.1%. In summer though dense scrub (7.7% ± 2.9) had higher

visitation than other habitats the difference was not significant. Despite the effort, only four sightings of caracal were obtained: three from open scrub and one from grassland. Track counts also indicated the rarity of this species as tracks were seen only thrice in the open scrub and once in hill forests. Direct sightings showed the same trend as track counts in winter for jungle cat ($r = 0.71$, $p = 0.17$) and jackal ($r = 0.93$, $p < 0.05$). In summer however, in the case of jungle cat results from the two methods varied. Both jungle cat and jackal showed high crepuscular activity, but jackal was cathemeral whereas jungle cat was crepuscular and nocturnal. Vehicle drive counts were the most reliable way of obtaining sightings of predators.

Potential prey species identified were: ground birds (class 1 = < 250 gm., class 2 = 250 - 500 gm. and class 3 = > 1 kg.), murid rodents and hare. Track plot results show that in winter, peafowl abundance was highest in mosaic (70% ± 4.6), partridge in open scrub (68% ± 5.0) and small birds were equally abundant in open scrub, dense scrub, grassland and mosaic (59% - 60%). Use of hill forests was significantly ($p < 0.05$) lower than all other habitats for all three classes of birds. In summer, track counts of birds were similar in all habitats. Visitations to plots by hare was highest in the open scrub during both seasons (winter = 22% ± 3.9 ; summer = 17% ± 4.6). Encounter rates of ground birds on transects showed similar results as track plots for peafowl, which were encountered most often in mosaic (1.4/km. ± 0.31) and was significantly higher than in other habitats. There was no significant difference in encounter rates of other prey among the various habitats in winter. In summer, no significant difference was noted among different habitats for any prey.

Trapping success of murid rodents was very low (0.9%). Three murid rodents were captured: *Tatera indica* found in dense scrub and grassland, *Golunda ellioti* in grassland and *Mus platythrix* in open scrub, mosaic, dense scrub and hill forest. Murid rodents

showed an inverse relationship with use of habitat by domestic livestock and were more abundant in dense scrub and grassland.

Food habits of jungle cat, caracal and jackal were determined only for the open scrub and dense scrub, through scat analysis. Very few scats were found in the other habitats and hence they were not included for this study. Though the mean diameter of scats of the three predators varied, they were not significantly different. Fats and bile acids present in scats separated using Thin layer Chromatography differed among the three predators. Under long wave UV radiation, canid scats had a red band (rf = 0.9) which was absent in felid scats. Probable scats of caracal had a yellow band (rf = 0.29) which was absent in jungle cat scats but present in 57% of canid scats. Scats of all three predators had a green band (rf = 0.85). A second green band (rf = 0.7) was present in all caracal scats, 36% jungle cat scats and 57% canid scats. All canid scats were assumed to be of jackal.

Scats were teased apart and the various food items were separated and results were presented as percentage of scats having a particular food item. Rodent dentition was used for identifying the rodents consumed and number of rodents eaten was obtained from number of jaws per scat. The average body weight of rodents from capture in field was used to calculate the biomass of each of the rodent species consumed. The energetics of the three predators and importance of rodent prey to them was predicted based on studies conducted on bobcats and coyotes. Bootstrap simulation showed that small mammals (< 250 gm.), especially rodents, formed the major prey of the three predators occurring in more than 90% of scats. Birds were the next most important prey occurring in 35% to 44% scats of all three predators during both seasons. Consumption of reptiles and invertebrates was very variable during both seasons. In winter 20% of jackal scats had seeds of Zizyphus fruits which were absent from felid scats. Apart from the higher consumption of fruits by

jackal in winter, no significant seasonal difference in food habits was observed in any of the predators. Excepting significantly higher consumption of vegetable matter by jackals than felids, Man Whitney U test results did not show any significant difference in the consumption of other food items among the predators. Of the rodents, *G. ellioti* was an important rodent prey for all three predators (approximately 35% of total rodent biomass consumed, during both seasons) and seemed to be preferred, as capture rates for this rodent were very low. *M. platythrix* was the principal rodent prey for caracal, *G. ellioti* and *T. indica* for jungle cat and *G. ellioti* for jackal. *M. platythrix* and *T. indica* were consumed according to their availability. There was no significant seasonal difference in consumption of rodents by any predator. Results from energetic predictions showed that felids depend to a larger extent on rodents than the jackal, obtaining between 60% - 93% of their total energy from this group. The jackal gets between 44% - 70% of its energy from rodents. This indicates that the felids are dietary specialists relative to the jackal. It is speculated that the jackal obtains much of its energy from scavenging which could not be quantified in the present study.

Co-existence of the three predators is facilitated by spatio-temporal separation. The felids being closely related occupy different habitats whereas the jackal is temporally separated from the felids. The different food habits of the predators is a reflection of spatio - temporal separation.

CHAPTER 1. INTRODUCTION

1.1 Competition and coexistence:

An enormous amount of literature is available on interaction among species, coexistence and competition and their role in structuring communities which has been reviewed by Conner and Simberloff (1986), Futuyma (1986), Begon *et al.* (1990), Peters (1991), Goldberg and Burton (1992), Huston (1994).

Due to many resources being limited, sharing can lead to competition for these resources and hence greater similarity between species would result in higher levels of competition between them. Since different species would perform dissimilarly in competition due to differences in their phenotypes and genotypes, the stronger competitor would have greater access to resources and would eventually wipe out the weaker species (Hardin 1960 ; Mayr 1976 ; Pontin 1982 ; Strong 1984). This was the basis of Gausse's "Competitive exclusion Principle". It also resulted in several other concepts such as character displacement, limiting similarity, diffuse competition, species packing and maximum tolerable niche overlap (Pianka 1983 ; Peters 1991). Overall it meant that for species to coexist there should be some difference in the resources they use or in the way they obtain their resources ie. there should be differences in their niches (Shoener 1975 ; Mayr 1976 ; Pontin 1982 ; Pianka 1983 ; Haldane 1932). Competition can occur not only between species (interspecific competition) but also within species (intraspecific competition) since requirements of individuals within a species would be more similar. This also suggests that intraspecific competition is density dependent (Begon *et al.* 1990)

Although it is accepted that competition does occur, its importance in structuring communities and the manner in which its importance is deduced has been controversial (Cole 1960 ; Pontin 1982 ; Pianka 1983 ; Price 1984 ; Strong 1984 ; Begon *et al.* 1990 ; Peters 1991 ; Goldberg and Burton 1992 ; Huston 1994). For example, resource

partitioning or overlap in resources is usually studied to measure the degree of competition between sympatric species assuming that greater overlap in resources used by two sympatric species would mean a higher degree of competition (Shoener 1975 ; Roughgarden 1983 ; Pianka 1983). Nevertheless, the opposite explanation could be given where extensive overlap could mean reduced competition, especially when resources are abundant and not limiting (Pianka 1983). Yet another opinion, "The ghost of competition past" argues that lack of competition could be due to previous competition between two species which have now evolved ways to coexist (Strong 1984). This has however been dismissed as a tautology as there is no way of disproving it (Strong 1984 ; Peters 1991). Peters (1991) further criticises the competition theory saying that the terms of the theory are very vague and different authors interpret and define these terms differently, and simply give historical explanations for certain observations without any predictive value. Besides, it is often extremely difficult to determine the presence and degree of competition between species without conducting manipulative experiments (Pontin 1982 ; Pianka 1983 ; Peters 1991). This is not practical in most situations. Many other factors which influence community structure such as specialisation, mutualism, predation, anthropogenic factors, environmental variability, random population fluctuations could be far more important in determining community structure and biological diversity in an area than competition alone (Pontin 1982 ; Roughgarden 1983 ; Price 1984 ; Begon *et al.* 1990 ; Peters 1991 ; Goldberg and Burton 1992 ; Huston 1994).

Most tropical countries are rich in the number of carnivore species they harbour (Corbett and Hill 1992). India is especially rich in species mainly because of its location at the convergence of three major biogeographic realms - Indomalayan, Palearctic and Ethiopian (Mackinnon and Mackinnon 1974 ; Mani 1974). With 55 species of carnivores distributed throughout India, several protected areas in the country have two or more

sympatric carnivores (Johnsingh 1986). Despite this there is a large void in information available on the ecology of most Indian carnivores especially the smaller ones. Carnivores, being at the apex of the food chain, have a major role to play in structuring communities (Terborgh 1988). Hence decline or loss of any one carnivore from an ecosystem could lead to drastic effects. Due to the paucity of information on carnivores, any carnivore study would first have to focus on the basic resource requirements of these species based on which more specific hypotheses can be framed.

Since it is impossible to determine and study all resources used by a species, most studies on resource utilisation look at one or two resources. The most frequently studied resources are food, habitat and time (Pianka 1983). Shoener (1974) conducted a survey to examine the way animals partition their resources and found that the most common way was by habitat partitioning followed by food and then time.

Dayan *et al.* (1990) studied character displacement in felids (caracal, jungle cat and African wild cat) from Israel, manifested in the diameter of canines which could be interpreted as an outcome of competition for food. However they mention that though there is evidence of character displacement between caracal and jungle cat, these two felids are also spatially separated. Caracal occupies the more drier habitats whereas jungle cat prefers habitats close to water sources and dense vegetation. Habitat separation is usually higher in the more closely related species than the ones that are relatively distant as seen in studies on coyotes and foxes and coyotes, foxes and bobcats (Viogt and Earle 1983 ; Major and Sherburne 1987 ; Harrison *et al.* 1989). In a study on jackal, jungle cat and fishing cat in Keoladeo Ghana National Park, Bharatpur, jungle cat and fishing cat were spatially separated whereas both felids were temporally separated from jackal (Mukherjee 1989). The patterns of resource use by sympatric carnivores derived from the short study in

Keoladeo Ghana prompted several questions and hypotheses which were tested in the present study.

Sariska Tiger Reserve (STR) was chosen as the study site for the present project due to several reasons. The dry deciduous vegetation of STR and extreme climatic conditions (Chapter 2) would enable a good seasonal comparison of resource use. Moreover due to several other projects being conducted in this area in the past, plenty of baseline information on management and vegetation was available.

1.2 Felidae and Canidae : A comparison of life history strategies :

1.2.1 Evolution:

The families Felidae and Canidae diverged from a common ancestor, the Miacids, 50 million years ago during the Eocene period (Nowell and Jackson 1996). The Miacids consisted of two main groups, (1) the Miacines that gave rise to modern day canids, bears, racoons and weasels and (2) the Viverravines which were ancestral to cats, civets, genets and hyaenas (Fox 1975 ; Kitchener 1991).

The modern day order Carnivora consists of (1) the Fissipeda or terrestrial carnivores and (2) the Pinnipeda or aquatic carnivores. The terrestrial carnivores are further divided into two superfamilies the Arctoidea or Canoidea which includes dogs, racoons, bears and weasels who lack retractile claws and have the tympanic bulla formed from a single tympanic bone (Fox 1975 ; Savage and Long 1986 ; Kitchener 1991) and (2) the Aeluroidea or Feloidea which has cats and its relatives. These possess retractile claws and their tympanic bulla are made of two bones which join to form a bilaminar septum (Kitchener 1991).

For any comparative study of two groups of animals it is necessary to examine their biogeographic distribution and life history patterns in some detail. Conversely it is felt that

variations in life history patterns could be linked to their food habits (Bekoff *et al.* 1984). Hence understanding food habits could explain certain patterns and support other studies that have attempted to do so.

1.2.2 Diet:

The specialised mode of feeding seen in Carnivora is evident from the dentition and skull morphology of species belonging to this Order. The upper 4th premolar and the lower 1st molar of this order have been modified into carnaisals or specialised scissor like cutting teeth whereas the unique jaw joint with a transverse hinge facilitates cutting and biting action by teeth (Fox 1975 ; Kitchener 1991). Generally, the members of this order have 42 teeth, but the felids have a reduced dentition of 30 or, in some cases like the caracal, lynxes' and golden cats', 28 teeth (Kitchener 1991). This reduction in number of teeth in cats has resulted in a shortened muzzle which can deliver a more powerful bite (Kitchener 1991). Most canids have 42 or more teeth (Fox 1975).

This difference in dental structure among different families can be traced to variation in diet. Generally speaking, canid diet is more flexible than felid diet and includes a variety of plant matter such as fruits and seeds. Felids are however far more carnivorous relying on animal tissue and fat to sustain energy demands. Their requirement for protein is especially high forming 22% of daily calorie requirement. The net dietary protein calorie percentage for a dog is 4.6 compared to 8.2 for cats (Scott 1968). Felids cannot digest uncooked carbohydrates well. However the major reason for felids requiring a strict carnivorous diet is due to their inability to synthesise essential nutritional components such as the amino sulphonic acid, taurine, vitamin A, arachodonic acid and niacin (vitamin B) (Scott 1968; Blaza and Loveridge 1984 ; Budavori 1989). Taurine is essential for proper retinal function in cats (Blaza and Loveridge 1984 ; Budavori 1989). Another reason for high protein

requirement in diet is thought to be due to cats not being able to efficiently regulate transaminases and urea cycle enzymes (Blaza and Loveridge 1984). Because of a strict carnivorous diet cats have relatively shorter guts than canids and is thought to be the reason why felids have a lower digestive efficiency (79%) as compared to canids (89%) (Kitchener 1991).

Not surprisingly, a review of diet of medium sized and small felids showed that their diet is entirely composed of animal tissue with small mammals especially rodents forming the major prey (Pearson 1964 ; Schaller 1972 ; Johnsingh 1983 ; Mukherjee 1989 ; Kitchener 1991). Birds formed the next most important dietary component (Schaller 1972 ; Johnsingh 1983 ; Mukherjee 1989 ; Kitchener 1991). Canid diet differs among different species and the extent of carnivory depends to a large extent on body size and social structure. Frugivory and seed eating is common in pair living (jackal and coyote) and solitary (foxes) canids. In some studies on jackals, vegetable matter (fruits and seeds) has been reported in more than 40% of scats and stomachs analysed (Haque *et al.* 1984 ; Posche *et al.* 1987). In one study more than 80% of jackal scats analysed had fruit remains (McShane and Grettenberger 1984).

1.2.3 Morphology, anatomy and behaviour:

As Eisenberg (1986) puts it "Behaviour is the dynamic of morphology". Felids with relatively short legs and powerful limb muscles are good climbers. The shortened face and hence more powerful kill bite, retractile claws, greater rotation of lower leg, flexible vertebrae articulation and absence of clavicle are some features that serve to make felids specialised carnivores (Eisenberg 1986 ; Prater 1965 ; Kitchener 1991). In comparison canids have longer limbs which are not flexible like those of cats and have thick strong claws for digging and for a cursorial mode of hunting prey (Eisenberg 1986). They have a

long rostrum for delivering a slashing bite (Eisenberg 1986). Canids have a very well developed sense of hearing and of smell having twice as many olfactory receptors as felids (Kitchener 1991). Felids are visual animals like primates, and rely more on their sense of sight and sound for hunting and other behaviour (Kitchener 1991). The felid eye is very well developed and the extent of binocular vision is comparable to that of primates. Along with this, their ability for extreme pupil dilation and contraction in accordance to prevailing light conditions, concentration of cones at the centre of the retina and presence of the tapetum lucidium aids nocturnal as well as diurnal activity (Kitchener 1991).

A cats' ability to detect sounds at the ultrasonic level lies well within the range of sounds that rodents, their principle prey, produce. It has been argued that this helps them to detect their prey (Eisenberg 1986 ; Kitchener 1991).

1.2.4 Social organisation:

Most cats with the exception of the lion, cheetah and domestic cat are solitary (Bekoff *et. al.* 1984). Canids have a much more complex social structure which is related to much of their behaviour (Fox, 1975). According to Fox (1975) there are three types of canids - Solitary, pair living and Pack living. The pack living canids like dhole (*Cuon alpinus*) and wolf (*Canis lupus*) are mostly carnivorous, crepuscular or diurnal and have more complex behavioural rituals and vocalisations than the other types (Fox 1975 ; Johnsingh 1982, 1983, 1992). The pair living are omnivorous and sometimes form packs to hunt larger prey, depending on the availability and abundance of prey. Examples of these are golden jackal (*Canis aureus*) and coyote (*Canis latrans*) (Mohelman 1986, 1989). Solitary canids are mostly frugivorous and insectivorous and are generally small e.g. foxes. Overall canids are far more diurnal than felids which are mostly nocturnal, and this could be related to the activity rhythm of their prey (Fox 1975 ; Kitchener 1991).

Hunting behaviour in felids is to a large extent typical. They capture prey by stealth, ambush or sudden attack and hence cover forms a major feature in their habitats. In contrast canids, especially the pack living ones chase down their prey and engage in co-operative hunting. Their distribution suggests that cats may have evolved in more forested habitats whereas canids in savannah and grassland habitats (Eisenberg 1986). This may be a reason why, out of the 36 cat species distributed world wide, 15 are found in India. Even China, covering a land area three times that of India has only 13 species of cats (Anon. 1989 ; Nowell and Jackson 1996). Many of these species are forest dwelling species and occur in rain forests. In comparison of the 34 canid species distributed world-wide only five occur in India and all except the dhole occur mostly in relatively open areas.

Another contrasting feature between canids and felids is that most felids are solitary and even during the reproductive period the male stays with the female solely for mating while rearing of young is left to the female. In canids, the male takes an active part in rearing of young and provides food for the young and female. This is true even for solitary canids (Fox 1979 ; Eisenberg 1986). Probably as a result of this, given any size class, litter size in canids exceeds that of felids (Eisenberg 1986). According to Eisenberg (1986) felids are relatively more k - selected when compared to canids and this should be taken into account while making conservation plans for these species.

1.3 Objectives:

The present study on three sympatric carnivores viz. jungle cat (*Felis chaus*), caracal (*Caracal caracal*) and jackal (*Canis aureus*) looks at the spatio - temporal use of food resources by two felids and one canid.

The hypothesis are as follows :

1) Jungle cat is relatively more eclectic in the kind of habitat it inhabits than the jackal.

2) The felids are mostly nocturnal whereas the jackal is both diurnal and nocturnal (cathemeral).

3) Diet of the three carnivores differs between seasons.

4) Small mammals (<1 kg. body weight) form the major diet of the felids and are taken in proportion to their abundance.

5) Jungle cat and caracal are dietary specialists relative to the jackal.

1.4 Study animals:

Caracal (*Caracal caracal*): This cat can be described as a medium sized cat (length 85 - 114 cm.) with long legs and a short tail (Prater 1965). Its coat colour is uniformly brick red or reddish sandy without any pattern and its ears are long, pointed and have the characteristic long black tufts (about 50 mm. in length) due to which it is often referred to as the 'desert lynx' (op. cit.). Nine subspecies of caracal are recognised by some authors but this has been disputed and not agreed upon universally. It is placed in CITES Appendix-II, but the Asian subspecies, *F. c. schmitzi* and *F. c. michaelis*, considered to be rare or threatened have been listed in CITES Appendix-I, (Nowell and Jackson 1996). *F. c. schmitzi* is distributed from central India to Arabia and because of its rarity is classified as a schedule-I species in the Indian Wildlife (Protection) Act (1972).

Although the caracal inhabits a wide range of habitats, and has a wide distribution globally, at present, within India its distribution is restricted to the drier parts (Corbett and Hill 1992 ; Kitchener 1991 ; Nowell and Jackson 1996). This extremely rare cat once had a distribution similar to the cheetah through most of the arid and semi arid regions of India. However in the past few decades rapid changes in land use patterns through most of its habitat has drastically reduced its range and numbers (Sharma and Sankhala 1984 ; Chavan 1987).

Wild population of caracal have nearly reached extinction in the thorn scrub jungles of Kutch and western India with not more than 10-15 individuals surviving, (Chavan 1987). Sharma and Sankhala (1984), estimated less than 50 individuals in the state of Rajasthan. In the present scenario of continued habitat degradation, rapid steps are urgently required to prevent this species becoming extinct from India like the Cheetah (*Accinonyx jubatus*). Despite the caracal being a rare and endangered species, except for a few anecdotal notes on its habitat and behaviour, (Prater 1965 ; Pabla 1984), to date there has not been a single detailed study on its distribution, status and ecology in India which would be vital for planning its conservation. Some information on its reproductive biology indicates that caracal has litter sizes ranging between 1 - 4 after a gestation of 78 - 81 days. It usually produces 1 litter annually (Nowell and Jackson 1996). Like all cats, caracal is highly territorial and home ranges vary greatly in different areas. Its social organisation is also typical with large male home ranges incorporating smaller exclusive female ranges (Stuart 1983 ; Eisenberg 1986 ; Weisbein and Mendelssohn 1990 ; Kitchener 1991).

Jungle cat (*Felis chaus*): The jungle cat (Plate 1) ranges through North Africa, Southwest Asia and Tropical Asia. In the east its distribution does not go beyond the Isthmus of Kra. (Nowell and Jackson 1996). It is generally considered to be common except in countries at the limits of its geographical range (Nowell and Jackson 1996). The most common wild cat in India, this felid is distributed through all different vegetation types and most climatic zones in the country. Despite this, there is dearth of information regarding its ecology and behaviour. Whatever little information is available on this cat suggests that it prefers areas with access to water sources and good cover (Dayan *et al.* 1990). Agricultural fields which offer sufficient cover and prey are said to be good habitat for this cat. Jungle cat is morphologically similar to caracal (Mukherjee 1989 ; Kitchener 1991 ; Nowell and Jackson 1996). Both have long legs, a short tail, long ears with small tufts at the tip. The

distinguishing features are the bands on the tail and legs of the jungle cat which are absent in the caracal. Jungle cat has a shorter gestation period, 63 - 68 days than caracal. They produce between 1 - 6 kittens in a litter (Nowell and Jackson 1996).

Golden Jackal (*Canis aureus*): Out of the four species of jackals found globally, 1 species - the Golden or Asiatic jackal occurs in India. This species is said to have the northernmost distribution among the jackals (Sheldon 1992). The golden jackal, (Plate 1) stands 38 - 50 cm. tall. Its head and body length measures between 60 -106 cm. and tail 20 - 30 cm. (Ginsberg and MacDonald 1990). This is the most common canid found in India. It is distributed throughout the country and occupies almost all the different climatic zones and vegetation types including farmlands and degraded scrub. Generally its habitat is open country with scrub and its global distribution is wide ranging through South east Europe, North and east Africa, South Asia upto Burma and Thailand (Ginsberg and MacDonald 1990 ; Sheldon 1992). The golden jackal is more nocturnal when it occurs near human habitation. In relatively less disturbed areas it is diurnal (Fox 1975 ; Sheldon 1992). It is an omnivorous, opportunistic feeder with very flexible dietary habits (Fox 1975 ; McShane and Grettenberger 1984 ; Sheldon 1992). The female is monestruos, with a gestation period of 63 days. Litter size ranges from 1 - 9 pups and as in most canids and the male participates in rearing of young. Territories are held by mated pairs and boundaries demarcated by scat deposition and urine (Sheldon 1992).

CHAPTER 2. STUDY AREA

2.1 General, location and topography:

Situated between 74^0 17' to 76^0 34'N and 25^0 5' to 27^0 33' E, Sariska Tiger Reserve (STR) is part of one of the oldest hill ranges of India - the Aravallis. It once served as hunting grounds for the royal family of Alwar till it was declared a Wildlife Sanctuary in 1955. After the launching of Project Tiger in 1973, it was raised to its current status as a Tiger reserve in 1982. Encompassing an area of 800 km^2., the Reserve also includes some revenue land and several villages. Three core areas are demarcated of which core 1, with an area of 273.8 km^2. forms the proposed National Park. This area functions as the main tourism zone. The Reserve is well connected to Delhi and Jaipur by road that runs through the Reserve.

STR is characterised by rugged terrain, valleys and plateaus with an altitudinal variation from 540 m. to 777 m. The two main plateaus are the Kankwadi plateau and the Kiraska plateau. A network of tarmac and dirt roads exists in the main tourism zone. The pucca road enters the Reserve at Sariska from the main gate towards the northern part of the Reserve and bifurcates after 10 km. one going 12 km. to the Pandupole temple and the other to Tehla, 12 km (Figure 2.1).

2.2 Climate:

Three distinct seasons, winter, summer and monsoon can be experienced in STR. Winter lasts the longest, from late October to March. Temperatures in peak winter (late December to early January) drop to zero and there is frost formation. Winter rain is a common occurrence. Summer is short, mid April to mid June but very harsh. Temperatures start shooting up from mid May and reach 48° C and sometimes 50° C (for short durations). Strong hot winds and dust storms are a regular feature at this time of the year and the entire Reserve undergoes a drastic change in appearance. In summer the arid nature of

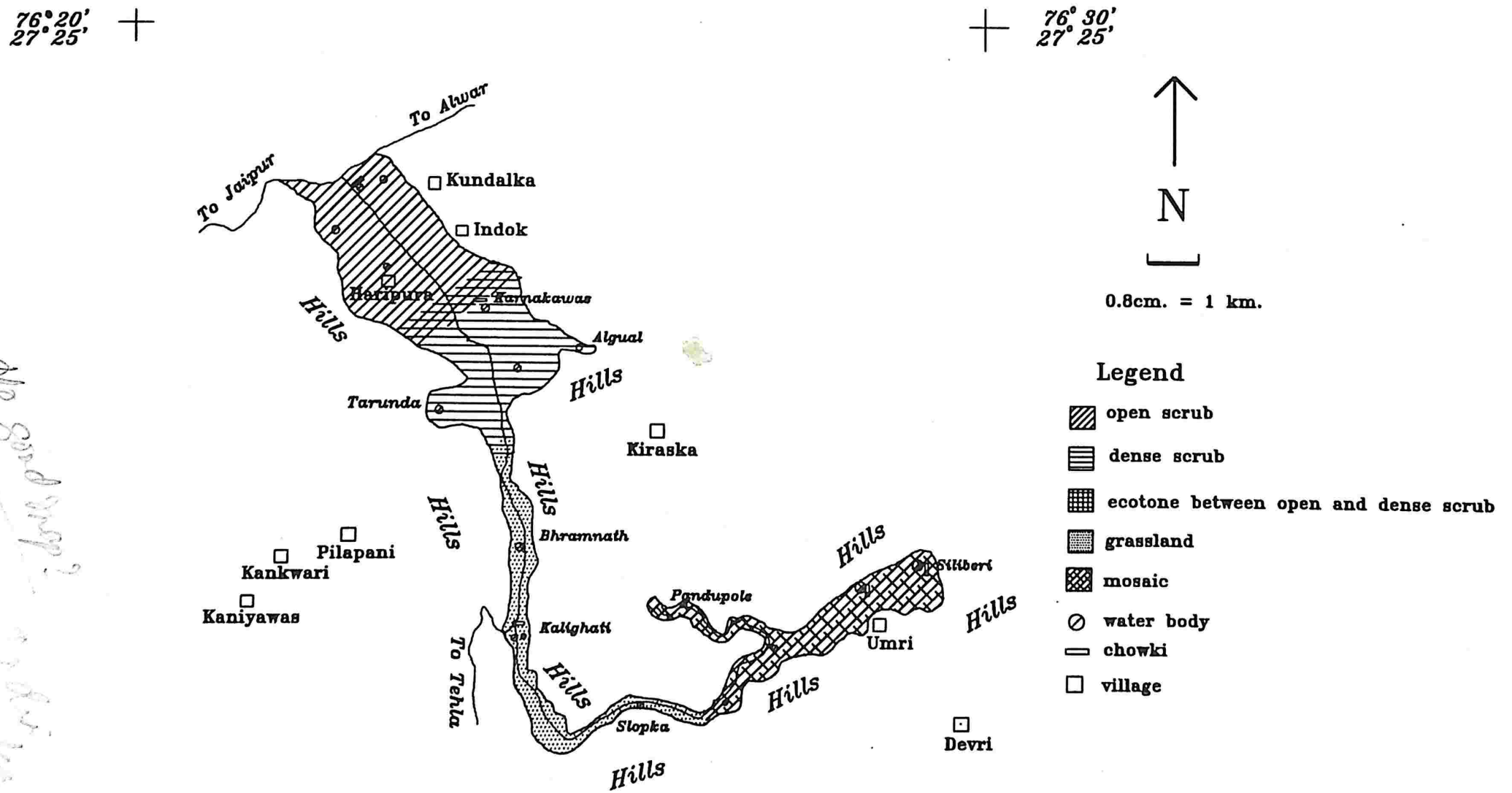


Figure 2.1: Map of study area showing different habitat types.

this region becomes much more apparent and visibility is increased to a great extent as a result of grass drying up and the trees and shrubs shedding their leaves. Due to dryness fires are a problem. Shortage of food and water makes summer the pinch period for most animals especially ungulates. Summer is followed by monsoon which is again of short duration from late June to late August. The area receives approximately 600 mm. of rainfall annually. However in some years, as in the past two years, this region experiences exceptionally heavy rainfall upto 1200 mm.

2.3 Geology and history:

The Aravalli range stretches from Delhi to north Gujarat covering a distance of about 692 km. oriented diagonally in a north-east to south-west direction. The major portion of the range (550 km.) traverses through Rajasthan and divides the state into two natural zones forming the eastern limit of the Thar desert. The area to the east of the range in the state forms the semi-arid region (Shetty and Singh 1987 ; Anon. 1994).The Aravallis are considered the oldest folded mountain range in the world. They were formed by orogenic forces acting on sediments deposited in the seas more than 570 million years ago towards the end of the Archaen period of the Precambrian era. They were nearly flattened during the Palaeozoic era, and later raised again in the Mesozoic era (Shetty and Singh 1985 ; Anon. 1994).

The geology of the area is complex due to the presence of the very ancient precambrian granitic and gneissic rocks along with more recent rocks, alluvium and wind blown sand (Anon. 1994). Geologically the rocks have been classified into the Aravalli, Dehli and Vidhyan supergroups and the Dehli super group can further be classified into the lower Railo, middle Alwar and upper Ajabgarh series. These strata contain highly metamorphised rocks and are of great commercial importance owing to the presence of

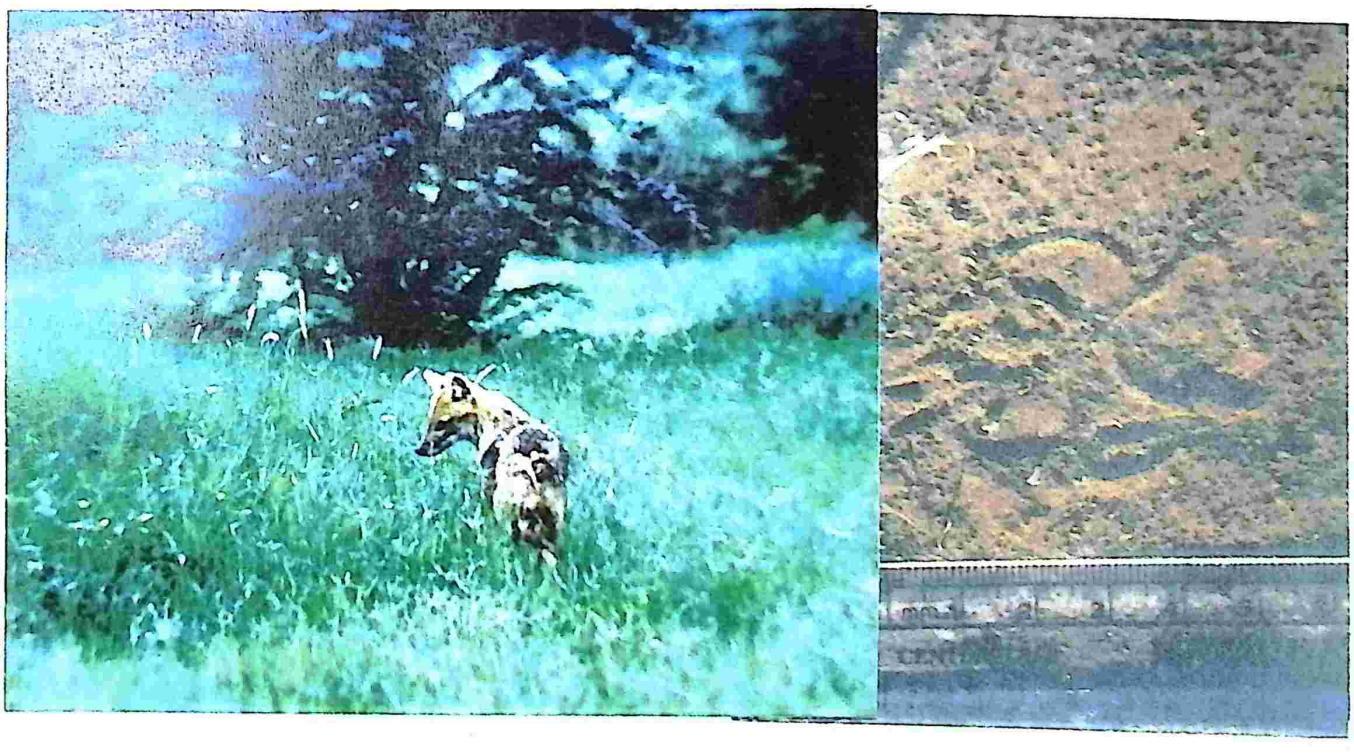
marble and mineral ores such as copper, this being evident by the presence of a large number of mines in the region. The ridges of the range are made of quartzite, conglomerates and grits whereas the valleys contain limestone, phylites and schists (Krishnan 1982, Parmar 1985, Shetty and Singh 1987, Mathur 1991, Anon. 1994 , Shankar, 1994).

The entire region, including Alwar district, has an interesting history. The *Moghul* emperors passed through Alwar during their invasion of the northern and western parts of the country and their memoirs contain graphic descriptions of the geography and natural history of the region. In *Babur Nama* (Babur 1493), which covers the period between 1493 to 1529, Babur the first *Moghul* emperor describes the Aravallis as rocky, low and densely forested. He also talks of the Ruparal or Barah river that flows through Sariska Tiger Reserve. The river originates from the hills of Thanagazi and ends in Bharatpur district. In the past the forests in the region were contiguous through the districts of Alwar, Jaipur, Dholpur, Kotah, Bundi, Tonk, Udaipur and the adjoining districts of Indore and Gwalior (Seshadhri 1986). It is however a matter of concern now, that the once densely forested Aravallis which acted as a barrier and prevented the spread of the desert, has rapidly undergone massive deforestation through most of its range especially around the districts of Alwar and Jaipur. This has created several gaps in the hill range through which wind blown sand is carried onto the eastern part of the range thus intensifying desertification (Ghosh *et al.* 1988).

Within STR there are several places of historical interest. The Pandupole temple which is a major attraction for tourists lies in the core zone of the reserve. The temple and the area surrounding it is associated to *Hanuman* the monkey God and the Pandavs when they were in exile in the Mahabharat legend (Seshadhri 1986). The Nilkanth temple and ruins of several other temples found on the outskirts of the Reserve are now protected by

PLATE 1

a. Jungle cat (*Felis chaus*) with paw print.



b. Golden jackal (*Canis aureus*) with paw print.

the Archaeological Survey of India. Evidence of *Moghul* invasion are retained in the forts located in and around the reserve. The Kankwarhi fort, now in ruins, located in the core area of the Reserve, is believed to be the place where Darashikoh the eldest son of the fourth *Moghul* Emperor, Shah Jahan took refuge when pursed by brother Aurangzeb (Seshadhri 1986).

2.4 Vegetation:

The vegetation of STR has been described by Champion and Seth (1968) as the tropical dry deciduous type and Tropical thorn forest. This classification has been followed by Parmar (1985) and Rodgers (1985). In fact the vegetation is a mosaic of different vegetation associations which has given rise to distinct vegetation types. Each covers a small area and are interspersed with each other. The valleys include scrubland, tall grassland and woodland and are distinct from the hill slope and hill top vegetation. After an initial reconnaissance in the study area for the present study the following categories of habitats were defined.

Scrubland: This region (Plate 2) is found in the more disturbed areas within the Park. These areas typically have grass and *Cassia tora* as ground cover and bushes such as *Grewia flavicens, Capparis decidua, Capparis sepiaria, Zyziphus nummularia* and *Adhatoda vasica* as the next layer. Trees are scattered, the predominant species being *Balanites aegyptiaca, Acacia leucophloea, Zizyphus mauritiana* and *Acacia senegal.*

Tall grassland and woodland: This area (Plate 2) occupies a small portion of the Reserve and is mostly found on either side of the tarmac road going through Core area -1 of the Reserve. It is distinct from other vegetation associations as the most obvious feature is the tall grass, the dominant species being *Chloris dolichostachya.* *Z. mauritiana* is the

predominant tree species found here in substantial numbers giving the area an appearance of a woodland.

Besides the *Zizyphus*- tall grassland area there are woodlands comprising primarily of *Butea monosperma* generally found at foothills with very little under storey.

Hill vegetation (Plate 2): The vegetation is very distinct, with slopes having a dense undergrowth of *G. flavicens* in *Anogeissus pendula* forests. The other tree species found on the hills are *Acacia catechu, Casssia fistula, Diospyros melanoxylon, Ehretia aspera, Flacourtia indica, Bauhinia racemosa, Terminalia tomentosa* and *Wrightia tinctoria.* Bamboo - *Dendrocalamus strictus* is found in some places along the slopes and along nallahs. On ridge tops *A. pendulla* forests are replaced by *Boswelia serrata* forest again with a dense undergrowth of *G. flavicens.*

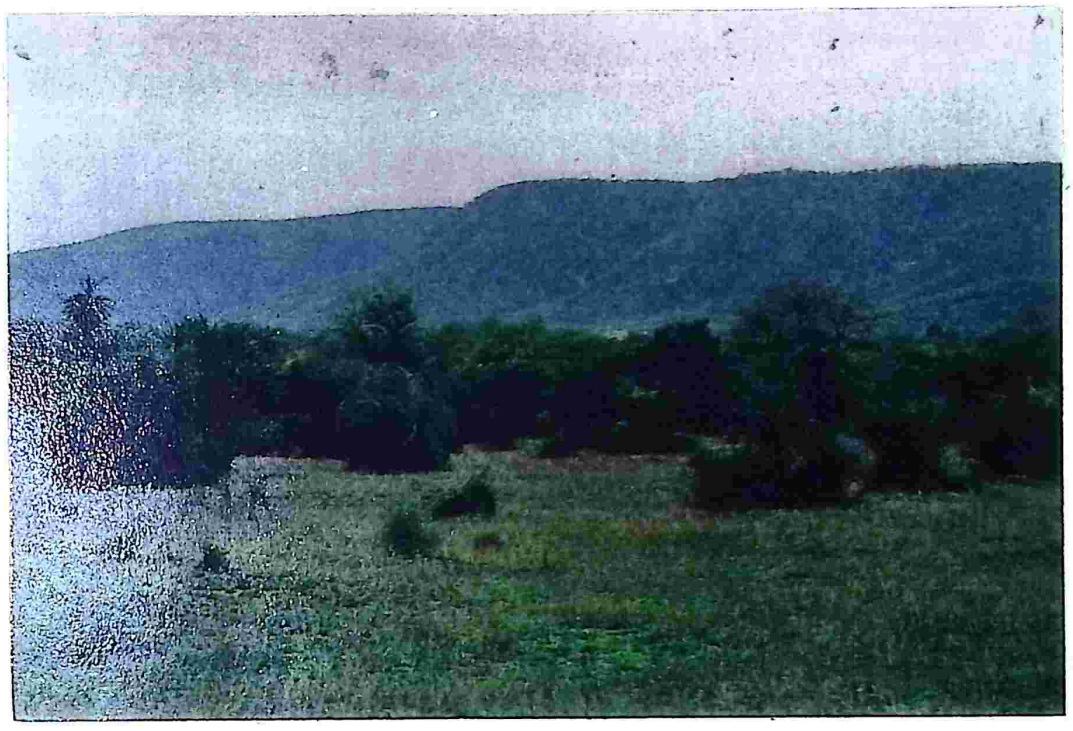
Apart from these main vegetation types the moist areas of STR, along nallahs and perennial streams have patches of forests comprising of *Phoenix sylvestris, Ficus spp.* and *Mallotus philippinensis* (Plate 3).

2.5 Fauna:

One of the most striking features of STR is the richness in mammalian fauna inhabiting the area. The nomenclature used here follows Corbett and Hill (1992). A total of 13 species of carnivores are found in STR, of which 5 are felids - tiger (*Panthera tigris),* leopard (*P. pardus*), caracal (*Caracal caracal*), jungle cat (*Felis chaus*) and rusty spotted cat (*Prionailurus rubiginosus*). Apart from cats, other carnivores are the striped hyaena (*Hyaena hyaena*), jackal (*Canis aureus*), Wolf (*Canis lupus*), common mongoose (*Herpestes edwardsii*), small Indian mongoose (*H. auropunctatus*), ruddy mongoose (*H. smithi*), Palm civet (*Paradoxurus hermaphroditus*) and the small Indian civet (*Viverricula indica*). Earlier, the Indian wild dog or dhole (*Cuon alpinus*) used to occur in STR but there

have been no sightings in the recent past. Wild ungulates forming a prey base for bigger carnivores include, nilgai (*Boselaphus tragocamelus*), chital (*Axis axis*), sambar (*Cervus unicolor*) and wild boar (*Sus scrofa*). Chowsingha or Four horned antelope (*Tetracerus quadricornis*) is found in some areas in low numbers. Two primates, common langur (*Presbytis entellus*) and Rhesus macaque (*Macaca mulata*) are found within the Reserve. Other fauna found are the rufous tailed hare (*Lepus nigricollis ruficaudata*), porcupine (*Hystrix indica*) and small rodents such as the Indian gerbille (*Tatera indica*), the bush rat (*Golunda ellioti*) and the spiny tailed mouse (*Mus platythrix*). Due to the presence of villages inside and on the periphery a large variety of domesticated animals also occur within the Reserve (Plate 3). These include buffaloes, cows, goats, camels, dogs and cats. A checklist of two hundred and eleven bird species belonging to 52 families have been identified in STR by Shankar *et al.* (1993). These include 73 migratory and 120 resident species. A number of aquatic birds also visit the Reserve during winter.

PLATE 2



a. Scrubland with hill forests in the background.

b. Grassland.

PLATE 3

a. Date palm (*Phoenix sylvestris)* trees,
typical vegetation of perennial springs and water courses such as nullahs.

b. Disturbance from human settlements around open scrub
(Wild boar young in foreground foraging with cattle).

PLATE 4

a. Mosaic: scrubland part.

b. Woodland part of mosaic.

2.6 People:

A total of 17 villages and 6 grazing camps occur within the Reserve. Most of the villagers within the Reserve belong to the *Gujar* and *Meena* community who keep cattle (cows and Bufaloes) and other livestock (sheep, goats and camels). They eke out a living by selling milk and milk products. In some areas they cultivate crops. Owing to these, biotic pressures from grazing, grass cutting, lopping and fuel wood collection are high (Plate 3). The Management plan for STR (Saini 1983) stresses the urgency for relocating the villages and cattle camps situated inside the Reserve. The final notification of the National Park (Core-1) remains pending as the rights of the people living inside have as yet to be settled. Re-locations have been conducted in the past as in 1967 when a grass camp from the Kalighati area which lies in core - 1 of the Reserve was removed and in 1975 the Karnakawas village from the scrubland area of core-1 was rehabilitated just outside the boundary of the Park (Vardhan 1979). However pressure from these villages still continue as they are located very close (1 - 2 km) to the park boundary and no alternative measures for fuel and fodder have been provided to them. The Forest Department provides employment to some villagers as daily wage labourers for short term projects such as cutting fire lines, building check dams, *anicuts*, road repairs etc. Some are permanently employed as Forest Guards.

A major threat to the Park comes from local poachers that reside in the villages surrounding the Reserve. Poaching is done using fire arms or explosives buried in baits and the target species are wild ungulates for their meat. The communities involved in these crimes are the *Meenas*, *Bhils* and *Rajputs*. Local nomadic tribes like the *Bawarias* and *Moghias* often employed by villagers for crop protection also poach (Saini 1983). Main areas where poaching occurs are the remote water holes. In the past, *'machans'* or hides on trees have been located in remote areas. These were presumably built for hunting large

cats. Though in the past two years *machans* have not been located, such activities cannot be ruled out. Timber poaching also exists and there is heavy pressure on *Acacia catechu* which is felled in large numbers, loaded onto trucks and smuggled out.

2.7 Tourism:

Tourism is not regulated and most of the tourists coming to the Reserve come for the Pandupole Temple especially on Tuesdays and Saturdays when entry to the Reserve is free. In the peak season which is from July to September there is a fair held at the Pandupole temple due to which there is very heavy traffic inside Core 1 even during the night. However on other days only day-time tourism is allowed and the Reserve remains closed after dusk. There is no restriction on the type or number of vehicles going in and most of the vehicles are diesel driven jeeps or buses. The major season for wildlife tourism is winter. The tourists either go in private vehicles or are taken on drives in tourist vehicles owned by hotels. Disturbance from tourists especially the ones coming for the Temple needs to be checked as the tourism Zone also forms part of Core 1 or the proposed National Park. On the other hand there is potential for developing regulated wildlife tourism.

2.8 Research:

A number of short and long term reseach projects have been conducted in STR (Parmar 1985 ; Rodgers 1985, 1990 ; Sharma 1989 ; Chakrabarty 1991 ; Rao 1991, Shankar 1994). Apart from these WII has been monitoring the vegetation and animal abundance (ungulates) since 1986 as part of its training courses.

CHAPTER 3. STATISTICAL ANALYSIS

3.1 Statistical analysis for Chapter 4:

The two - tailed Man Whitney U test (Siegel 1956) was used for examining differences in vegetation characteristics, track plot use by prey and predators and direct counts of ground birds on transects. For direct sightings of carnivores and for rodent abundance estimation descriptive statistics were used. For comparing direct and indirect methods for determining habitat use by predators, the two - tailed Spearman's rank correlation (Siegel 1956) was used. Rodent abundance in various habitats was correlated with use of these habitats by domestic livestock, using the one tailed Spearman's rank correlation (Siegel 1956). All analysis was done using the SPSS and Excel programmes. In text as well as in tables means are given along with standard error.

3.2 Statistical analysis for Chapter 5:

Since locating and analyzing sufficient numbers of scats for more reliable estimates of diet, is virtually impossible to obtain, the Bootstrapping simulation as suggested by Reynolds and Aebischer (1991) was used. The Bootstrap simulation was done for each predator in each season with 2000 subsamples of observations equalling sample size (Table 5.1). Means and 95% Confidence Intervals, for overall as well as seasonal diet of the three predators was generated by Bootstrap simulation using the programme SIMSTAT. For comparisons of percentage of scats having remains of mammals, birds, reptiles, invertebrates, vegetable matter and rodents for each predator during summer, winter and for overall diet, (without accounting for seasons) the bootstrap 95% confidence intervals were used. For comparing the above mentioned food categories for each predator between seasons and for comparing the same for different predators in each season, the

two - tailed Man Whitney U test (Siegel 1956) from SIMSTAT was used. This test was also used for scats of predators containing rodents for:

1. Comparing percent of scats having each species of rodent.
2. Comparing the number of individuals of each species of rodent occurring per scat.
3. Comparing the biomass of each rodent species found per scat.

The above mentioned comparisons were done for each predator, overall (without accounting for seasons) and for each season (summer and winter), between seasons and between predators.

CHAPTER 4. PREY, PREDATORS AND HABITAT CHARACTERISTICS

4.1. Introduction:

It has long been known that a study of an animal's habits cannot be done in isolation of its environment (Forbes 1887 ; Noss and Murphy 1995). The factors constituting the environment of any species are numerous and intricately related. This complexity increases with the incorporation of scale e.g. macrohabitat, microhabitat (Brock and Brennan 1993). Due to this, terms such as "habitat" being components of environment are vaguely defined as they vary according to the species studied (Brock and Brennan 1993 ; Peters 1995). One of the simplest definitions of habitat is "The place in which the species lives" (Darwin 1859). Southwood (1977) emphasized the importance of the relationship of organisms to their habitat by comparing habitat to a template which molds or structures the communities and in the process gets altered by the organisms inhabiting it. According to Brock and Brennan (1993) "habitat is the subset of physical environmental factors that a species requires for its survival and reproduction". They feel that habitat is part of the term "niche" which has been defined as an "n dimensional hypervolume", (Hutchinson 1957, 1959) and the two are closely connected. In this respect habitat can be viewed as "space", one of the dimensions of niche.

The most commonly studied resources are space, food and time. Defining space can be complicated as space itself has several characteristics and the importance of these vary with species (Southwood 1977). Although space has been defined as a physical term having structural properties, it can also have functional properties as it serves as a base for obtaining food (Pontin 1982 ; Begon *et al.* 1990). The functional parameters were vegetation as possible food for prey, prey abundance, disturbance and abundance of sympatric predators. The structural parameter measured was vegetation, as cover for both

predators and prey. For short term studies, time can be viewed as diel or annual rhythms such as seasons.

The importance of habitat structure for carnivores is known from earlier studies (Eisenberg 1986 ; Kruuk 1986 ; Ginsberg and MacDonald 1990 ; Nowell and Jackson 1996). Generally, canids are adapted to more open habitats whereas most felids are forest dwellers and the ones that have invaded open areas such as jungle cat and caracal are also dependent on good amount of cover (Eisenberg 1986 ; Nowell and Jackson 1996). The necessity of suitable cover for felids stems from their mode of hunting, social organisation and behaviour which have been discussed in Chapter 1. The same factors are responsible for canids requiring relatively open habitats (Eisenberg 1986). Moreover the structure of habitats would also be responsible for the type of prey that are found within the habitat (Kruuk 1986).

4.2 Objectives:

The aim of this chapter is to examine use of space with respect to time (both diel and annual) by caracal, jungle cat and jackal. This in turn would be related to temporal changes in structural and functional attributes of habitats.

Apart from this, two hypothesis will be tested:

1. The felids are more eclectic in the habitat it inhabits than the jackal.
2. The felids are mostly nocturnal while the jackal is cathemeral.

To examine the relationship of habitat characteristics with use of habitats by jackal, caracal and jungle cat various parameters were studied in the different habitats in STR. These were

1. Vegetation
2. Prey

3. Predators
4. Disturbance

Several questions addressed for each parameter that was measured in the various habitats were:

Vegetation:

1. Do the various habitats differ in the amount of grass cover, grass height, number of bushes as cover and percent of green grass they contain?
2. Is there a seasonal difference in these parameters within each habitat?

Prey:

1. Do the various categories of prey (ground birds and murid rodents) differ in different habitats?
2. Is there a seasonal difference in prey abundance in the various habitats?
3. Do the different methods used to estimate prey abundance support each other?

Predators:

1. Is there a seasonal difference in use of habitats by the predators?
2. Do the predators avoid each other?
3. Is there a difference in time of activity of the predators in the various habitats?
4. Does time of activity of predators change with seasons?
5. Do the various methods of estimating predator abundance corroborate each other?

Disturbance:

1. Is there a difference in the level of disturbance between various habitats?
2. Is there a seasonal difference in the level of disturbance within each habitat?

4.3 Methods:

Methods for predator and prey abundance have been separated into Direct and indirect methods. Direct methods are those that rely on actual sightings of animals whereas indirect ones use signs such as tracks, and other spoor.

4.3.1 Vegetation:

The overall vegetation of STR is tropical dry deciduous and thorn scrub (Champion and Seth 1968). Different broad vegetation zones were identified visually from their appearance e.g. Scrubland, hill slopes, hill tops and woodland. In the initial reconnaissance, the broad vegetation categories sampled for various parameters were grass height (in centimetres), (grass of 5 cm. height and less was recorded as < 5 cm), percent above ground grass cover and percent green grass (occularly to nearest 5% interval), number of bushes for cover and amount of disturbance from humans and domestic livestock as lopping evidence and presence of dung piles. This was done in 10m. radius plots set in a random systematic manner in the various broad vegetation categories.

Based on these initial results the broad zones could be further divided into finer scales and several potential habitats for the three carnivores could be identified. A description of these categories is given in Chapter 2. A fifth habitat, mosaic, which constituted small patches of the other four habitats was identified after the reconnaissance (Plate 4). Monitoring of vegetation plots for grass attributes and bushes continued after the reconnaissance. Since there was a drastic change in ambient temperature and structural appearance of vegetation from winter to summer the various vegetation parameters were monitored for the two seasons to detect seasonal differences in various habitats.

4.3.2 Prey:

Prey abundance was measured through several techniques depending on the group they belonged to. Rodents (Murids and Sciurids), birds and hare which constituted a major portion of the predators' diet (identified from an initial analysis of scats and other studies : Schaller 1967, 1970 ; Johnsingh 1983 ; Kitchener 1991) were quantified from direct and indirect methods. Some other potential prey such as reptiles (snakes, skinks, monitor lizard and other lizards) and arthropods (various insects such as beetles and hoppers and scorpions) were not included .

4.3.2.1 Indirect methods

Track plots: This method was initially used to determine an area which was most visited by the three carnivores to facilitate trapping and subsequent radio collaring. Since the initial idea was to have the scrubland (open and dense) as the intensive study site, in the first year, track plots were made only in these two habitats. However as the study progressed the method was found to be very useful for estimating relative abundance of prey and the method was extended to the other habitats. Along with information on predator distribution (use of habitats by predators), pressure from human settlements in the form of presence of domestic livestock by track counts could also be quantified and compared between the different habitats. As the name suggests this method involves using signs for an indirect assessment of animal abundance (Plate 5). A small patch of ground is cleared off vegetation and other material such as pebbles and litter and is flattened and smoothened. A thin layer of soft soil is then sieved over the plot so that any animal walking over the plot leaves its impression behind. A number of such plots can be used for sampling an area over a time period. Several modifications of this method have been used in different studies. The most popular way is to use it as a `scent station' where a small vial of lure is

placed on the track plot as an attractant for the species to be monitored (Humphrey and Zinn 1982 ; Roughton and Sweeny 1982).

In each habitat, plots were spaced 500m apart. The first plot was made at the beginning of the dirt tract and the others followed. Plots were monitored in the mornings during summer and winter after which they were set up for the next 24 hours. Data was recorded as presence or absence of tracks of species per plot. The total number of plots per habitat was the number of days plots were monitored multiplied by number of plots made per habitat (Table 4.1) (Some plots, in some habitats could not be monitored after the monsoon due to water logging). Index of use of habitat by any species was obtained per plot as, total number of days on which tracks were recorded divided by total number of days plots were monitored. The resultant figure was multiplied by 100 and expressed as percent visitation to plots in different habitats. During the summer of 1995 track plots could not be monitored in the mosaic zone due to certain problems within the park in that area.

Table 4.1 Details of track plots for winter and summer

Season	Habitat	No. of days	Number of plots	Total plots
winter	Open scrub	39	11	429
	Dense scrub	44	10	436
	Hill forest	10	21	191
	Mosaic	28	13	364
	Grassland	10	10	100
summer	Open scrub	11	11	120
	Dense scrub	11	10	109
	Grassland	5	10	50

Avian prey were grouped in three classes according to their body weights. Class 1 had small birds with body weights less than 250 gm. Partridge sized birds (250 - 500 gm.) formed the next category followed by peafowl in class 3 (> 1 kg.).

Rodent burrow counts, number of bushes and bushes having burrows: This method was used for obtaining indices of rodent abundance in the various habitats. Rodent burrows

were counted in a 30m x 30m. plot in the different habitats once each season and one plot per habitat. Species of rodent were identified from burrow size, *M. platythrix* burrows were very small compared to *T. indica* burrows which were not only larger, but had several openings. In the 10m. radius vegetation plots, the number of bushes containing burrows were counted. From this the percentage of bushes having rodent burrows was calculated for each habitat as an index of rodent abundance and bush cover.

4.3.2.2 Direct methods

Foot transects: This method was used for determining abundance of ground birds and hare. One km. transects (Verner 1982) were cut through the various habitats and walked in the evenings from 1600 hrs. in winter and 1730 hrs. during summer. Details of transects are given in Table 4.2. Bird species, number of individuals, angular distance and angle of sighting was recorded on these transects. Initially data was to be analysed using the TRANSECT programme. However, in some habitats there was inadequate replication while data from some habitats and in some body weight classes e.g. peafowl was not sufficient for robust statistics, hence simple indices of abundance as encounter rates per km. was used for these.

Table 4.2: Details of foot transects in various habitats for prey abundance.

Season	Habitat	No. of transects
Winter	Open scrub	12
	Dense scrub	5
	Grassland	1
	Mosaic	6
	Hill forest	1
Summer	Open scrub	13
	Dense scrub	9
	Grassland	2
	Mosaic	1
	Hill forest	2

Capture: Sherman live traps baited with peanut butter were used for capturing murid rodents for identification and estimating their abundance in the various habitats. The traps

were spaced 10m. apart and were set up as a linear grid. Each grid was 10 m. apart from the next. In winter there were two trapping sessions for each habitat. In December 1995, 50 traps were set for 6 days and nights. The area for the first session was chosen randomly and traps were set up systematically, at a distance of 10 m. from the previous. In February 1996, there were 600 trap nights with 100 traps set for 6 days and nights. For this session, the area was chosen opportunistically, in areas where there were many rodent burrows. This was done to see if there was any difference in random and opportunistic sampling.

In summer, there was one trapping session in April 1996 of 1000 trap nights with 200 traps set for 5 days and nights and the area was chosen randomly. The effort was equal for all habitats in both seasons. During both seasons traps were monitored three times daily (early morning, at midday and late evening). After completing a trapping exercise in a habitat, the traps were thoroughly cleaned and then set up in another habitat. Animals caught were identified, weighed and measured for tail length, body and head length and length of hind. Animals were released at the site of capture.

4.3.3 The Predators

4.3.3.1 Indirect methods

Track plots used for monitoring prey was used to estimate index of predator abundance by counting number of plots which had tracks in the different habitats (Table 4.1) (Plate 6).

4.3.3.2 Direct methods

Direct sightings were obtained by five ways:

1. Drives on metal roads
2. Drives on dirt roads.

3. Walks on metal roads

4. Walks on dirt roads and

5. Foot transects through various habitats.

For every sighting, the species, number of individuals, activity if recordable, time and place of sighting was noted. Time of activity was estimated by separating a 24 hr period into different time intervals (broadly, daylight: 0500 hr. - 1800 hr. dusk: 1800 hr. - 1900 hr. and night: 1900 hr. to 0500 hr. in winter. In summer, these categories were: daylight, 0500 hr. - 1830 hr. ; dusk, 1830 hr. - 1930 hr. and night, 1930 hr - 0500. This was done for each habitat over two seasons. Since encounters of predators through direct methods were very low no statistical test could be conducted to check for differences between habitats and seasons. Hence only trends are given and are compared to indirect methods.

4.3.4 Disturbance

Presence of livestock was considered as an index of disturbance from human settlements inside the Park. Habitat use by livestock was measured from track plots which have been described earlier.

4.4 Results

4.4.1 Broad vegetation characteristics

Grass height: In winter the grassland area had the tallest grass with a mean grass height of 111 cm $\pm$ 7.81, followed by dense scrub (25 cm. $\pm$ 3.17), mosaic (mean 5.5 cm. $\pm$ 0.5) and open scrub (< 5.0 cm.). Grassland differed significantly from dense scrub, $U = 3.0$, $p < 0.001$; open scrub $U = 0$, $p < 0.001$ and mosaic, $U = 0$, $p < 0.001$ (Table 4.3). Dense scrub had significantly taller grass than open scrub, $U = 49.5$, $p < 0.001$ and mosaic $U = 17.5$, $p < 0.001$ (Table 4.3) . There was no significant difference in grass height between open scrub

and mosaic. In summer the trend remained the same as in winter with grassland having maximum grass height (mean 75 cm. ± 7.3). Dense scrub and hill forests followed with mean grass heights of 53cm. ± 12.6 and 50 cm. ± 10 respectively. These were not significantly different from each other and from grassland. However there was a significant difference in grass height between these three habitats and open scrub (dense scrub vs. open scrub: $U = 0$, $p < 0.001$; grassland vs. open scrub: $U = 0$, $p < 0.001$, hill forest vs. open scrub: $U = 0$, $p < 0.001$) and mosaic (dense scrub vs. mosaic: $U = 0$, $p < 0.001$; grassland vs. mosaic: $U = 0$, $p < 0.001$; hill forest vs. mosaic: $U = 0$, $p < 0.001$). There was no seasonal difference in grass height in open scrub and mosaic. Grass height in dense scrub was significantly ($U = 0$, $p < 0.001$) higher in summer than in winter whereas in grassland, grass height was significantly ($U = 38$, $p < 0.005$) higher in winter than in summer.

Percent above ground grass cover: (Table 4.3) In winter amount of grass as ground cover was similar among open scrub, dense scrub and grassland (56% - 63%). However these were significantly higher than mosaic (27% ± 6.51) (open scrub vs. mosaic: $U = 41$, $p < 0.001$; dense scrub vs. mosaic: $U = 37.5$, $p < 0.001$; grassland vs. mosaic: $U = 14.5$, $p < 0.01$) (Table 4.3). In summer, grassland had a significantly higher amount of grass cover (mean 53.2% ± 4.04) than open scrub (mean 29% ± 4.27) ($U = 28.5$, $p < 0.001$) and mosaic (mean 24.5% ± 7.36) ($U = 37$, $p < 0.005$). Although grass cover in dense scrub (mean 38% ± 7.42) was lower than in grassland the difference was not significant. There was no significant difference in grass cover between open scrub, dense scrub and mosaic in summer. Hill forests had the lowest amount of grass cover (mean 4.3% ± 3.05) and this was significantly different from open scrub ($U = 3.5$, $p < 0.001$), dense scrub ($U = 5.5$, $p < 0.001$) and grassland ($U = 1.0$, $p < 0.001$). Percent grass cover was significantly ($U = 30$, p

< 0.001) higher in winter than in summer in open scrub and dense scrub. There was no seasonal difference in grass cover in mosaic and grassland.

Percent green grass: In winter, mosaic had the highest percentage of green grass (mean 79.5% ± 10.5) and was significantly higher than the other habitats (mosaic vs. open scrub: U = 33, p < 0.001 ; mosaic vs. dense scrub: U = 29.5, p < 0.001; mosaic vs. grassland: U = 5.5, p < 0.001) (Table 4.3). There was no significant difference in the amount of green grass between open scrub, dense scrub and grassland ranging from 12.5% to 21%. In summer too, percent green grass was highest in mosaic which had a mean of 87% ± 3.59. This was significantly higher than dense scrub (mean 4.5% ± 0.9) (U = 0, p < 0.001) and grassland (mean 7% ± 3.5) (U = 0, p < 0.001). Open scrub (mean 67% ± 7.1), had relatively large amounts of green grass but was significantly lower (U = 22, p < 0.05) than mosaic and higher than dense scrub (U = 0.5, p < 0.001) and grassland (U = 6.0, p < 0.001). There was no green grass in the hill forests in summer. There was no seasonal difference in percent green grass in mosaic and grassland. Open scrub had significantly (U = 23, p < 0.001) higher amounts of green grass in summer as compared to winter whereas dense scrub had significantly (U = 91.5, p < 0.05) greater proportions of green grass in winter.

No Fig?

4.4.2 Predators

4.4.2.1 Indirect methods

Track plots: In winter, jackal abundance expressed as percent visitation to plots (Table 4.4) was highest in the open scrub which had a mean track plot visitation rate of 32.2% ± 5.5. Mosaic followed with mean visitation of 22.8% ± 4. This was not significantly different from open scrub. However, open scrub had significantly higher visitations by jackal than dense scrub (mean = 10.3% ± 2.8) (U = 80.5, p < 0.001) and grassland (mean = 4% ± 3)

(U = 20.5, $p < 0.001$). Mosaic too had significantly higher jackal abundance than grassland (U = 11, $p < 0.001$) and dense scrub (U = 56, $p < 0.01$). Dense scrub had significantly higher (U = 57, $p < 0.05$) jackal abundance than grassland. Jackal abundance was very low in the hill forests (mean = 0.4% $\pm$ 0.4) and this was significantly different from the other habitats (dense scrub: U = 160, $p < 0.001$; open scrub: U = 30, $p < 0.001$; mosaic: U = 6, $p < 0.001$ and grassland: U = 173, $p < 0.05$).

In winter, jungle cat abundance (Table 4.4) was highest in dense scrub which had a mean of 20.44% $\pm$ 4.0. Relative to dense scrub, the other habitats had much lower visitations to track plots by jungle cat. Dense scrub had significantly higher jungle cat abundance than open scrub (mean = 8.13% $\pm$ 2.1) (U = 122, $p < 0.05$) and mosaic (mean = 5.4% $\pm$ 1.6) (U = 63, $p < 0.05$). The difference was greater between dense scrub and hill forest significant (U = 161.5, $p < 0.001$) which had a mean of 6.1% $\pm$ 2.2. Grassland with a mean of 3% $\pm$ 1.5 jungle cat visitations also varied significantly (U = 30, $p < 0.01$) from dense scrub. There was no significant difference in jungle cat abundance between open scrub, mosaic and grassland. Open scrub had significantly more (U = 284, $p < 0.005$) jungle cat visitations per track plot than hill forest.

In summer there was no significant difference in visitations by both predators to track plots between any habitat. Visitations in all habitats in summer was relatively low for jungle cat as well as jackal when compared to winter data (Table 4.4). Open scrub had maximum visitation by jackal followed by dense scrub and grassland. Mean visitation per plot by jungle cat was similar for all habitats. Mosaic and hill forests could not be monitored during summer. A significant seasonal difference was seen in the open scrub for both predators. In this habitat, there were significantly more visitations to plots by jungle cat (U = 161.5, $p < 0.05$) as well as jackals (U = 120, $p < 0.005$) in winter than in summer. Jungle cat showed a seasonal difference in track plot use in the dense scrub too, where significantly (U = 94, p

< 0.005) more visits were made in winter than in summer. In winter jungle cat and jackal used both habitats (open scrub and dense scrub) more uniformly whereas in summer their distribution seemed to be more clumped and sparse (Figure 4.1).

Possible Caracal tracks were encountered only thrice in open scrub and once in hill forests. This indicates the rarity of this species, due to which statistical comparisons with other predators based on track counts could not be made.

Apart from seasonal difference, the data seemed to suggest that jungle cat and jackal were avoiding each other. Certain plots that had high jackal visitations showed low visitation by jungle cat and vice versa in both habitats (Figure 4.2). Results showed no strong negative relation that was expected if the hypothesis was true.

Table 4.3 : Seasonal variation in grass attributes among various habitats.

Variables	Habitat								
	Open scrub		Dense scrub		Grassland		Mosaic		Hill forest
	Winter (n = 33)	Summer (n = 10)	Winter (n =30)	Summer (n = 10)	Winter (n = 10)	Summer (n = 20)	Winter (n = 10)	Summer (n =10)	Summer (n =8)
Grass height	< 5.0 cm.	< 5.0 cm.	25 ± 3.17 (18.5 - 31.4)	53.5 ± 12.6 (24.9 - 82.0)	111.0 ± 7.81 (93.3 - 128.6)	75.0 ± 7.3 (59.7 - 90.2)	5.5 ± 0.5 (4.3 - 6.6)	5.5 ± 0 (5.0 - 5.0)	50.0 ± 10.0 (6.9 - 93.0)
% Grass cover	56.8 ± 2.67 (51.3 - 62.2)	29.0 ± 4.27 (19.3 - 38.6)	58.8 ± 3.4 (51.8 - 65.7)	38.0 ± 7.42 (21.2 - 54.7)	63.0 ± 7.42 (46.2 - 79.7)	53.2 ± 4.04 (44.7 - 61.7)	27.0 ± 6.51 (12.3 - 41.7)	24.5 ± 7.36 (7.8 - 41.1)	4.3 ± 3.05 (-2.8 - 11.5)
% Green grass	21.52 ± 3.62 (14.1 - 28.9)	67.0 ± 7.12 (50.9 - 83.1)	20.5 ± 3.62 (13.7 - 27.8)	4.5 ± 0.9 (2.4 - 6.5)	12.5 ± 6.55 (-2.3 - 27.3)	7.0 ± 3.54 (-0.4 - 14.4)	79.5 ± 10.5 (55.7 - 103.2)	87.0 ± 3.59 (78.8 - 95.1)	0

(Values in parentheses are 95% CI's)

Table 4.4 : Visitations to track plots by jungle cat and jackal in winter and summer in the various habitats

Variables	Habitat							
	Open scrub		Dense scrub		Grassland		Mosaic	Hill forest
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Winter
Jackal	32.2 ± 5.5 (20.6 - 43.8)	13.5 ± 3.5 (6.1 - 20.9)	10.3 ± 2.8 (4.2 - 16.3)	10.0 ± 4.4 (0.2 - 18.7)	4.0 ± 3.0 (-2.9 - 10.9)	4.0 ± 2.6 (-2.0 - 10.0)	22.8 ± 4.0 (13.9 - 31.6)	0.4 ± 0.48 (-0.49 - 1.4)
Jungle cat	8.1 ± 2.3 (3.2 - 13.0)	4.98 ± 2.1 (0.5 -9.4)	20.4 ± 4.0 (11.9 - 28.9)	7.7 ± 2.9 (1.0 - 13.2)	3.0 ± 1.5 (-0.4 - 6.4)	4.0 ± 2.6 (-2.0 - 10.0)	5.49 ± 1.6 (2.0 - 8.9)	6.1 ± 2.2 (1.7 - 10.6)

(Values in parentheses are 95% CI's)

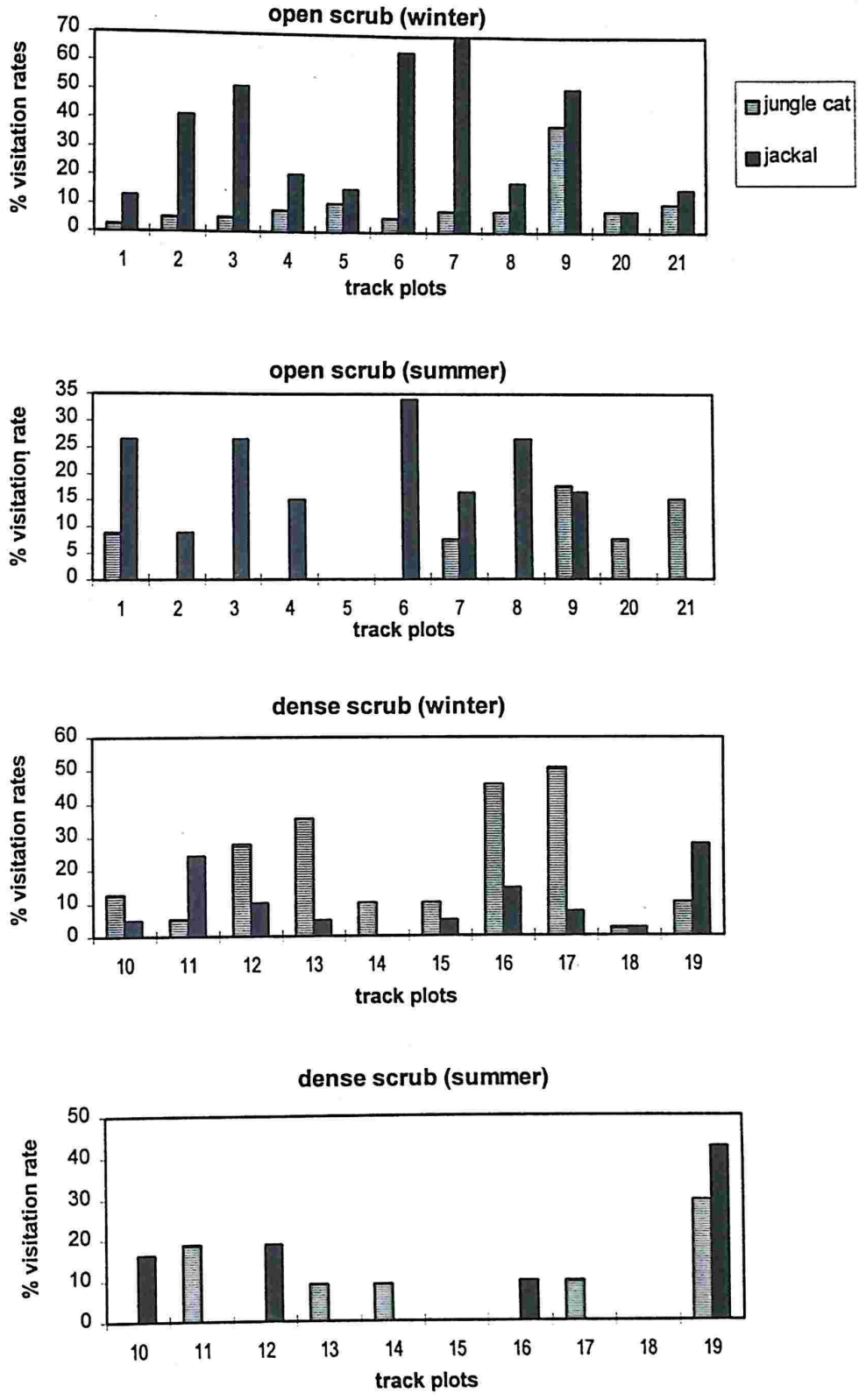


Figure 4.1: Visitation to track plots by jungle cat and jackal.

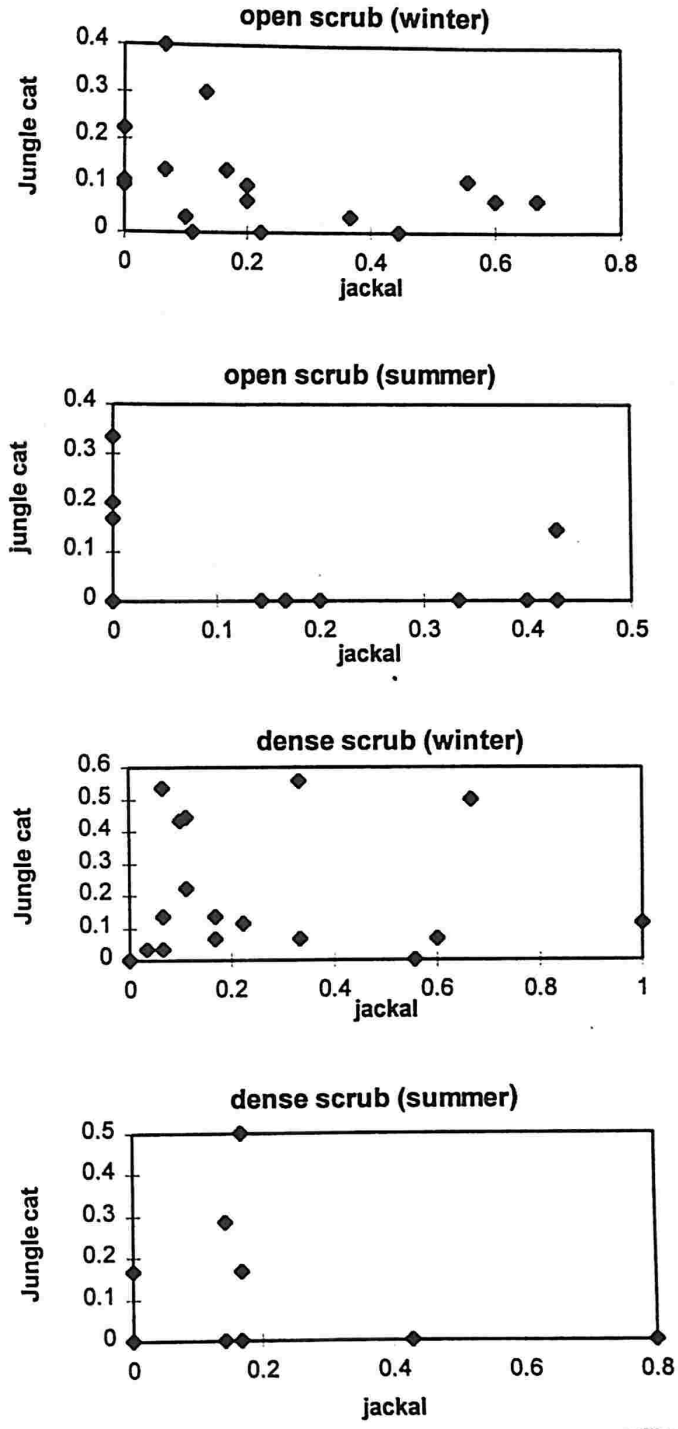
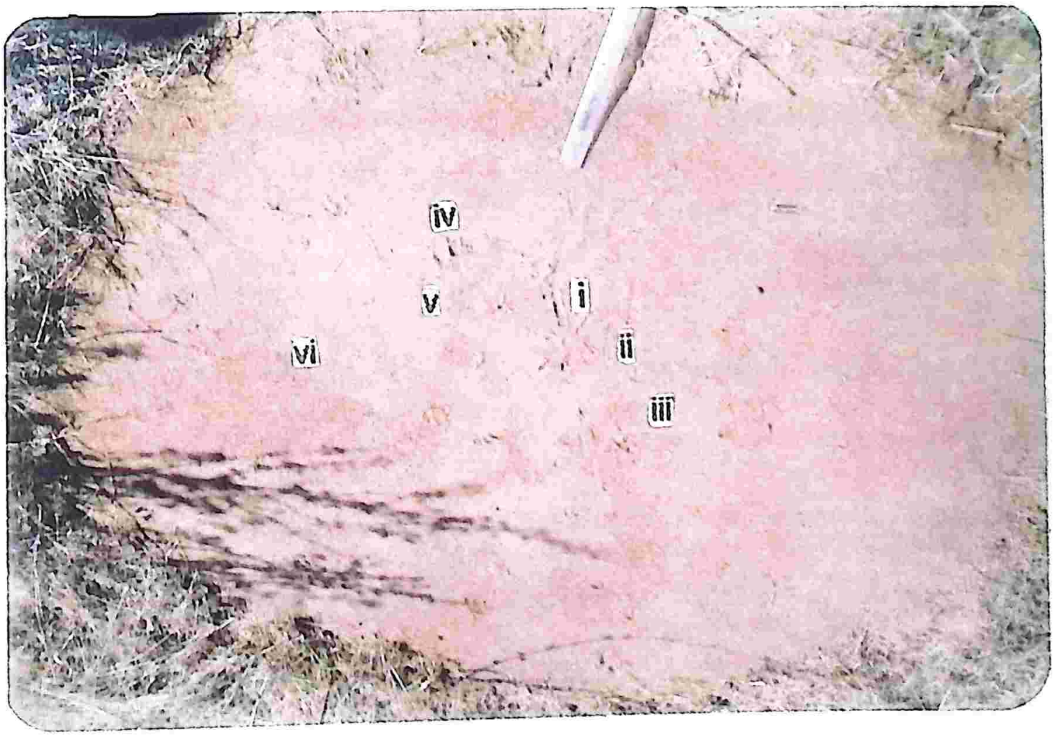


Figure 4.2: Relationship between jungle cat and jackal in visitation to track plots

PLATE 5

a. Track plot.



b. Tracks of (i) peafowl, (ii) partridge, (iii). small birds, (iv) wild ungulates (v) jungle cat and (vi) impression of jungle cat resting.

4.4.2.2 Direct Methods:

Results have been expressed as encounter rates (E.R.) of animals per kilometre (Figure 4.3). In winter jackal was encountered most often in the open scrub (mean = 0.05/km ± 0.005) and mosaic (mean = 0.048 ± 0.008). Dense scrub and grassland had mean encounters of 0.03 ± 0.004 and 0.019 ± 0.003 respectively. No jackal was encountered in the hill forest. Encounter rates of jungle cat in winter were quite similar for all habitats with dense scrub showing the highest mean of 0.018/km ± 0.003, followed by open scrub (mean = 0.016/km ± 0.003), mosaic (mean = 0.0127/km ± 0.003), grassland (mean = 0.0123/km ± 0.001) and hill forest (mean = 0.001/km ± 0.001).

In summer, E.R. for jackal was more varied across habitats than in winter. The trend was the same as in winter. Open scrub still had the highest E.R. (mean = 0.07/km ± 0.013) and was much higher than for the other habitats. Dense scrub and mosaic had similar E.R.'s for jackal with means of 0.022/km ± 0.005 and 0.02/km ± 0.013 respectively. Grassland had the lowest E.R. with a mean of 0.014/km ± 0.002. The trend for jungle cat in summer was different from winter although as in winter E.R.'s did not vary much between habitats. E.R.'s for jungle cat was maximum in grassland which had a mean of 0.029/km ± 0.005. This was followed by open scrub which had a mean E.R. of 0.027 ± 0.003. Dense scrub had mean E.R of 0.022/km ± 0.005 and mosaic had a mean of 0.013/km. ± 0.004. In summer there were no encounters of either jungle cat or jackal in the hill forest but in the other habitats there were more encounters in this season with jungle cats than in winter. For jackal this was true only in the open scrub. All other habitats showed lower encounters with jackal in summer as compared to winter.

Despite the effort, direct encounters with caracal were extremely rare. Three sightings were made in the open scrub and one in grassland.

4.4.2.3 Comparison of different methods for obtaining direct sightings:

A comparison of the different methods used for obtaining direct sightings showed that vehicle drives on main roads and dirt tracks had lowest variation (Table 4.5). This meant that drives on main roads were more reliable than other methods such as foot transects. Although the latter showed relatively higher E.R. than vehicle drive counts, for both predators during both seasons, the result was based on very few sightings. The effort required to obtain substantial numbers of sightings of rarer animals such as the jungle cat was absurdly high for walks. In some areas such as mosaic and grassland, drives on main roads was the only method through which sightings of jungle cat was obtained. However, in the hill forest there was no metal road traversing through the habitat and so this method could not be used there. Apart form showing least variation, drives also enabled analysis of temporal differences in activity of the two predators. This was because it was possible to use this method after dark which was not possible for foot transects and other walks.

4.4.2.4 Comparison of direct (sightings) and indirect methods (track plots):

Jungle cat: In winter the correlation between visitation rate and encounter rate for jungle cat was strong (Figure 4.4). In summer sample size was small but a strong negative correlation was observed between direct sightings and track plot indices (r_s = -1.0 p = 0.000).

Jackal: For jackal, in winter and in summer there was a strong correlation between the two methods (r_s = 1.0, p = 0.000) (Figure 4.4).

Caracal: Both methods indicated rarity of caracal and both methods showed use of open scrub by caracal.

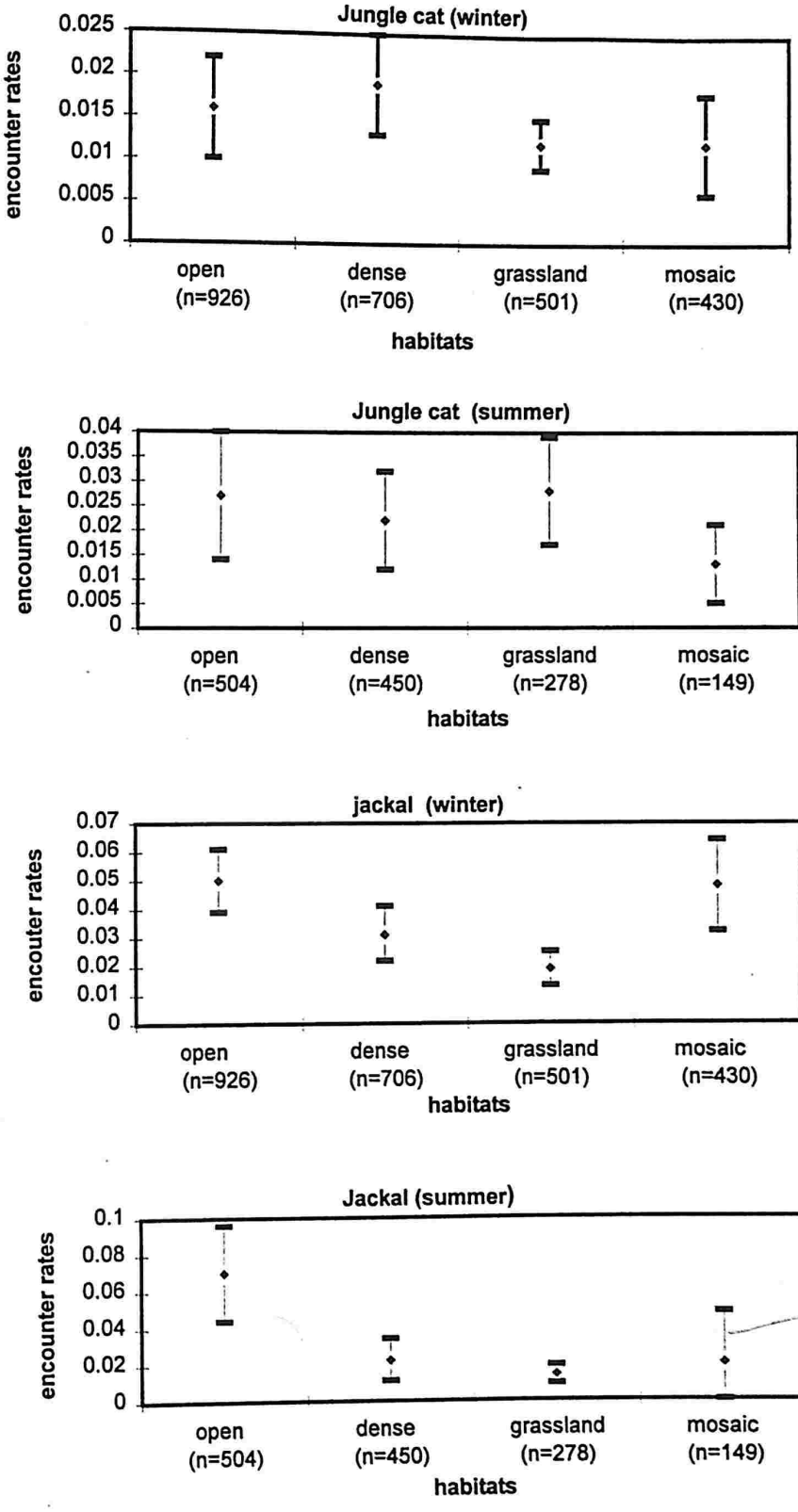


Figure 4.3: Encounter rates (number of individuals/km) of jackal and jungle cat during summer and winter (n = km. travelled).

Table 4.5: Comparison of methods for obtaining direct sightings of predators in the open and dense scrub.

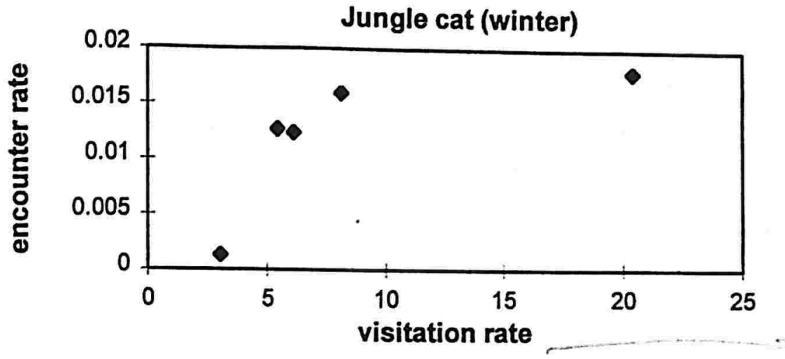
Winter

Habitat	Method	Distance travelled (km.)	Jungle cat	Jackal
Open scrub	VDMR	574	0.009 ± 0.002 (0.005 - 0.013)	0.043 ± 0.005 (- 0.054 - 0.032)
	VDDR	259	0.023 ± 0.008 (0.007 - 0.039)	0.039 ± 0.006 (- 0.052 - 0.026)
	FT	25	0.08 ± 0.05 (- 0.034 - 0.194)	0.14 ± 0.089 (- 0.04 - 0.32)
	FMR	13	0.05 ± 0.03 (- 0.024 - 0.126)	0.076 ± 0.076 (- 0.091 - 0.243)
	FDR	45	0.02 ± 0.01 (- 0.001 - 0.045)	0.126 ± 0.049 (0.027 - 0.225)
Dense scrub	VDMR	491	0.018 ± 0.018 (0.01 - 0.026)	0.03 ± 0.006 (0.022 - 0.044)
	VDDR	176	0.025 ± 0.006 (0.012 - 0.038)	0.02 ± 0.006 (0.008 - 0.032)
	FT	6	0	0
	FMR	5	0	0
	FDR	21	0	0.03 ± 0.03 (- 0.035 - 0.097)

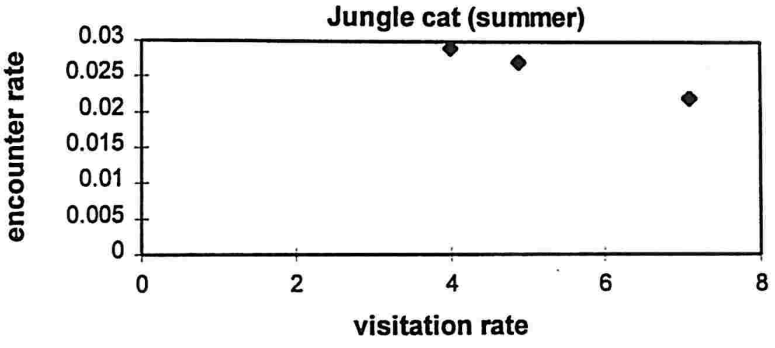
Summer

Habitat	Method	Distance travelled (km.)	Jungle cat	Jackal
Open scrub	VDMR	388	0.016 ± 0.005 (0.005 - 0.027)	0.027 ± 0.005 (0.016 - 0.038)
	VDDR	63	0.046 ± 0.019 (0.008 - 0.084)	0.10 ± 0.029 (0.043 - 0.161)
	FT	31	0.048 ± 0.035 (- 0.024 - 0.12)	0.37 ± 0.126 (0.111 - 0.629)
	FMR	1	0	0
	FDR	10	0	0.16 ± 0.113 (- 0.091 - 0.423)
Dense scrub	VDMR	371	0.024 ± 0.005 (0.014 - 0.034)	0.014 ± 0.004 (0.006 - 0.022)
	VDDR	58	0.004 ± 0.004 (- 0.004 - 0.012)	0.03 ± 0.018 (- 0.007 - 0.067)
	FT	15	0.066 ± 0.066 (- 0.076 - 0.208)	0
	FDR	3	0	0.33 ± 0.33 (- 1.1 - 1.76)

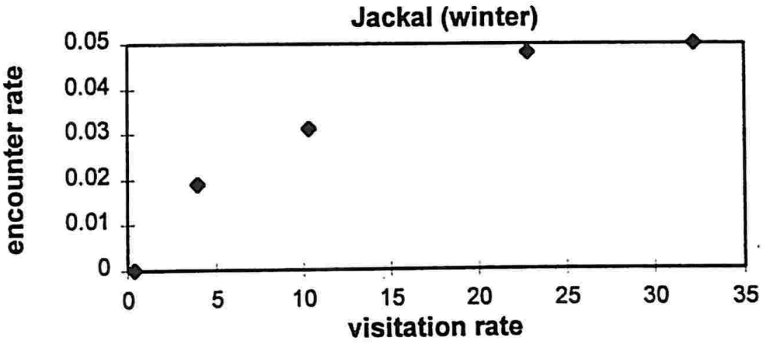
VDMR = Vehicle Drive Main road, DR = Dirt road, FT = Foot Transect, FMR = Foot Main Road, FDR = Foot Dirt road.
(Values in parentheses are 95% C.I.)



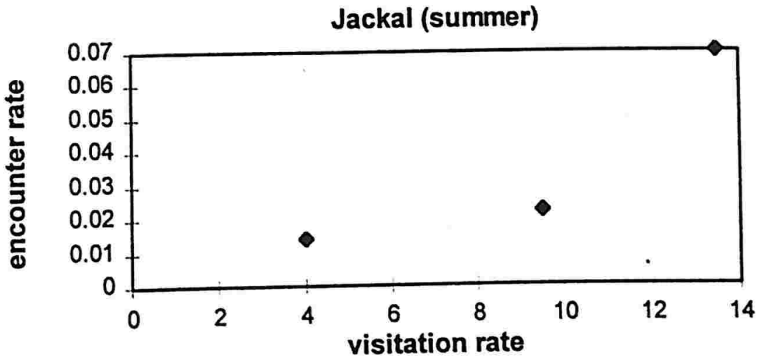
$r_s = 0.90$
$p = 0.04$



$r_s = -1.0$
$p = 0.000$



$r_s = 1.0$
$p = 0.000$



$r_s = 1.0$
$p = 0.000$

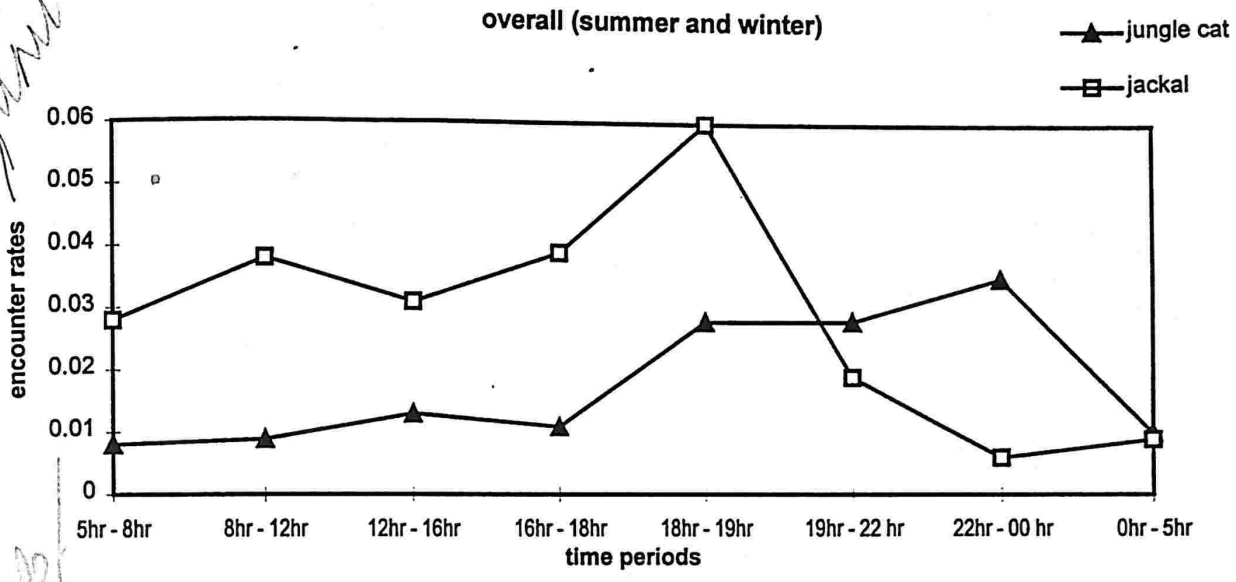
Figure 4.4: Relationship between visitation rates to track plots and encounter rates of the two predators in winter and summer.

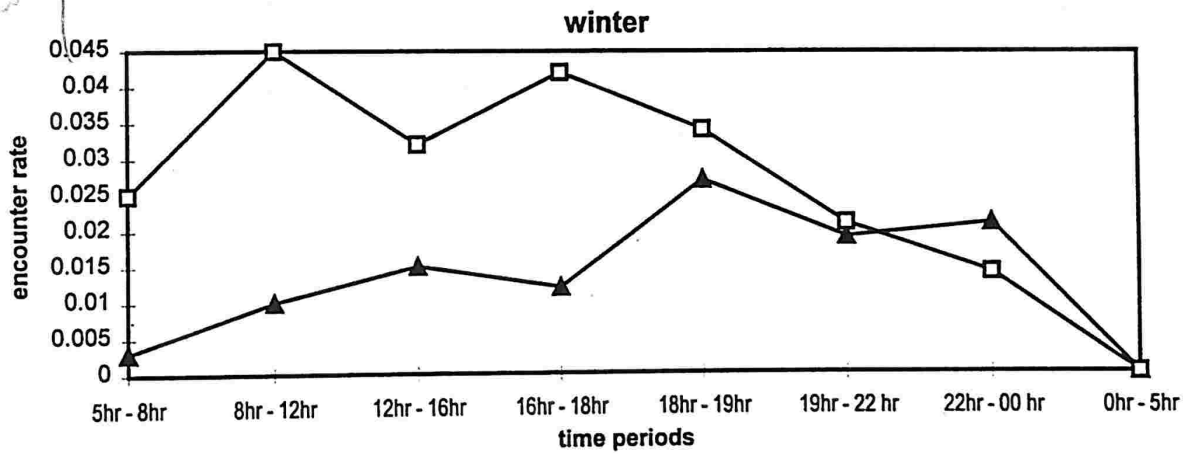
4.4.2.5 Time of sightings:

Time of sightings was considered to be indicative of activity unless the animals were actually seen resting. Overall, results (Figure 4.5) supported part of the hypotheses that jungle cat is nocturnal. Jackal was cathemeral in some habitats (dense scrub and grassland) tending to be more crepuscular in open scrub and diurnal in open scrub and mosaic. Both predators showed high crepuscular activity but jungle cat tended to be more nocturnal while jackal was more diurnal. However a more detailed look at the results shows that time of activity changes with seasons and habitat (Figure 4.6). In winter jungle cat was mostly crepuscular with sightings reaching a peak between 18:00 hrs. and 19:00 hrs. (0.027/km.) and a slightly lowered peak at night between 22:00 hrs. and 00:00 hrs. (0.021/km.). Daytime sightings were relatively low not going above 0.015/km. Jackals showed high diurnal activity in winter with maximum sightings (0.045/km.) obtained during 08:00 hrs. and 12:00 hrs. and a second peak between 16:00 hrs and 18:00 hrs. (0.042/km.). Crepuscular activity was also high with a rate of 0.034/km. After this sightings of jackal fell indicating a fall in activity level. In summer both predators showed reduced diurnal activity. Jungle cat activity increased after 18:30 hrs and reached a peak (0.04/km.) between 22:00 hrs and 00:00 hrs. Jackals were mostly crepuscular during summer with a sighting rate of 0.055/km.

Why no statistical test? most of the above are sample variation?

P. 51 to 49





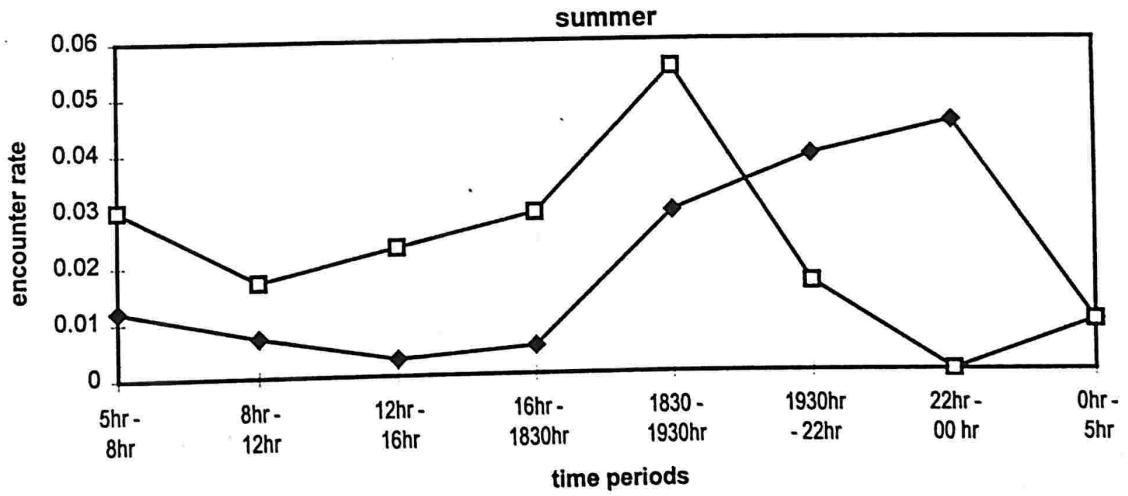


Figure 4.5: Variations in daily sightings of jungle cat and jackal.

A comparison between habitats (Figure 4.6) shows that in winter jungle cats were relatively more nocturnal in open scrub and mosaic whereas in the other habitats they tended to be more crepuscular. This was most noticeable in the dense scrub. In summer nocturnal activity increased in the dense scrub and grassland, it being more conspicuous in the latter. Crepuscular activity in open scrub was higher in summer than in winter. Mosaic remained the same except for the absence of daytime sightings in summer. Jackals tended to be more crepuscular in the open scrub during both seasons. During winter they were mostly diurnal in mosaic and open scrub whereas in dense scrub and grassland they tended to be cathemeral. Crepuscular activity increased in the dense scrub during summer while they remained cathemeral in grassland. Diurnal activity was reduced during summer in mosaic and jackals tended to be cathemeral here. Maximum diurnal activity for jackals in summer was seen in the open scrub.

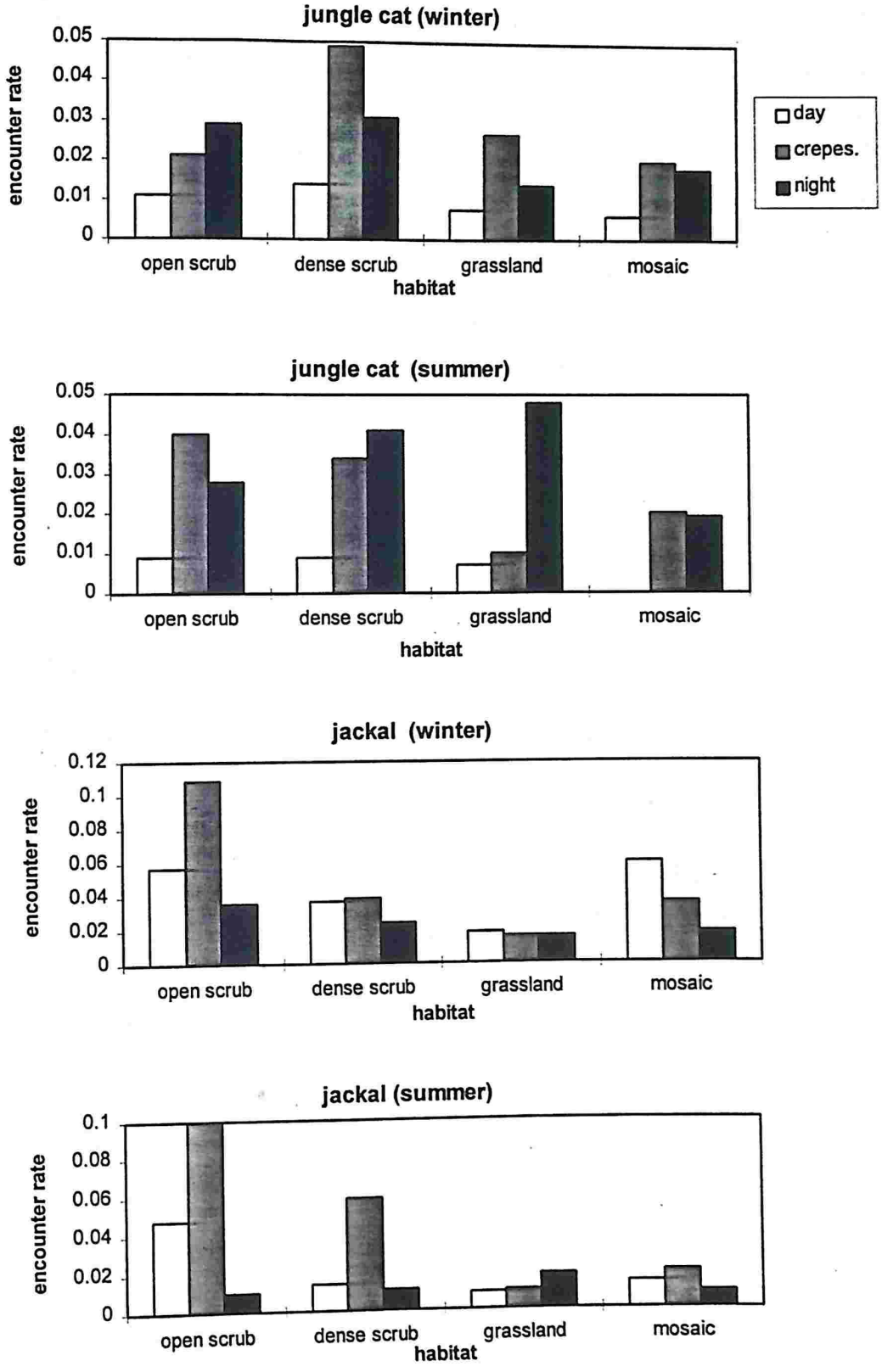


Figure 4.6: Variations in daily encounter rate of jungle cat and jackal in different habitats.

4.4.3 Abundance of Prey species

4.4.3.1 Indirect methods

(1) Track plots:

Peafowl: In winter peafowl abundance was highest in mosaic which had mean visitation of 70% ± 4.6. The other habitats had very similar visitations, open scrub with a mean of 47% ± 4.3, dense scrub had a mean of 42% ± 7.0 and grassland had 41% ± 5.6 (Table 4.6). Hill forest had a relatively low abundance with 5.7% ± 2.0. Mosaic had significantly higher peafowl abundance than all other habitats (mosaic vs. open scrub: $U = 49$, $p < 0.001$; mosaic vs. dense scrub: $U = 56$, $p < 0.01$; mosaic vs. grassland: $U = 11$, $p < 0.001$ and mosaic vs. hill forest: $U = 3$, $p < 0.001$). No significant difference was recorded between open scrub and dense scrub, though both the scrublands had significantly higher peafowl visits to track plots than hill forests (dense scrub vs. hill forest: $U = 111.5$, $p < 0.001$ and open scrub vs. hill forest: $U = 54.5$, $p < 0.001$). There was no significant difference between either of the scrublands and grassland.

Partridge: In winter partridge abundance was highest in the open scrub (mean = 68% ± 5.0) (Table 4.6). Open scrub had significantly higher abundance of partridge than dense scrub ($U = 141.5$, $p < 0.05$) which had a mean of 49.7% ± 6.8 and grassland ($U = 42$, $p < 0.005$) with a mean of 34% ± 9.2. Dense scrub did not show a significant difference with grassland or mosaic (mean 47.2% ± 8.0). Hill forest had the lowest abundance with a mean of 11.4% ± 2.9 and this was significantly different from the rest (hill forest vs. open scrub: $U = 57$, $p < 0.001$; hill forest vs. dense scrub: $U = 117$, $p < 0.001$; hill forest vs. grassland: $U = 94$, $p < 0.005$ and hill forest vs. mosaic: $U = 71$, $p < 0.001$).

Small birds: During winter, open scrub, dense scrub and grassland had high abundance of small birds with means of 60% ± 4.3, 59.8% ± 8.2 and 59.6% ± 4.2 respectively (Table 4.6).

Mosaic had a mean of 45% ± 8.6. There was no significant difference in small bird abundance between any of these four habitats (open scrub, dense scrub, grassland and mosaic). Hill forest had the lowest abundance of small birds and this was significantly different from open scrub ($U = 244.5$, $p < 0.005$), dense scrub ($U = 247.5$, $p < 0.01$) and mosaic ($U = 121$, $p < 0.005$).

In summer visitations to track plots remained similar for birds belonging to all three body size classes across the various habitats and there was no significant difference in bird abundance between habitats. A comparison between seasons showed that in open scrub, there were significantly ($U = 150$, $p < 0.05$) more visitations to track plots by partridges in winter than in summer, whereas in grassland there were more visitations by partridges ($U = 23$, $p < 0.05$) and small birds ($U = 23.5$, $p < 0.05$) in summer than in winter.

Rodents (Sciurids and Murids): In winter, mosaic had the highest abundance of rodents (mean = 33.2% ± 5.2), followed by dense scrub (mean = 20.8% ± 4.4) (Table 4.6). Open scrub with a mean of 19.7% ± 4.0, was similar to dense scrub and there was no significant difference between the two. Both open and dense scrub differed significantly from mosaic (mosaic vs. open scrub: $U = 78$, $p < 0.05$ and mosaic vs. dense scrub: $U = 77$, $p < 0.05$). Open scrub and mosaic had significantly higher rodent abundance than hill forest (mean = 9% ± 2.4) (open scrub vs. hill forest: $U = 229$, $p < 0.001$ and mosaic vs. hill forest: $U = 69$, $p < 0.001$) and grassland (mean = 6% ± 4) (open scrub vs. grassland: $U = 41.5$, $p < 0.005$ and mosaic vs. grassland: $U = 11$, $p < 0.001$). Dense scrub showed a significant difference ($U = 213$, $p < 0.001$) with hill forest but did not show a difference when compared to grassland. Rodents showed a seasonal difference in the open scrub ($U = 173$, $p < 0.1$) and were more abundant in summer than in winter.

Hare: In winter open scrub (mean = 22.8% ± 3.9) had significantly higher hare abundance than all other habitats though the degree to which it differed varied (Table 4.6). Mosaic and dense scrub followed open scrub and had means of 7.4% ± 1.5 and 7.7% ± 3.2 and there was no significant difference between the two. The difference between open scrub and mosaic was significant at $p < 0.05$ ($U = 79$) and open scrub and dense scrub at $p < 0.005$ ($U = 107.5$). Open scrub differed maximally from grassland and hill forest ($U = 222$, $p < 0.001$) which had mean visitations of 2% ± 1.3 and 9% ± 2.9 respectively. Dense scrub did not differ significantly from grassland and hill forest. There was no significant difference in hare abundance between open scrub and dense scrub. In grassland there were no visitations by hare to any of the track plots in summer.

(2) Burrow count: In the 30 x 30m plot count for burrows number of burrows found were : open scrub = 5 burrows ; dense scrub = 14 burrows ; grassland = 18 burrows, hill forest = 13 burrows and mosaic = 7 burrows. Open scrub and mosaic had only *M. platythrix* burrows whereas dense scrub had *T. indica* and *M. platythrix* burrows. Grassland had burrows of *T. indica*.

3) Bushes with burrows: Although mosaic had the highest mean number of bushes in 10m radius plots (mean = 9.9 ± 2.7), the number of bushes having burrows was very low (mean = 0.1 ± 0.1) (Table 4.7). Dense scrub had the highest number of bushes that had burrows (mean = 2.0 ± 0.42) and had a mean of 4.5 bushes (± 0.34) per plot. Open scrub had a mean of 2.4 bushes per plot (± 0.76) and the mean number of bushes having burrows were 1.0 ± 0.44. Grassland had a mean of 0.6 ± 0.26 bushes having burrows . The mean number of bushes in this habitat was 1.2 ± 0.38. Overall dense scrub and grassland had the highest percentage of bushes having burrows with 44.4% and 50% of bushes containing burrows in these habitats

respectively. 41.6% of bushes in the open scrub had burrows and in mosaic only 1% bushes had burrows (Table 4.7).

4.4.3.2 Direct methods

Foot transects: As mentioned in section 4.3.2.2 there were adequate replicates in only some habitats for the two seasons and only these will be compared statistically. In winter these habitats were open scrub, dense scrub and mosaic whereas in summer they were open scrub and dense scrub.

The two - tailed Man Whitney U test results show that in winter there were significantly more peafowl in mosaic (mean = 1.4/km $\pm$ 0.31) than in open scrub (mean = 0.12/km. $\pm$ 0.027) ($U = 0$, $p < 0.001$) and dense scrub (mean = 0.16/km $\pm$ 0.07) ($U = 0$, $p < 0.005$) (Figure 4.7). There was no significant difference between open scrub and dense scrub in peafowl abundance (Figure 4.7). No other group of prey showed any difference across the various habitats in winter. There were no hare sightings in dense scrub in winter (Figure 4.7). In summer open scrub (mean = 0.08/km. $\pm$ 0.02) had a significantly ($U = 32$, $p < 0.05$) higher abundance of hare than dense scrub which had a mean of 0.02/km. $\pm$ 0.01. No difference was seen between habitats for any other prey in this season (Figure 4.7). There were significantly more hare ($U = 47$, $p < 0.05$), peafowl ($U = 12$, $p < 0.001$) and partridges ($U = 35$, $p < 0.01$) during winter than in summer in the open scrub. There was no seasonal difference in prey abundance in the dense scrub (Figure 4.7).

K-W test - 15

Table 4.6: Abundance of prey from track plot data → give more what are the numbers?

Variables	Habitat							
	Open scrub		Dense scrub		Grassland		Mosaic	Hill forest
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Winter
Peafowl	47.0 ± 4.3 (37.9 - 56.1)	46.21 ± 5.5 (34.7 - 57.7)	42.7 ± 7.0 (27.9 - 57.6)	46.3 ± 8.1 (29.3 - 63.2)	41.0 ± 5.6 (28.1 - 53.8)	36.0 ± 9.8 (13.8 - 58.1)	70.6 ± 4.6 (60.5 - 80.6)	5.7 ± 2.0 (1.5 - 9.9)
Partridge	68.0 ± 5.0 (57.4 - 78.6)	54.7 ± 3.9 (46.5 - 62.9)	49.78 ± 6.8 (35.5 -64.0)	63.0 ± 7.7 (46.6 - 79.3)	34.0 ± 9.2 (13.1 - 54.8)	66.0 ± 9.4 (44.6 - 87.3)	47.2 ± 8.0 (29.8 - 64.6)	11.4 ± 2.9 (5.5 - 17.2)
Small birds	60.6 ± 5.9 (48.2 - 72.9)	67.6 ± 4.3 (58.7 - 76.5)	59.8 ± 8.2 (42.5 - 77.0)	75.6 ± 7.7 (59.4 - 91.9)	45.0 ± 8.6 (25.5 - 64.4)	68.0 ± 7.4 (51.2 - 84.7)	59.6 ± 4.2 (50.3 - 68.9)	33.3 ± 4.4 (24.4 - 42.2)
Rodents (Sciurids)	19.7 ± 4.0 (11.3 - 28.0)	25.7 ± 3.7 (17.8 - 33.6)	20.8 ± 4.4 (11.6 - 30.1)	29.5 ± 6.5 (15.8 - 43.1)	6.0 ± 4.0 (-3.0 - 15.0)	16.0 ± 11.0 (-9.0 - 41.0)	33.2 ± 5.2 (21.7 - 44.7)	9.0 ± 2.4 (4.0 - 14.0)
Hare	22.8 ± 3.9 (14.5 - 31.0)	17.2 ± 4.6 (7.4 - 26.9)	7.7 ± 3.2 (0.9 - 14.5)	13.7 ± 3.0 (3.7 - 16.6)	2.0 ± 1.3 (-1.2 - 5.0)	0	7.4 ± 1.5 (3.9 - 10.8)	9.5 ± 2.9 (3.1 - 14.9)

(Values in parentheses are 95% CI's)

Table 4.7 : Number of bushes and percentage of bushes having rodent burrows in various habitats

Variables	Habitat			
	Open scrub	Dense scrub	Grassland	Mosaic
Number of bushes (a)	2.4 ± 0.76 (0.68 - 4.12)	4.5 ± 0.34 (3.73 - 5.27)	1.2 ± 0.38 (0.4 - 2.0)	9.9 ± 2.7 (3.76 - 16.04)
Bushes with burrows (b)	1 ± 0.44 (-0.01 - 2.01)	2 .0 ± 0.42 (1.05 - 2.95)	0.6 ± 0.26 (0 - 1.2)	0.1 ± 0.1 (0 - 0.2)
a/b x 100	41.6	44.4	50	1.01

(Values in parentheses are 95% CI's)

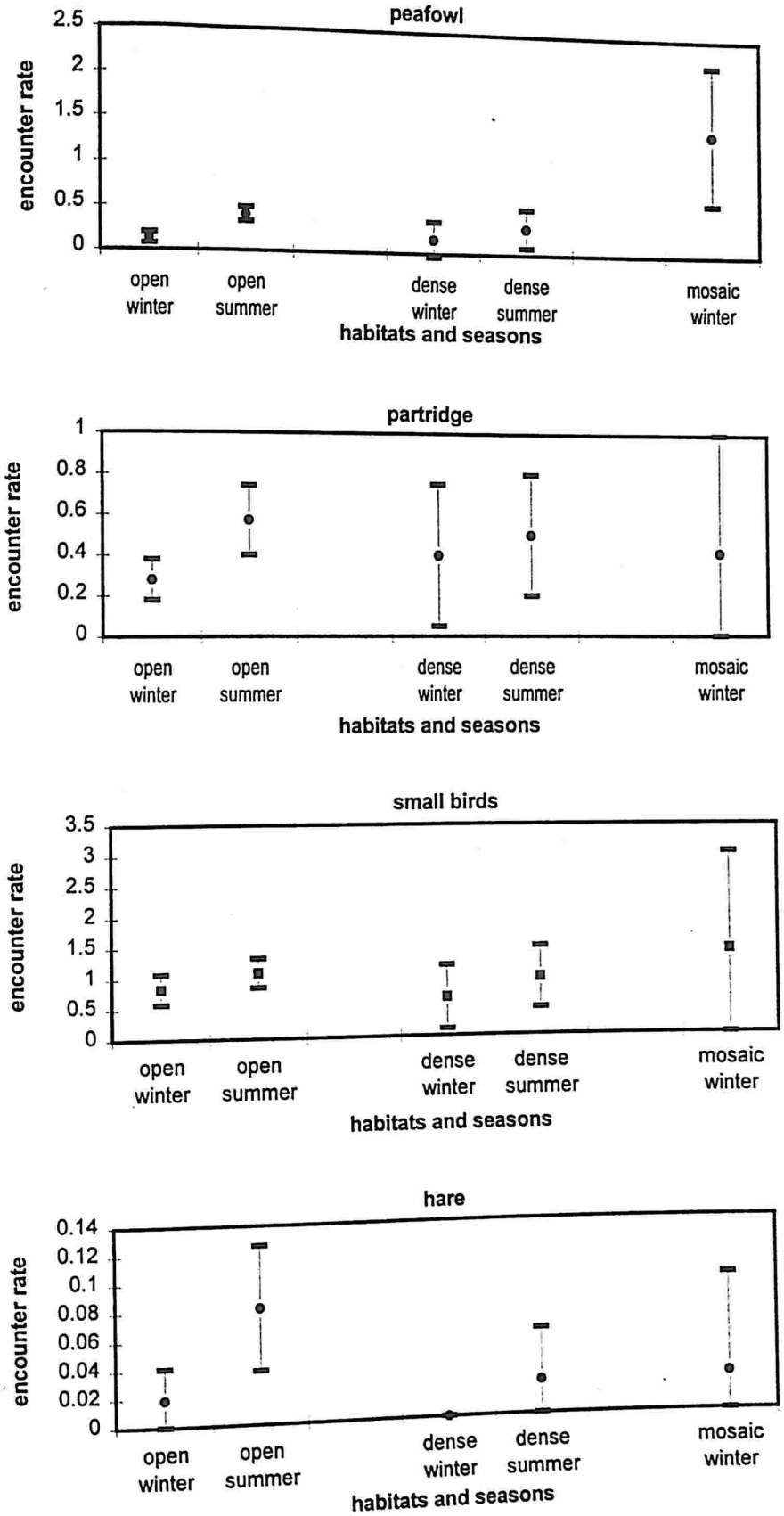


Figure 4.7: Encounter rate of peafowl, partridge, small birds and hare in various habitats. (means plotted with 95% C.I.)

Capture of rodents: Four rodent species belonging to family Muridae (Plate 7) were identified from the five habitats. These were: *Mus platythrix* from open scrub, dense scrub, mosaic and hill forest; *Tatera indica* from dense scrub and grassland ; *Golunda ellioti* from grassland and *Rattus gleadowi* from hill forest. Generally trapping success was low. In a total of 9,500 trap nights for two seasons in all habitats, 84 animals were caught (0.9% trapping success) (Table 4.8). Table 4.8 summarises capture success of each rodent species in various habitats. Overall *T. indica* was the most abundant rodent forming 70% of the total captures. Percent occurrence for *M. platythrix* was 26%, *G. ellioti* 2.3% and for one individual of *R. gleadowi* 1.1%. *T. indica* was captured only from dense scrub and grassland and its overall percent occurrence was 48% and 52% in these habitats respectively. *M. platythrix* was most abundant in mosaic with 45% of total *M. platythrix* captures in this habitat. The next most important habitat for *M. platythrix* was the dense scrub which had 32% of total captures. Open scrub had 18% of captures for *M. platythrix*. Only 4.5 % of total *M. platythrix* captures were in hill forest. In the open scrub and mosaic this was the only species captured. *G. ellioti* was captured only form grassland.

In dense scrub, during winter *T. indica* (63% occurrence) was more abundant than *M. platythrix* (37%) and total trapping success in this habitat was 2.1%. In hill forests, there was one capture of *M. platythrix* in winter (0.16% trapping success). Two *G. ellioti* were captured in grassland forming only 4% of total captures in this habitat. *T. indica* formed 93% of captures in this habitat in winter. Trapping success in winter for grassland was 1.6%. Trap index in mosaic for winter was 1.1% and in hill forest it was 0.1%. In summer no captures were made in open scrub, dense scrub and mosaic. However, in grassland trapping success was high 3.4% (all *T. indica*) compared to the other habitats. Hill forest had a success of 0.1 % for one capture of *R. gleadowi*. Random trapping had higher success in dense scrub (5.3%) as opposed to

opportunistic trapping (0.5%). For grassland and mosaic opportunistic trapping gave better results (2.3% as opposed to 0.33% for random in grassland and 1.6% in opportunistic and 0 in random for mosaic).

4.4.4 Disturbance from Livestock:

Based on results from track plots, open scrub had the maximum disturbance from livestock in winter and this was significantly higher than dense scrub ($U = 78$, $p < 0.001$), grassland ($U = 10.5$, $p < 0.001$), hill forest ($U = 72.5$, $p < 0.001$) (Table 4.9). Open scrub also differed significantly form mosaic though the difference was lower ($U = 69$, $p < 0.01$) than the other habitats. Mosaic, the next most disturbed habitat was significantly more disturbed than hill forest ($U = 58$, $p < 0.001$) and grassland ($U = 12$, $p < 0.001$), but the degree was slightly lower ($U = 64$, $p < 0.01$) when compared to dense scrub. Dense scrub was significantly more disturbed than hill forest ($U = 240$, $p < 0.005$) and grassland ($U = 49.5$, $p < 0.05$). There was no significant difference in disturbance levels between hill forest and grassland. In summer, again open scrub had the highest level of disturbance and was significantly higher than dense scrub ($U = 60$, $p < 0.001$) and grassland ($U = 70$, $p < 0.05$) (no livestock tracks were recorded in grassland). As mentioned earlier mosaic and hill forest were not monitored during summer. Disturbance was significantly higher in winter than in summer for open scrub ($U = 158.5$, $p < 0.05$) and dense scrub ($U = 115.5$, $p < 0.01$).

Table 4.8: Number and percent trapping success of rodents captured in various habitats in winter and summer .

Rodent sps.	Open scrub		Dense scrub		Grassland		Mosaic		Hill forest	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
T. indica	0	0	12 (1.3%)	0	13 (1.44%)	34 (3.4%)	0	0	0	0
G. ellioiti	0	0	0	0	2 (0.22%)	0	0	0	0	0
M. platythrix	4 (0.44%)	0	7 (0.77%)	0	0	0	10 (1.11%)	0	1 (0.11%)	0
R. gleadowi '	0	0	0	0	0	0	0	0	0	1 (0.1%)

winter n = 900 trap nights, summer n = 1000 trap nights.

Table 4.9: Disturbance due to domestic livestock based on track plot data.

Season	Habitat	Mean (%)
Winter	open scrub	48.6 ± 5.4 (37.3 - 59.8)
	dense scrub	18.7 ± 5.1 (7.9 - 29.5)
	hill forest	7.1 ± 2.0 (3.0 - 11.2)
	mosaic	27.2 ± 3.3 (19.9 - 34.4)
	grassland	5.0 ± 3.0 (-1.9 - 11.9)
Summer	open scrub	33.2 ± 4.1 (24.7 - 41.7)
	dense scrub	6.3 ± 2.4 (11.7 - 11.4)
	grassland	0

(Values in parentheses are 95% CI's)

PLATE 6

Indian gerbil

(*Tatera indica*)

Bush rat
(*Golunda ellioti*)

Spiny tailed mouse
(*Mus platythrix*)

Three rodent species, with upper and lower jaws showing dentition

(scale: 1 unit = 1 millimeter)

4.4.5 Effect of domestic livestock on distribution and abundance of murid rodents:

A negative correlation (r_s = -0.8, p = 0.1) observed between the distribution and abundance of the three murid rodents and level of disturbance from domestic livestock (Figure 4.8). Although abundance of livestock in grassland was lower than dense scrub, rodent abundance was higher in the latter possibly as a result of higher bush cover in the dense scrub.

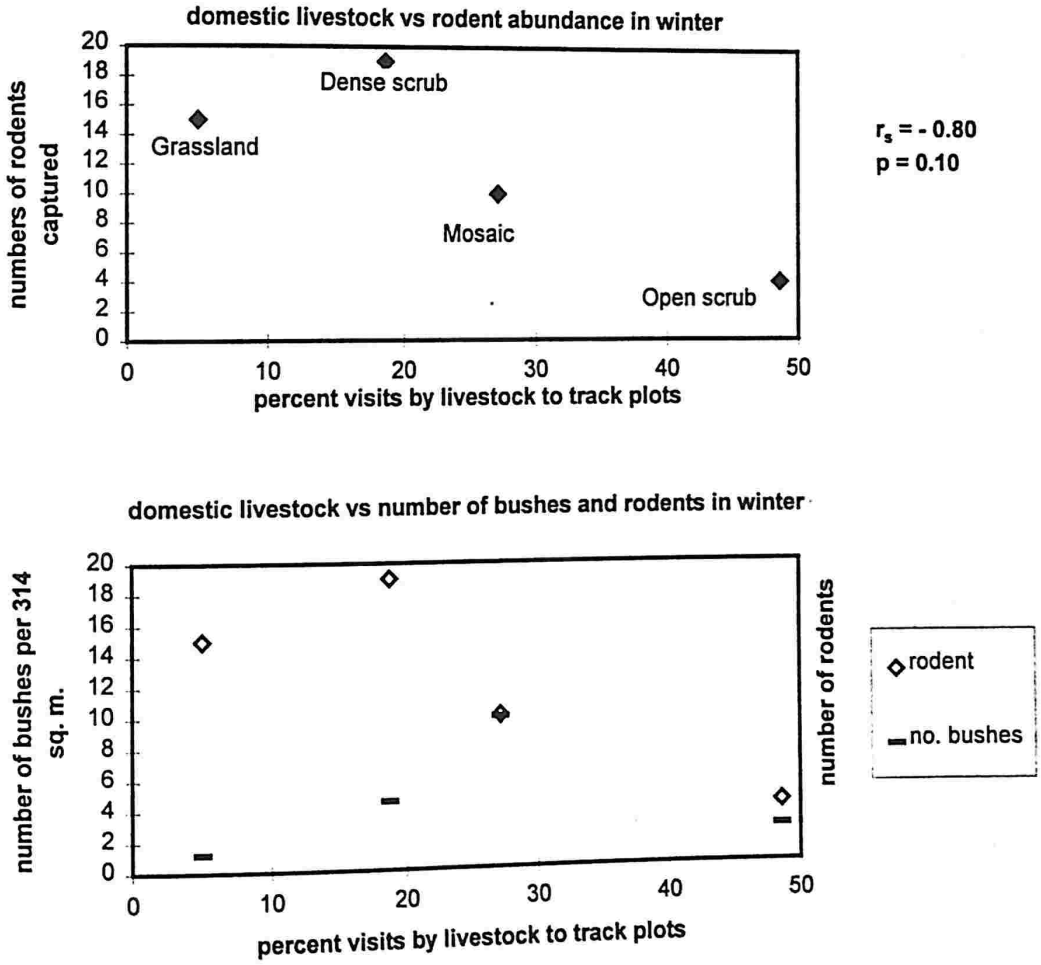


Figure 4.8: Relationship between domestic livestock and rodent abundance.

4.5 Discussion:

4.5.1 Predator abundance:

As expected, visitations and encounter rates for both predators, especially jungle cat, was lower than prey (Table 4.4 and 4.6, Figure 4.3 and 4.7). Jackal was more abundant than jungle cat in open scrub and mosaic (Table 4.4 and Figure 4.3). Higher abundance of jackal as compared to jungle cat was also documented by Sultana and Jaeger (1989) in Bangladesh. This fits the generalisation made by Eisenberg (1986) of canids exceeding felids in numbers, in a given size class. However in grassland jackal and jungle cat abundance was similar whereas in hill forest no jackal was recorded. This suggests that hill forest in STR was a relatively poor habitat for jackal although the Ginsberg and MacDonald (1990) report mentions jackals inhabiting areas upto 2000 m. altitude. The possible reasons for the observation from the present study will be discussed later after discussing prey distribution.

Overall results indicate that the scrublands (open scrub and dense scrub) were important habitats for the two predators (E.R > 0.015/km and visitation > 5% during both seasons). A closer look at jungle cat and jackal distribution in the scrubland (open scrub and dense scrub) reveals that for jungle cat, the ecotone between open and dense scrub was very crucial especially during summer (Figure 4.1). Track plot 9, from the open scrub and plots 19,10 and 11, from the dense scrub were located in this ecotone. Without taking seasons into account, approximately 40% of jungle cat sightings from the open and dense scrub were from this zone. This area was especially crucial during summer when 50% of jungle cat sightings in the scrublands were obtained in this area. Jackal too showed greater use of the ecotone during summer (35% of total summer sightings for scrubland) as compared to winter (18% of total sightings). This result was expected as the area includes a huge water body, the Karnakawas anicut (Figure 2.1).

For jungle cat, in the dense scrub the shift towards the anicut was more pronounced in summer (55%) than in winter (28% sightings). In the open scrub, for both seasons, sightings in the ecotone zone was high (> 35% of total sightings in that habitat, going upto 46% in summer). This shows that jungle cats from open scrub tended to be distributed more towards the convergence zone whereas in the dense scrub they were not only more abundant than in open but also more dispersed. Track plot data (Figure 4.1) also show the same trend when shift in use of area is seen from winter to summer. The relatively more even distribution of jungle cat in dense scrub as compared to the open scrub (most visits on track plot 9) is also clear. It may be inferred from this that dense scrub is a comparably better habitat for the jungle cat than the open scrub. Dense scrub had a higher mean number of bushes per 10 m. radius plot (mean = 4.5/plot $\pm$ 0.34) than open scrub which had a mean of 2.4/per plot $\pm$ 0.76. These bushes provide jungle cats a refuge during the day when they rest and when the disturbance is at its maximum (pers obv). Apart from this dense scrub had three water bodies (excluding the anicut at the convergence zone). In the open scrub all water bodies were either very close (< 500m.) to the main entrance of the Park or close to the village and hence heavily disturbed due to the presence of people and vehicles (Figure 2.1).

The higher use by jungle cat of dense scrub when compared to other habitats in STR is consistent with information available on jungle cat from other areas where dense cover and water are important for deciding its distribution (Nowell and Jackson 1996). The importance of cover has been demonstrated for other savannah cats too (Nowell and Jackson 1996). Studies on bobcats (*Lynx rufus*), Canadian and Iberian lynx (*Lynx canadensis* and *Lynx pardinus*) and ocelots *(Leopardus pardalis)* have shown dense cover to be an important factor in determining choice of habitat in felids (Nellis and Keith 1968 ; Rolley and Warde 1985 ; Koehler and Hornocker 1989 ; Ludlow and Sunquist 1987 ;

Palomares *et al.* 1991, 1996). This need for dense cover has been attributed to the need for suitable resting sites, escape from danger and protection from climatic extremes (Koehler and Hornocker 1989). Others associate felid dependence on cover to their hunting strategy and prey capture success (Kruuk 1986 ; Koehler and Hornocker 1989). It is likely to be a combination of both factors, along with social organisation and other behavioural traits that make cover a crucial factor for felids (Eisenberg 1986). Amount of disturbance and distribution of prey in the different habitats are discussed later. Although results for grassland show a relatively high abundance of jungle cat in summer by direct sightings (Figure 4.3) it could be explained as a problem with the method. This habitat was linear and narrow in shape stretching to 11.5 km. along the paved road, with the greatest width spanning < 500 m. The metal road ran through the centre of the habitat (Figure 2.1). Hence there was a possibility of having more sightings of animals in this habitat due to it being constricted in shape as compared to other habitats, which were more "circular". This effect would be more pronounced in summer due to the distribution of waterholes at the edge of the paved road. The results show the expected trend and sightings of jungle cats on the paved road in summer (mean = 0.03/km. $\pm$ 0.006) were higher than in winter when mean sighting rate on the paved road in this habitat was 0.013/km. $\pm$ 0.002.

Most canid species inhabit relatively open areas which can be attributed to their life history traits like social organisation and other behaviour, as in felids. (Eisenberg 1986). Generally canids are more social than felids and the canid hunting strategy is a social activity unlike that of felids (Fox 1975 ; Kingdon 1989 ; Eisenberg 1986 ; Mohelman 1989 ; Sheldon 1992). Open areas are more favourable for group hunters (Kingdon 1989 ; Eisenberg 1986 ; Mohelman 1989). Although such social hunting was not observed in S.T.R. groups of jackals of 5 to 7 adult individuals were observed in the study area on few occasions (Figure 4.9). These sightings were in the more open areas such as the open

scrub and mosaic. Overall a higher percentage of sightings (55.5%) were of solitary individuals. However solitary jackals were sighted more often In dense scrub and grassland (64% and 67% of total sightings respectively) as compared to open scrub (52%) and mosaic (35%). In the dense scrub and grassland the largest group size observed was of 4 individuals.

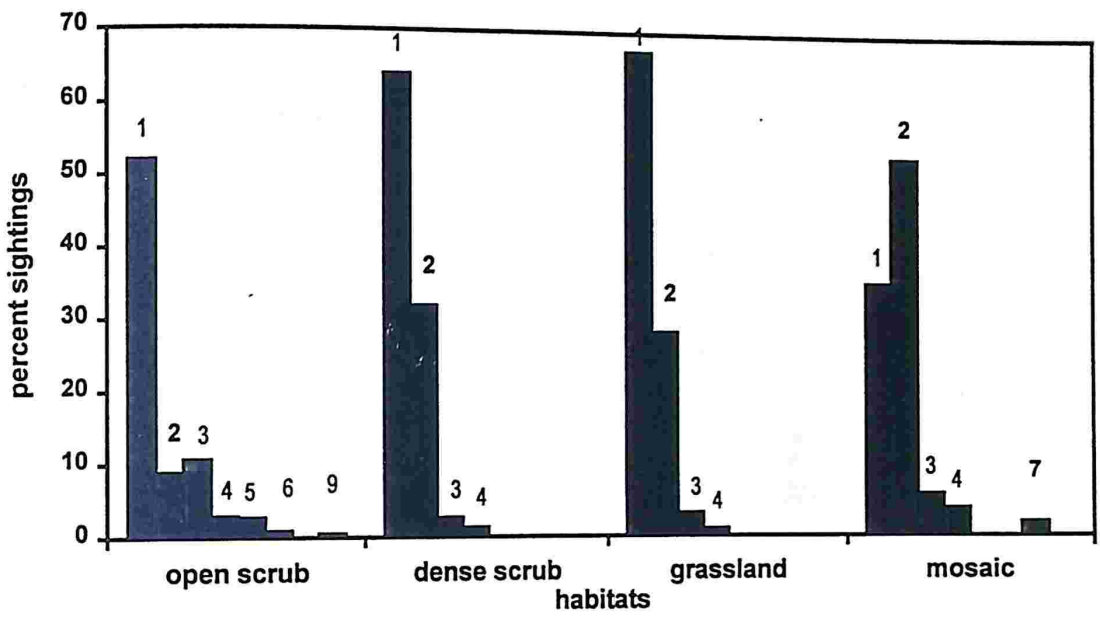


Figure 4.9: Percent sightings of different group sizes of jackals in various habitats.

(Figures above bars indicate group sizes)

Results support the hypotheses that jungle cat is more eclectic in the habitat it inhabits than the jackal. Jackal abundance was relatively high in three habitats (> 10% visitation and E.R. > 0.015/km) viz. open scrub, mosaic and dense scrub whereas the jungle cat was relatively abundant during both seasons only in the dense scrub.

4.5.2 Prey abundance:

In order to answer why the carnivores are more abundant in some habitats, their presence was related to prey abundance, disturbance and structural parameters of the habitat such as cover. It was observed that hill forest had a low abundance of ground birds and rodents when compared to other habitats (Table 4.6, Figure 4.7). Within the remaining

four habitats hare, rodents, peafowl and partridges were more common in areas with low ground cover (open scrub and mosaic) and small birds were equally abundant in all four habitats (Table 4.6, Figure 4.7). The opposite was noted for murid rodents, which were more abundant in areas with higher ground cover and lower disturbance (Figure 4.8). Murid rodents were most abundant in grassland (58% of all rodents captured for both seasons) and dense scrub (22.6% of all captures) (Table 4.8). Since earlier studies as well as an initial survey of food habits from scats from Sariska, have shown rodents to be the major prey of jungle cats and other small cats these will be discussed in detail (Mukherjee 1989 ; Kitchener 1991).

4.5.2.1 Murid rodents:

The murid rodents (Plate 7) belonged to four species *T. indica*, *G. ellioti*, *M. platythrix* and *Rattus gleadowi*. Burrow counts showed that open scrub had only *M. platythrix* burrows whereas dense scrub had *T. indica* and *M. platythrix* burrows and grassland had only *T. indica* burrows. These counts supported capture results form all habitats except hill forest. In the hill forest although there were many burrows capture success was very low. Both methods showed that numbers of murid rodents were higher in dense scrub and grassland when compared to open scrub and mosaic.

A large amount of information is available on structure of rodent communities in savannahs and deserts and several factors that are responsible for structuring rodent communities in these regions have been identified. These factors could be historical (phylogenetic and evolutionary), anthropogenic (changes in habitat of rodents due to changing land use patterns by humans), ecological (vegetation structure, intra and interspecific competition, presence of other animals) or geological (soil type, terrain and altitude) (Delany and Hapold 1979 ; Bowers and Brown 1982 ; Hapold 1983 ; Abramsky

1988 ; Agarwal and Prakash 1992 ; Jain 1992 ; Rana *et al.* 1992 ; Rogovin *et al.* 1994 ; Prakash *et al.* 1995 a, b). Since most of these factors are not totally independent of one another it is very likely that usually a combination of these factors structures communities in any area.

In the present study, there tended to be an inverse relationship between abundance of rodents and domestic livestock (Figure 4.8). Low sample size may be responsible for the relatively low significance. Delany and Hapold (1979) and Hapold (1983) have also reported this negative relationship of rodents with high levels of grazing and trampling in the savannahs of Africa. They attributed low use by rodents of areas frequented by large herbivores, to trampling and grazing by the latter, resulting in lowered food and cover availability to rodents. This study did not support the opinion of Prakash *et al.* (1995 a) that areas heavily grazed by cattle harbour larger numbers of Mus spp. Results from the present study indicate that *M. platythrix* occurs in more open areas that are not heavily used by cattle. The habitat, mosaic, as its name suggests was a mosaic of small patches of woodland and scrub (Plate 4). In winter, during the first session of trapping no captures of any rodent was made. This site was utilised heavily by livestock and people due to its vicinity to a village. The second site for trapping during winter in this habitat was relatively less disturbed by people and cattle, and all the captures of *M. platythrix* for this habitat were made here. This area was a woodland patch with scanty ground cover (Plate 4). Studies have reported *T. indica* as a serious pest in crop fields all across the country. However this species was absent from crop fields surrounding the Park, probably because areas connecting the crop fields to the Park are totally denuded off vegetation and such patches of denuded land were approximately 1 km. long at the shortest distance.

Bowers and Brown (1982) demonstrated the importance of competition in structuring granivore rodent communities in North American desert regions. The lower numbers than

expected of *M. platythrix* form dense scrub could be explained by its preference for open areas and also by the possibility of competition it faces from the more aggressive and prolific *T. indica,* despite the difference in size. However this can only be speculative at this juncture. The same reasoning (that of interspecific competition) can be applied to the low numbers and absence of *G. ellioti* from grassland and dense scrub respectively. From other studies it is noted that, this species which is comparatively mild tempered, is not prolific in other habitats, barring crop fields (Roberts 1977). Jain *et al.* (1992) emphasise the need to cover and hide traps carefully when trapping diurnal species like *G. ellioti* to maximise catches. Table 4.10 gives a descriptive comparison of the habits of the three species of rodents. Despite taking these precautions trapping success for this species was low in this study. This may well reflect the actual low abundance of this species in Sariska. Apart from this, rodents seemed to be clumped in their distribution in the different habitats and the reason for this cannot be fathomed from the resources that were quantified in the present study. Although in dense scrub the areas where traps were placed for different trapping sessions in winter and summer were seemingly alike, trapping success differed markedly (0 - 5.3 %). Moreover, although Jain *et al.* (1992) say that opportunistic trapping by placing traps close to burrows in the case of *T. indica* is more successful, it did not seem to be the case in dense scrub. No rodents were trapped in areas that were sampled opportunistically. However this proved successful in grassland which had an index of 2.3% (2.1% *T. indica* and 0.16% *G. ellioti*) as opposed to 0.33% by random sampling and this was for one capture of *G. ellioti.* No *T. indica* was caught by random sampling in grassland. It is also difficult to explain the difference in trapping success in summer between dense scrub and grassland. Both were done opportunistically and while grassland had a success of 3.4 % , in dense scrub there were no captures. *T. indica* and *M. platythrix* are reported to breed throughout the year whereas *G. ellioti* usually breeds in summer.

An understanding of microhabitat requirements, along with resources at a higher scale would better explain the patterns seen in any habitat (Abramsky 1988 ; Storch 1997). When compared to the number of rodent species documented along the Aravallis (11 species excluding squirrels), Sariska has low abundance and richness of rodent species. However all 11 species were not recorded from a single habitat but were spread throughout the Aravallis. In fact each habitat had between two to four species of rodents and only some crop fields and areas on the western part of the Aravallis had seven species occurring together (Rana *et al.* 1992 .; Prakash *et al.* 1995 a, b). In areas close to Sariska such as Bahratpur and Jaipur only one or two species were documented and in Bharatpur *T. indica* was the predominant rodent (Rana *et al.* 1992). In these habitats however, trapping index was higher than in Sariska. Since the disturbance levels from livestock and the amount of cover available is not known from these areas it is difficult to attribute this difference in trapping index to any factor.

Among the three murid rodents, *G. ellioti* was the only diurnal rodent, the remaining two being strictly nocturnal (Goyal and Ghosh 1992 ; Jain *et al.* 1992).

Table 4.10: Comparison of three murid rodents

Biological and ecological attributes	*T. indica*	*G. ellioti*	*M. platythrix*
*Food and habit	omnivore, gregarious and prolific	herbivore, not gregarious and not very prolific	omnivore, not gregarious and not very prolific
Habitat in STR and Abundance	Dense scrub, grassland High, high	Grassland low	Dense scrub, open scrub and mosaic medium, low, high
Body size	avg. wt. 80 - 100 g.	avg. wt. 50 - 60 g	avg. wt. 15 - 20 g.
*Breeding season	Throughout the year peak in spring and monsoon	Summer months	throughout the year

*(Roberts 1977)

4.5.3 Summary of all factors in different habitats:

For the jungle cat dense scrub not only provides a combination of cover and water with minimum disturbance compared to other habitats, but also more prey. There could be

several reasons why jackals use the disturbed areas more than the relatively undisturbed ones. In case of the dense scrub one reason could be interspecific competition with jungle cats. One personal observation in STR where a jungle cat managed to drive away two jackals from a peafowl road kill supported earlier observations of jungle cats being very aggressive (Prater 1965). Hence they could out-compete jackals by direct interactions in some areas that form good jungle cat habitat. This is speculative and can be tested only through manipulative experiments which was not possible during this study. Studies have shown that jackals are more prolific than jungle cats in most areas (Mukherjee 1989 ; Sultana and Jaeger 1989) and it is possible that jackals simply prefer open areas and are more tolerant of disturbance from humans. A stronger reason for jackals using disturbed and open habitats more could be that being omnivores and scavengers, proximity to villages is more beneficial in terms of locating food such as carcasses of domestic livestock and other refuse (Ginsberg and MacDonald 1990). Other scavengers and omnivores such as hyaena and vultures were also more often found close to villages and were more common in open scrub and mosaic.

Both predators showed high crepuscular activity in all habitats with higher diurnal activity in jackal and greater nocturnal activity by jungle cat. Crepuscular and nocturnal activity increased in summer presumably as a direct outcome of daytime ambient temperature. Ambient temperature in shade during peak summer was often 48° C and sometimes shot upto 50° C. Time of activity varied in different habitats for both predators. For jungle cat, shown to be sensitive to disturbance, activity could be related to level of disturbance and in more disturbed areas nocturnal activity can be expected to be higher (Eisenberg 1986 ; Kitchener 1991 ; Nowell and Jackson 1996). The same explanation could be given for seasonal change in crepuscular and nocturnal activity. In winter, disturbance is higher especially in the open scrub and crepuscular activity of jungle cat is also reduced as

compared to nocturnal activity. In summer, when disturbance is lower, crepuscular activity increases. Crepuscular to nocturnal activity with very little diurnal activity is documented for most cats (Anderson 1990 ; Kitchener 1991). Time of activity of prey could also influence predator activity (Eisenberg 1986 ; Ludlow and Sunquist 1987). Of the three murid rodents captured in the various habitats *T. indica* and *M. platythrix* are nocturnal, and since rodents form the major prey of small cats and it is possible that jungle cats track rodent activity. This will be clearer in the next chapter once food habits are discussed. In winter, jackals show high diurnal activity in open scrub and mosaic relative to the other habitats. Jackals are omnivores and diet includes a variety of fruits (Haque *et al.* 1984). In winter, fruits such as Zizyphus are abundant in most habitats and this may be the reason for their diurnality. This again can only be explained from food habits (Chapter 5). However, this again is speculative and it is not possible from this study to distinguish cause from effect. Nevertheless it is more likely that a combination of factors decides activity pattern of predators. In summer, for jackals high diurnal activity continued in the open scrub but was reduced in all other habitats. This is indicative of higher tolerance to disturbance by jackal as compared with jungle cat. However it does not agree with the comment that jackals are strictly nocturnal in areas of human habitation and disturbance, as found in other studies. In a study on three sympatric species of jackals in Kenya the authors found that amongst the three, golden jackal was the most diurnal along with being crepuscular. They observed that the other jackals were mostly crepuscular (Fuller *et al.* 1989).

4.6 Conclusion:

Dense scrub was the most important habitat for the jungle cat and provided all resources such as cover, food and water with minimum disturbance relative to other habitats. Jackals used the open disturbed areas more than the other habitats probably as it offered them optimal amount of food.

Time of activity of the two predators was as expected and generally agreed with the hypotheses that jungle cat is more nocturnal while jackal is cathemeral. However time of activity differed in different habitats and the expected pattern was more prominent in some habitats.

All three classes of birds were common in the more open habitats such as open scrub and mosaic. This result was consistent with other studies that showed greater use of more open areas by peafowl and partridge. Hare also preferred the more open habitats to the relatively more vegetated areas. Hill forest in STR was not a good habitat for prey as indicated by low use of this habitat by all prey species.

Overall trapping success of murid rodents was very low. *T. indica* was found in dense scrub and grassland whereas *M. platythrix* was more abundant in the more disturbed habitats and occurred in all habitats except grassland. *G. ellioti* was captured only from grassland and *R. gleadowi* only from hill forests. Overall rodent abundance was negatively related to presence of domestic livestock.

Drive counts on main and dirt roads were the most efficient method for obtaining direct sightings of predators and it compared well with indirect indices of habitat use from track plots. Direct encounters from drive counts had an additional benefit of providing information on activity time of the predators. Track plots served as an efficient method for determining extent of habitat use by ground birds and hare.

CHAPTER 5. FOOD HABITS

5.1 Introduction

Numerous factors govern the choice of habitat for any organism, the prime resource being food. According to Eldridge (1995) every organism has two functions in its life time: the economic and the reproductive. The later is considered to be a "luxury" and happens only when the former has been obtained adequately. Moreover food is of prime importance throughout an individuals life. It is little wonder then, that this resource has been studied in detail for several carnivores (Hiscocks and Perrin 1987 ; Cooper 1990 ; Stephenson and James 1982 ; Johnsingh 1983 ; Karanth 1993, 1995 ; Ravi Chellam 1993 ; Chundawat 1992 ; Schaller 1972 ; Jhala 1991 ; Kruuk 1972). Several life history traits of an organism are related to its food habits and hence studying diet can help predict other patterns such as movement, ranging and ultimately its chances of survival in an ever-changing environment. Besides, the relative ease with which data on food habits can be collected, makes it an ideal topic for short duration projects. Indirect methods for studying food habits have been refined over the years (Floyd *et al.* 1959 ; Joslin 1973 ; Moore *et al.* 1974 ; Keogh 1983 ; Fritts and Seleander 1978 ; Weaver and Hoffman 1979 ; Perrin and Campbell 1980 ; Ackerman *et al.* 1984 ; Gese *et al.* 1988 ; Jhala 1991 ; Mukherjee *et al.* 1994 a,b). These techniques generate a lot of data without causing much disturbance to the species studied. In India, to date most studies on carnivores have focused on the larger species. No detailed study has been undertaken to look at small carnivore-prey communities although most of the members of Order Carnivora are small (Corbett and Hill 1992). Little is known of the basic requirements of even the relatively common species such as jackal. Amongst the small cats from India, the jungle cat is relatively common yet little studied. The information presently available on these small carnivores is trivial, of superficial nature and inadequate to predict or understand their ecology. Moreover, by studying the relatively

more abundant species of a Family, techniques for studying the rarer species can be standardised (Kruuk 1986). This is more relevant for cats since they are very similar in most of their habits (Eisenberg 1986 ; Kruuk 1986).

A number of methods such as monitoring radio tagged individuals, direct observations of predators while foraging, locating kills and analysis of stomach contents have been used for studying food habits of carnivores, but by far the most popular method is scat analysis (Robinette *et al.* 1959 ; Schaller 1972 ; Stephenson and James 1982 ; Johnsingh 1983 ; Hiscocks and Perrin 1987 ; Cooper 1990). This method has the advantage of being non intrusive to the animal while generating plenty of data. Other methods that rely on direct observations or investigations of stomach contents and kills are not only intrusive and destructive but also limited in scope and amount of data obtained (Koppikar and Sabnis 1979 ; Witt 1980 ; Johnsingh 1983 ; Ballard *et al.* 1987) . Scats not only provide data on diet but also on some behavioural aspects, habitat use, marking of territories, relative abundance and den site locations (Kruuk 1972 ; Fuller and Keith 1980 ; Stephenson and James 1982 ; Johnsingh 1983 ; Palmer and Fairall 1988).

Prior to analysis, scats have to be categorised according to species of predators. The usual method is to differentiate scats of various predators from their scat diameter which is believed to be related to the size of the predator (Norton *et al.* 1986 ; Palmer and Fairall 1988 ; Fuller 1989). However, there is usually an overlap in the diameter of scats of species that are similar in size (Johnson and Belden 1984 ; Danner and Dodd 1982 ; Palmer and Fairall 1988 ; Crawley and Krebs 1992). Some other studies have shown that diet may influence size of the scat and hence relying on its diameter alone for differentiation will give biased results (Floyd *et al.* 1978 ; Major *et al.* 1980 ; Danner and Dodd 1982). Major *et al.* (1980) found that bile acids excreted along with scats, and separated using thin layer chromatography, can be used for predator identification as bile acid patterns are species

specific. Of late, this technique has been used in several studies to identify scats of sympatric, similar sized carnivores (Capurro *et al.* 1997 ; Fernandez *et al.* 1997). Bile acids are conjugated to fats and act as emulsifiers, aiding fat digestion. Since most carnivores have a diet rich in fat, relatively high amounts of bile acids are secreted in their intestines which can be detected in scats (Stryer 1995).

Although many studies have expressed food habits of carnivores as mere occurrence of prey items in diet, it is more meaningful to give amount or biomass of prey consumed. This will show the importance of different prey items to the predator which cannot be fathomed from mere presence - absence data (Corbett 1989). A step further would be to look at energetic requirements of the species and estimate the contribution of each prey to the predators energy demands.

5.2 Objectives:

The aim of this study is to examine food habits of jungle cat, caracal and jackal and relate them to the use of various habitats.

The questions addressed were:

1. Is there a seasonal difference in the diet of predators across various habitats?
2. How similar are canid and felid diets?
3. Do the predators use prey species according to availability in different habitats and seasons?
4. How many scats are required for obtaining reliable estimates of diet for jungle cats and jackals in the different seasons?

5.3 Methods:

There are several stages in determining diet through scat analysis: (1) Collection, (2) Identification and (3) Analysis. The analysis itself has several phases (a) Qualitative: where contents are identified. (b) Quantitative: where contents are quantified and (c) Analytical: where statistical comparisons are made.

5.3.1 Collection:

Scats were collected on transects used for ground bird abundance estimation, on dirt tracts, along paved roads and during random searches within each of the 5 habitats. On collection, the location, date and any other important note such as tracks and signs around scat if present were recorded on the collection bag. Scats were sun-dried in field and later oven dried at 60° C. in the laboratory.

5.3.2 Identification of predators through scats:

The diameter of scats was measured with a Vernier callipers and compared for identification. Apart from diameters, fat and bile acid contents of scats were used for identification using Thin Layer Chromatography. The chromatographic plates used were ready-made manufactured by Merck (T.L.C. aluminium sheets 0.2 mm thickness, Silica gel 60 F_{254}, 20 x 20 cm.). The procedure followed Major *et al.* (1980) with some modifications (plates were not sprayed with colouring agent and were viewed directly under U.V. radiation). 1 gm of scat was mixed in 20 ml. of 1:1 ratio of benzene and methanol and left for a period of 3 hours with intermittent shaking. After this the solution was filtered in a beaker of known weight. The filtrate was evaporated over a water bath and the residue weight was obtained by subtracting beaker weight from the weight of the beaker with residue. The residue was re-dissolved in 1:1 Benzene: methanol keeping a constant weight

by volume ratio. The plates were spotted with 20 micro litres of aliquot and placed in a chamber containing the solvent system. The solvent used for this study was Petkoff's solution (56 ml. hexane, 36 ml. ethyl methyl ketone and 8 ml. acetic acid) (Major *et al.* 1980). The solvent front was allowed to run to 3/4 of the plate after which the plate was removed and dried over cool air to allow the separated compounds to move to the surface of the gel for detection (Bauer *et al.* 1991). Plates were then viewed under long wave U.V. radiation (300 - 400 nm) in a U.V. chamber without spraying.

5.3.3 Prey identification:

Scats were teased apart and the remains of different food items such as mammals, birds, reptiles, invertebrates and vegetable matter were separated. Mammal remains were further separated into hair, jaws and other bones. Jaws usually belonged to rodents and at times hare. Rodent jaws were identified to the species level from dentition, compared with standards, and photographs and descriptions from Roberts (1977). Hair was identified from medullary patterns compared with standards, observed under a microscope at 200 times magnification (Moore *et al.* 1974). All occurrences of mammals, birds, reptiles, invertebrates and vegetable matter were recorded as presence - absence. These were then interpreted as the percent of scats having any of these food items.

5.3.4 Number of rodent individuals per scat:

Since jaws of rodent species could be identified, numbers of each species consumed could be calculated (the jaws usually appeared as 2 halves of upper and 2 halves of lower jaws, hence 4 parts would make one individual). Assuming that each rodent consumed (all jaw parts) would be excreted in a single scat, the presence of any portion of a jaw was recorded as one individual. Less than 10% scats had hair but no jaws. These scats were

excluded when estimating proportions of rodent prey. Scats containing rodents represent only *T. indica, G. ellioti* and *M. platythrix.*

5.3.5 Biomass of rodents per scat:

From the records of weights of different rodent species in STR during the capture sessions, the average weight of each species was estimated. The number of individuals of each species found per scat was then multiplied by the average body mass in order to estimate biomass intake per scat. Table 5.1 gives the sample sizes for estimating the overall diet as well as the amounts of three species of rodent prey (*T. indica, G. ellioti* and *M. platythrix)* in the diet of the three predators.

Table 5.1: Number of scats analysed per predator species for determining diet.

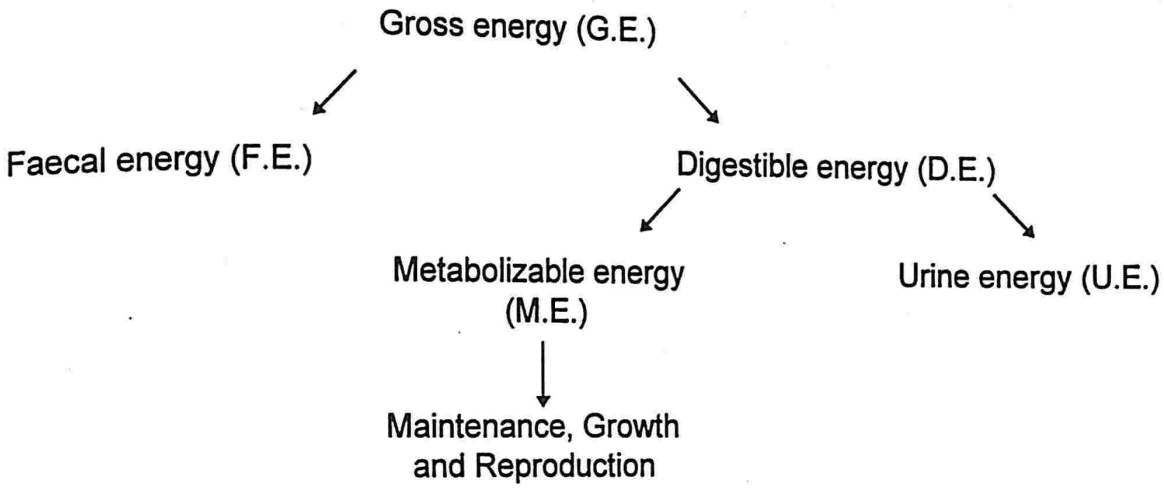
Season	Species	No. scats used for estimating food items	No. of scats used for quantifying rodent prey
Winter	Jungle cat	32	20
	Caracal	15	14
	Jackal	58	39
Summer	Jungle cat	36	23
	Caracal	8	6
	Jackal	78	55

5.3.6 Energetics:

Most studies have shown that carnivores, on an average consume food equalling 7 to 10 % of their body weight per day (Golley *et al.* 1965 ; Kolenosky 1972 ; Nellis *et al.* 1972 ; Brand *et al.* 1976 ; Hilton 1978 ; Johnsingh 1983 ; Gasperetti *et al.* 1985 ; Caro 1989 ; Aldama 1991 ; Jhala 1991 ; Strander *et al.* 1997). Using these figures the expected consumption of prey by jungle cat (average adult body weight of 4 kg - Pocock 1985), and jackal (average body weight of 8 kg - Roberts 1977) per day was calculated. Most literature on caracal from the Indain region do not mention the body weight of this felid. However, skull measurements of male caracal from the Indian region are recorded in Pocock (1985), and these are smaller than those recorded by Dayan *et al.* (1990) for male caracal from

Israel. In fact skull measurements of Indian male caracal were close to those recorded for female caracal from Israel which weighed between 5.8 to 8 kg. Since Indian female caracal would weigh less, mean weight of caracal from STR was assumed to be 6 kg.

Animals partition their energy intake as follows:



(Schwartz and Hobbs 1985)

Feeding trials conducted on bobcats by Golley *et al.* (1965) and by Powers *et al.* (1989) showed that between 72% and 77% of total G.E. intake by bobcats was metabolizable. Similar feeding trials on coyotes (Livaitis and Mautz 1980) estimated around 84.5% of total G.E. as metabolizable and for red foxes M.E. was estimated at 87% of G. E. (Vogtsberger and Barett 1973). Assuming the physiology of digestion of jungle cat to be similar to bobcat, and that of jackal to be similar to coyote, the results of the feeding trials on bobcat was extrapolated to jungle cat and those of coyote to jackal.

From Golley *et al.* (1965), Livaitis and Mautz (1980), Powers *et al.* (1989) and Peter's (1986) the following definitions have been used:

Approximately 30% of animal tissue is dry matter (D.M.).

1 gm. of D.M. has approximately 5.4 kcal

Gross energy (G.E.) (kcal.) = D.M. X 5.4

Digestable energy (D.E.) = energy obtained after production of faeces.

Metabolizable energy (M.E.) = D.E. - (energy in urine + growth) (Expressed as per cent G.E.)

According to Golley *et al.* (1965) and Livaitis and Mautz (1980) digestibility of protein in felids and canids is approximately 90%.

Hence faecal energy (amount not digested) = approximately 10% of G.E. (Golley *et al.* 1965 ; Livaitis and Mautz 1980).

Energy per dry gram of faeces containing bird and small mammal remains = approximately 2.7 kcal. (Golley *et al.* 1965).

Therefore, faecal energy in kcal / 2.7 = dry weight of faeces expected.

5.4 Results

5.4.1 Identification:

5.4.1.1 Diameter: Though the mean scat diameter for caracal (20.03 mm. ± 0.01) was higher than for jungle cat (18.8 mm. ± 0.01) and jackal (19.02 mm. ± 0.01) there was no significant difference among them (Figure 5.1).

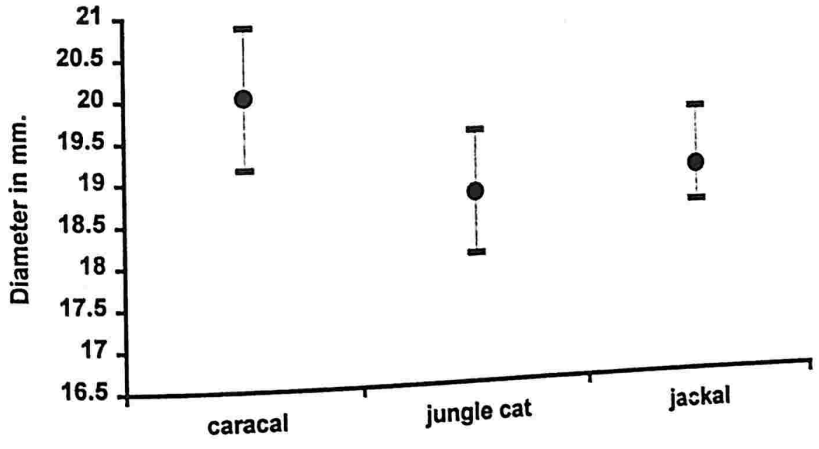


Figure 5. 1: Diameter of scats in three predators (mean, with bootstrap 95% C.I.).

5.4.1.2 Thin layer Chromatography:

Results from known scats of jungle cats and jackals from zoos, on campus and from STR, showed that canid scats possessed a bright red band (rf = 0.91 ± 0.01) (Figure 5.1) under long wave UV radiation which was lacking in felid scats. Among the felid scats some large scats, that were thought to belong to caracal as they were collected from an area where caracal had been sighted, had a band of yellow colour at rf = 0.29 ± 0.018 (Figure 5.1). Since no known caracal scats could be procured for comparison (there being no captive caracal in the country), it was assumed that these scats were of caracal. 57% canid scats also had the yellow band. All scats had a green band (green 1) at rf = 0.85 ± 0.007. A second green band was present in some scats of canids (57% scats) and felids (caracal = 100% and jungle cat = 36% scats) at rf = 0.7 ± 0.01 (Figure 5.1). For this study all canid scats were assumed to be those of jackal.

A total of 23 caracal, 68 jungle cat and 136 jackal scats were analysed for the scrubland collectively. This was done as the two habitats were contiguous and it was possible for animals to feed in one area and defecate in the other. This was more likely in the area where the two habitats overlapped.

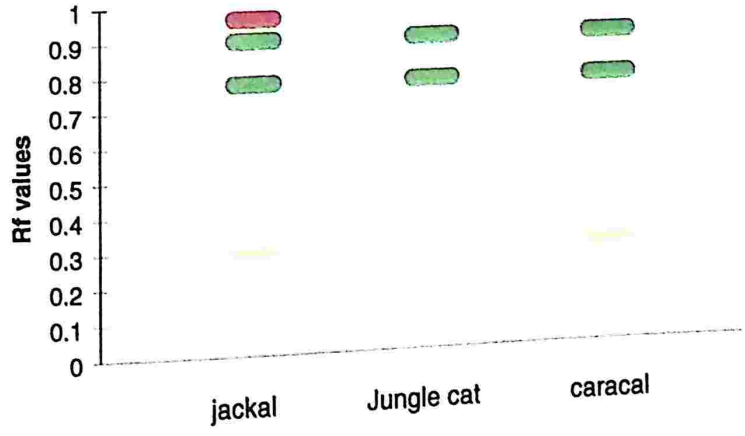


Figure 5.2: T.L.C. of fats and bile acids from scats of three predators viewed under U.V. radiation

5.4.2 Overall diet:

5.4.2.1 Number of food items per scat:

All predators had a higher percentage of scats having multiple (more than one) food items (mammal, bird, reptile, invertebrate and vegetable matter) as compared to a single food item. The felids (jungle cat 34.3% and caracal 34.8%) had a higher percentage of scats having a single major food item as compared to jackal (25.7% scats) (Figure 5.3). A maximum of four food items occurred together in jungle cat and jackal scats whereas a maximum of three food items occurred in caracal scats.

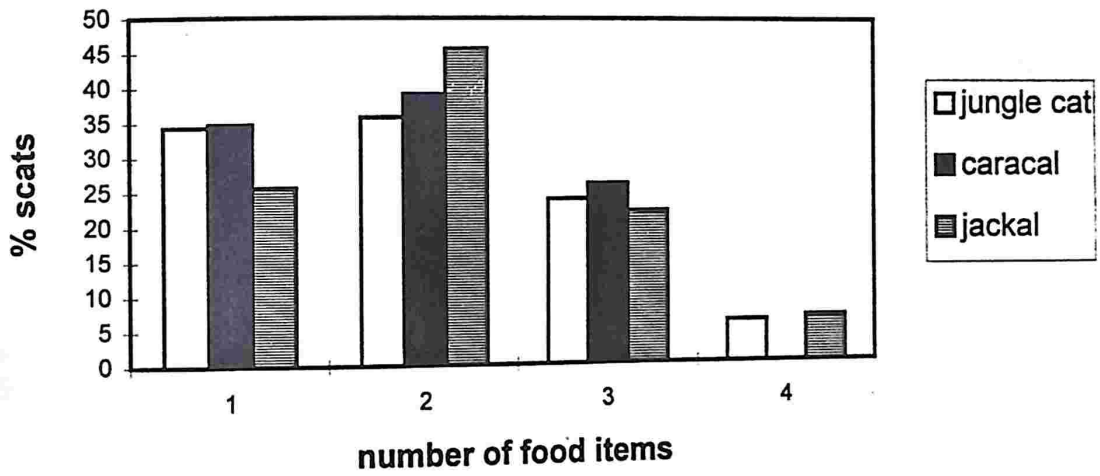


Figure 5.3: Percentages of scats of three predators having single and multiple food items.

5.4.2.2 Major food groups:

A total of 11 food items (wild ungulates, cattle, hare, four species of rodents, birds, reptiles, invertebrates, *Zizyphus* fruits and other vegetable matter such as grass and seeds), belonging to five groups (mammals, birds, reptiles, invertebrates and vegetable matter) were identified. Within mammals, rodents were treated separately) were identified from scats of the three species. However, only food items found in more than 20% of the scats have been considered to form a major portion of diet and have been discussed.

Results of the Bootstrap simulation with 2000 sub-samples (Table 5.1 for number of

observations) showed that the overall diet of each of the three predators was dominated by mammals (occurring in 90% scats) (Table 5.2). Among mammals, rodents formed the most important prey, occurring in 87% scats of caracal and 75% scats of jungle cat and jackal. Rodents were found in a significantly ($p < 0.05$) higher percentage of scats of all three species as compared to birds, reptiles (snakes and lizards) and invertebrates (scorpions and insects). Birds also formed a major portion of their diet occurring in 30.4% scats of caracal, 41.2% of jungle cat and 39.7% of jackal.

Overall there was no difference in the number of scats containing mammal, and bird remains between caracal, jungle cat and jackal. There was no significant difference between any predator in the percentage of scats having rodent remains. There was no significant difference between any predator in the percentage of scats containing reptiles and invertebrates (Table 5.2). A significantly higher percentage of jackal scats (42.6%) had vegetable matter as compared to caracal (17.4%) ($U = 1169$, $p < 0.05$) and jungle cat scats (16.2 %) ($U = 3361$, $p < 0.001$).

Table 5.2: Overall (winter and summer) percentage of scats of caracal, jungle cat and jackal containing different food items, in scrubland.

Food item	Caracal	Jungle cat	Jackal
Mammals:	91.3 (69.6 - 100)	95.6 (89.7 - 100)	94.9 91.2 - 98.5)
Rodents	87.0 (65.2 - 95.7)	75.0 (63.2 - 85.3)	75.7 (68.4 - 83.1)
Birds	30.4 (17.4 - 56.5)	41.2 (29.4 - 52.9)	39.7 (30.1 - 47.1)
Reptiles	21.7 (4.3 - 39.1)	25.0 (14.7 - 35.3)	16.2 (11.0 - 23.5)
Invertebrates	30.4 (17.4 - 52.2)	22.1 (11.8 - 30.9)	16.2 (10.3 - 22.8)
Vegetable matter	17.4 (0 - 26.1)	16.2 (7.4 - 23.5)	42.6 (33.8 - 50.0)

Sample means with Bootstrap 95% CI in parentheses.

5.4.2.2 Rodent prey:

Rodents found in scats belonged to four species, three of which could be identified as *Tatera indica*, *Golunda ellioti* and *Mus platythrix* from their dentition (Plate 8). The fourth species could not be identified and was put in the unknown category.

Caracal: Of the caracal scats containing rodent remains, *M. platythrix* (80%) was found in a significantly higher percentage of caracal scats than *T. indica* (15%) ($U = 98.5$, $p < 0.001$) and *G. ellioti* (30%) ($U = 149.5$, $p < 0.005$) (Table 5.3). There was no significant difference between the percentage of scats having remains of *G. ellioti* and *T. indica*. The number of individuals of *M. platythrix* was the highest (2.55) followed by *G. ellioti* (0.55) and *T. indica* (0.15). Number of individuals per scat of *M. platythrix* was significantly higher than *T. indica* ($U = 98.5$, $p < 0.001$) and *G. ellioti* ($U = 127$, $p < 0.001$). There was no significant difference in the number of individuals of *G. ellioti* and *T. indica*. Biomass of *M. platythrix* per scat (mean = 39.52 gm.) was significantly ($U = 136$, $p < 0.001$) higher than that of *T. indica* (16 gm.) the difference with that of *G. ellioti* not being significant. There was no significant difference in the biomass of *G. ellioti* and *T. indica* per caracal scat.

Jungle cat: There was no significant difference in the percentage of jungle cat scats containing *T. indica* (46.5%), *G. ellioti* (62.8 %) and *M. platythrix* (44.2 %). (Table 5.3). There was also no significant difference in the number of individuals per scat of any rodent species. The was no significant difference in the mean biomass of *G. ellioti* and *T. indica* in jungle cat scat but the difference between *G. ellioti* ($U = 565$, $p < 0.001$) and *M. platythrix* (14.05 gm.) was significant. There was no significant difference between the biomass of *T. indica* and *M. platythrix* per scat.

Jackal: The percentage of jackal scats containing *G. ellioti* (66.0%) were significantly higher than those containing *T. indica* (34.1%) ($U = 3008$, $p < 0.001$) and *M. platythrix* (37.2%) ($U = 3149$, $p < 0.001$) (Table 5.3). There was no significant difference in the

percentage of jackal scats containing *T. indica* and *M. platythrix*. The number of individuals of *G. ellioti* (mean = 0.86) per jackal scat was significantly higher than *M. platythrix* (0.77) ($U = 3503.5$, $p < 0.01$) and *T. indica* (0.37) ($U = 2820$, $p < 0.001$). There was no significant difference between *M. platythrix* and *T. indica*. Biomass of *G. ellioti* (51.7 gm.) was significantly higher than *T. indica* (29.78 gm) ($U = 3518$, $p < 0.01$) and *M. platythrix* (11.87 gm) ($U = 2340$, $p < 0.001$) in jackal diet. There was no significant difference in the biomass of *T. indica* and *M. platythrix* per jackal scat.

Table 5.3: Overall (winter and summer) rodent consumption by caracal, jungle cat and jackal.

Rodent species	Variables	Caracal	Jungle cat	Jackal
T. indica (80 gm.)	% occurrence	15 (00 - 30.0)	46.5 (30.2 - 60.5)	34.0 (24.5 - 43.6)
	number indiv. per scat	0.2 (00 - 0.45)	0.48 (0.32 - 0.65)	0.37 (0.25 - 0.5)
	biomass per scat (gm.)	16.0 (00 - 36.0)	39.0 (26.04 - 52.09)	29.78 (20.42 - 40.0)
G. ellioti (60 gm.)	% occurrence	30.0 (10.0 - 50.0)	62.8 (46.5 - 79.1)	66.0 (56.4 - 75.5)
	number indiv. per scat	0.55 (0.2 - 0.95)	0.83 (0.55 - 1.02)	0.86 (0.70 - 1.02)
	biomass per scat (gm.)	33.0 (12.0 - 57.0)	50.23 (33.48 - 61.39)	51.7 (42.12 - 61.27)
M. platythrix (15.5 gm.)	% occurrence	80.0 (60.0 - 95.0)	44.2 (27.9 - 62.8)	37.2 (27.7 - 46.8)
	number indiv. per scat	2.55 (1.65 - 3.75)	0.97 (0.55 - 1.46)	0.76 (0.51 - 1.04)
	biomass per scat (gm.)	39.5 (25.57 - 58.12)	14.05 (8.65 - 22.7)	11.87 (7.91 - 16.16)

Sample means with Bootstrap 95% Confidence intervals in parentheses ; Sps. with average body weight.

5.4.3.3 Comparison between predators:

Between the felids, jungle cat had significantly higher numbers of scats having *T. indica* ($U = 294.5$, $p < 0.05$) and *G. ellioti* ($U = 296$, $p < 0.05$) than caracal. Jungle cat had significantly higher ($U = 303$, $p < 0.05$) number of individuals and biomass per scat of *T. indica* than caracal. There was no significant difference in the number of individuals and

biomass *G. ellioti* per scat between jungle cat and caracal. A significantly ($U = 274$, $p < 0.01$) higher percentage of caracal scats had remains of *M. platythrix* than jungle cat scats. The number of individuals and biomass of *M. platythrix* found per caracal scat was significantly ($U = 215$, $p < 0.001$) higher than found per jungle cat scat.

Although percent of jackal scats having *T. indica* was twice that of caracal the difference was not statistically significant. However, percentage of jackal scats having remains of *G. ellioti* was significantly ($U = 602$, $p < 0.005$) higher than caracal scats. A significantly ($U = 538$, $p < 0.001$) higher percentage of caracal scats had remains of *M. platythrix* than did jackal scats. There was no significant difference between jackal and caracal in the number of individuals and biomass of *T. indica* per scat. Jackal had significantly higher ($U = 683$, $p < 0.05$) number of individuals and biomass per scat of *G. ellioti* than caracal. The number of individuals and biomass per scat, of *M. platythrix* was significantly ($U = 428.5$, $p < 0.001$) higher in caracal scats than in jackal scats (Table 5.3).

Total rodent biomass per scat: There was no significant difference in the total rodent biomass found per scat between any of the predators (Table 5.4).

Table 5.4: Mean biomass of rodents per predator scat.

Predator	mean biomass (gm.)
Jungle cat	103.36 (85.8 - 122.15)
Caracal	88.52 (64.42 -113.07)
Jackal	93.13 (83.68 -112.00)

Sample means with Bootstrap 95% Confidence intervals in parentheses.

5.4.3 Seasonal diet:

5.4.3.1 Caracal:

In winter 40% of caracal scats had remains of a single food item, 26.7% had two food items and 33.3% had three food items (Figure 5.4).

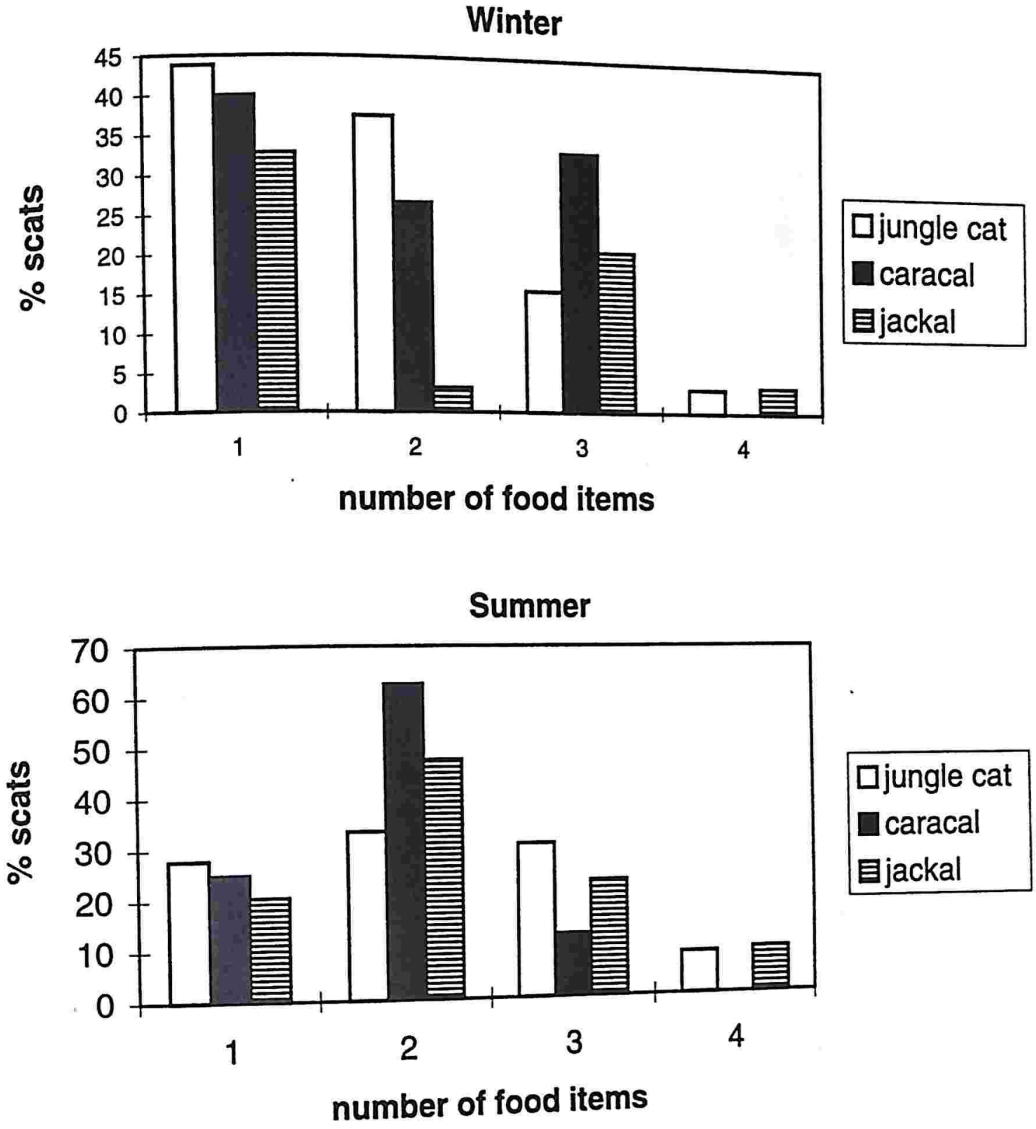


Figure 5.4: Percentage of scats with single and multiple food items in winter and summer.

In winter all scats of caracal had mammal remains. The major food items of the caracal in winter were rodents (93%), invertebrates (26.7%), birds (26%) and reptiles (20%) (Table 5.5). Vegetable matter occurred in 20% scats. Rodents occurred in significantly ($p < 0.05$) more scats than birds, reptiles and invertebrates. There was no significant difference in the percentage of scats having invertebrates, birds and reptiles. Of the scats containing rodent remains (Table 5.6) *T. indica* was found in 14% scats, *G. ellioti* in 35.7% and *M. platythrix* in 85.7% scats. *M. platythrix* occurred in a significantly higher percentage of scats than *T. indica* ($U = 29$, $p < 0.001$) and *G. ellioti* ($U = 50$, $p < 0.005$). There was no significant difference in the percentage of scats having *G. ellioti* and *T. indica*. Number of

individuals of *M. platythrix* (mean = 3.07) was significantly (U = 18, p < 0.001) higher than *T. indica* (mean = 0.14) and *G. ellioti* (0.57) (U = 28.5, p < 0.001). There was no significant difference in the number of individuals found per scat of *G. ellioti* and *T. indica*. Mean biomass of *M. platythrix* per caracal scat in winter (47.6 gm.) was significantly higher than *T. indica* (U = 39, p < 0.001) (11.49 gm.). There was no significant difference between *G. ellioti* and *T. indica* and *G. ellioti* and *M. platythrix*. The total rodent biomass per caracal scat in winter was 93.3 gm. (Table 5.7).

Most caracal scats from summer had remains of two food items. 25% caracal scats from summer had a single food item and 12.5% had three items (Figure 5.4). In summer (Table 5.5) there was no significant difference in the percentage of scats having any of the food items. Of the scats containing rodents, (Table 5.6) *T. indica* and *G. ellioti* were found in 16.7% scats and *M. platythrix* in 66.7% scats. Due to small sample size this difference was not significant. Similarly there was no significant difference in the number of individuals and biomass of *T. indica* (0.33), *G. ellioti* (0.5) and *M. platythrix* (1.3). The total rodent biomass per caracal scat in summer was 77.3 gm. (Table 5.7).

A larger percentage of scats from summer had multiple food items as compared to winter (Figure 5.4). In winter all caracal scats had remains of mammals and this was significantly (U = 45, p < 0.05) higher than in summer (Table 5.5). Though the percentage of scats with rodent remains were also higher in winter than in summer, the difference was not significant. There was no significant seasonal difference in the percentage of scats having bird, reptile and invertebrate remains (Table 5.5). There was no significant seasonal difference in the percent occurrence, number of individuals and biomass per scat among the three rodents (Table 5.6). Although total rodent biomass per scat caracal was higher in winter than in summer, the difference was not significant (Table 5.7).

Table 5.5: Seasonal diet - percentage of scats of caracal, jungle cat and jackal containing different food items.

Season	Food item	Caracal	Jungle cat	Jackal
Winter	Mammals	100	90.6 (80.1 - 100)	94.8 (86.7 - 100)
	Rodents	93.3 (80.0 - 100)	75.0 (56.0 - 92.0)	74.1 (62.2 - 86.7)
	Birds	36.7 (6.7 - 46.7)	43.8 (24.0 - 64.0)	34.5 (22.2 - 48.9)
	Reptiles	20.0 (0 - 40.0)	15.6 (4.0 - 32.0)	19.0 ± 0.1 (8.9 - 31.1)
	Invertebrates	26.7 (6.7 - 46.7)	9.4 (0 - 20.0)	12.1 (4.4 - 22.2)
	Vegetable matter	20.0 (0 - 46.7)	18.8 (4.0 - 36.0)	34.5 (20.0 - 48.9)
	Zizyphus fruits	0	0	19.0 (8.6 - 29.3)
Summer	Mammals	75.0 (25.0 - 100)	100	94.9 (87.3 - 100)
	Rodents	75.0 (25.0 - 100)	75.0 (56.0 - 92.0)	76.9 (65.5 - 87.3)
	Birds	37.5 (12.5 - 87.5)	38.9 (20.0 - 56.0)	43.6 (30.9 - 58.2)
	Reptiles	25.0 (0 - 62.5)	33.3 (16.0 - 52.0)	14.1 (5.5 - 23.6)
	Invertebrates	37.5 (12.5 - 87.5)	33.3 (16.0 - 52.0)	19.2 (9.1 - 30.9)
	Vegetable matter	0	13.9 (4.0 - 28.0)	48.7 (35.5 - 68.1)
	Zizyphus fruits	0	0	7.7 (2.6 - 14.1)

Sample means with Bootstrap 95% Confidence intervals in parentheses.

Table 5.6: Seasonal rodent consumption by caracal, jungle cat and jackal.

Season	Species	Variables	Caracal	Jungle cat	Jackal
Winter	*T. indica*	Per cent occurrence	14.3 (0 - 35.7)	55.0 (30.0 - 75.0)	25.6 (12.8 - 41.0)
		no. of indivs. per scat	0.143 (0 - 0.357)	0.60 (0.35 - 0.85)	0.256 (0.128 - 0.41)
		biomass per scat (gm.)	11.42 (0 - 28.57)	48.0 (28.0 - 68.0)	20.51 (10.25 - 32.82)
	G. ellioti	per cent occurrence	35.7 (14.3 - 64.3)	65.0 (40.0 - 90.0)	61.5 (46.2 - 76.90)
		no. of indivs. per scat	0.57 (0.143 - 1.0)	0.95 (0.55 - 1.4)	0.87 (0.59 - 1.17)
		biomass per scat (gm.)	34.28 (8.57 - 60.0)	57.0 (33.0 - 84.0)	52.3 (35.38 - 70.76)
	M. platythrix	per cent occurrence	85.7 (64.3 - 100)	40.0 (15.0 - 65.0)	38.5 (23.1 - 53.8)
		no. of indivs. per scat	3.07 (1.8 - 4.5)	1.1 (0.35 - 2.05)	0.95 (0.513 - 1.462)
		biomass per scat (gm.)	47.6 (28.7 - 70.8)	17.05 (5.42 - 31.77)	14.70 (7.94 - 22.65)
Summer	*T. indica*	Per cent occurrence	16.7 (0 - 50.0)	39.1 (17.4 - 60.9)	40.0 (27.3 - 52.7)
		no. of indivs. per scat	0.33 (0 - 1.00)	0.39 (0.17 - 0.60)	0.45 (0.291 - 0.618)
		biomass per scat (gm.)	26.6 (0 - 80.0)	31.3 (13.9 - 48.6)	36.36 (23.27 - 49.45)
	G. ellioti	per cent occurrence	16.7 (0 - 50.0)	60.9 (39.1 - 78.3)	69.1 (56.4 - 81.8)
		no. of indivs. per scat	0.5 (0 - 1.5)	0.739 (0.47 - 1.08)	0.85 (0.67 - 1.03)
		biomass per scat (gm.)	30.0 (0 - 90.0)	44.3 (28.6 - 65.2)	51.27 (40.36 - 62.18)
	M. platythrix	per cent occurrence	66.7 (33.3 - 100)	47.8 (26.1 - 69.6)	36.4 (23.6 - 49.1)
		no. of indivs. per scat	1.3 (0.33 - 2.3)	0.737 (0.39 - 1.17)	0.636 (0.364 - 0.945)
		biomass per scat (gm.)	20.66 (5.1 - 36.1)	11.47 (6.06 - 18.19)	9.86 (5.63 - 14.65)

Table 5.7: Total biomass of rodents per scat of predators during winter and summer.

Season	Species	Mean (g)
Winter	jungle cat	122.0 (93.17 - 155.0)
	caracal	93.3 (69.1 - 120.1)
	jackal	87.3 (72.1 - 105.2)
Summer	jungle cat	87.1 (72.6 - 102.9)
	caracal	77.3 (25.8 - 128.8)
	jackal	97.5 (84.9 - 108.6)

Sample means with Bootstrap 95% Confidence intervals in parentheses.

5.4.3.2 Jungle cat:

In winter, 43% of jungle cat scats had remains of a single food item, 37.5% had two food items, 15.6% had three and 3.1% had four food items (Figure 5.4). Rodents and birds formed the major diet of jungle cat in winter (Table 5.5) occurring in 75% and 43.8% scats respectively. There was no significant difference in the number of scats containing rodent and bird remains in winter. The percentage of scats containing *T. indica*, *G. ellioti* and *M. platythrix* were 55%, 65% and 40% respectively, the difference not being significant. Similarly, there was no significant difference in the number of individuals of *T. indica* (mean = 0.6), *M .platythrix* (1.1) and *G. ellioti* (0.95) per scat. There was no significant difference in biomass obtained by jungle cat diet in winter from *T. indica* (mean = 48.0 gm/scat) and *G. ellioti* (57.0 gm /scat). Jungle cat obtained significantly higher biomass from *T. indica* ($U = 136$, $p < 0.05$) and *G. ellioti* ($U = 126$, $p < 0.05$) than *M. platythrix* (17.05 gm/scat) in winter. The overall rodent biomass per jungle cat scat in winter was 122 gm. (Table 5.7).

In summer 27.8% scats of jungle cat had remains of a single food item, 33.% had two items, 30.6% had three and 8.3% had remains of four food items (Figure 5.4). Rodents (75%), birds (38.9%), reptiles (33.3%) and invertebrates (33.3%) formed the major diet of jungle cat (Table 5.5). Rodents occurred in significantly ($p < 0.05$) higher proportions of scats than the other major prey (Table 5.5). There was no significant difference in the percentage of scats containing bird, reptile and arthropod remains. From the scats containing rodents, (Table 5.6) the percent occurrence of the three species of rodents did not differ. There was no significant difference in the mean number of individuals of *T. indica* (0.39), *G. ellioti* (0.739) and *M. platythrix* (0.737) per jungle cat scat. However the biomass obtained from *G. ellioti* (44.38 gm.) was significantly ($U = 153$, $p < 0.05$) higher than *M. platythrix* (11.47 gm.). There was no significant difference in the biomass of *T. indica* (31.3 gm.) and *G. ellioti* and between *T. indica* and *M. platythrix* per scat.

A larger percentage of scats from summer had multiple food items as compared to winter (Figure 5.4). There was no significant seasonal difference in the percent of scats having mammal, bird and reptile remains (Table 5.5). Invertebrate presence in scats was significantly ($U = 420.5$, $p < 0.01$) higher in summer than in winter. The percent occurrence of jungle cat scats containing rodents was similar during summer and winter. There was no significant seasonal difference in the per cent occurrence, number of individuals and biomass per jungle cat scat, of each of the three species of rodent (Table 5.6). Although the total biomass of rodents per scat in winter (122.0 gm.) exceeded summer (87.1 gm.), the difference was not significant (Table 5.7)

5.4.3.3 Jackal:

Among the 58 scats of jackals from winter, 32.8% scats of had remains of a single food item, 43.1% had two items, 20.7% had three and 3.4% had remains of four items (Figure 5.4). A significantly ($p < 0.05$) higher percentage of scats (94.8%) had mammals than the percentage of scats containing birds (34.5%), vegetable matter (including *Zizyphus* fruits) (34.5%) and reptiles (19%), all of which formed the major diet of jackal in winter (Table 5.5). There was no significant difference in the percentage of jackal scats containing birds, vegetable matter and reptiles. *Zizyphus* fruits occurred in 19% scats (55% of the scats containing vegetable matter). Rodents formed the major mammalian prey and occurred in 74.1% scats. This was significantly ($p < 0.05$) higher than the percentage of scats containing bird, reptile and vegetable matter. Among the scats containing rodent remains, (Table 5.6) the percentage of scats containing *G. ellioti* (61.5%). was significantly higher than those containing *T. indica* (25.6%) ($U = 487.5$, $p < 0.001$) and *M. platythrix* (38.5%) ($U = 585$, $p < 0.05$). There was no significant difference between scats containing *T. indica* and *M. platythrix*. The number of individuals per scat were also significantly higher

for *G. ellioti* (U = 452.5, p < 0.001) than *T. indica*. There was no significant difference between the mean number of individuals of *M. platythrix* (0.949) and *T. indica* (0.25) and *M. platythrix* and *G. ellioti* (0.87) found per jackal scat in winter. Biomass contributed per scat by *G. ellioti* in winter (52.3 gm.) was significantly (U = 537.5, p < 0.01) higher than *T. indica* (20.5 gm.). The difference was more significant (U = 456, p < 0.001) between *G. ellioti* and *M. platythrix* (14.7 gm.). There was no significant difference in the biomass of *T. indica* and *M. platythrix* per jackal scat in winter. The total biomass of rodents per jackal scat in winter was 87.3 gm. (Table 5.7).

In summer 20.5% scats of jackals had a single food item, 47.4% had two items, 23.1% had three and 9.0% had four items (Figure 5.4). Of the 78 jackal scats analysed for summer, (Table 5.5) 94.9% contained mammal remains. The other major food items for the jackal in this season were birds (43.6%), vegetable matter (48.7%) and invertebrates (19.2%). Number of scats containing mammals were significantly (p < 0.05) greater than those containing all other major food items. The number of scats with bird remains were significantly (p < 0.05) higher than scats having reptiles (14.1%) and invertebrates. There was no significant difference in the percentage of scats having bird and vegetable matter. *Zizyphus* fruits occurred in 15.8% scats containing vegetable matter. Rodents were the major mammalian prey of jackals and occurred in 76.9 % scats. Rodents were found in significantly (p < 0.05) higher numbers of scats than the other major prey (birds, invertebrates and vegetable matter). Among the scats containing rodents (Table 5.6), *G. ellioti* (69.1%) occurred in a significantly higher percentage of scats than *T. indica* (40%) (U = 1072.5, p < 0.005) and *M. platythrix* (36.4%) (U = 1017.5, p < 0.001). There was no significant difference in the percentage of scats containing *T. indica* and *M. platythrix*. The number of individuals of *G. ellioti* (0.85) per scat was also significantly higher than *T. indica* (0.45) (U = 1016, p < 0.001) and *M. platythrix* (0.636) (U = 1093, p < 0.01). There was no

significant difference between the number of individuals of *T. indica* and *M. platythrix* found per jackal scat in summer. Biomass contributed by *G. ellioti* (51 gm.) per scat was significantly ($U = 724.5$, $p < 0.001$) higher than *M. platythrix* (9.86 gm.). There was no significant difference of biomass per jackal scat between *G. ellioti* and *T. indica* and *T. indica* and *M. platythrix.* The total biomass of rodents per scat in summer was 97.5 gm. (Table 5.7).

A larger percentage of scats from summer had multiple food items as compared to winter (Figure 5.4). There was no significant difference in the percentage of jackal scats containing mammals, birds, reptiles or invertebrates between summer and winter (Table 5.5). However the consumption of *Zizyphus* fruits was significantly ($U = 231$, $p < 0.005$) higher in winter than in summer (Table 5.5). There was no significant seasonal difference in the percentage of scats having any species of rodent (Table 5.6). There was no significant seasonal difference in the number of individuals and the biomass of the different species of rodents per jackal scat (Table 5.6). The total rodent biomass per scat also did not show a seasonal difference (Table 5.7).

5.4.5 Seasonal comparison among predators:

5.4.5.1 Winter:

Number of food items per scat: Although, all predators had a higher percentage of scats having multiple food items, felids (Jungle cat 43.8%, caracal 40%) had a higher percentage of scats having remains of a single food item as compared to jackal (32.8%). Jungle cat and jackal had a maximum of four food items occurring together in a scat. Caracal had a maximum of three food items occurring together per scat (Figure 5.4).

Overall diet: There was no significant difference among any predator in the percentage of scats having remains of all mammals, rodents, birds, reptiles and invertebrates and

vegetable matter in winter (Table 5.5). The percentage of scats having *Zizyphus* seeds were significantly higher ($U = 752$, $p < 0.01$) in jackal (mean = 19% ± 0.1) than in jungle cat, which had no scats containing *Zizyphus* seeds. Caracal scats from winter also had no *Zizyphus* seeds.

Rodents: For scats containing rodent remains, (Table 5.6), jungle cat (55%) had a significantly higher percentage of scats having remains of *T. indica* than jackal (25.6%) ($U = 275.5$, $p < 0.05$) and caracal (14.3%) ($U = 83$, $p < 0.01$). The number of individuals and biomass per scat for *T. indica* was also significantly higher in jungle cat scats than in caracal scats ($U = 270.5$, $p < 0.05$) and jackal scats ($U = 82$, $p < 0.01$). There was no significant difference between caracal and jackal in the percentage of scats having remains of *T. indica* nor in the number of individuals and biomass per scat from this rodent. There was no significant difference between any predator in the percentage of scats having *G ellioti* nor in the number of individuals and biomass per scat of this rodent in winter (Table 5.6). Caracal had a significantly higher percentage of scats having remains of *M. platythrix* compared to jungle cat ($U = 75$, $p < 0.01$) and jackal ($U = 144$, $p < 0.005$) (Table 5.6). The number of individuals and biomass per scat of this rodent were also significantly higher in caracal scats as compared to jungle cat ($U = 63.5$, $p < 0.005$) and jackal ($U = 110.5$, $p < 0.001$). There was no significant difference between jungle cat and jackal in the percentage of scats having remains of *M. platythrix*, nor in the number of individuals and biomass of this rodent per scat (Table 5.6). There was no significant difference in the total rodent biomass per scat between any predator in winter (Table 5.7).

5.4.5.2 Summer:

Number of food items per scat: All three predators had a similar percentage of scats with a single food item. Caracal (62% scats) had a higher percentage of scats having remains of two items than jungle cat (33.3%) and jackal (47.4%) (Figure 5.5).

Overall diet: In summer, all jungle cat scats had mammal remains and this was significantly higher than caracal ($U = 105$, $p < 0.01$) (Table 5.6). A significantly higher ($U = 250$, $p , 0.05$) percentage of jackal scats had mammal remains compared to caracal. There was no significant difference in the percentage of scats having mammal remains between jungle cat and jackal (Table 5.6). There was no significant difference in the percentage of scats having rodent and bird remains between any predator. Reptile remains were found in significantly higher ($U = 1089.5$, $p < 0.01$) numbers of jungle cat scats than jackal. There was no significant difference between jungle cat and caracal in the percentage of scats having reptile remains (Table 5.5). There was no significant difference between any predator in the percentage of scats having remains of invertebrates. In summer a significantly higher percentage of jackal scats had vegetable matter as compared to jungle cat ($U = 895$, $p < 0.001$) and caracal ($U = 199$, $p < 0.05$) which had no scats having vegetable matter (Table 5.5).

Rodents: For scats containing rodents there was no significant difference between any predator in the percentage of scats having *T. indica* nor in the number of individuals and biomass of this rodent per scat (Table 5.6). A significantly higher percentage of jungle cat ($U = 38.5$, $p < 0.05$) and jackal ($U = 78.5$, $p < 0.01$) scats had remains of *G. ellioti* compared to caracal. There was no significant difference between jungle cat and jackal in the percentage of scats having remains of *G. ellioti*. There was no significant difference in the number of individuals and biomass of *G. ellioti* per scat between any predator. In summer there was no significant difference between any predator in the percentage of

scats having remains of *M. platythrix* nor in the number of individuals and biomass of this rodent per scat (Table 5.6). There was no significant difference in the total rodent biomass per scat between any predator in summer (Table 5.7).

5.4.6 Energetics: Details of scat production and energy obtained from rodents by the three predators in summer and winter is summarised in Table 5.9. For calculations refer to section 4.3.5, Table 5.7. and Table 5.8.

Table 5. 8: Energetics of caracal, jungle cat and jackal extrapolated from bobcats and coyotes.*

Predator species. (body weight)	Daily D.M. intake (7- 10% of body weight)	G.E. (kcal.)	Expected wt. of faeces (gm.)	M.E. (kcal.)
Jungle cat (4 kg)	84 gm. - 120 gm.	453.6 - 648	16.8 - 24	349.2 - 498.9
Caracal (6 kg)	126 gm. - 180 gm.	680.4 - 972	25.2 - 36	523.9 - 748.4
Jackal (8 kg)	168 gm. - 240 gm.	907.2 -1296	33.6 - 48	766.5 - 1095.1

* **Golley *et al.* (1965) ; Livaitis and Mautz, (1980) ; Powers *et al.*, (1989).**

Table 5.9: Energy obtained from rodents by caracal, jungle cat and jackal in winter and summer.

Season	Species	Expected scat weight (gm.)	Observed mean scat wt. (gm.)	No. of scats per day	Rodent biomass (gm.) ingested per day	M.E. (kcal.) obtained from rodents	% M.E. obtained from rodents. (kcal.)
Winter	Jungle cat	16.8 - 24	9.4	2	244	304.3	60.9 - 87.2
	Caracal	25.2 - 36	7.54	4	373	465.2	62.1 - 88.9
	Jackal	33.6 - 48	9.74	4	348	476.3	43.5 - 62.1
Summer	Jungle cat	16.8 - 24	7.0	3	261	325.5	65.2 - 93.2
	Caracal	25.2 - 36	8.4	4	373	465.2	62.1 - 88.9
	Jackal	33.6 - 48	10.0	4	390	533.8	48.7 - 69.6

5.5 Discussion

5.5.1 Diet:

In many cases, although the means were very different no significant difference was noted. Reasons for this could be small sample size or inherent variability. Confidence intervals for the rarer food items were usually larger, indicating inherent variability.

Mammals were the most important prey occurring in more than 90% scats of all three predators. This agrees with other studies on small felids and canids (Schaller 1970, 1972 ; Gipson 1974 ; Nellis and Keith 1976 ; Jones and Smith 1979 ; Johnsingh 1983 ; McShane and Grettenberger 1984 ; Ludlow and Sunquist 1987 ; Palmer and Fairall 1988 ; Koehler and Hornocker 1989 ; Mukherjee 1989 ; Sultana and Jaeger 1989 ; Silero-Zubiri and Gotetelli 1995).

Rodents: Among the scats that had remains of mammalian prey 75% scats of jungle cat and 87.5% of caracal had rodent remains. Studies in other areas have shown rodents to be their major prey of jungle cats (Kitchener 1991 ; Johnsingh 1983 ; Schaller 1972 ; Mukherjee 1989). Caracal diet varies over its geographical range although its principal prey is mammals (Stuart 1983 ; Palmer and Fairall 1988 ; Weisbien and Mendelsohn 1990). It differs from the jungle cat in the size of prey it takes. In South Africa it feeds on rodents as well as medium sized ungulates such as small antelopes and the proportions of these in caracal diet depends on abundance of prey (Stuart 1983 ; Palmer and Fairall 1988). In Israel caracal diet consisted mainly of rodents and gazelles (Weisbien and Mendelssohn 1990). In STR, rodents were by far the most important prey for both felids. The importance of rodents in the diet of many other small cats from different areas has been documented through various studies e.g. bobcat, ocelot, African wildcat and feral cats (Pearson 1964 ; Comman and Brunner 1972 ; Jones and Smith, 1979 ; Ludlow and Sunquist 1987 ; Palmer and Fairall 1988 ; Koehler and Hornocker 1989). Small cats seem to specialise on catching

rodents and other small mammals (Pearson 1964 ; Lin and Batzli 1995). Felids being highly specialised carnivores combine knowledge of their habitat along with prey activity and habits while hunting (Griffiths 1975 ; Thapar 1986 ; Pearson 1964 ; Bothma and Le Riche 1989). Feral cats can identify rodent runways and burrows and concentrate their activities in these zones (Pearson 1964). This technique of identifying runways is also used by lynx for catching snowshoe hare (Brand *et al.* 1976). Although small cats are considered opportunistic predators which predate on the most abundant prey, they seem to specialise on small mammals and consume the most abundant species within this group (Kruuk 1986). This has been demonstrated in studies that have shown prey switching where switching occurred from one rodent species to another (Koehler and Hornocker 1989).

Studies have shown that despite trapping index of small mammals being low, cats were able to maintain proportions of rodents and other small mammals in their diet (Jones and Smith 1979 ; Pearson 1964 ; Koehler and Hornocker 1989 ; Martin *et al.* 1996). Some authors feel that high nocturnal activity of felids reflects their specialisation in catching rodents which are also nocturnal (Ludlow and Sunquist 1987). However a high percentage of jungle cat scats from Sariska had remains of the diurnal rodent *G. ellioti* (62.8%) and a low percentage of the two nocturnal rodents *T. indica* (46.5%) and *M. platythrix* (44.2%). Biomass obtained from *G. ellioti* was also higher. According to Griffiths (1975), most vertebrate carnivores take into account the size and number of their various prey and feed as "energy maximizers" when prey is abundant and as "number maximizers" (opportunistic) when prey are scarce. Johnsingh (1992) discusses variable profitability of prey species to different predators (tiger, leopard and dhole) depending on their mode of hunting, sensitivity to disturbance and body size. For the jungle cat the preference for the bigger *G. ellioti* (60 gm.) over *M. platythrix* (15.5 gm.) is explainable energetically, as many more *M. platythrix* would have to be consumed than *G. ellioti*. However *T. indica* (80 gm.)

was heavier than *G. ellioti* and thus an energetically better option. Results of trapping of rodents in the scrubland (Chapter 4) shows that *T. indica* (63% occurrence in traps) was the most abundant rodent followed by *M. platythrix* (37% occurrence in traps) with no captures of *G. ellioti*. This implies a preference for *G. ellioti* by jungle cats. There could be two other reasons for the high percentage of scats having remains of this rodent: (1) The Sherman traps used for estimating rodent abundance was biased against *G. ellioti*, and (2) *G. ellioti* being bush dwelling, slow moving and less aggressive is more vulnerable to predation than the aggressive and fossorial *T. indica* which has better anti predator strategies. As in feral cats and lynx, jungle cats may be able to identify *G. ellioti* nests by the runways leading to them. Since these rodents are diurnal and bush dwelling they would be more susceptible to predation at night.

In caracal diet, *M. platythrix* was the most important rodent occurring in 80% of the scats. This was significantly higher than the other two rodents. Biomass of *M. platythrix* was significantly higher than *T. indica* but only marginally higher than *G. ellioti* (Table 5.3). From sightings and from scat locations, caracal seemed to use the open scrub area more than the dense scrub. *M. platythrix* was the only rodent captured from this habitat and the caracal hence is eating the most abundant rodent. No *T. indica* were caught from the open scrub, nor were their burrows located in this area. The low numbers of *T. indica* in the diet of caracal is probably a reflection of its low numbers or absence in this habitat. It is possible that the few *T. indica* in caracal scats were caught from the dense scrub. Jungle cat had high *T. indica* in their diet probably as they used dense scrub more than open scrub and most of the *T. indica* was obtained from the dense scrub. Although the mean percentage of scats of jungle cat having *G. ellioti* remains was significantly higher than scats of caracal, there was no significant difference in the mean biomass of *G. ellioti* found per jungle cat scat compared to caracal (Table 5.3). This meant that although fewer caracal scats had *G.*

ellioti remains they ate more individuals of this rodent when they had the opportunity. Hence the caracal too prefers *G. ellioti*.

In S.T.R. rodents were found in 75.7% of jackal scats which was significantly higher than all other items. *G. ellioti* was found in significantly more scats than *T. indica* and *M. platythrix* (Table 5.3). Biomass of *G. ellioti* consumed was significantly higher than the other rodents *T. indica* and *M. platythrix* (Table 5.3). Hence for the jackal too *G. ellioti* was the most important rodent. Jackals being diurnal would probably catch *G. ellioti* during the day when the rodent was active. Thus the lower proportions of nocturnal rodents in jackal diet could be a result of greater diurnal activity of jackals. Although another reason could also be low abundance of *T. indica* as there were no captures or burrows of this species in the open scrub which was most used by jackals. However if the influencing factor was rodent abundance, then *M. platythrix* which was the only rodent trapped in open scrub should have been found in a greater proportions in scats, as seen in Caracal. Moreover as mentioned earlier *G. ellioti* being bush dwelling would be less abundant in areas which have low bush cover as in open scrub, but more visible or available to jackals during the day when both are active as well as some may have been procured in dense scrub. The Ethiopian Wolf (*Canis simensis*) is a diurnal solitary canid and specialized in hunting rodents. It was observed that its diet comprised predominantly of diurnal rodents (96% scats) while there were no nocturnal species (Silero-Zuberi and Gottelli 1995). As mentioned earlier the principle rodent prey of silver jackals in Serengeti, Africa was a diurnal rodent and jackals used to travel large distances (6 to 8 km.) to hunt rodents (Mohelman 1986). In STR although jackals were mostly diurnal and crepuscular, some amount of nocturnal activity was also seen which could explain the presence of the nocturnal rodents in their scats.

When jackal diet is compared to caracal diet (both use open scrub more) the difference in consumption of nocturnal and diurnal rodents between the two predators is clear. Jackals consume significantly more *G. ellioti* than caracal, whereas caracal consume significantly higher quantities of *M. platythrix* than jackals (Table 5.3). However this difference was not seen when jackal diet was compared to jungle cat diet. Both predators showed higher consumption of *G. ellioti* than of *T. indica* and *M. platythrix*. It is interesting to note that the two predators use different habitats (the jackal showing greater use of open scrub while the jungle cat preferring dense scrub) and yet have similar diet. The explanation could lie in the different strategies used by the two predators discussed later. For the jungle cat, catching *G. ellioti* is energetically more profitable whereas for jackal it is its activity pattern that makes it easier to catch *G. ellioti*. Low abundance (in the open scrub) and fossorial habits of the bigger rodent *T. indica* are probable reasons for low capture success of this rodent by jackals.

Nevertheless, it is clear that overall *G. ellioti* is an important rodent prey in S.T.R. forming more than 35% of biomass consumption of all rodents for all three carnivores during both seasons.

Birds: According to Kitchener (1991), cats are not good at catching birds and most birds taken are hunted opportunistically. Kingdon (1989) is of the opinion that the principle prey of the caracal are birds which it hunts during the night when the birds are roosting. The importance of bird prey in diet probably depends largely on presence of cover, abundance of birds as well as abundance of small mammalian prey (Kitchener 1991).

The occurrence of bird remains in the scats of jungle cats in Sariska is comparable to that in Bharatpur (55%), both being greater than reported from other sites (Kitchener 1991 ; Schaller 1972 ; Johnsingh 1983 ; Mukherjee 1989). In the present study 30.4% scats of caracal had remains of birds. This is similar to the study in Israel which reported 24%

caracal scats having bird remains (Weisbien and Mendelsohn 1990). In Sariska one sighting of caracal was in the open scrub (in daytime in the month of June (summer) while the cat was plucking a freshly killed a peacock in a dense *Capparris separia* bush. The peacock had been caught while it was displaying. Thereafter, approximately 17 peafowl kills were found (with their feathers plucked) dragged in dense bushes in the scrubland (mostly open) and in grassland during summer. Since the kills were relatively old at the time of location, it was not possible to determine the identity of the predator. However they could have been made by the caracal since there were reports of caracal sightings in these habitats during that season. In Ranthambore Tiger Reserve caracal was seen stalking peafowl in daylight during summer in the month of April, 1998 (Valmik Thappar pers comm.). It is possible that peafowl forms a major portion of caracal diet in summer when the birds are lekking and are more susceptible due to their large trains. Moreover, peafowl vocalisation and the general increase in visibility in the area during summer probably makes these birds more prominent. The average weight of peafowl being approximately 5 kg (Roberts, 1991) is nearly 90% of the body mass of a caracal. It is known that when felids kill large prey they gorge themselves and sometimes even cache remains (Nellis and Smith 1968 ; Golley *et al.* 1965 ; Kitchener 1991). Hence peafowl should be an energetically preferable option as compared to small mammals. The proportion of birds in caracal diet was higher though not significantly in summer (37.5%) than in winter (26.7%).

Since birds were not identified to the species level it is not known what percentage of total birds eaten were peafowl. Although the larger feathers could be easily identified, results could be biased (underestimated) as most of the identifiable large feathers are plucked before consumption and only occasional scats may have these feathers. The opposite form of bias would be overestimating peafowl in the diet of cats, when the amount of flesh eaten from a large prey is not known and hence the number of scats produced from

that prey cannot be estimated. Hence feathers of a single bird may appear in several scats and be recounted by the presence - absence method (Crawley and Krebs 1992). Without knowing the species and actual numbers eaten it is impossible to estimate relative importance of birds (energy in kcal. obtained) in diet and compare them to rodents (Crawley and Krebs 1992). Although peafowl are a seemingly more lucrative option energetically, their actual availability to the predators is not known. Studies on capture success of cats on peafowl and other birds compared to that on rodents could provide insight into this (Kruuk 1986). The open scrub, as discussed in the previous chapter, is highly disturbed. Most of the caracal scats and two of the four sightings (two others were in grassland) of caracal were from the open scrub. Disturbance and low cover in the open scrub would make it difficult for any felid to hunt successfully especially during the day as they rely on stealth and cover for hunting. However whether the caracal always hunts other birds and peafowl in daylight is not known and a couple of sightings cannot be taken as conclusive evidence.

One sighting of a jungle cat in the dense scrub in STR revealed that this individual took roosting doves and pigeons by climbing the tree. On examining the area around the tree, several (six) dove and pigeon remains were located probably hunted by the same cat. Twice jungle cats were seen in dense scrub, catching peafowl chicks by the ambush technique in tall grass. As in the Kalahari leopards (Bothma and Le Riche 1989) and in the Ranthambore tigers, (Thappar 1986) techniques used by cats may be flexible and may vary according to the experience of the individual. This has also been reported for the Canadian lynx by Nellis and Keith (1968).

39.7% scats of jackal had bird remains. This is similar to golden jackals in Bangladesh and Niger, Africa which had 31% and 23.7% scats respectively containing birds (Sultana and Jaeger 1989 ; McShane and Grettenberger 1984). However, it was higher than other studies which had less than 20% scats having remains of birds (Mukherjee 1989 ; Poche *et*

al. 1987). Diet of jackals from Kanha and Southern India did not include birds (Schaller 1967, 1970).

Reptiles and Invertebrates: The percentage of felid scats from STR having reptile and invertebrate remains (Table 5.4) were similar to other studies on jungle cat and caracal which showed a range of 5 - 15% scats having these food items. In jungle cats a significant seasonal difference was seen in the consumption of invertebrates and they consumed more of these in summer than in winter. The reason could be due to the greater availability of insects in the warmer months as compared to winter. The greater nocturnal activity of jungle cats in summer (Figure 4) (Chapter 4) may have made invertebrates more available to them as most invertebrates such as scorpions and some insects are nocturnal.

The percentage of jackal scats having reptile and invertebrate remains (Table 5.2) was lower than some studies on golden jackals in other areas. Schaller (1979) recorded 29% scats of jackals having reptile remains. Invertebrate remains were found in 28% jackal scats from Bharatpur, Rajasthan (Mukherjee 1989) and in 70.6% golden jackal scats from Niger (McShane and Grettenberger 1984). Since abundance estimates for reptiles and invertebrates are not available from any of these studies including the present one it is difficult to attribute the reason for this difference to any factor. However as seen from some other studies on golden jackals it is clear that the proportion of reptiles and invertebrates is very variable and are probably taken opportunistically as available (Schaller 1967 ; Poche *et al.* 1987 ; Sultana and Jaeger 1989).

Vegetable matter: The major difference between felid and canid diet was the amount of vegetable matter consumed. Jackal diet throughout its geographical range is very flexible depending on the availability of different food items. Being an omnivore, fruits and other vegetable matter are also included in its diet (Kingdon 1989). In India, a variety of fruits such as cashew, mango, jackfruit and melons are included in their diet (Kingdon 1989). In

some areas of Bangladesh jackals are considered serious pests of crops such as melon. More than 45% of stomachs of jackals investigated had vegetable matter (Haque *et al.* 1984 ; Poche *et al.* 1987). However, crop raiding is done by jackals living in and around crop fields. The diet of jackals living in natural habitats comprise mainly of mammals (> 60%). A study on silver backed and golden jackals in Serengeti, Africa revealed that golden jackals were more carnivorous than silver jackals (Mohelman 1986).

Fruits included in diet of jackals in natural habitats are usually fallen fruits (McShane and Grettenberger 1984). In the present study, 19% scats of jackals from winter had *Zizyphus* fruit seeds. Jackals were sighted on several occasions feeding on fallen *Zizyphus* fruits. McShane and Grettenberger (1984) also found *Zizyphus* seeds in jackal scats. 83.2% of scats analysed by them had vegetable matter including *Zizyphus* fruits, seeds of *Acacia* sps., *Cordia sinensis* and some unidentified seeds and grasses. Silver backed jackals in the Serengeti plains of Africa, consumed large numbers of *Balanites aegyptica* fruits during the whelping season (Mohelman 1986). These fruits have high sugar content and along with diurnal rodents formed the principle food of silver backed jackals during that period (Mohelman 1986). *Balanites aegyptica* also occurs commonly in STR in the scrubland. Although several fallen fruits were present there were no sightings of golden jackals feeding on them nor were there remains of this fruit in their scats. Most of the fallen fruits were predated upon by rodents. In the present study 42.6% scats had vegetable matter (Table 5.2). All 14 jackal scats (100%) from Bharatpur contained vegetable matter including *Prosopis juliflora* pods and grasses (Mukherjee 1989).

Since fruit and seed availability is seasonal, they are taken opportunistically. Since *Zizyphus* fruits in winter, in STR a clear seasonal difference was seen in consumption of fruit (Table 5.5). The fruits present in summer scats were probably consumed during the beginning of summer especially in the year 1996 when fruiting was very good and there

were surplus fruits which lasted till the start of summer. In some years as in 1995, a brief period of fruiting occurs in summer after a few showers. However the fruits were very few in number.

Scavenge: Plenty of carrion is also included in jackal diet. It is however difficult to quantify scavenge as it is very likely that the animals feed on muscle and internal organs while totally rejecting indigestible skin and hair. Hence no identifiable matter would be excreted leading to underestimates of carrion in diet. However direct observations and stomach content analysis show a high proportion of scavenge in jackal diet (Schaller 1972 ; Poche *et al.* 1987). McShane and Grettenberger (1984) found 23% scats of golden jackals from Niger, Africa, having remains of domestic livestock.

In STR, possible scavenge was found in less than 10% scats (wild ungulate = 8.8%, cattle = 2.2% and refuse = 8.1%). However, jackals were seen scavenging on several occasions on abandoned tiger kills, on carcasses of dead livestock around villages and around garbage dumps, and the importance of scavenge in terms of the amount of biomass and energy obtained is surely underestimated from scats analysis. As mentioned by Kingdon (1989), jackals are very efficient at tracking vultures and crows and homing in to kills. On several occasions in STR jackals were observed watching vultures and running toward the kill site from distances of over 1 km. Apart from tacking vultures their keen sense of smell must also help in locating carcasses.

Another problem in indirect methods for assessing food habits is the impossibility of identifying actual kills from scavenge. Kingdon (1989) reports of groups and pairs of jackals hunting Thompson's gazelles. This is more common during the whelping season (Kingdon 1989 ; Mohelman 1989). Jackals in STR were usually seen in pairs (> 90% sightings). Groups of upto 5 adults have been sighted during summer. These large groups were seen mostly around kills and hence were loose packs. Co-operative hunting of larger mammals

(fawns of deer or nilgai) was never observed. However on a couple of occasions sambar and chital were heard giving alarm calls due to the presence of a single or a pair of jackals nearby. It is possible that jackals take young fawns occasionally. However sambar and chital were heard giving alarm calls even due to the presence of jungle cat on two occasions. There have been no documented reports of jungle cats in India hunting fawns of deer or antelope. Thus alarm calls may be given due to the presence of any predator viewed as a potential predator by prey and does not necessarily mean that these predators hunt young fawns.

4.5.2 Energetics:

Amount of food ingested by an animal depends on its Basal Metabolic Rate (BMR). BMR in turn is influenced by several factors, the principle ones being body size and food habits (Schmidt-Nielson 1979 ; Peters 1986 ; McNab 1988, 1989). Carnivores have higher BMR than herbivores of similar size. Within the order Carnivora, the ones that have a pure meat diet and rely wholly on vertebrate meat to fulfil their energy demands (e.g. felids, mustelids) have higher BMR than omnivores (e.g. jackal, coyote *Canis latrans*, some viverrids) (McNab, 1988, 1989) The reason being the higher Specific Dynamic Action (SDA = metabolic cost of processing) of proteins as compared to carbohydrates and fat (Peters 1986).

Energetics of the three predators were predicted from McNab's (1989) equation of BMR of carnivores as follows:

$VO_2/m = 4.05 \times m^{-0.288}$ (m = body weight in grams)

Field metabolic rate (F.M.R.) is approximately 2 - 3 times basal (Peters 1983 ; Power's *et al.* 1989).

One litre of oxygen gives 4.8 kcal. (Schmidt-Nielson 1994).

Species	B.M.R. ($cm^3 g^{-1} hr^{-1}$)	F.M.R. ($cm^3 kg^{-1} hr^{-1}$)	kcal. ingested per day (from F.M.R.)	kcal. ingested per day from consumption of prey between 7 - 10 % of body mass.
Jungle cat (4 kg.)	0.37	0.74 - 1.11	340.8 - 511.2	346 - 499
Caracal (6 kg.)	0.33	0.66 - 0.99	456.1 - 684.2	523 - 784.4
Jackal (8 kg.)	0.30	0.6 - 0.9	552.8 - 829.2	776 - 1095

Jungle cat: Kcal ingested as calculated from F.M.R. is similar to the M. E. intake of kcal. calculated for jungle cat if it ingests prey equalling 7% - 10% of its body weight. However the BMR of other cats such as ocelot (*Leopardus pardalis*) and bobcat (*Lynx rufus*) are 11% and 52% higher, respectively, than predicted by the equation. Jungle cat BMR may also be higher than the above mentioned figures. Accurate estimates can only be obtained by experiments on captive jungle cats or by estimating FMR by capturing jungle cats and using double labelled water (Nagy 1987).

Caracal: Energy ingested as calculated if the animal consumes between 7 - 10% of its weight in food is slightly lower than the FMR. As mentioned earlier cats are known to have higher than predicted BMR's and hence the figure predicted by the 7 - 10% (kcal.) intake may be more accurate. Palmer and Fairall (1988) estimated energy requirement for a 12 kg. caracal from South Africa as 752.5 kcal per day (6.5325 l O_2 hr^{-1}). This is lower than what would have been predicted for a 12 kg carnivore from calculations used in this study (748 - 1123 kcal. from McNab's (1989) equation and FMR 2-3 times BMR). However Palmer and Fairall, (1988) used Kleiber's (1961) equation ($VO_2/M_b = 0.676 \times M_b^{0.75}$, where M_b is body weight in kilograms, from Schmidt - Nielson 1979) for predicting BMR. Although this gives a higher BMR than McNab's (1989) equation, their estimation of FMR being 1.5 times (instead of 2-3 times as used in this study) higher than BMR, may have resulted in lower values than calculations from this study.

Jackal: Energy calculated if consumption of prey equals 7% - 10% of body weight is higher than that calculated from F.M.R. The M.E. intake is likely to be an overestimate as jackals are omnivores and as mentioned earlier food habits influence BMR. Since BMR of jackal is not known, it was assumed to be similar to that of coyote which is also an omnivore. The BMR. of coyote (10 kg.) is 0.27 $cm^3\ g^{-1}\ hr^{-1}$ or 96% of the prediction from McNab's (1989) equation (0.28 $cm^3\ g^{-1}\ hr^{-1}$) (McNab 1989). Consequently, BMR of jackal can be expected to be close to 0.3 $cm^3\ g^{-1}\ hr^{-1}$ (552.8 kcal. - 829.2 kcal.) as predicted by McNab's (1989) equation. This means that jackals consume less than 7% - 10% of their body weight in food, the more conservative figure being between 5% - 7% (552.8 - 829.2 kcal. per day). This would result in a lower scat production (between 2 - 3 scats per day). Hence rodent consumption per day would be around 217.5 gm. (87 gm./scat x 2.5 scats) or 297.7 kcal. in winter and 243.7 gm. (333.6 kcal.) in summer. The resulting energy obtained from rodents would hence be between 35.9% - 53.8% in winter and 40% - 60% in summer.

Jackal obtained lower amounts of energy from rodents than the two felids (Table 5.10) which supports the notion that most smaller felids are specialised in preying on rodents. The reason for this being that felids are anatomically and physiologically constrained to a dependence on meat for survival. They cannot synthesise important dietary materials such as vitamin A, vitamin B (Niacin) and the amino acid taurine and arachodonic acid (Scott 1968 ; Blaza and Loveridge 1984, Budavori 1989). Their relatively shorter intestines than canids, are adapted for digesting the more easily digestible food stuffs such as proteins and fats. Felids cannot metabolise carbohydrates efficiently and apart from fat, rely to a large extent on protein metabolism to meet their energy demands (Scott 1968 ; Blaza and Loveridge 1984). Jackals may have obtained a large amount of energy from carrion and other scavenge which could not be accounted for in this study. However, results agree with other studies, of jackals being omnivores

with a very flexible diet and a capability to survive in disturbed and relatively open habitats. In fact disturbed habitats probably increase their chances of obtaining scavenge.

5.5.3 Coexistence:

Studies have shown that sympatric species using similar food resources coexist by occupying different habitats, by using different strategies for hunting or by consuming different size classes or type of food (Mohelman 1986 ; Dayan *et al.* 1990 ; Johnsingh 1992 ; Murray *et al.* 1995). Habitat separation is usually higher in the more closely related species than the ones that are relatively distant as seen in studies on coyotes and foxes and coyotes, foxes and bobcats (Viogt and Earle 1983 ; Major and Sherburne 1987 ; Harrison *et al.* 1989). In a study on coyotes, foxes and bobcats, greater habitat separation was seen between foxes and coyotes than between bobcats and coyotes. This was despite bobcats and coyotes having greater overall niche overlaps (Major and Sherburne 1987).

Competitive character displacement is believed to be one of the mechanisms of co-existence. This is usually manifested by a constant size difference in an important feature for the group e.g. in felids certain skull measurements such as canines, condylo-basal length (CBL) and zygomatic breadth (ZB) are considered to be the most important feature (Dayan *et al.* 1990). This enables closely related sympatric predators to exploit different sizes of prey. Dayan *et al.* (1990) have shown character displacement in sympatric caracal, jungle cat and wild cat (*Felis sylvestris lybica*) in Israel and Sind (Pakistan) from skull measurements, especially from their canine diameters. Due to a large degree of sexual dimorphism in felids, males and females were considered as different species called morphospecies They found a constant size ratio of 1.15 to 1.25 in canine diameters and between 1.07 to 1.1 in CBL between the 6 different morphospecies of the three sympatric speceis of felids. For the Indian region records of canine diameters are not available, but

the CBl and ZB measurements of jungle cats and caracal from Pocock (1985) show the 1.09 to 1.1 ratio between the different sexes of each species and between male caracal and male jungle cat and female caracal and female jungle cat. The male jungle cat and female caracal had similar measurements. However, the sample size for caracal was very small (3 males and 2 females). Both species of felids were much smaller than the ones found in Israel. This was also noted by Dayan *et al.* (1990) where the same felids from Sind were much smaller than the ones from Israel. Although the constant size ratios indicate competitive character displacement, the authors caution against the interpretation of this result as being strictly due to competition for food as it is not known if minor differences in measurements of these features would ensure separation (Dayan *et al.* 1990). Habitat separation is likely to be a major factor in aiding coexistence and though superficially it may appear that the two felids use the same habitat at a finer scale habitat separation was seen in these two felids in Israel. Jungle cat prefers marshes and streams whereas the caracal does not prefer these (Dayan *et al.* 1990). In STR jungle cat seemed to prefer well vegetated areas close to water bodies and caracal sightings and scats were located mainly from more open areas (Chapter 4). Since prey availability as perceived by carnivores is not known and it cannot be concluded if prey is limiting for competition to take place (Dayan *et al.* 1990). Though a larger body size enables exploitation of larger prey, in STR caracal was consuming the smallest rodent (*M. platythrix*) while jungle cat was consuming the largest (*T. indica*). This was more a reflection of the habitat they occupied as *M. platythrix* was the only rodent found in caracal habitat and the bigger rodents were found in jungle cat habitat. It is possible that caracal also obtained much of its energy from peafowl. Although caracal and jackal occupied the same habitat, caracal obtained more of its energy from rodents than jackal (Table 5.10) and differed from the jackal in the species of rodent it

consumed most. (Table 5.4). Jackal fed primarily on *G. ellioti* the diurnal rodent and probably obtained a lot of its energy also from scavenge (Table 5.4).

Knowledge of the strategy employed by a predator in catching prey can give valuable information on reasons for specialisation as well as explain coexistence with other predators (Johnsingh 1992 ; Murray *et al.* 1995). This would also enable future researchers to improve techniques for assessing prey abundance. The abundance of prey estimated by a technique may not reflect availability to the predator (Jones and Smith 1979 ; Kruuk 1986 ; Johnsingh 1992). Generally two modes of hunting are used by predators: the mobile and the stationary or ambush (Bell 1990). Cats use both strategies depending on prey abundance, cover and age, sex and social position of the individual (Nellis and Keith 1968 ; Brand *et al.* 1976 ; Taylor 1976 ; Rolley and Warde 1985 ; Kruuk 1986 ; Bothma and Le Riche 1989 ; Harvey and Gittleman 1992 ; Murray *et al.* 1995). However, the ambush and mobile methods are a continuum and many predators use both together. Some may ambush for a few minutes while others may wait for hours and days (Bell 1990). In the present study one jungle cat was radio-tagged with an activity transmitter and monitoring of this individual showed that it used a combination of both strategies by moving for a while, then waiting for approximately five minutes and then moving again. The same behaviour was observed in a fishing cat in Bharatpur, which waited for 15 minutes at the edge of the water then moved to another area where it waited again and continued doing this till it chanced upon a fish (Mukherjee 1989). In a study on hunting success in lynxes relative to cover, results indicated that lynxes were more successful in catching snowshoe hares when ambushing than by using the mobile method. However, low vegetative cover forced lynxes to chase hare since ambushing requires dense cover (Murray *et al.* 1988). Once the prey has been detected it is stalked from cover, the duration of the stalk depending on the distance of the predator from the prey (Eisenberg 1986 ; Kruuk 1986).

As in felids mode of hunting in canids is flexible and depends on prey size and canid body and group size. Larger prey are hunted in pairs and groups whereas as group size decreases, the amount of small prey in diet increases (Mohelman 1986, 1989). The usual mode of hunting is by chasing down prey which is done when hunting larger ungulates and lagomorphs. Due to this their hunting success is higher in relatively open country (Wells and Bekoff 1982). While hunting rodents and sometimes, lagomorphs, they approach the prey to a close distance and then pounce on them (Murray *et al.* 1995). Hence in the present study the two felids which would rely on similar strategies for hunting and are both nocturnal are spatially separated while the canid has a different strategy for obtaining its food and is temporally separated from the felids.

5.5.4 Methods for studying food habits:

Diameters of scats, though different, was not a good method for identification as there was a lot of overlap between caracal and jackal and jackal and jungle cat scat measurements. Although caracal scats were larger than jungle cat scats, the difference was not significant. A combination of techniques is necessary for reliable identification. However T.L.C. is time consuming relatively expensive and requires the usage of harmful chemicals (Benzene, Methanol, Acetic acid) (Budovari 1989). Recent studies have suggested the use of Methylene chloride which is less harmful, as a substitute for Benzene (Capurro *et al.* 1997).

5.6 Conclusions

Diameters of scats of the three predators varied but not significantly. It is hence necessary to use more than one technique for identifying scats of sympatric and similar sized predators. The T.L.C. technique was more reliable as it gave better results for identification.

Mammals, especially rodents formed the major portion of the diet of all three predators followed by birds. *G. ellioti* was an important rodent prey for all three carnivores. *M. platythrix* was the principle rodent prey for the caracal, *G. ellioti* for jackal, and *G. ellioti* and *T. indica* for the jungle cat. The importance of rodents also differs, with the felids depending on this group to a larger extent than the jackal which also rely on scavenge. The number and biomass of rodents consumed was calculated from jaws and dentition in scats and along with body weight, was used to interpret results as energetic values. More detailed studies including feeding trials and experiments on captive canids and felids are necessary for a better understanding of energetics of these species.

The three predators co-exist, using different habitats, and within habitats by exploiting different food resources and by temporal separation. The felids being more closely related and hence expected to have similar hunting strategies occupy different habitats whereas the jackal is temporally separated from the felids. The different food habits of the predators are a reflection of this spatio - temporal separation.

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