Chapter 1

INTRODUCTION

1.1 Sympatric associations among large carnivores

Top predator species are the major indicators of the healthy ecosystem. Large carnivores have become flagship species for conservation in many parts of the world. Much of the attention gained by the carnivore species reflects their charismatic image, but there are also some evidences that large carnivores play an important role as top-down controls on community structure and processes (Corlett, 2011). Large carnivores require effective conservation in terms of assessment of complex mix of ecological, ethical and symbolic inter-relationships (Kellert et al., 1996). In the last hundred years there has been a decline in large carnivore species (Linnell et al., 2001; Woodroffe, 2001). When ecologically similar species are in sympathy, different species often partition the use of resources, resulting in niche differentiation, to facilitate species coexistence (Schoener, 1974; Gordon, 2000; Chiang et al., 2012). Differentiation in habitat selection among sympatric species may depend on niche partitioning, species interactions and selection mechanisms. (Rauset et al., 2012). Competition for space and food resources is one of the major determinants of community structure of carnivores (Morin, 1999). Recently, the role of interference competition among predators has been shown to affect space use, diet and behavior among predators (Linnell & Strand, 2000; Tannerfeldt et al., 2002; Switalski, 2003; Thompson & Gese, 2007). Interspecific competition is one of the most important factors that limit the number of species occupying similar ecological niches (Di Bitetti et al., 2010), it also affects the population of the subordinate species (Palomares & Caro, 1999; Fedriani et al., 2000). Studies on felids suggest that competition by larger cats may influence the diets and space use of smaller cats (Iriarte et al., 1990; Hart et al., 1996; Durant, 2000; Hass, 2009).

Population size is a major determinant of extinction risk. However, controversy remains as to how large populations need to be to ensure persist existence of the species (Reed et al., 2003). To predict the long-term persistence of animal populations, accurate estimates of population size as a function of environmental
change and habitat disturbance are necessary (Kohn et al., 1999). Abundance or population size is a state variable that provides the most critical information about the status of any animal population (Kaavya, 2008). Estimation of abundance for animal populations involves two basic issues. First, areas those are sufficiently large that ground surveys cannot be conducted over the entire area of interest (Thompson, 1992; Lancia et al., 1994; Thompson et al., 1998; Yoccoz et al., 2001; Mackenzie et al. 2002). Secondly, the idea that animal survey methods seldom detect all animals present in any surveyed area or sample unit (Royle & Nichols, 2003).

Tiger *Panthera tigris*, leopard *Panthera pardus* and the Asiatic wild dog or dhole *Cuon alpinus* are sympatric within most of their range. How these sympatric species with similar morphology or diet are able to coexist is one of the major ecological questions (Ramesh et al., 2012b). Little information exists on the extent to which tiger, leopard and Asiatic wild dog may favour human-influenced landscapes over wilderness, or how anthropogenic factors may influence the coexistence of these three species. Several studies have suggested that selecting different size class of prey foster coexistence of these carnivores in same area and activity patterns also allows them to co-exist (Johnsingh, 1983; Karanth & Sunquist, 1995; Venkataraman et al., 1995; Karanth & Sunquist, 2000). Though prey selection plays a major role for coexistence (Kumaraguru et al., 2011), behavioural patterns also allow them to coexist in tropical forests of India (Karanth & Sunquist, 2000).

The patterns of prey selection exhibited by various predator species tend to be shaped by a suite of factors, including predator and prey behaviour, morphology, and habitat requirements related to hunting or escape (Bakker, 1983; Kruuk, 1986). Differences among large carnivore species with respect to use of tropic, temporal, and spatial aspects of their environments have frequently been used to clarify how the component species coexist. Segregation along one or more of these niche dimensions facilitates partitioning of resources and thereby the ecological separation of species (Karanth & Sunquist, 2000). Whether the separation is causally related to competitive interactions, due to stochastic effects, or to other structuring factors has, however, been the subject of some debate (Weins, 1977; Schoener, 1982). Several hypotheses have been proposed to explain prey selection by the predators (Karanth & Sunquist, 1995). These hypotheses pertain to ultimate causal factors such as energetic benefits
and costs involved (Griffiths, 1975) as well as to proximate mechanisms of selection such as search images or prey vulnerability (Curio, 1976; Temple, 1987). Large carnivore prey selection is a complex phenomenon (Bekoff, et al., 1984; Kruuk, 1986; Sunquist & Sunquist, 1991). A large number of studies have examined large carnivore predation in animal communities of temperate zone forests (Bergerud, et al., 1983, Messier, 1991; Gasaway et al., 1992) and of tropical savannas (Kruuk, 1972; Schaller, 1972; Packer et al., 1990; Mills & Shenk, 1992; Stander & Albon, 1993). Terborgh (1990) has argued that large carnivores may play a relatively major role in shaping prey communities in the stable environments of tropical forests (Karanth & Sunquist, 1995) and field studies on prey selection have been scarce in these habitats (Schaller, 1967; Griffiths, 1975; Johnsingh, 1983; Rabinowitz & Nottingham, 1986; Emmons, 1987; Rabinowitz, 1989). As a result large carnivore prey selection pattern in tropical forests are poorly understood (Karanth & Sunquist, 1995).

Illegal hunting poses dual threat to large carnivores, through direct removal of individuals and by prey depletion (Datta et al., 2008a). There is a growing body of literature that demonstrates the significant impacts of hunting on wildlife in tropical forests (Robinson & Bennett, 2000). With improved hunting technologies and penetration into remote forest areas, wild meat consumption has increased (Robinson & Redford, 1991; Wilkie & Carpenter, 1999). Market demands for wild meat have contributed in pushing the harvest levels of wildlife to unsustainable limits (Fa et al., 1995, 2003; Apaza et al., 2002). The effect of hunting by rural people has led to quantified changes in structure of mammal assemblages (Jerozolimski & Peres, 2003). Hunting is a serious issue for conservation of wildlife throughout north eastern India (Dutta, 2002), at least 23 species are actively hunted for local meat consumption in western Arunachal Pradesh alone (Mishra et al., 2004, 2006). Humans have been hunting now for almost 100,000 years, it is predicted that the current rates of population and overhunting will not sustain species even if human density is maintained at 1 km² in tropical forests (Gopi et al., 2012). Large carnivores are especially sensitive to the growth of human populations. Because they may kill livestock and even, occasionally, people, carnivores are tolerated by few human societies (Woodroff, 2000). Retaliatory killing, hunting and livestock depredation are the cause and effect which pose a threat to carnivore populations. The development process has caused shrinkage of wildlife habitats especially construction of human
dwellings area near forests. Carnivores have been facing tremendous pressure from humans. Encroachment by humans in terms of fuel wood collection, cattle grazing, stealing of the prey, and timber collection have pushed them to high degree of isolation and local extinction (Johnsingh, 1985).

In view of the above, this study attempts to address the conservation of sympatric large carnivores such as tiger, leopard and Asiatic wild dog by collecting biological and ecological information in Tropical semi evergreen forests of north eastern India. Sympatric association of these species has been studied in tropical forests of southern (Karanth & Sunquist, 2000), central (Majumdar, 2012), northern India (Harihar et al., 2011) and in temperate forests of Bhutan (Wang, 2009), it has however not been studied in the north eastern Indian region. The present study aims to address how these carnivores coexist despite of severe hunting pressures and what factors influence their coexistence. The outcome of the study would be immensely useful for the conservations of large carnivores.

1.2 Study species profile

1.2.1 Tiger

The tiger *Panthera tigris* has been used as charismatic flag ship species to protect the entire range of biodiversity in several Asian countries. Based on the size, skull characters, pelage coloration and stripe patterns, eight sub species are recognised, 1. Bengal tiger *Panthera tigris tigris*, 2. Siberian tiger *P. t. altaica*, 3. Chinese tiger *P. t. amoyensis*, 4. Indo-Chineses tiger *P. t. corbetti*, 5. Caspian tiger *P. t. virgala*, 6. Sumatran tiger *P. t. sumatrae*, 7. Balinese tiger *P. t. balica*, and 8. Javan tiger *P. t. suntaiica*. Out of eight sub species three are extinct (Seidensticker & Lumpkin, 1997).

1.2.1a General descriptions

The tiger pelage is light tawny orange with under parts of legs, abdomen, cheek and throat white. The black colour stripe patterns are different from individual to individual. Body length and weight of male is 270-310 cm and 175-200 kg and of female is 240-265 cm and 240-265 kg. First reproduction stage for male is 4.8 years and for female it is 3.8 years. Longevity is 12-15 years in the wild and gestation
period is 106-112 days. Litter size is generally 1-7, most of the time 1-2 is common (Prater, 1980).

1.2.1b Geographical distribution
Historically, the tiger was distributed over a wide geographical region that extended from Russia through southern China, South east Asia, the Indian subcontinent and into Indus river valley in Pakistan (Seidensticker & Lumpkin, 1997). Tigers occur in a broad variety of forest types ranging from the dry forests of India and Indochina to the tropical rainforests of Sumatra and Malaysia, and from the mangroves of the Sundarban in Bangladesh and India to the taiga forests of China and the Russian Far East (Chundawat et al., 2012). In India, currently tigers occur largely in the forest areas of 17 states within 42 tiger reserves (Jhala et al., 2010) while other Indian states viz. Goa, Nagaland, Meghalaya, and Haryana, have reports of occasional tiger occurrence (Chundawat et al., 2012).

1.2.1c Conservation status and threats
The IUCN 2000 Red List of Threatened Species has classified the tiger species as Endangered and it is listed in Appendix I of CITES. Indian Wildlife (Protection) Act, 1972 has placed it under Schedule I. The major threat to its survival is habitat loss and its poaching and poaching of its prey (Nowell & Jackson, 1996). Widely prevalent perception attributes this decline of tigers to illegal killing for trade in their body parts. However prey depletion is the main reason for tiger decline (Karanth & Stith, 1999).

1.2.2 Leopard
The common leopard Panthera pardus is the most widely distributed cat in the world (Bailey, 1993) and occurs in almost all types of habitats. Leopards are generally thought to prey on medium-sized ungulates (Hayward et al., 2006a). Seven subspecies of leopard have been identified based on variations in coat colour and spot size (Hes, 1991) while based on DNA eight sub species have been described (Mithathapala et al., 1996).
1.2.2a General descriptions
The body colour of leopard is yellow with black spots. Large black spots are grouped into rosettes on the shoulders. The coat colour varies from pale yellow to deep gold or tawny, and is patterned with black rosettes. Absence of pigments (Melenistic) makes it the black panther which occurs mostly in humid forest (Kingdon, 1977; Daniel, 1996). Leopard has solitary life style which territory has five to 40 km$^2$ that may overlap several females. The leopards are generally most active between sunset and sunrise, and kill more prey at this time (Hamilton, 1976; Bailey, 1993). The leopard is exceptionally strong and capable of climbing trees while carrying prey up to three times its own weight.

1.2.2b Geographical distribution
The geographical distribution of leopard extends throughout Africa, Central Asia, South-East Asia and North Amur valley in Russia. Leopards are found throughout the Indian sub-continent with the exception of deserts, the Sundarban mangroves, and densely settled areas (Khan, 1986; Johnsingh et al., 1991).

1.2.2c Conservation status and threats
Common leopard is classified as a threatened species in the IUCN Red list data book and Appendix-1 of CITES. It had been given the highest level of protection (listed as Schedule I species) under the Indian Wildlife (Protection) Act, 1972.

1.2.3 Asiatic wild dog
Asiatic wild dog or dhole *Cuon alpinus* one of the major predator of the wild and a least studied social carnivore in wild (Fox, 1984) when compared with other pack hunting canids. Unlike African wild dogs and only few studies of specific aspects of their ecology and behaviour are available in literature (Johnsingh, 1982).

1.2.3a General descriptions
Ellerman and Morrison-Scott (1966) recognized 10 subspecies of Asiatic wild dog in the world. On the basis of body size and dentition Mivert (1890) described two species, *Cuon javanicus* and *Cuon alpines*, ten subspecies were described by Stains (1975) and 11 by species Muller-Using 1975. In 1990 Ginsberg and Mac Donald identified 11 sub species across the world.
The size and coloration of wild dogs varies regionally (Sheldon, 1992; Menon, 2003). Asiatic wild dog very difficult to recognize the individual due to the uniform color (Kotwal, 1981). Distribution in northern parts of India is slightly larger than in the southern India and males’ average weight is greater than females’ (Cohen, 1977; Prater, 1980; Johnsingh, 1982; Fox, 1984). Average weight of the males is 15-20 kg and females 10-13 kg (Cohen, 1978). Body length is 80-113 cm and tail length 40 to 50 cm (Prater 1980; Johnsingh 1982). The legs are long and slender (Novikov, 1956; Stroganov, 1962; Sosnovskii, 1967) some Asiatic wild dogs have tuft of white or grey at the end of the tails (Brander, 1923; Burton, 1941, 2003; Cohen, 1977, Cohen et al., 1978; Prater, 1980; Davidar, 1973, 1975 ; Fox, 1984). Females have 14 to 16 mammae instead of usual 10 found in canis (Pocock, 1936, 1939; Krishnan, 1972; Cohen et al., 1978).

1.2.3b Geographical distribution

The distribution of Asiatic wild dog extends throughout eastern and central Asia, and (Sheldon, 1992) south, east and Southeast Asia (Durbin et al., 2004, 2008). Asiatic wild dogs are the most wide spread canids of the Indian, the Indomalayan and the Indo Chinese of the oriental region. The early pre-historic distribution is detailed by Thenius (1954). Historically they were distributed from Tian-shan and Altai mountains, southwards through Mongolia, Korea, China, Tibet, Nepal, India, Indochina and possibly in Pakistan. Currently their distribution is restricted to central and eastern Asia, India, Nepal, Bhutan, Bangladesh, Indochina, Myanmar, Indonesia and Malaysia. C. a. alpinus is found in Eastern Russia, including Amur, C. a. adustus is found in northern Myanmar and Indo-China, C. a. dakhunensis is found South of the Ganges in India, C. a. fumosus is found in Western Szechuan, China, and Mongolia. C. a. infuscus is found in Southern Myanmar, Malaysia, Thailand, and Vietnam C. a javanicus is found in Java. C. a laniger is found in Kashmir and Southern Tibet, C. a. lepturus is found south of the Yangze in China, -fur C. a. primaevus is found in Himalayan regions of Nepal, Sikkim (India), and Bhutan, and has long hair on the paws C. a. sumatrensis is found in Sumatra, C. a. hesperius is found in Eastern Turkestan, Southern Siberia and Western China (Altai & Tienshan). The first study on Asiatic wild dog distribution (Jerdon, 1867) stated that Asiatic wild dog was common in India and Sri Lanka. In 1975, Stains mapped the Asiatic wild dog distribution, and it indicates the absence of Asiatic wild dog species from southern tip
of the Indian sub continent. Among the south Asian sub population *C. a. dhukenensis* found in south of the river Ganga, Central Indian highland and southern India (Johnsingh, 1983). *C. a. primaevus* was sighted by Israel and Sinclair (1987) in Corbett tiger reserve and Chitwan (Israel & Sinclair, 1987; Stewart, 1993) *C. a. laniger* also rare in Ladakh. *C. a. adjustus* found in north east India. In Arunachal Pradesh it shows decline in numbers (Datta et al., 2008a&b). *C. a. infuscus* is found in Myanmar and Bangladesh.

Asiatic wild dogs *Cuon alpinus infuscus* and *Cuon alpinus adjustus* are still common in most of the forested tracts of Burma, (Johnsingh, 1985). In India *Cuon alpinus dakhunensis* still common (Johnsingh, 1983) especially in central Indian highland and southern states of the India. Three sub species are known to be present in India (Prater, 1980) and based on morphology Ginsberg and Macdonald (1990) recognized four sub species in India. In east India, Asiatic wild dogs are rare (Johnsingh, 1983) with the exception of the Garo Hills area of Meghalaya (Assam) where they are reportedly still common. In the Itanagar Wildlife Sanctuary, Arunachal Pradesh Asiatic wild dogs are frequently sighted by local villagers (Aiyadurai, 2003). Indirect evidence indicates presence of Asiatic wild dogs in Namdapha Tiger Reserve, Arunachal Pradesh (Datta et al., 2008b).

### 1.2.3c Conservation status and threats

Indian wildlife (Protection) Act, 1972 placed the Asiatic wild dog in Schedule II, whereas endangered status is given by IUCN and Appendix II of CITES. Now it is protected from hunting, unless there is permission from chief wildlife warden of the state the Asiatic wild dog cannot be legally shot in Arunachal Pardesh. In Russia, Asiatic wild dogs received the status of “Protected Animals” in 1974 from the Russian federations. In Vietnam, Asiatic wild dogs are protected by Decree18/HDBT and the amendment Decree 48/2002/ND-DP under category IIB, which limits extraction and utilization.

Population of Asiatic wild dog is particularly vulnerable to extinction due to the anthropogenic pressure, particularly habitat loss and hunting. Poisoning, den digging and killing of pups caused the Asiatic wild dogs decline (Fox, 1984; Johnsingh, 1985; Durbin, 2004). Prey depletion by humans in terms of poaching one of the major
reasons for Asiatic wild dogs decline (Fox, 1984) 98% of the barking deer, the major prey for Asiatic wild dog is hunted by local tribes in Arunachal Pradesh (Aiyadurai, 2007). Many of the highways pass through the wildlife habitat, this also a possible reason for Asiatic wild dog mortality (Woodroffe & Ginsberg, 1998; Durbin, 2004).

1.3 Review of present knowledge

One of the important challenges for any sympatric carnivore studies is to understand their ecological separation (Seidensticker, 1976). Whether the separation is causally related to competitive interactions, due to stochastic effects, or to other structuring factors has however been the subject of some debate (Weins, 1977; Schoener, 1982). Different forest types and their resource availability in India, helped to form different large and medium body sized carnivore associations as tiger, leopard and dhole in tropical moist, rain and dry deciduous forests.

1.3.1 Abundance of large carnivores

Stable coexistence occurs when each species can recover from low abundance in the presence of competitors at their stochastic equilibrium abundance (Chesson, 2000). Real abundance of predators and prey is a fundamental factor to understand the prey-predatory relationships and competitions (Ramesh, 2010). Reliable estimates of populations are critical for the conservation of large terrestrial carnivores as they play an important role in evaluating the effectiveness of conservation efforts and also provide benchmark data for future management decisions. But estimating populations of large carnivores has always been controversial. Tiger and leopard population estimation was started with pug mark census (Choudhary, 1970, 1971; Panwar, 1979; Sawarkar, 1987; Sharma, 2001) which lacked statistical accuracy and precision (Karanth & Nichols, 1998; Karanth et al., 2003). The first camera trapping census started in India in 1995 (Karanth, 1995) based on capture –recapture technique (Otis et al., 1978). For tiger and other forest dwelling carnivores, mark –recapture using camera traps provides very useful techniques for estimating population size and other population parameters (Karanth & Nichols, 1998; Karanth et al., 2004 a & b). Tiger densities were derived from radio telemetry in Chitwan National Park, Nepal, with assessment of habitat quality and prey abundance, using a Geographical Information System (GIS) approach (Smith, 1984; Smith et al., 1987). Radio telemetry provides
data on carnivore home range size and social organization, which can be used to derive estimates of densities (Sunquist, 1981; Smith et al., 1987). Tiger density through this method is constrained by the high cost of radio collars, being able to tag a small number of animals simultaneously and uncertainty of untagged animals and the high effort involved (Contractor, 2007). Ecological studies of prey requirements often leads to development of a simple mechanistic model for predicting tiger density as a function of prey density (Karanth et al., 2004a).

Leopard is the most adaptable wide spread species whose population is negatively affected by prey depletion, direct hunting, and habitat conversion (Henschel & Ray, 2003). Based on pugmark censes in India the leopard population was estimated as 9,844 during 2001 (Chundawat et al., 2012). The camera trap method is the widely used technique similar to that for tiger census (Wikramanayake et al., 1998). This method has been used in Jigme Singye Wangchuck National Park in (Wang, 2008) in temperate forest of Bhutan, arid region in Sariska (Sankar et al., 2008; Mondal et al., 2012), Satpura (Edgaonkar et al., 2007; Edgaonkar, 2008), Shivalik range of Chilla (Harihar et al., 2009b) and the Western Ghats landscape in Mudumalai Tiger Reserve (Ramesh, 2010). The density of leopard/100 km$^2$ ranged from 1.0 to 25.5 individuals in the Indian sub-continent. Estimating the abundance of Asiatic wild dog is extremely difficult in the field and its population has been estimated by various method such as vehicle transect in Mudumalai (Ramesh, 2010) and occupancy survey in Pench (Majumdar, 2012). Asiatic wild dog abundance was estimated in Pench Tiger Reserve (0.24± 0.08/100 km$^2$) and in Mudumalai Tiger Reserve (43.7/km$^2$) (Ramesh, 2010).

1.3.2 Food habits, predation patterns and prey selectivity

All three species are morphologically specialized for killing of prey larger than themselves and in most places their prey base consists of cervids, bovids and suids. Tigers and leopards exploit this common suite of prey species as solitary, stalk-ambush hunters, whereas Asiatic wild dog are coursing pack hunters (Schaller, 1967; Seidensticker, 1976; Sunquist, 1981; Johnsingh, 1983; Karanth, 1993). A recent study conducted in Anamalai Tiger Reserve, found that sambar was the preferred prey for these carnivores and it is constitutes 35% of the overall diet of tiger, whereas it constitutes 17% and 25% in leopard and Asiatic wild dog diets, respectively.
Abundance of ungulate prey species, as well as their availability in different size classes are both critical factors that facilitate sympatry among the three predators (Andheria et al., 2007). Tiger is obligate carnivore mainly preying on large ungulate (Seidensticker & Lumpkin, 1997) and selectively on large bodied prey (Karanth & Sunquist, 1995; Andheria, 2006; Ramesh et al., 2010). Biswas & Sankar (2002) noticed in central India, if there is prey choice it can kill large to medium sized prey and they recorded highest predation on chital. Studies on food habits of leopard suggests that it has a more diverse diet ranging from lower size classes of animals to medium sized wild prey weighing less than 50 kg (Eisenberg & Lockhart, 1972; Seidensticker et al., 1990).

Leopard is obligating carnivore and they are highly opportunistic generalist prey species ranging from arthropod to mammal (Ray et al., 2005). Leopards tend to select prey smaller than themselves (Johnsingh, 1983; Karanth & Sunquist, 1995), and the diet of the leopard consists of medium size ungulates (Ray et al., 2005; Andheria et al., 2007), larger prey (Mondal, et al., 2012) and also smaller prey such as rodents (Johnson et al., 1993). Ahemed & Khan (2008) studied the food habits of leopard and found 20 prey items in 74 scats in Duduwa National Park. Leopards coexist with other carnivores because of their ability to climb trees and reduce spatial overlap and food competition by occupying habitats not favoured by tiger and Asiatic wild dog (Eisenberg & Lockhart, 1972). In Mudumalai while examining communal hunting in the Asiatic wild dogs. Venkataraman et al., (1995) and later, Venkataraman (1998), found no relation between adult pack size and weight of the prey killed. However, in the dense habitats, it was not always possible to determine the size of the hunting group responsible for a particular kill. Re-analyses of Johnsingh (1982) data revealed a negative relation between food intake and pack size. From these results, it was suggested that co-operative hunting might not be the main function of Asiatic wild dog’ sociality (Venkataraman et al., 1995).

Asiatic wild dog are also known to rob leopards of their kills (Morris, 1942). However, a large male leopard can resist attack or defend its kill from small Asiatic wild dog packs (Burton, 1941). Tiger, leopard and Asiatic wild dogs are differed in their activity periods in their micro habitat usage and they occurs in high density due to high prey availability and forest contiguity in Banipur-Nagerhole-Mudumalai
landscape (Karanth & Sunquist, 2000; Ramesh, 2010). The immense size of the tiger means that it is able to subdue larger prey than the leopard or Asiatic wild dog. For example, in the tropical forests of Nagarahole National Park, southern India, where ungulates were very abundant, Karanth & Sunquist (1995) found that tiger usually selected prey weighing more than 176 kilograms, while leopard and Asiatic wild dog "focused on prey in the 31-175 kilogram size class. In the tropical forests of Nagarahole National Park, Karanth & Sunquist (1995) found that five species of ungulates comprised 89-98% of the diet of sympatric tiger, leopard and Asiatic wild dog. The five ungulates were gaur *Bos gaurus*, sambar *Rusa unicolor*, chital *Axis axis*, barking deer *Muntiacus muntjak* and wild pig *Sus scrofa*. All three carnivores preyed on each ungulate species, but there were differences in frequency. Tiger preferred gaur and avoided barking deer, while the leopard avoided wild pig. Asiatic wild dog predation on these ungulates did not differ from random.

### 1.3.3 Factors governing the co-occurrence

The ecological interactions and the mechanisms promoting the coexistence of sympatric species have been studied and debated for many decades (MacArthur & Levins, 1967; Schoener, 1974, 1982; Weins, 1977; Gordon, 2000; Austin, 2002). For large felines with similar body sizes such coexistence may be the result of exploitative competition through some degree of food partitioning (Johnson et al., 1993) or use of different prey species (Taber et al., 1997; Nu´nez et al., 2000; Scognamillo et al., 2003). Prey abundance and availability are vital in shaping interactions between similar large felines and can certainly alter patterns of coexistence (Iriarte et al., 1990; Ramakrishnan et al., 1999; Nu´nez et al., 2000). Scognamillo et al., (2003) investigated the factors that facilitated the coexistence of these cats in a mosaic landscape in the Venezuelan llanos. A high degree of spatial overlap was observed between jaguars and pumas, which may be related to the abundance and distribution of prey species. Major segregation was found in food habits, jaguars selected large prey and pumas medium-sized prey. In the Indian subcontinent, few studies investigated patterns of coexistence and space use of large carnivores, from radio-collared individuals (Karanth & Sunquist, 2000; Acharya, 2007), direct observations (Johnsingh, 1983) and camera traps (Ramesh et al., 2012a&b). Tigers, leopards and Asiatic wild dog are sympatric with each other by competing and coexisting for thousands of years through subtle ecological and behavioural mechanisms such as
differential prey selection and spatio-temporal use of the habitat (Johnsingh, 1992; Karanth & Sunquist, 1995). In the tropical forest habitats of southern Asia, tiger, leopard and Asiatic wild dog form a three-species predator assemblage over a large region (Karanth & Sunquist, 2000). Behavioral factors are likely to contribute to the coexistence of tiger, leopard and Asiatic wild dog in the tropical forests of Nagarahole (Karanth, 1993; Karanth & Sunquist, 1995, 2000), where as available prey biomass and prey selection allow them to coexist in the in Anamalai Tiger Reserve (Kumaraguru et al., 2011).

### 1.3.4 Human-carnivore conflict

Where humans and large carnivores interface, conflicts of three types are common: livestock depredation, prey depletion from overhunting and direct human-caused mortality of carnivores (Treves & Karanth, 2003; Miquelle et al., 2005; Rabinowitz, 2005; Johnson et al., 2006). Human- carnivore conflicts pose an urgent challenge worldwide because these conflicts often pit human communities against carnivores (Karanth & Madhusudan, 2002; Treves & Karanth, 2003). Large carnivores most often get in conflicts with people because they compete for resources that humans require-space and food (Nijhawan, 2008). Carnivore protein rich diets and large home ranges draw into recurrent competitions with humans, who have somewhat similar needs (Treves & Karanth, 2003). Indeed many large carnivore are specialized for ungulate predation therefore some individuals readily kill domestic ungulates when the opportunity arises (Karanth et al., 1999).

Hunting is practiced globally and is a threat to the rich biodiversity of this planet. Hunting of wildlife for human consumption has been identified as both conservation and livelihood issue (Bennet et al., 2002; Brown, 2003; Milner-Gulland & Bennett, 2003). Unsustainable hunting of wildlife or bush meat for human consumption across the globe threatens both the wildlife population and the livelihood of the people who depend on these resources. Studies on sustainability have shown that species are being extracted much above sustainable limits (Hill et al., 1997; Hill & Padwe, 2000; Hart, 2000). Market demands for wild meat have also contributed in pushing the harvest of wildlife to unsustainable limits (Fa et al., 1995; Apaza et al., 2002). The effect of hunting by rural people has lead to quantified changes in structure of mammal assemblages (Peres, 2000). With improved hunting technologies and
penetration into remote forest areas, there is greater wild meat consumption (Robinson & Redford, 1991; Wilkie & Carpenter, 1999).

The Pakke Tiger Reserve, Arunachal Pradesh offers an excellent opportunity to study the ecology of large carnivores. Very few studies have been conducted on the inter-specific relationships, competition among carnivores in this geographical landscape except some of the short term studies (Datta et al., 2008 a & b). The north east region has 64% forest cover which is considerably higher than other areas of India. Fifty-six% of these forests is community forests with a predominantly tribal population and an area of 173,000 km$^2$ under jhum cultivation. From 1991 to 1999, estimates show a decrease of 1800 km$^2$ in forest cover in north east India (FSI) (Datta et al., 2008a). The outcome of the study would be immensely useful for the Reserve administration for conservation and management of these species and their habitats.

1.4. **Objectives**

Keeping in view of above background, the presence study aims to achieve following objectives,

1. To estimate the abundance of sympatric large carnivores such as tiger, leopard and Asiatic wild dog in the Pakke Tiger Reserve.
2. To examine the food habits and prey selectivity of these carnivores in the Reserve.
3. To quantify the factors governing the co-occurrence of these species; and
4. To quantify the extent of human-carnivore conflict in and around the Reserve.

1.5. **Key questions**

In order to achieve above objectives this study will provide the answer for following questions.

1. What is the population status of tiger, leopard and Asiatic wild dog in the Pakke Tiger Reserve?
2. Knowing that these species differ in their behaviour; do they exhibit any specific food preference?
3. What are the key factors that determine occurrence of the above mentioned large carnivores in the Reserve?

4. What is the status of awareness, attitude and perception about the importance of large carnivores and their conservation among the local communities?

1.6. Organization of thesis
This thesis is organized in eight chapters. Chapter 1 deals with the study background, a review of the literature, objectives, and key research questions of the study. Chapter 2 describes the study area in detail, providing a biogeography and historical background. Chapter 3 deals with the population estimation of large carnivores. Chapter 4 deals with the prey availability, biomass and sex of major prey species. Chapters 5 presents prey selection by large sympatric carnivores. Chapter 6 discusses the factors governing the coexistence of large sympatric carnivore. Chapter 7 is on human-carnivore conflict in and around the Reserve. Chapter 8 brings out the conservation implications of the study and gives pointers for future work. Chapters 3 to 7 have summary, introduction, methods, result and discussion sections.