CHAPTER 1

INTRODUCTION

1. 1. Introduction:

India is rich in species diversity because of the location in convergence of three Bio-geographic realms-Indomalayan, Paleartic and Ethopian (Mackinnon and Mackinnon, 1974; Mani, 1974). Most of the tropical countries are rich in the number of carnivore species they harbor (Corbett and Hill, 1992). With 55 species of carnivores distributed throughout India, several protected areas in the country have two or more sympatric carnivores (Johnsingh, 1986). The disappearance of top predator from fragmented systems may have community wide implications (Sovada *et al.,* 1995; Ralls and White, 1995; Terborgh *et al.,* 1999) and may lead to the ecological release of mesopredators (Sargeant *et al.,* 1983; Soule *et al.,* 1988; Sovada *et al.,* 1995; Crooks and Soule, 1999). Meso-carnivores represent an ecologically diverse and influential guild of vertebrates playing key roles as predators and seed dispersers. Carnivore species, having small body size, have varied life histories showing highly species-specific responses to habitat and human-induced habitat changes, and attain varied conservation status. They are much more diverse in their behavior and ecology.

1.2. Canids:

Canids form one of the most prominent families of carnivores, with 36 taxa in 13 genera that occur throughout most of the world (Zubiri, Hoffmann and Macdonald, 2004). Foxes, dholes, dingoes, wolves, jackals, coyotes and various dogs comprise the family. As a family, canids occupy every continent except Antarctica. The order canidae evolved in open grassland and modern members are adapted to a wide range of habitats. Canid possess morphological adaptations that help them run swiftly after their prey such as long legs, digitigrade feet, non-retractile claws, fused scaphoid and lunar bones (wrist bones) which give their wrists unidirectional strength and locked radius and ulna which prevents rotation of the upper fore legs. The family Canidae belongs to a large group of predatory mammals characterized by their common

possession of a pair of carnassial teeth (upper fourth premolar and lower first molar) that are modified to maximize efficiency for shearing skins, tendons, and muscles in their prey. Canids are characterized by an inflated entotympanic bulla (bony chamber enclosing the middle ear region) that is divided by a partial septum along the entotympanic and ectotympanic suture. Other feature characteristics of canids are the loss of a stapedial artery and the medial position of the internal carotid artery that is situated between the entotympanic and petrosal for most of its course and contained within the rostral entotympanic anteriorly (Wang and Tedford 1994). These basicranial characteristics have remained more or less stable throughout the history of canids.

The smallest canid member is the Blanford's and fennec foxes (*Vulpes cana* and *V. zerda*) with 24 cm body height and body weight of less than 1 kg where, the largest member is the Gray wolf with 200 cm of body high and exceeding 60 kg body weight. Canid distributions may be highly restricted (Yankhe *et al*. 1996) or span several continents, about 70 million km² in the case of the red fox (Lloyd 1980) where, the grey wolf was the most widely distributed terrestrial mammal. Their diets range from omnivory (with, at times, almost exclusive emphasis on frugivory or insectivory) to strict carnivory—and they glean these livings in habitats ranging from deserts to icefields, from mountain to swamp or grassland, and from rain forest to urban 'jungle' (Johnson *et al*. 1996; Macdonald 1992b). To do this they may travel home ranges as small as 0.5 km^2 (island fox—Roemer *et al*. 2001b) or as large and non-defensible, as 2000 km^2 in African wild dogs (*Lycaon pictus*) (Frame *et al*. 1979). Canid dispersal is important to several aspects of evolutionary biology, including population genetics and fitness; the theoretical importance of dispersal was as a primary factor whose costs were offset against possible benefits of group-living (Vehrencamp 1983; Macdonald and Carr 1995). The Canidae are the most widespread family of extant Carnivora, with at least one species present in all continents except Antarctica. A perusal of the ranges of all canid species (Macdonald and Sillero-Zubiri 2004b) indicated that over the last century the geographical ranges of seven species have increased, eight have decreased and nine have remained stable. The kaleidoscope of species diversity has changed and there are places where the grey wolf and the red fox have been replaced by what amounts to their 'ecological average', the coyote, once confined to mainly arid areas in western North America

and now found in every state, province and country north of Panama (Moore and Parker 1992; Reid 1997; Bekoff and Gese 2003).

Many Canidae groups have distributions that span a whole continent. Red foxes and grey wolves have the most extensive natural range of land mammal (with the exception of humans and some commensal rodents). Red foxes are the only canid species present on five continents, recorded in a total of 83 countries. Grey wolves occur naturally in North America, Europe and Asia with their range spanning 62 countries. Two species are present on three continents, namely the golden jackal (*canis aureus*) and Arctic fox (*Alopex lagopus*) and two other, the red fox and dingo were introduced in Australia and Oceania.

Although behavioral monogamy is fundamental to canid societies (Kleiman 1977; Kleiman and Malcolm 1981), Macdonald and Moehlman (1982) noted that canid social systems appeared to be size related (Creel and Macdonald 1995). Canids can be categorized according to three size classes. Small canids (<6 kg) are either largely monogamous e.g. Blanford's, swift (*V. velox*) and kit foxes (Geffen and Macdonald 1992; Cypher *et al*. 2000; List and Macdonald 2003) or form small, loose knit groups with a female-biased sex ratio, from which young males tend to emigrate, and females stay in their natal range as helpers until a breeding opportunity arises e.g. red and Arctic foxes (Macdonald 1979a; Hersteinsson and Macdonald 1982). Medium-sized canids (probably excluding the bush dog) (6–13 kg) have an equal adult sex ratio and emigration rate, and both sexes may be helpers and thus both sexes also disperse (golden, black-backed (*Canis mesomelas*) and side-striped jackals, coyotes, and crab-eating foxes (Bekoff and Wells 1982; Moehlman 1983; Macdonald and Courtenay 1996; Loveridge and Macdonald 2001). Larger canids excluding the maned wolf (Dietz 1984), and perhaps the grey wolf (Packard *et al*. 1983) (>13 kg), in contrast, exhibit an adult sex ratio skewed towards males, female emigration and male helpers e.g. Ethiopian wolves, dholes, African wild dogs (Kuhne 1965; Johnsingh 1982; Sillero-Zubiri *et al*. 1996a) and perhaps the bush dog is an atypically diminutive member of this category (Macdonald 1996b).

Geographical variability in body size can be explained by differences in availability of food, with small canids (e.g., fennec fox) usually associated with arid and poor habitats in which only a small body mass can be supported year round,

whereas large canids (e.g., Ethiopian wolf and African wild dog) are often associated with habitats in which prey is abundant (table.1). Thus, canids have borne a high proportion of the conflict between humans and carnivores. The more prolific and adaptable canids, like the jackal and coyote, have fared well despite this competition, while the more specialized members of the family, like the Ethiopian wolf, have become threatened with extinction.

At least 155 of the 192 countries across the world have canid species (81%) where, Sudan is the country with the highest number of species (10 species), followed by USA (9 species) and Ethiopia (8 species). Those countries that do not host any canid species are island states are Caribbean islands, Madagascar, Malta and most Australasian islands. Africa, Asia and South America support the greatest diversity with more than 10 canid species each. Red foxes are sympatric with 14 other canids from three geographical regions, golden jackals with 13 from two regions and grey wolves with 11 from three regions. Within any one location, canid diversity is usually limited to one to five species.

There are five canid species endemic to a single country i.e. Ehtiopia. Most are also threatened (red wolf, Ethiopian wolf, Darwin's fox, island fox and hoary fox – *Pseudalopex vetulus*), with the Sechuran fox (*P. sechurae*) a near-endemic to Peru. Of the two continents with the highest species diversity, South America harbours nine species (out of 11 species present) confined entirely to south of Panama, while Africa has eight endemics (of 13 species present). Of 12 canid species found in Asia, only two are restricted to that continent i.e Indian fox (*Vulpes bengalensis*) and dhole (*Cuon alpines*).

The protein-coding gene phylogeny, which is consistent with tree based genetic approaches, shows that the wolf genus *Canis* is a monophyletic group that also includes the dhole or Asian wild dog. The grey wolf, coyote and Ethiopian Wolf or Simien Jackal (*Canis simensis*) form a monophyletic group, with the golden jackal (*C. aureus*) as the most likely sister taxon (Figure.1.1). The black-backed (*C. mesomelas*) and side-striped jackals (*C. adustus*) are sister taxa, but they do not form a monophyletic group with the golden jackal and Ethiopian wolf. Basal to *Canis* and *Cuon* are the African wild dog and a clade consisting of two South American canids, the bush dog (*Speothos venaticus*) and the maned wolf (*Chrysocyon brachyurus*).

Consequently, although the African wild dog preys on large game as does the grey wolf and dhole, it is not closely related to either species but is sister to the clade containing these species. In sum, the living Canidae is divided into five distinct groupings. These include the wolf-like canids, which consists of the coyote, grey wolf, Ethiopian wolf, jackals, dhole and African wild dog. This clade is associated with a group containing bush dog and maned wolf in some trees and, further, this larger grouping is associated with the South American foxes (Wayne *et al*. 1997). The red fox group is a fourth independent clade containing *Alopex* and *Vulpes* (including the fennec fox). Finally, three lineages have long distinct evolutionary histories and are survived today by the raccoon dog, bat-eared fox and island and gray fox.

Table.1.1. Canid species and their distribution in the World

Species	**Common name**	**Geographic range**
Canis aureus	Golden jackal	Old World
Canis adustus	Side-striped jackal	Subsaharan Africa
Canis mesomelas	Black-backed jackal	Subsaharan Africa
Canis simensis	Simien jackal	Ethiopia
Canis lupus	Gray wolf	Holarctic
Canis latrans	Coyote	North America
Canis rufus	Red wolf	Southern US
Cuon alpinus	Dhole	Asia
Lycaon pictus	African wild dog	Subsaharan Africa
Speothos venaticus	Bushdog	Northeast S. America
Lycalopex uetulus	Hoary fox	Northeast S. America
Cerdocyon thous	Crab-eating fox	Northeast S. America
Chrysocyon brachyurus	Maned wolf	Northeast S. America
Vulpes aelox	Kit fox	Western US
Vulpes vulpes	Red fox	Old and New World
Vulpes chama	Cape fox	Southern Africa
Alopex lagopus	Arctic fox	Holarctic
Fennecus zerda	Fennec fox	Sahara
Otocyon megalotis	Bat-eared fox	Subsaharan Africa
Urocyon cinereoargenteus	Gray fox	North America
Nycteruetes procyonoides	Raccoon dog	Japan, China

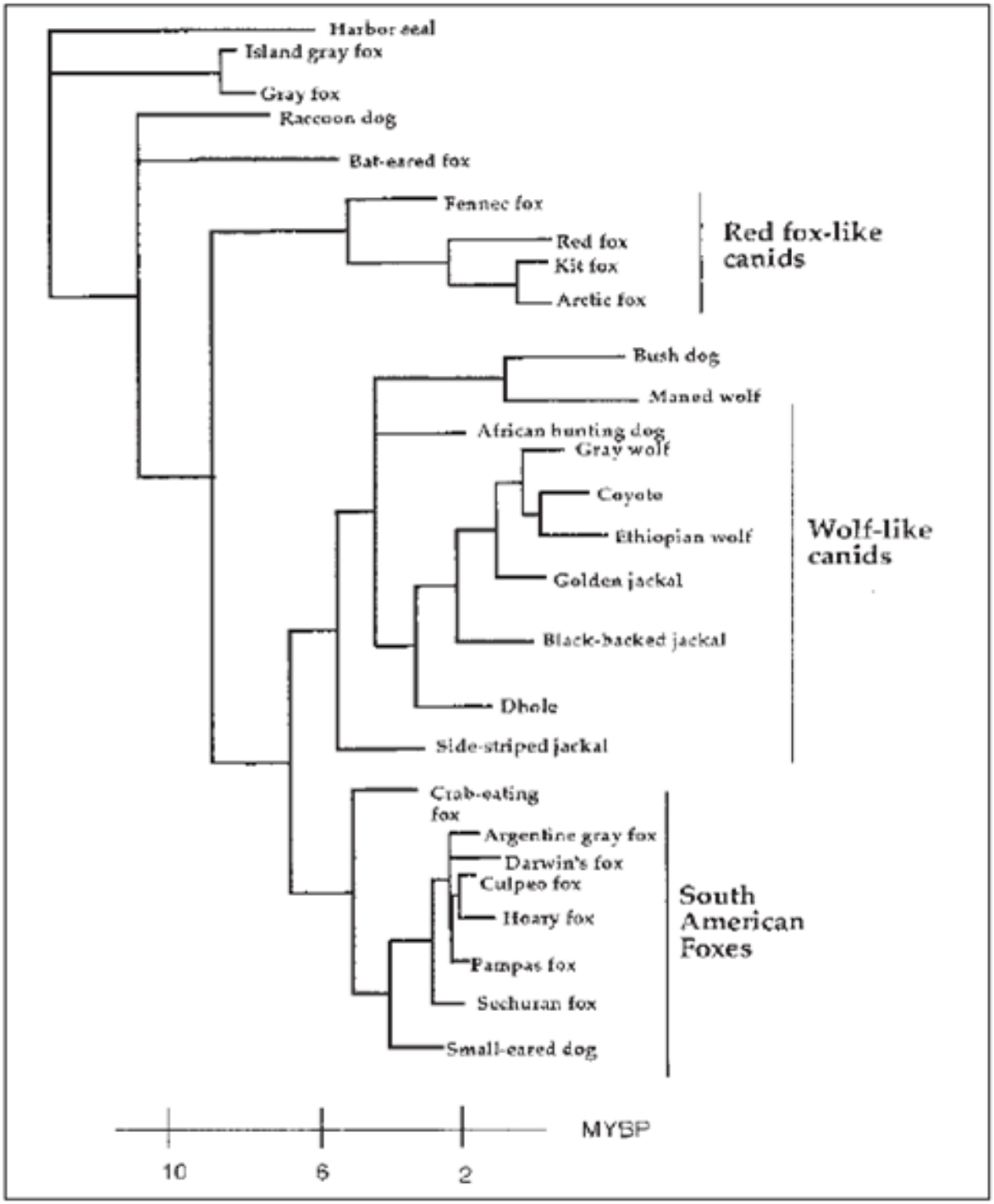

Figure.1.1. Consensus tree of 26 canid species based on analysis of 2,001 bp of DNA sequence from mitochondrial protein coding genes (Wayne *et al*. 1997). Time scale in millions of year before present (MYBP) is based on comparisons of DNA sequence divergence to first appearance times in the fossil record.

1.3. Golden Jackal:

Golden Jackal (*Canis aureus*) is a medium sized canid, considered a most typical representative of genus Canis, and is one of the 37 species of Canidae (Moehlman, 1983) occurring in the world. The golden jackal is widely distributed from East Africa through Middle East into South Asia. According to IUCN Red List and Indian Wildlife (Protection) Act, 1972 they are placed in Lower risk and Schedule III respectively. Three Indian races of jackal are recognized – *Canis aureus aureus, C. aureus indicus* and *C. aureus naria* (Prater, 1980). Jackal is a generalist predator and occurs in variety of habitats from savannah and woodland in Protected Area (Moehlman, 1983; Fuller *et. al.*, 1989) to farmland around human habitation (Pouche *et. al.*, 1987; Jeager *et. al.*, 2001). In areas, particularly where large predators have been eliminated they are most abundant carnivores (Yom-Tov *et. al.*, 1995; Krystufek *et. al.*, 1997). The golden jackal is widespread in North Africa and north-east Africa, occurring from Senegal on the west coast of Africa to Egypt in the east, in a range that includes Morocco, Algeria, and Libya in the north to Nigeria, Chad and Tanzania in the south. They have expanded their range from the Arabian Peninsula into Western Europe to Austria and Bulgaria (Genov and Wassiley 1989; Sheldon 1992), and eastwards into Turkey, Syria, Iraq, Iran, Central Asia, the entire Indian subcontinent, then east and south to Sri Lanka, Myanmar, Thailand and parts of Indo-China (figure.1.2). The golden jackal is fairly common throughout its range. High densities are observed in areas with abundant food and cover.

In India, jackal populations achieve high densities in pastoral areas such as Kutch, Maharashtra, Rajasthan, and Haryana. Based on intensive observations on breeding pack units and radio-collared individuals, jackal densities in the semi-arid Velavadar National Park were estimated between one and two jackals per km^2 (Y. Jhala *et al*. unpubl.); On the African continent, in the Serengeti National Park, densities can range as high as four adults per km^2 (Moehlman 1983, 1986, 1989). Population estimates for Africa are not available. Due to their tolerance of dry habitats and their omnivorous diet, the golden jackal can live in a wide variety of habitats. These range from the Sahel Desert to the evergreen forests of Myanmar and Thailand. They occupy semi-desert, short to medium grasslands and savannahs in Africa; and forested, mangrove, agricultural, rural and semi-urban habitats in India and Bangladesh (Clutton-Brock *et al*. 1976; Poche *et al*. 1987; Y. Jhala pers. obs.).

Golden jackals are opportunistic and will venture into human habitation at night to feed on garbage. Jackals have been recorded at elevations of 3,800m in the Bale Mountains of Ethiopia (Sillero-Zubiri 1996) and are well established around hill stations at 2,000m in India (Prater 1980).

Golden jackals are omnivorous and opportunistic foragers, and their diet varies according to season and habitat. Great quantities of vegetable matter occur in the diet of jackals and, during the fruiting season in India, they feed intensively on the fruits of *Ziziphus* sp., *Carissa carvanda*, *Syzigium cuminii, Phoenix sylvestris* and pods of *Prosopis juliflora* and *Cassia fistula* (Kotwal *et al*. 1991; Y. Jhala pers. obs.). Single jackals typically hunt smaller prey like rodents, hares and birds. They use their hearing to locate rodents in the grass and then pounce on them by leaping in the air; they also dig out gerbils (*Tatera indica*) from their burrows. They have been observed to hunt young, old, and infirm ungulates that are sometimes 4–5 times their body weight (Van Lawick and Van Lawick- Goodall 1970; Eisenberg and Lockhart 1972; Kotwal *et al*. 1991; Y. Jhala pers. obs.). Indeed, cooperative hunting permits them to harvest much larger prey in areas where it is available, and cooperative hunting of langurs (*Presbytis pileata* and *P. entellus*) has been reported (Newton 1985; Stanford 1989). Aggregations of between five and 18 jackals have been sighted scavenging on carcasses of large ungulates (Y. Jhala pers. obs.), and Macdonald (1979a) reports similar aggregations on clumped food resources in Israel. Golden jackals cause damage to melon, peanut, grape, coffee, maize and sugarcane crops; they sometimes take to killing lambs, kids, weak sheep, goats and poultry (Jerdon 1874; Kingdon 1977; Prater 1980; Poche *et al*. 1987).

The social organization of golden jackals is extremely flexible depending on the availability and distribution of food resources (Macdonald 1979a; Moehlman 1983, 1986, 1989; Fuller *et al*. 1989; Moehlman and Hofer 1997). The basic social unit is the breeding pair, which is sometimes accompanied by its current litter of pups and/or by offspring from former litters (Moehlman 1983, 1986, 1989). In Tanzania, golden jackals usually form long-term pair bonds, and both members mark and defend their territories, hunt together, share food, and cooperatively rear the young (Moehlman 1983, 1986, 1989). Moehlman and Hofer (1997) reported average group size of jackal as 2.5 in the Serengeti, Tanzania, while average pack size in Velavadar National Park, India, was 3.0 (n=7) (Y. Jhala unpubl.). Scent marking by urination

and defecation is common around denning areas and on intensively used trails. Such scent flag posts are considered to play an important role in territorial defense (Rosevear 1974). Although Moehlman (1983) reports maintenance of year-round exclusive territories in Tanzania, aggregations in Israel (Macdonald 1979a) and India (Y. Jhala pers. obs.) point towards the flexibility of social organization depending on available food resources. Data obtained by telemetry from the Bhal area of India suggest that most breeding pairs are spaced well apart and likely maintain a core territory around their dens (Y. Jhala unpubl.). Jackals were observed to range over large distances in search of food and suitable habitat, and linear forays of 12–15km in a single night were not uncommon (A. Aiyadurai and Y. Jhala unpubl.). Recorded home range sizes vary from 1.1–20km^2 (Van Lawick and Van Lawick-Goodall 1970; Kingdon 1977; Poche *et al*. 1987; Y. Jhala unpubl.), depending on the distribution and abundance of food resources. Affiliative behaviours like greeting ceremonies, grooming, and group vocalizations are common in jackal social interactions (Van Lawick and Van Lawick-Goodall 1970; Golani and Keller 1975). Vocalization consists of a complex howl repertoire beginning with 2–3 simple, lowpitch howls and culminating in a high-pitched staccato of calls. Jackals are easily induced to howl and a single howl evokes responses from several jackals in the vicinity. Golden jackals often emit a warning call that is very different from that of their normal howling repertoire in the presence of large carnivores like tigers, hyaenas and wolves (Jerdon 1874; Y. Jhala pers. obs.). In India, howling is more frequent between December and April, a time when pair bonds are being established and breeding occurs, perhaps suggesting a role in territory delineation and defence (Jaeger *et al*. 1996).

Over its entire range, except in Protected Areas, the jackal population is steadily declining (MacDonald and Zubiri, 2004). Traditional land use practices are being replaced by intensive agriculture, while wilderness area and rural landscape are being rapidly urbanized. Jackal population can adapt to this change up to some extent and may persist for a while, but eventually disappear from such area. Estimated 80,000 jackal remain on the Indian subcontinent, but there are no estimates for Africa (Jhala and Moehlman, 2004).

A few long term (Moehlman, 1993; Vanlewick Goodall and VanLawick, 1970; Sharma, 1998) and short term studies (Sankar, 1994; Mukherjee *et. al.*, 2004; Aiyadurai and Jhala, 2005; Home and Jhala, 2010) have been conducted on jackal in

Indian sub continent. Golden jackal occupies variety of habitats by adapting to the varied condition. Therefore, several aspects of jackal ecology are not fully understood (Patil and Jhala, 2008).

Deriving meaningful estimates of their abundance is a challenging task. As National Parks and Sanctuaries become subjected to greater human use, carnivores are severely affected by developmental activities, wildlife trade and hunting (Johnsingh 1986, Ashraf et al., 1993, Gupta 1997). There is a large void in the information available on the ecology of most of the small Indian carnivores (Mukherjee 1989, Mukherjee 1998). They are in urgent need of a focused conservation program which can achieve many successes with many challenges and identify a range of future work. They suffer from common issues of lack of awareness of their plight and the deficiency of reliable data on their distribution and conservation requirements.

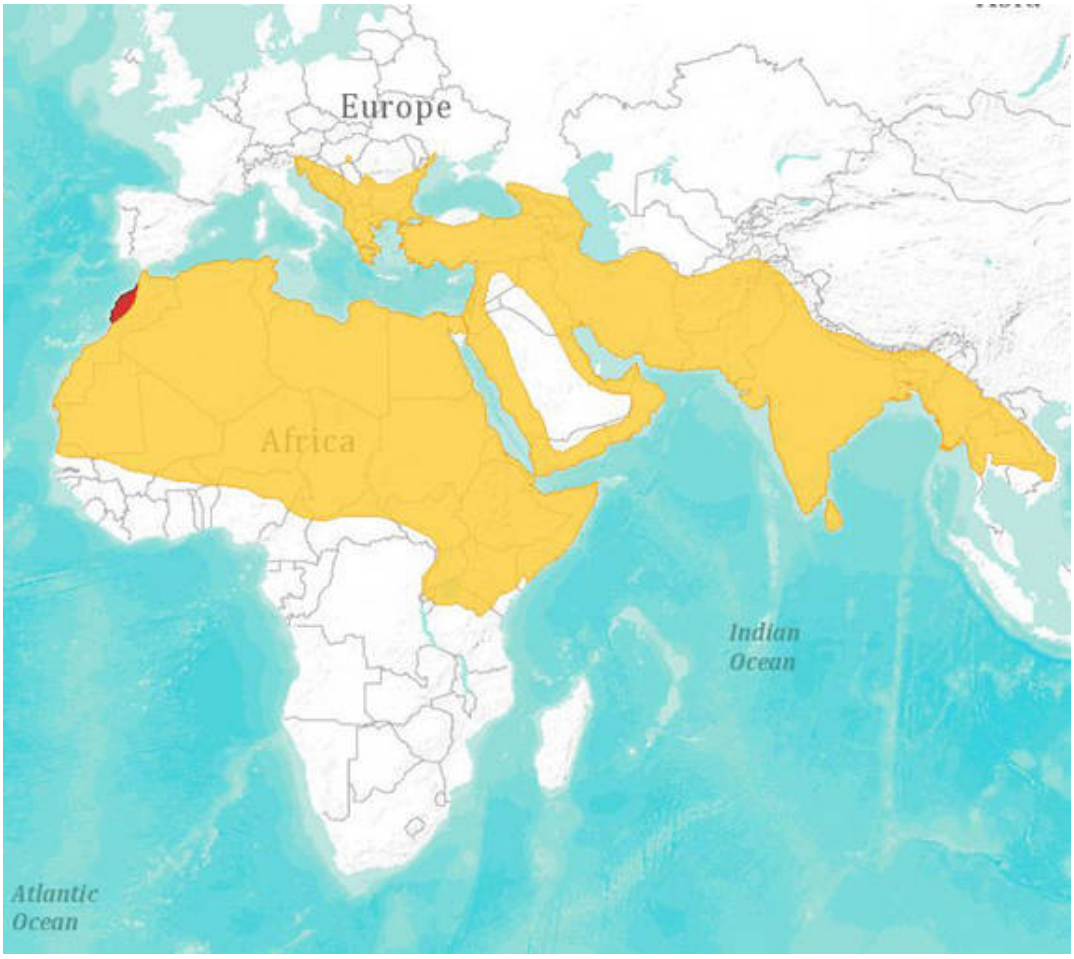

Figure.1.2. Geographical distribution of golden jackal

1.4. Literature Review:

Despite their widespread distribution, studies on jackal had been limited mostly to certain parts of African Savannahs (Wyman, 1967; Van Lawick Goodall and Van Lawick, 1970; Moehlman, 1986). Towards the end of last century, studies on jackal were conducted in Middle East (McDonald, 1979; Golani and Keller, 1975) and parts of Indian subcontinent (Sankar, 1988; Sharma, 1998; Soni *et. al.*, 1995). Sankar (1988) and Moehlman (1993) explained their usefulness in any ecosystem as a scavenger and controllers of rodent population. Fuller *et al.* (1989) worked on ecology of sympatric jackal species in the Rift Valley of Kenya. Mukherjee (1989) studied ecological separation of three sympatric carnivores including jackal, in Keoladeo National Park, Bharatpur. Jaeger *et al.* (1996) reported the impact of jackal population on pre-harvest rat damage in Bangladesh. Kotwal *et al.* (1991) worked on immobilization and radio collaring of golden jackal in Gujarat. Atkinson *et al.* (2002) identified 24 species of fruits in the diet of jackal in Zimbabwe. Mukherjee *et al.* (2004) studied the importance of small mammals in the diet of sympatric lesser carnivores in Sariska Tiger Reserve by analyzing 140 scats and reported that more than 90% of jackal scats contained remain of small mammals. Gupta (2006) worked on food habits of golden jackal in Keoladeo National Park, Bharatpur and reported contribution of 56% of *Zizyphus* fruits in their diet.

Jhala and Moehlman (2004) stressed the need for more intensive studies on jackal. They also emphasized that jackal ecology needs to be studied in forested ecosystems of Southeast Asia where a different set of factors are likely to operate affecting food availability, ranging patterns and survival of the species.

1.4.1. Abundance Estimation

There is lack of reported efforts at estimating abundance of jackal using direct sightings in a given habitat. Pyrah (1984) had used den area surveys and siren station method to estimate an index of coyote (*Canis latrans*) population in North Central Montana. Since, indirect methods only give an index of abundance of an animal species and direct methods give number or densities; integration of these two methods can give reliable results.

Recent advancements in occupancy based techniques (Mac Kenzie *et. al.*, 2004; Royle and Nichols, 2003; Gopalaswamy, 2006; Nag. K, 2008) allowed to estimate population status of animals using detection/non-detection data from repeated surveys at several sampling units (or sites). To estimate the abundance of species whose identification was not possible, Royle and Nichols (2003) model was used by Gupta (2009) in Sariska Tiger Reserve for small and medium sized carnivore by considering home range area of species as a unit for estimating abundance. Home range size of golden jackal was estimated as 14.3 km^2 in Velavedar National Park (Ambika, 2005). Gupta (2009) reported that golden jackal are found to be abundant in number based on direct sightings in the study area but showed low capture rates in camera traps. This may be attributed to not using of trails/roads frequently by this species in the study area.

Capture-recapture methods require repeated efforts to capture or observe animals (Otis *et al.*, 1978; Pollock *et al.*, 1990). The vehicle based transects (Verman and Sukumar, 1995) can be used for estimating densities of animal species where obtaining adequate sample size may be difficult, in low density areas only the indirect sings can give a better estimation of abundance of a species. Mukherjee (1998) used direct sighting methods to estimate an index of predator abundance in the Sariska using vehicle and foot transects across various habitats. A comparison of the different methods used for direct sightings in her study showed that the vehicle based transects were more reliable than foot transect.

1.4.2. Evaluation of food availability:

Carnivores occupy the top position in the terrestrial food chain and greatly influence the communities they inhabit. Selection of prey is of primary interest in the ecology and management of predators and their prey. The characteristic of habitat, availability of prey species and prey behavior have much influence on hunting technique and on selection of prey by predators.

Examination of prey selection by carnivore and the factors influencing such selection could aid in predicting the effects of these predators on prey populations. Partitioning of prey because of interference and exploitation competition between carnivores could produce additive effects on prey populations. The patterns of prey

selection exhibited by various predator species tend to be shaped by a suite of factors, including predator and prey behavior, morphology, and habitat requirements related to hunting or escape (Kruuk, 1986). In general, such factors interact to affect predator-prey encounter and capture probabilities, and thus ultimately determine prey selection patterns occurring within a particular predator-prey system. Yet, even within a given prey species the attributes of depredated individuals may vary spatially, temporally, or between predator species.

Canids are coursing predators, and thus typically exhibit prolonged pursuit of prey through relatively open terrain (Kruuk, 1972; Schaller, 1972). Because canids usually chase swift prey, capture success tends to be low and depredated individuals typically are disadvantaged in some way (Schaller, 1972; Ewer, 1973; Kunkel *et al.*, 1999).

Golden jackal is reported to prey primarily upon rodents (Sankar, 1988; Mukherjee, 1998; Lanszki and Heltai, 2002; Gupta, 2009), including bandicoot rats (Khan and Beg, 1986). Rodents are also an important prey for side-striped jackal (*C. adustus*) (Atkinson *et. al.*, 2002). They also consume a variety of fruits and vegetables, together with poultry and livestock (Sarker and Ameen, 1990). Golden jackal is omnivorous and opportunistic foragers, and their diet varies according to season and habitat. In East Africa, although they consume invertebrates and fruit, over 60% of their diet comprised of rodents, lizards, snakes, birds (from quail to flamingos), hares and Thomson's gazelle (*Gazella thomsoni*) (Wyman, 1967; Moehlman, 1983, 1986, 1989). In Bharatpur, over 60% of jackal's diet comprised of rodents, birds and fruit (Sankar, 1988) and while in Kanha, Schaller (1967) found that over 80% of the diet consisted of rodents, reptiles and fruit. In Sariska Tiger Reserve, scat analysis revealed that their diet comprised mainly mammals (45% occurrence, of which 36% was rodents), vegetable matter (20%), birds (19%), and reptiles and invertebrates (8% each) (Mukherjee, 1998). Great quantities of vegetable matter occur in the diet of jackal and during the fruiting season, they feed intensively on the fallen fruits of *Ziziphus* spp, *Syzigium cuminii*, pods of *Prosopis juliflora* and *Cassia fistula* (Kotwal *et al*., 1991; Gupta, 2006).

Results from the study by Gupta (2009) showed the dominance of mammalian prey species in the diet of striped hyena, golden jackal and jungle cat. These

carnivores utilized broad diet in Sariska. For striped hyena, chital and hare were the seasonal prey consumed while livestock (cattle and goats) are supplementary food item, and peafowl was utilized opportunistically. The *Zizyphus* fruits were consistently eaten by golden jackal in its fruiting season. Chital were seasonal food items for golden jackal. Small mammals like hare and rodents were eaten consistently while peafowl and cattle were eaten opportunistically in Sariska by golden jackal. In the diet of jungle cat, rodents were the most consistently eaten prey species and hare were the seasonal prey item, while utilization of cattle and chital by jungle cat was attributed due to scavenging on large carnivore kills during winter and summer (Gupta, 2009).

Prey abundance has been studied using several techniques depending upon the group of animals they belong to. The ungulates, rodents (Murids and Sciurids), birds and hare, which constitute major portion of predator's diets (Schaller, 1967, 1972; Johnsingh, 1986; Mukherjee, 1998) can be quantified using direct and indirect methods. Line transects have been found to be very effective and reliable in estimating densities of ungulates in the Indian Subcontinent (Karanth *et. al.*, 2004). Small mammals are an integral component of forest animal communities and they form an important prey base for medium sized carnivores (Emmons, 1987; Golley *et al.*, 1975; Hayward and Phillipson, 1979). Anderson *et al.* (1983) estimated the density estimation of small mammal populations using a trapping web and distance sampling methods. Iriarte (1989) studied the small mammal availability and consumption by Fox (*Dusicyon culpaeus)* in Central Chilean scrublands. In recent past, many workers contributed to the distribution pattern of rodents throughout India. But these were taxonomic studies rather than assessing the ecological aspects of species assemblage, co existence and diversity in the natural habitat. Prakash (1959, 1972, 1975, 1977, 1981 and 1995) extensively studied the rodent distribution in Rajasthan.

The study by Gupta (2009) reported that, hare remains were found in 25.9 % of jungle cat's dite, 14.6 % in the diet of striped hyena and 4.4 % in the diet of golden jackal in Sariska where, the density of hare was probably underestimated since they were counted on line transects during morning hours. Rabbits and hare are crepuscular/nocturnal, and their activity follows circadian rhythms; thus, the timing of the census can significantly affect the results (Ballinger and Morgan, 2002).

To quantify rabbit abundance and population trends, crude population indices such as the kilometric abundance index (KAI), i.e. the number of individuals observed per kilometer, have been widely used in Spain (Beltrán, 1991; Moreno, *et al.*, 2007) and France (Marchandeau and Gaudin, 1994). Night counts have been widely used to monitor rabbit populations (Marchandeau and Gaudin, 1994; Martins *et al.*, 2003; Marchandeau *et al.*, 2006) and to estimate population trends (Caley and Morley, 2002; Williams *et al.*, 2007). Caley and Morley (2002) selected the population growth model to estimate the observed rate of increase of rabbits and the precision of spotlight-counts as an index of rabbit abundance, and to evaluate the utility of spotlight-count data for detecting significant changes and trends in rabbit abundance.

1.4.3. Feeding habit and dietary niche overlap

The extent of niche differentiation and resource partitioning determines the degree to which different species can either coexist or competitively exclude each other (Pianka, 1973; Carvalho and Gomes, 2004). An important mode of resource partitioning is the degree of dietary overlap between sympatric species (Hayward and Kerley, 2008). This overlap is influenced not only by each species' physical ability to obtain food (Radloff and du Toit, 2004; Owen-Smith and Mills, 2008), but also by variation in the spatial and temporal availability of food (Azevedo *et. al.*, 2006). Complex and dynamic patterns of spatial and temporal coexistence within carnivore guilds therefore often require long-term studies to disentangle the interactions between predators and prey species (Carvalho and Gomes, 2004; Azevedo *et. al.*, 2006).

One of the basic tenets of community ecology is that sympatric species occupying a common tropic level tend to exhibit niche differentiation and resource partitioning (Pianka, 1969; Schoener, 1974, 1986). Among the most important modes of resource partitioning in ecological communities is the differentiation of food resources, such that cases of extensive dietary overlap between similar species are limited. Patterns of resource partitioning and characterizing resident carnivore populations within particular ecological communities may be complex and dynamic. For distinct carnivore guilds different mechanisms seem to be involved, such as

different body sizes of predators (Carvalho and Gomes, 2004), different prey species (Karanth and Sunquist, 2000), different prey sizes (Juarez and Marinho-Filho, 2002), different activity patterns (Loveridge and Macdonald, 2003) and differential microhabitat use (Johnson and Franklin, 1994a). Gupta (2009) studied medium and small sized carnivore in Sariska and reported that, the overall niche breath for three carnivores (hyena, jackal and jungle cat) was narrowest for the jackal (0.5) followed by striped hyena (0.7) and jungle cat (1.7). The overall diet overlap was high between hyena and jackal (0.75) and medium between jungle cat and jackal (0.52) and hyena and jungle cat (0.49) (Gupta, 2009).

Dietary studies based on prey remains in feces are generally accepted to represent accurately the components of an animal's diet (Putman, 1984), and in carnivores it is possible to identify remains to the level of family. Habitat conditions are usually well indicated by the diet composition and feeding habits of predators. The jackal is a typical food generalist carnivore. Depending on food availability, jackal may be solitary hunters, co-operate in pairs or hunt as groups (mainly while the parents teach the offspring to hunt). Jackal cannot run persistent like the wolf; it is derived from its anatomy (relatively short legs). That is why jackal attacks from ambush mainly (Szabó *et. al.*, 2010). Jackal feeding habits were studied in Hungary (temperate climate agricultural area, Lanszki *et. al*., 2006), Greece (Mediterranean marshland, Giannatos *et. al.*, 2005), and Israel (Mediterranean agricultural area, Yom-Tov *et. al.*, 1995). Large differences were detected in the consumption of domestic animals between the above mentioned study areas. According to biomass consumption the highest rates were recorded in Israel (74.0%), medium in Greece (62.6%) and substantially lower levels in Hungary (1.4%). In Israel, domestic animal food type consumption by jackal was dominated by poultry followed by eggs, cow and cat. In Greece jackal consumed mostly goats, sheep, poultry, dogs (2.9%) and cats. Cat and poultry consumption was also recorded in the Hungarian study. According to Yom-Tov *et. al.* (1995), domestic animals along with small wild mammals were the most important dietary components of jackal in Israel. Small mammals also were found to be a main food source also in Kazakhstan, Azerbaijan and Uzbekistan, India, Bangladesh as well as in Tanzania close to the equator (Macdonald and Zubiri, 2004).

In Greece, having extensive grazing and Israel where high density of poultry farming reported, the primary foods of jackal were mainly goat and poultry respectively. While jackal are able to hunt the young of domestic ungulates especially during their birth season (Yom-Tov *et. al.*, 1995) or poultry, direct predation by jackal on goat and poultry was minimal in the study areas in Greece and Israel. The consumption of domestic animals (excluding domestic dog and domestic cat) cannot be attributed to seasonal predation, but rather to carcasses left in the field (Greece) and around poultry farms (Israel) which are consequently cleared up by the scavenging jackal (Mac-donald, 1979). Gupta (2009) reported the presence of *Zizyphus* fruits in golden jackal's diet in Sariska and chital were utilized as seasonal food item. Small mammals like hare and rodents were eaten consistently while peafowl and cattle were opportunistically consumed.

1.4.4. Den Site Selection

The availability and use of denning sites are important aspect of the ecology of most of canids and are indicative of breeding units within the habitat (Tannerfeldt *et. al.*, 2003) as well, the reproductive success of a den dependent species would directly depend on the availability of good denning habitats (Alt, 1984; Ruggiero *et. al.*, 1998). The selection of denning and resting sites can be considered as a form of resource selection therefore; the availability of suitable denning and resting sites may be limiting factors for carnivore distribution and abundance (Lesmeister *et. al.*, 2008; Zielinsnki *et. al.*, 2004). The availability of such crucial resource could potentially limit where a den dependent species may be present. The response of a species to changes induced in the habitat by human presence may be positive or negative depending on the generalist or specialist nature of the species (Kamler *et. al.*, 2003). If the species is a specialist dependent on the native habitat, then loss of the native habitat may affect the species negatively. An example in this case would be the Swift fox (*Vulpes velox*), which has been shown to decline in number due to the loss of native prairie habitat. Whereas, red foxes (*Vulpes vulpes*) are known to thrive even in urban areas (Kamler *et. al.*, 2003). Finding a suitable den site might be a stronger limiting factor for specialist carnivores living in human dominated areas, whereas generalist species may find greater denning opportunities due to habitat alteration in

such landscapes. Therefore, understanding factors that influence resource selection for such carnivore species becomes important.

Dens offer a number of benefits, such as thermoregulation (Magoun and Copeland, 1998), protection for altricial offspring (Linnell *et. al.*, 2000) and security from predators (Frafjord, 2003), and therefore finding a suitable den may influence the territory size as well as ranging behavior of a carnivore (Doncaster and Woodroffe, 1993; Fernandez and Palomares, 2000). Habitat for denning could be largely determined by factors such as patchiness (Dell'Arte and Leonari, 2007), food availability (Eberhardt *et. al.*, 1983), presence of conspecific predators (Tannerfeldt e*t. al.*, 2003; Arjo *et. al.*, 2003; Szor *et. al.*, 2008) and human disturbance (Rova, 2003). Earlier, researchers thought jackal breed throughout year (Prater, 1980) but detailed study revealed that jackal have distinct breeding season, which generally coincides with the abundant availability of food (Van Lawick Goodall and Van Lawick, 1971). Jackal form permanent pair bonds and they show elaborate precopulatory sequences (Golani and Keller, 1975). Golden jackal makes or occupy den at the onset of breeding season and maybe used for many years (Sharma, 1998). Preferred den sites are natural or manmade embankments viz., rivulets, gullies, road and check dam embankments (Soni *et. al.*, 1995; Jhala and Moehlman, 2004). Dens may be 2 to 3 m long tunnels leading into a large chamber 0.5 to 1 m below the ground surface (Jhala and Moehlman, 2004).

1.4.5. Habitat use.

Resource selection by animals is a scale-dependent hierarchical process of behavioral responses to environmental factors. Lack of information on such habitat selection dynamics can hamper the conservation management of species and habitats. The inconsistency in the distribution and abundance of carnivore is associated with many of their prey species, temporal or demographic variability in prey vulnerability to predation, the influence of intra- as well as interspecific competition on carnivore food habits and even the potentially strong individual-based variability in carnivore food preference (Maddock and Perrin, 1993; Wu, 1999). Evidence suggests that breeding pairs of jackal were annual residents that defended cover sites but not foraging areas beyond (Jaeger *et. al.*, 2007). The golden jackal is a habitat generalist,

similar to the coyote (*Canis latrans*) in North America (Bekoff and Gese, 2003). Both species are generalist predators with adaptable social systems (Macdonald, 1979) that are able to exist in close proximity to humans and exploit agro-ecosystems. However, in some parts of their range, golden jackals have either disappeared or their numbers are shrinking due to anthropogenic causes (Jhala and Moehlman, 2004). Surveys in Greece indicate that jackals have a fragmented distribution associated with coastal wetlands and that local populations are disappearing coincident with the destruction of the remaining patches of this habitat (Giannatos *et. al.*, 2005). In contrast, golden jackal are reported to be expanding their range in Bulgaria (Krystufek *et. al.*, 1997). Breeding adults may not occur where they cannot be territorial throughout the year, as seems to be the case for the coyote (Shivik *et. al.*, 1996; Gantz and Knowlton, 2005). High overlap in resource utilization could increase the potential for resource competition between species and, theoretically, result in decreased inferior species abundance (Case and Gilpin, 1974). Shifts in habitat use by less competitive species can occur as large carnivores recolonize or are reintroduced into areas where other carnivore species are established. Differential use of habitat types or topographic characteristics is one method of spatial partitioning that allows for coexistence of congeneric species. Therefore, a better understanding of the extent of resource overlap between species could contribute in understanding its role in ecosystem. The behaviour and ecology of golden jackal has been studied in detail in East Africa. On the short-grass plains of the Serengeti National Park, monogamous pairs of jackal defend territories of 1 to 3 km^2 within which subadult helpers contribute to pup-rearing (Moehlman, 1979, 1983, 1986, 1989). The range size over three months of an adult pair of radio-tagged golden jackal in Acacia woodland in Kenya was 2.4 km^2 (Fuller *et. al.*, 1989). Flexibility in golden jackal social organization is illustrated by a study in Israel where, over two months, jackal feed primarily on a rubbish tip occurred in stable groups of ten and twenty individuals and defended territories of <0.1 km^2 (Macdonald, 1979). The literature on spatial memory (Macdonald, 1976; Roberts, 1979, 1981; Vander Wall, 1982, Kamil and Balda, 1985) and navigation in animals (Tolman, 1948; Menzel, 1973; Peters, 1978; Gould, 1986; Chapuis *et. al.*, 1987; Gallistel, 1993) suggests following orderly paths is within the capabilities of a wide variety of species. Canids are well-equipped to detect and follow specific scent trails (Neuhaus, 1953; Kaimus, 1955; Becker *et. al.*, 1957; Moulton *et. al.*, 1960; Albone, 1984; Hepper, 1988; Thorne, 1995), to re-trace paths (Peters and Mech,

1975; Macdonald, 1979 a, b; Bowen and McTaggart Cowan, 1980), to orient an individual (Eisenberg and Kleiman, 1972; Walther, 1978; Wells and Bekoff, 1981), and to otherwise increase foraging success (Henry, 1977; Harrington, 1981, 1982). It is therefore highly feasible that a foraging jackal can track the resources within its home range, perhaps using prior knowledge of locations and a navigational strategy based on the ‘‘principle of least effort’’ (Zipf, 1949). Indeed, there is evidence that canids can and do follow predictable routes (red foxes, *Vulpes vulpes*, Doncaster and Macdonald 1997; Blandford's foxes, *Vulpes cana*, Geffen and Macdonald, 1993).

1.5. Justification of the Study:

Golden jackal can be regarded as either meso-carnivores or apex predators, depending on the presence or absence of larger carnivores. Despite of its wide range of distribution, little is known about the ecology of the species in general, and in forested ecosystem, in particular, where a different set of factors operate, affecting food availability, ranging patterns and survival of the species. Little quantitative information is available on jackal densities, habitat use, and ranging patterns in relation to food availability. Some important aspects of jackal ecology such as den site selection and dietary niche overlap with other carnivore in the study area were addressed in the present study. The jackal fills an ecological niche as predators and scavengers in their ecosystem. Thus the present study is on the role and importance of the jackal as a small mammal predator in the semi-arid landscape thus become useful to plan an efficient conservation and management strategy of the species.

1.6. Objectives:

1. To determine the abundance of golden jackal.
2. To estimate the food availability, food habits and dietary niche overlap between golden jackal and other meso-carnivores.
3. To evaluate the den site selection by golden jackal and,
4. To evaluate the habitat use by golden jackal.

The study was conducted from November 2010 to June 2013 in two different seasons winter (November to February) and summer (March to June) in Sariska Tiger Reserve Rajasthan.

1.7. Organization of the thesis:

The thesis is organized in five chapters. Chapters 1 and 2 deal with the introduction and study area respectively. Chapters 3, 4 and 5 are based on the three broad objectives of the present study. Each chapter includes a brief introduction followed by methodology, results arrived at and discussion of the results. The Chapter-1 provides general introduction and details of canid group and study species followed by literature review based on objectives. It further describes the objectives and duration of study. Chapter-2 deals with the study area, different vegetation types and available flora and fauna in Sariska Tiger Reserve. Chapter-3 deals with abundance estimation of the study species based on camera traps. Chapter-4 deals with the food availability, food habits of study species and comparison between dietary niche overlap with other meso-carnivores. Chapter-5 deals with the evaluation of the den site selection and Chapter-6 deals with evaluation of habitat use and habitat suitability modeling based on Ecological Niche Factor Analysis 'ENFA' and logistic regression using different environmental variables (including different vegetation classes) and generated habitat suitability maps for the species in Sariska Tiger Reserve.