Chapter 1
INTRODUCTION

1.1 GENERAL INTRODUCTION

The distribution and population abundance of large carnivores is shaped by three extrinsic factors (i) habitat and landscape features, (ii) the distribution and availability of resource (e.g. prey), and (iii) human attitudes and activities; as well as the intrinsic adaptive capacity of the species concern (Zimmermann, 2004). Habitat loss, fragmentation, depletion in prey populations, poaching and persecution are well documented threats for carnivore species (Nowell and Jackson, 1996; Inskipp and Zimmerman, 2009). The large carnivores are more vulnerable to decline due to their large home range and dietary requirements. As a result, their geographic ranges have reduced; populations have decrease in size and have become more isolated. Basically, removal of threats and successive habitat and prey restoration can lead to a population recovery through growth and immigration, if the connectivity to adjoining populations is facilitated and the dispersal rate sufficient (Zimmermann, 2004, Gurung et al., 2008; Harihar et al., 2009a).

The large carnivores’ predatory behaviour and the frequent damage to livestock have always caused conflicts with humans (Nowell and Jackson, 1996; Inskip and Zimmerman, 2009). The conflicts can be the most serious cause of carnivore mortality in human dominated landscapes (Arthreya et al., 2004; Goyal et al., 2007) and even along the reserve borders (Gurung et al., 2008; Blame et al., 2010). Livestock depredation is the greatest source of conflict with humans and a major underlying cause for the disappearance of large cats from considerable areas of their former range (e.g. tiger Panthera tigris from most parts of China, Nowell and Jackson, 1996).

Conservation of large carnivores is a global priority due to numerous socio-cultural values and the critical roles they play in maintaining ecosystems (e.g., Wikramanayake et al., 1998; Merrill et al., 1999; Mladenoff et al., 1999). Effective management of carnivore populations is dependent on our understanding of the distribution, abundance and response of species to various available resources. Habitat
quality, prey availability and prevailing disturbances have long been recognized as the primary influences in determining carnivore use and abundance in a given area, with habitat selection models as the primary tool for identifying those relationships. Conservationists believe that the management of large carnivore requires integrative ecosystem management at broad spatial scales (e.g., Wikramanayake et al., 1998; Mladenoff et al., 1999; Carroll et al., 2001) that leads to conservation of all the attributes of ecosystem (Steneck, 2005); therefore carnivores in general are a good taxon for the development of a predictive model of conservation (Cardillo et al., 2004).

In order to develop effective conservation strategies, biologists and managers need to understand and evaluate various resources that are available and the threats which confront populations, to predict the potential distribution and explore ways to reach it (Zimmermann, 2004). The Remote Sensing and Geographic Information System (GIS) combined with habitat modeling have proved to be an important tool to assess large scale habitat requirement for a given species. The habitat model gives information about the spatial extent, arrangement and fragmentation of habitat (Zimmermann, 2004). This is a necessary prelude to estimate the potential population size (Mladenoff and Sickley, 1998). Though considerable research and conservation effort has been directed towards the large and widely recognized cat species, leopards have received comparatively little attention.

1.2 ROLE OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

Spatial tools of remote sensing and GIS provide practical and quickest means for inventory and evaluation of natural resources. These techniques are useful to generate many vital information needed for conservation planning by deriving spatial and ecologically relevant predictor variables such as land covers (Roy et al., 1986; Hansen et al., 2001; Shrestha, 2004; Gutierrez et al., 2005; Edwards et al., 2006; Thompson et al., 2006; Davis et al., 2007; Collingwood, 2008; McDermid et al., 2005, Midha, 2008; Paliwal, 2008; Wang et al. 2010), canopy closure (Hyde, 2005), leaf area index (LAI; Chen and Black, 1992; Qi et al., 2000; Li et al., 2008). The classified thematic maps are the key inputs for most studies on landscape pattern analysis (Turner, 1990; Shao and Wu, 2008; Wang et al., 2009; Midha and Mathur, 2010; Muni et al., 2010).
The GIS offers an important tool to develop spatially referenced estimates of key environmental resources on a landscape (Best, 1984) which are the keys to predict animal distribution. The growing accessibility of remotely sensed data and GIS tools has encouraged the extensive application of such an approach to a wide variety of management problems.

1.3 LEOPARDS

1.3.1 Distribution

The leopard (*Panthera pardus*) is a most widespread wild representative of the family Felidae (Nowell and Jackson 1996). The leopard’s range spanned most of sub-Saharan Africa, as remnant populations in North Africa, Arabian Peninsula and Sinai/Judean Desert, south-western and eastern Turkey, and through Southwest Asia and the Caucasus into the Himalayan foothills, India, China and the Russian Far East, as well as on the islands of Java and Sri Lanka (Seidensticker and Lumpkin 1991; Nowell and Jackson, 1996; Sunquist and Sunquist, 2002; Henschel *et al.*, 2008) (Figure 1.1).

Figure 1.1 Global range of leopard distribution (Map source: http://www.pictures-of-cats.org/Leopard-Habitat.html)
1.3.2 Population Status

Leopards are typically deemed to warrant low conservation priority because of their widespread distribution and ecological flexibility, however, global population status is still uncertain (Nowell and Jackson, 1996; Henschel et al., 2008) because of difficulty in monitoring on account of their cryptic nature, large home range and low population densities (Rabinowitz, 1989; Bailey, 1993; Nowell and Jackson, 1996). Traditional pugmark survey method used to monitor abundance of large cats (Panwar, 1979; Riordan, 1998) has been found to lack statistical rigor (Karanth, 1987; 1988; 1995). Radio telemetry has been used to study these felids, but their nocturnal habits, low density, and wide-ranging behaviour makes application of this technique difficult (Karanth, 1995).

Camera-trap surveys in combination with standard capture-recapture population models provides useful alternative method for non-invasive monitoring of large numbers of individuals and statistically rigorous density estimates (Karanth, 1995; Karanth and Nichols, 1998). Density estimates of leopards in different areas across the range vary from ~1 to 30.9 individuals 100 km$^2$ with no obvious relationship with broad habitat type (Kostyria et al., 2003; Khorozyan, 2003; Chauhan et al., 2005; Spalton et al., 2006; Ngoprasert et al., 2007; Edgaonkar, 2008; Henschel, 2008; Sankar et al., 2008; Simacharoen and Dungchantrasiri, 2008; Harihar et al., 2009b; Wang and Macdonald, 2009a; Chapman and Blame, 2010), but the site-specific factors such as levels of prey availability, fine-scale habitat variables, presence of co-predators and human disturbance might have influence the density. The effecting sampling area used to estimate leopard density ranged from 42.4 to 226.44 km$^2$ with limited number of trap locations (see review Chapter 5). Small effective sampling area is probably related to inflated density estimates (Dillon and Kelly, 2007; Maffei and Noss, 2008; Foster, 2008).

1.3.3 Diets and Prey Availability

The leopard’s wide geographic distribution is often referred to as its wide habitat tolerance and versatility as a generalist predator (Nowell and Jackson, 1996). Bailey (1993) noted a minimum of 92 prey species used by leopards in sub-Saharan Africa, and known prey ranges in size from arthropods (Fey, 1964) to an adult male Sambar
or Gaur (Sedeinstericker, 1976a, Karanth and Sunquist, 2000). Despite such an enormous prey size range, leopard diet is generally dominated by medium sized wild ungulates (<50 kg body weight) (Schaller, 1967; Essenberg and Lockart, 1972; Seidensticker, 1976a; Johnsingh, 1983; Rabinowitz, 1989; Seidensticke et al., 1990; Johnsingh, 1992; Bailey, 1993; Karanth and Sunquist, 1995; Edgaonkar, 2008; Wang and Macdonald, 2009). Recent analysis of 33 studies on leopard feeding ecology revealed that leopards preferentially prey upon species within a weight range of 10–40 kg (Hayward et al., 2006a). Low densities of medium sized ungulate prey force leopard to switch to more abundant sub optimal prey such as rodents (Ramakrishnan et a., 1999; Sankar and John singh, 2002) and/or secondary prey (livestock and dogs) (Seidensticker et al., 1990; Edgaonkar and Chellam, 2002; Goyal et al., 2007; Chauhan, 2008; Shah et al., 2009).

Distribution and abundance of carnivore species depends on the availability of different sized ungulate prey species (Karanth and Nichols, 1998; Carbone and Gittleman, 2002). However, information on the abundance of ungulate prey species is sparse in Nepal Terai (Seidentiscker, 1976; Dinerstein, 1980; Tamang, 1982; Malla, 2009; Wegge et al., 2009).

1.3.4 Spacing and Habitat Utilization

The leopard is solitary and aside from mating, interactions between individuals appear to be infrequent (Jenny, 1996). Like other solitary carnivores, the female leopards expected to space themselves according to resource availability, while the male spacing is based on both receptive female and availability of food resources. Reported home range of leopard varies from 6 km² (Seidensticker et al., 1990) to over 2000 km² (Bothma et al., 1997), however generally male territories ranged between 30 and 78 km², whereas 15–16 km² are common for females (Nowell and Jackson, 1996).

In Bardia National Park, Nepal, annual home ranges of male leopard have been found at about 48 km² with an overlap of only 7%; while female ranges at 17 km²; female home territories were seen to decrease to just 5.2 to 6.6 km² when she had young cubs (Odden and Wegge, 2005).

Information on the habitat use of leopard has been derived from the home range study using telemetry with small sample size (see review, Marker and Dickman, 2005;
Odden and Wegge, 2005). The broad habitat utilization of leopard are not unanimous and shown a tendency of utilization on the variety of forest and grassland habitats (Marker and Dickman, 2005). Recently, Simcharoen et al. (2008) reported that the mixed deciduous and dry ever green forest types, flat slope and areas close to stream channels are important landscape features for leopard habitat selection in Thailand. Similarly, Ngoprasert et al., (2007) found leopard habitat use positively increased with distance from the human disturbances. Seidensticket (1976a) reported that habitat use of leopard was influence by the presence of tiger in that area. Information on the habitat utilization of leopard, influence of landscape/habitat features and human activities on spatial distribution of this species is meager.

1.3.5 Leopards, Human and Livestock

Human-leopard conflicts most commonly involve killing of livestock, occasionally involve attacks on humans and leopard persecution (Mizutani, 1995; Nowell and Jackson 1996; Negi, 1996; Edgaonkar and Chellam, 1998; Mukherjee and Mishra, 2001; Goyal et al., 2007; Kissui, 2008; Tamang and Baral, 2008; Chauhan, 2008; Dar et al. 2009; Inskipp and Zimmerman, 2009). Therefore, effective conflict management strategy is essential for conservation of leopards. Any attempts to mitigate human–leopard conflict (Arthreya, 2006; Arthreya and Belsare, 2007) and improve the conservation of the culprit species should be based on an explicit understanding of the conflict patterns (Dar et al., 2009) and perceptions.

1.3.6 Major Threats

Like other large carnivores leopards are declining throughout their range due to habitat conversion, prey depletion, intense persecution and poaching for trade (Nowell and Jackson, 1996; Ray et al. 2005; Breitenmoser et al., 2006, Breitenmoser et al., 2007). Main threat of leopards in African rainforest is probably competition with human hunters for prey (Henschel, 2008). Nonetheless, leopard is somewhat tolerant of habitat conversion, and may persist close to large human populations provided they have suitable cover and prey (Hunter et al. in press). Still, leopards are found throughout most of their range; however, their populations have dramatically reduced over the last hundred years (Nowell and Jackson, 1996; Nowak, 1999; Uphrkyna, 2001; Henschel et al., 2008). A rapidly increasing threat to leopards is the poisoning
of carcasses targeting carnivores, either as a means of predator control or incidentally (Henschel et al., 2008) and poaching for international trade (Breitenmoser et al., 2006; 2007).

1.3.7 Conservation and Management

The Wild Cat Status Survey (IUCN/SSC Cat Specialist Group) has categorized leopard as one of the Near Threatened felids (Henschel et al., 2008). The leopard is placed in Appendix I in the Convention on International Trade in Endangered Species (CITES), and is protected under national legislation throughout most of their range (Nowell and Jackson, 1996). In Nepal leopard is protected under the National Park and Wildlife Conservation (NPWC) Act 1973. However, leopard has not been included in the Schedule I (the list of protected species) of the NPWC Act and there is no specific management strategy for its conservation outside the PAs, where they are surviving in considerable conflicts with people.

1.4 STATEMENT OF THE RESEARCH

Before the large-scale conversion of forests and the expansion of agricultural areas as a result of rapid growth of human population, the leopard was distributed throughout the Terai and Hills of Nepal, but now it is surviving as highly fragmented and disjunct populations (Shah et al., 2004). Although some research on leopard diets, activity, spacing and home range, and interaction with tiger have been done in Chitwan (Seidensticker, 1976a; 1977; Sunquist, 1983; MacDougal, 1988; Seidensticker et al., 1990) and Bardia (Eliassen, 2003; Odden and Wegge 2005, Odden et al., 2010). However, leopard has not received any specific management attention in Nepal due to lack of reliable population data.

In recent years leopard-human conflicts are increasing in many parts of the country due to habitat restoration through community forestry programmes and plantations (Shah et al. 2004). Small patches of restored forests can provide temporary hiding place for leopard but such patches cannot support sufficient prey species, consequently leading to increased level of conflicts with humans. In areas around CNP, successful habitat restoration measures through effective management of buffer zone and corridors have provided additional habitats for wild animal species (Gurung, 2008). At the same time the area is subject to many natural interactions, succession
and anthropogenic disturbances, which are creating habitat heterogeneity. Furthermore, increase in tiger population in the CNP has displaced the leopard to the peripheral areas, resulting in increased levels of conflicts with people (MacDougal, 1988). Thus, the knowledge on the ecological requirements, available resources and response of leopard to various landscape and anthropogenic factors are needed to plan long term conservation strategy for this species.

1.5 SCOPE AND AIM OF THE STUDY

Effective conservation of leopard requires a detailed understanding of factors that govern the species’ spatial distribution and habitat use. Information that describe resource availability (habitat quality and prey abundance), constraints (conflicts with humans) and distribution and abundance of leopards are important requisites to devise the conservation strategy for the species. The objective of this study is to evaluate leopard habitat in and around Chitwan National Park using remote sensing, GIS and field data. The specific objectives are to:

(i) evaluate landscape characteristics in order to determine habitat quality,

(ii) determine distribution and relative abundance of leopard across habitat and disturbance gradients;

(iii) analyze diets of the leopards across the habitats;

(iv) assess the extent and nature of leopard - human conflict and suggest mitigatory strategies, and

(v) examine habitat use and preference of leopard

1.6 ORGANIZATION OF THE THESIS

The thesis is organized into nine chapters. This thesis consists of introduction (Chapter 1), description of study area (Chapter 2), six research chapters (Chapter 3-8) and conclusions (Chapter 9). Each of these research chapters (3-8) includes a brief introduction based on literature review followed by methodology, results and discussion. Chapter one provides general introduction and describes the background of the study, the role of remote sensing and GIS and ecological aspects of leopards.
Chapter 2 deals with the study area, its physical, biological environment and socioeconomic aspects of Chitwan National Park and Buffer zone. Chapter 3 evaluates the land cover and landscape spatial patterns of CNPBZ. Chapter 4 provides the density and biomass estimates of major prey species in the northern part of Chitwan National Park (CNP) and buffer zone (BZ). Chapter 5 provides population and density estimates of leopard using camera trap survey and analysis of data by both non-spatial capture-recapture and Bayesian spatially-explicit capture-recapture models. Chapter 6 describes food habits and prey selection of leopard by comparing prey frequency of composition between summer and winter season, and between prey rich and prey poor habitats. Chapter 7 evaluates human-leopard conflicts and compares the problems of leopard with that of tiger in the buffer zone of CNP. Chapter 8 deals with the use of various habitat types by leopard and also evaluates the effect of landscape and anthropogenic factors on habitat use. Chapter 9 presents the overall conclusion of the thesis. It also highlights the important findings, synthesis and management implications of the research.