Chapter 1

INTRODUCTION

1.1. BACKGROUND

No group of organisms offers more challenges to conservation biology and conservation politics than large carnivores. Now-a-days the decline of large predator population is a global problem. From Asia and Africa to America, the largest of the felids, canids and ursids suffer from multiple pressures of habitat degradation, hunting, disease and commercial market of body parts. Tiger (*Panthera tigris*), Asiatic black bear (*Salenarctos thibetanus*), jaguar (*Panthera onca*), African wild dog (*Lycaon pictus*) and leopard (*Panthera pardus*) all face the prospect of extinction or local extermination. In a general review of 30 large carnivore species in five families, Fuller (1995) found that 22 of the species were cited as endangered by IUCN. Yet, despite this status, more than half of these species are ‘poorly studied' including leopard. Increasing the understanding of leopard ecology and reversing their decline are among the most urgent conservation challenges for management of leopard population in the Indian sub-continent.

Regardless of the conceptual merit of ecosystem management, ecosystems are complex, and they generally cannot be managed directly. Ecosystems can be identified as vegetation types or habitats, can be mapped and can be evaluated in terms of current area and extent of change from historical conditions (Crumpacker *et al.* 1988, Scott *et al.* 1993, Noss *et al.* 1995). But managing an ecosystem requires attention to specific, measurable indicators of the composition, structure and function of that system (Franklin *et al.* 1981, Noss 1990, 1995). Those indicators can be
monitored and to some extent managed. The concept of "management indicator species," whereby a single species is assumed to represent the status of all others associated with the same habitat (Landres et al. 1988, Noss 1990). In most of the Indian National Parks, tiger and leopard play the leading role as the representative of the associated ecosystem. So it is well understood that leopard as the top carnivore in many Indian forests needs special attention (specifically population monitoring) for the better management of respective forest and food chain. To understand the population trend in the Sariska National Park, the density and survival rates of leopard are estimated in the present study between 2007 and 2010.

Ecological studies of large carnivores in northern North America suggest they are capable of controlling their own numbers through social behavior (Hornocker 1969, 1970, Seidensticker et al. 1973, Beecham 1983, Hornocker and Bailey 1986), but their numbers can respond to changes in prey abundance (Fuller 1989, Quigley et al. 1989). In some cases, such as wolves (Canis lupus) at high latitudes (Bergerud and Ballard 1988), predators have been shown to regulate prey populations. Where natural predators have been eliminated or severely reduced, dramatic increases in herbivore populations are more likely than they would be in the presence of large carnivores (Ballard et al. 1987, Warren 1991). Alternatively, prey population is also found to contribute to survival rates of a predator population (Carbone and Gittleman 2002), as prey-predator relations (in terms of availability and consumption) always play a key role to maintain the balance of an eco-system. In the present study, to understand the relation between leopard and its prey, prey availability and prey consumption are estimated in Sariska National Park for consecutive four years.

In many of the research areas of conservation biology, population viability analysis, reserve design and landscape use by the carnivore are the matter of concern,
which is directly related with the trophic status of the species. It is commonly assumed that a conservation plan focused on large carnivores will protect most other species as well (Foreman 1992). Evidently, tiger and leopard as the top carnivores act as the "umbrella species" and provide a "coattail effect" (Soule 1985) for all the species associated in the eco-system. Hence it is always necessary to understand the habitat requirements and the pattern of habitat use by the carnivore for conservation of a landscape. In the present study, the ranging pattern and resource selection of leopards are estimated and a habitat suitability model is predicted for Sariska Tiger Reserve and its adjoining areas.

As the larger predator in Asia, the leopard has been revered as a cultural icon throughout of its former and present range. Yet for more than a millennium this predator has been relentlessly hunted for sport, killed for its body parts believed to have medicinal properties, and both feared and persecuted because of its ill-deserved reputation as a dangerous killer of human and livestock. Only recently people have come to the alarming realization that this large felid is facing tremendous population decline (http://www.wpsi-india.org/statistics/leopard.php), which may lead to imbalance in the eco-system.

1.2. LEOPARD ECOLOGY

The leopard has the greatest geographic distribution of any felid. Its range has been reduced in recent times, although historically leopard was distributed throughout northern Africa and over much of sub-Saharan Africa. Beyond Africa, the leopard range extended through Central Asia, India, Sri Lanka, Southeast Asia, China, Tibet and the Russian Far east (Figure 1.1) (Smithers 1983, Stuart 1981, Harrison and Bates 1991, Kingdon 1977, Corbett and Hill 1992). The oldest leopard fossils have
been found in the Siwalik Hills of the Indian subcontinent. They date to about 2 million years ago, which was during the early Pleistocene. This evidence indicates that leopards may have originated in Asia, probably during the late Pliocene. However, leopards did not stay in Asia. They migrated and colonized Africa and other regions to a great extent. By the middle of the Pleistocene, leopards were distributed extensively in East Asia, including Southeast Asia. Some migrated into Northeast Asia, including Japan. Leopards came into Europe during the middle of the Pleistocene. Fossils of them have been found as far west as the British Isles. A large number of leopard fossils have been found in a cave site in Italy called Equi. Leopards died out in Europe and in many parts of Asia. Today they are found in Africa and parts of southern Asia. Their numbers have declined sharply, partly due to hunting and habitat degradation (Robbins 2005).

As might be predicted from its widespread distribution, the leopard can be found in many different habitat types (Jerdon 1867). Although they are absent from true deserts and over the tree line in mountains, leopards do live in almost every type of habitat. It is revealing to consider which factors may limit this cat’s distribution. Limitations in food, cover and water are usually the major factors affecting an animal’s distribution (Stuart 1981), but for a leopard the definition of these basic requisites is extremely broad. Leopards were found to consume a number of species from beetles to large ungulates like eland and sambar. Leopards even can survive in few scattered shrubs and trees to dense moist tropical evergreen forest (Bothma and Le Riche 1986). Desert leopard have been known to drink only once in ten days and in China and Russia they survive long periods of sub-freezing temperatures although they do not appear to be well adapted to deep snow (Bothma and Le Riche 1986, Miquelle et al. 1996)
Leopard is found in a range of forests from woodlands to Acacia savannas, scrub forest, exotic pine plantations, rocky hills and mountain terrains from sea level to elevations of 5000 m (Harrison and Bates 1991). Leopards can live areas receiving almost no rainfall (50 mm per year) as well as in parts of West Africa and Tropical Asia where the mean annual rainfall is well over 2000 mm (Anon. 2005).

The two major factors that appear to limit the distribution of this rough and versatile generalist cat are the presence of competitors and the presence of humans. In many parts of its range the leopard co-exists with other large predators. In Africa it lives alongside lions and hyenas and in Asia it shares many habitats with tigers and wild dogs (Ramesh et al. 2008). Leopards do have their livelihood strategy to co-exist
with these predators, similarly, they can live in proximity to humans as long as they are not persecuted and have a safe retreat (Bothma and Le Riche 1986).

Despite the leopard’s widespread distribution, there is little detailed information available on this elusive cat. The work of Hamilton (1976) in Tsavo National Park, Kenya represented the first major study of leopards to incorporate radio-telemetry techniques. At the same time, Bailey (1993) initiated his study in Krugar National Park. The longest telemetry study of leopards is that of Ilany (1981) in Israel, he tracked many individuals over a 12 years period. Small scale radio-tracking studies on leopard have been conducted in conjunction with lion research in the Serengeti by Schaller (1972) and Bertrum (1982). Mizutani and Jewell (1998) studied 11 radio-tagged leopards on a ranch in Kenya. In northern Namibia, Stander et al. (1997) studied 18 radio-tagged leopards. Radio-tracking studies of leopard have also been part of the research on tigers in southern Nepal and Southern India (Seidensticker 1976, Sunquist 1981, Karanth and Sunquist 1995).

There is a general belief that leopards are mostly nocturnal. But, leopards are reportedly less nocturnal and more terrestrial in areas lacking tigers and lions (Grassman 1999, Eisenberg and Lockhart 1972, Karanth and Sunquist 2000). Seidensticker (1976) found that leopards living within Chitwan National Park in Southern Nepal, where tigers are also numerous, were active and moving at any time of the day and night. In contrast, those leopards living along the Park-village interface were essentially nocturnal, they were seldom found moving about during the daytime, presumably to avoid villagers (Sunquist 1981).

In the Kalahari Desert, leopards typically spend the daytime hours resting under vegetation or in burrows made by porcupines or aardvarks. Male leopards are too large to use most burrows and usually rest under bushes and trees. Kalahari
leopards move mainly at night, but they frequently rest during the early part of the night and again just before dawn (Bothma and Le Riche 1986). In contrast, leopards living in the Judean desert of southern Israel rarely hunt at night, except when occasionally hunting porcupines or house cats in human settlements. The main food items of leopards in this area are hyraxes and ibex, both of which are diurnal and so leopard in also diurnal (Ilany 1981).

In Huai Kha Khaeng Sanctuary, Thailand, a male and female leopard radio-tracked by Rabinowitz (1989) were found to be moving during the day time as at night and both were active 49-67% of the time. A similar activity pattern was recorded for leopards in Kaeng Krachen National Park, Thailand (Grassman 1999). This pattern and degree of activity is different from most of observations of leopards, although a female leopard with small cubs in Chitwan National park was active about 75% of the time (Seidensticker 1976).

The movement pattern in terms of distance traveled by leopards in their daily activities is highly variable. The walking speed of leopard is 3-6 km per hour and they can cover up to 12-14 km in one night (Bailey 1993, Turnbull-Kemp 1967). Distances of 3-5 km per day were measured in areas with abundant prey, but in less productive habitats leopards may walk 10 to 20 km during hunting in night time (Hamilton 1976). In the interior of the Kalahari Gemsbok National Park, both males and females moved 16 to 33 km per day. It was also found that leopards in Kalahari moved increasingly longer distances per day as the number of days since they last fed increased (Hamilton 1976, Bothma and Le Riche 1990).

Leopards often catch prey opportunistically, killing vulnerable animals as they are encountered. In the Kalahari Desert, tracks revealed that leopards usually killed small prey without deliberate stalk or chase (Bothma and Le Riche 1986).
Serengeti, Bertram (1982) reported seeing leopards investigating small clumps of vegetation and pursuing any small animals flushed out. A leopard takes whatever it can catch and its diet in many areas consist largely of small to medium sized mammals (5 to 120 kg). Leopard has the ability to survive on extremely small prey, which allows them to exist in places where large prey has been exterminated. Leopards take much wider range of prey of different sized and types than most of other large cats. A number of 92 prey species were recorded in the diet of sub-Saharan leopards (Bailey 1993). In the Serengeti, a sample of 137 leopard kills included 31 different prey species (Schaller 1972). A list of mammals killed by leopards includes numerous kinds of rodents, hares, several species of deer duiker, antelope, pigs, zebras, jackals and foxes, porcupines, pangolins and monkeys. Leopard also fed on birds which include doves, partridge, guinea-fowl, peafowl, vultures, ostriches etc. Reptiles, amphibians, invertebrates and grass are also eaten by leopard. In areas where leopards live in proximity to humans, their diet often includes dogs, cats and domestic livestock including goats, sheep, calves of cow and buffalo, pigs. Instances of ‘surplus killing’ of domestic livestock sometimes occur and while large numbers of animals may be killed in this situation, few are actually eaten (Turnbull-Kemp 1967).

Where the leopard lives with lions and tigers, they feed on many of the same species, though competition may exists between them. Few studies have looked at leopard food habits in areas where they are sympatric with lions or tigers (Sankar and Johnsingh 2002, Ramesh et al. 2008). In presence of sympatric competitor, leopard generally feed on a wider variety of prey, many of which are small animals or the young of the larger prey species. In the Serengeti, leopards feed on Thomson’s gazelles, Grant’s gazelles, reedbuck and a variety of small prey species, while lions in the same area eat mainly wildbeasts, zebras, Thomson’s gazelles and wild buffalo.
(Schallar 1972). In the Kalahari Desert, leopards take juveniles of various species including bat-eared foxes, porcupines, aardvarks, steenbok, duiker and gemsbok, whereas the main food of the lion is adult gemsbok and springbok (Bothma and Le Riche 1984). In contrast, impalas are the dominant prey of both leopards and lions in Kruger National Park, South Africa.

In Chitwan National Park, leopards feed primarily on ungulates weighing less than 50 kg, including wild pigs, hog deer and fawn or yearling of chital and sambar. Tigers in the same area tend to take prey weighing more than 50 kg which include more adult sambar, chital and wild pigs in their diet (Sunquist 1981). In Nagarhole Tiger Reserve, leopards prey extensively on chital, whereas tigers take the larger gaur and sambar (Karanth and Sunquist 1995). In Huai Kha Khaeng Wildlife Sanctuary, the major prey of both tiger and leopard is barking deer but leopards feed upon a greater diversity of small species and they take more primates than tigers do (Rabinowitz 1989).

The principal means of social integration among leopards appears to be via olfactory information carried in urine, anal sac secretions and feces. Scent may not carry information as far as a call but it is more persistent (Anon 2005), and it is not diminished by darkness as visual signs would be. Scent also has the advantage of being able to convey information long after the animal has left the spot. Auditory, tactile and visual signals are also used to attract mates or advertise that an area is occupied, but scent markings appears to be an efficient method of communication among these wide-ranging, solitary predators. Scent markings are typically deposited along commonly used travel routes, especially at road junctions or trail intersections or at conspicuous places along home range boundaries. Some marks are renew at intervals of a few days to a month or more, suggesting that these marks remain
effective for relatively long periods (Smith 1977). Feces and scrapes are also left at these sites, thus providing both an olfactory and visual mark (Bothma and Le Riche 1984). Researchers in the Kalahari found that leopards urinate in two different ways. One is copious urination that lacks any apparent informational significance, while the other involves squirts of small volume deposited at regular intervals. These squirts are directed at shrubs, low branches, tree trunk or grass and are sometimes followed by raking with the hind feet (Bothma and Le Riche 1984).

The coughing, sawing or rasping vocalization of the leopard may also function to bring animals together for mating or to space out individuals, depending upon their sex and their reproductive and social status. Under favorable condition, the sawing vocalization can carry for 2 to 3 km. The leopard in making this vocalization keeps its mouth partly open and expels and inhales air back and fore across the soft palate (Brander 1923).

Leopard females can come into estrus at any time of the year and remain in heat for one or two weeks. If conception does not occur, the female may cycle again. The average length of time between estrous periods is 45 days with a variation from 20-50 days (Sadleir 1966). The onset of a heat is associated with an increase in head rubbing, rolling and vocalizing. If a male and female are not familiar with each other, aggressive encounter may occur before mating (Desai 1975). During the peak of estrous mating occurs frequently, one pair copulated 60 times during nine hour period (Desai 1975). Leopard cubs are born after a gestation period of 96 days, although zoo records suggest that gestation can take from 90 to 105 days (Hemmer 1979, Seager and Demorest 1978). Litter size of leopard commonly varies from one to three and there are records of females giving birth as many as six cubs but most litter consists of two cubs (Zuckerman 1953, Dobroruka 1968, Reuther and Doherty 1968). Female
leopards use caves, thickets, hollow trees, abandoned burrows and rock piles as birth dens (Hemmer 1979).

1.3. OBJECTIVES

The present study on ecology of leopard in Sariska Tiger Reserve, Rajasthan, was carried out with the following objectives:

1. To estimate the prey availability of leopard
2. To study the food habits and prey selection of leopard
3. To estimate the population of leopard and
4. To study the home range and habitat use of leopard.

1.4. STUDY PERIOD

The study was conducted from November 2006 to June 2010 covering two different seasons winter (November to February) and summer (March to June).

1.5. STUDY SPECIES

Since Carl Linnaeus published his description of leopards in the 10th edition of Systema Naturae in 1758, as many as 27 leopard subspecies were subsequently described by naturalists from 1794 to 1996. The most common of all the leopard subspecies are:

- African leopard (P. p. pardus), (Linnaeus, 1758) — inhabits sub-Saharan Africa;
- Indian leopard (P. p. fusca), (Meyer, 1794) — inhabits the Indian Subcontinent;
- Javan leopard (P. p. melas), (Cuvier, 1809) — inhabits Java, Indonesia.
- Arabian leopard (*P. p. nimr*), (Hemprich and Ehrenberg, 1833) — inhabits the Arabian Peninsula;
- Amur leopard (*P. p. orientalis*), (Schlegel, 1857) — inhabits the Russian Far East, Korean Peninsula and Northeast China;
- North Chinese leopard (*P. p. japonensis*), (Gray, 1862) — inhabits northern China;
- Caucasian leopard (*P. p. ciscaucasica*), (Satunin, 1914), later described as
- Persian leopard (*P. p. saxicolor*), (Pocock, 1927) – inhabits central Asia: the Caucasus, Turkmennistan and northern Iran;
- Indo-Chinese leopard (*P. p. delacouri*), (Pocock, 1930) — inhabits mainland Southeast Asia;

A morphological analysis of characters of leopard skulls implies the validity of two more subspecies

- Anatolian leopard (*P. p. tulliana*), (Valenciennes, 1856) — inhabits Western Turkey;
- Baluchistan leopard (*P. p. sindica*), (Pocock, 1930) — inhabits Pakistan, and possibly also parts of Afghanistan and Iran.

In the present study, the Indian subspecies of leopard is *Panthera pardus fusca* was studied. This species was first described by Friedrich Albrecht Anton Meyer in 1974, in his first description of *Felis fusca*, in which he gave account of a panther-like cat from Bengal. On the Indian subcontinent, topographical barriers to the dispersal of *Panthera pardus fusca* are the Indus River in the west and the Himalaya in the North.
In the east, the lower course of the Brahmaputra and the Ganges Delta form natural barriers to the distribution of the Indo-Chinese leopard. Indian leopards are distributed all over India, Nepal, Bhutan, Bangladesh and parts of Pakistan. They inhabit in a range of forests from tropical rain forests to deciduous forests, temperate forests and coniferous forests up to an altitude of 2500 m (8200 ft) above sea level. But Indian leopard do not inhabit in the Thar desert, above tree line in Himalaya and the mangrove forests of the Sundarbans.

*Panthera pardus fusca* is listed as a species of near threatened by the IUCN red list. In India, this species is listed in Schedule I of the Indian Wildlife (Protection) Act, 1972, under the highest level of protection. Habitat destruction, loss of wild prey, poaching for skins, bones and claws, and poisoning carcasses of livestock killed by leopards are a significant threat to the species. As a result the geographic ranges of leopard have contracted and their populations have declined. There is an urgent need to conserve many carnivore species including leopard and the first step towards this is to obtain knowledge about their basic biology: how many exist, what they eat and where they live.

1.6. **ORGANIZATION OF THESIS**

The thesis is structured into six chapters.

**First chapter** gives introduction to the study which includes the background of carnivore conservation and details in ecological aspects of leopard. This chapter also describes the study species and the objectives of the study.

**Chapter 2** deals in descriptive account of the study area, which includes the topography and vegetation, available fauna and the human settlement in the study area.
Chapter 3 deals with the prey species abundance in the study area. This chapter further explains the method for estimation of prey species abundance, density estimates and trend in population in for four consecutive years.

Chapter 4 describes prey selection and food habits of leopard, which includes the percentage occurrence of each prey species in leopard’s diet, proportion of their biomass consumption and prey selection of leopard.

Chapter 5 covers population estimation of leopard using different methods in the study area. This chapter also describes the methodology for population estimation of leopard following different models, density estimates and the survival rates of leopard in the study area.

Chapter 6 describes the home range estimation and habitat use of leopard in the study area, which includes home range estimates of leopard using different methods and resource selection of leopard comparing with different vegetation types available. This chapter also explains a habitat suitability model for leopard for Sariska Tiger Reserve and surrounding areas.

Chapter 7 discussed the issues raised from this study on conservation of leopard in Sariska Tiger Reserve.