Artist’s depiction of a true incident of a leopard that was sitting on an overhanging branch of a tree near the roof of a house. After a couple of such instances, the farmer cut the tree down (Drawing: Vinod More)
Conflict between wild animals and people has been defined as “the situation that arises when the behaviour of a non-pest, wild animal species poses a direct and recurring threat to the livelihood or safety of a person or a community and, in response, persecution of the species ensues” (Inskip & Zimmermann 2009). Most commonly, conflict occurs when wild animals and humans share spaces, either due to humans colonising areas where wild animals are present or wild animals using human-dominated landscapes.

In either case, the impact of the interaction can be serious for both. In the case of large carnivores, human caused mortality of wild animals, especially of large predators is extremely high and has resulted in widespread declines from much of their historical ranges (Woodroffe & Ginsberg 1998; Woodroffe 2000; Breitenmoser et al. 2005; Loveridge et al. 2010). Protected areas aim to separate the use of space between humans and large carnivores (Sanderson et al. 2002). However, protected areas by themselves are not always enough to sustain predator populations, especially large-bodied species, which range over large distances and therefore come into contact with humans. In such contexts, human-use landscapes can become very important for the persistence of viable populations of large carnivores (Breitenmoser et al. 2005) as well as facilitate their dispersal between protected areas. However, whether the large carnivores can persist in human-use landscapes depends on the tolerance of the local people (Breitenmoser 2005) because a serious consequence of large carnivores in human-use landscapes is the potential for conflict (Inskip & Zimmermann 2009).

Conflict is often an issue of perception and losses might not be as serious as people view them (Breitenmoser 1998) but on the other hand it could also result in a serious loss to a marginal farmer whose livelihood is at stake (Madhusudan 2003). This is especially true in countries in Africa and Asia where rural farmers depend on their crops and livestock for their livelihood. Many studies, in the social and ecological sciences, have researched the factors affecting conflict but these are mainly located in Africa, Americas or Europe (Madden 2004; Inskip & Zimmermann 2009; Dickman 2010). The results from these studies may not be
applicable to a country like India with very high human (average > 300/km²), and livestock population density, and where conflict can be extremely severe because of the continued presence of large carnivores in human-use landscapes (Banerjee et al. 2010; Athreya et al. 2011).

India faces a serious conservation challenge because wildlife laws are highly protectionist, many species of wild herbivores and carnivores cause losses to people (including human deaths), and information on conflict that is relevant to management is scarce. Some species of large carnivores occur in human-use areas but the lack of information on their ecology does not allow the use of effective mitigatory management actions. The leopard (*Panthera pardus*) is a common species which often comes into conflict with humans in different parts of India but till date there has been no study on its ecology in human-use landscapes, especially in relation to conflict.

This study has two broad aims (i) to understand the ecology of the leopard and the levels of conflict when the species shares spaces with high density of humans and (ii) use the resulting knowledge to generate science-based management inputs to mitigate human leopard conflicts at the study area as well as in other parts of India.

**STRUCTURE OF THE THESIS:** The thesis is presented as six chapters. An outline of the structure is presented below.

**CHAPTER 1. INTRODUCTION**

Human - wildlife conflict is of growing concern because it threatens the survival of many wildlife species. This is especially true in the case of large felids, most of which are threatened primarily due to anthropogenic causes, with conflict accounting for the highest mortality (Loveridge et al. 2010a). The creation of protected areas aims to separate the use of space by large cats and humans thereby reducing the potential for conflict (Sanderson et al. 2002). However, all large cats are wide ranging, are obligate carnivores and human-use areas are
usually resource rich because of the high density of domestic animals. Thus in many situations, large cats, especially around the edges of protected areas venture into human settlements to prey on livestock and sometimes attack humans (Inskip & Zimmermann 2009).

India provides a particularly interesting case study with respect to large cats in human-use landscapes because it offers an example of a lesser known but extreme type of human - large cat interaction; where high density of humans and ranges of large felids overlap. Such interactions are rarely studied in other countries because in most cases, large felids are killed when they venture outside protected areas. In India, however, large felids are strictly protected by the law even outside protected areas and on private lands, and higher levels of tolerance in the society has allowed many species of wild animals including large cats, to occur in human-use areas (Karanth et al. 2008; 2009). Although the tiger Panthera tigris is largely restricted to protected areas (Karanth et al. 2010), the snow leopard Panthera uncia (Bagchi & Mishra 2006), Asiatic lion Panthera leo (Banerjee et al. 2010; Meena et al. 2011) and the leopard Panthera pardus (Seidensticker et al. 1990; Daniel 2009) occur outside forests even in human-use landscapes where they do kill livestock and, in the case of the lion, tiger and leopard, occasionally attack humans.

Of the four species of large cats, the leopard is the most adaptable (Bailey 1993), residing in and around human settlements where it preys on medium sized domestic animals (Daniel 2009). Since its interface with humans is higher than the other large felids, conflicts are not uncommon and can also be very severe (Athreya et al. 2011). Despite the severe conflict levels, the current understanding of the drivers of human-leopard conflict in human-dominated areas is poor.

In this thesis, I attempt to elucidate the ecological and social factors that drive such conflict in an agricultural landscape in Maharashtra, western India.
Specifically, the main research questions are

(i) At what densities do leopards occur in a human-dominated landscape?
(ii) What is their main prey species and how does it relate to the potential prey base available in the human-dominated landscape?
(iii) What are the conflict levels, specifically, the extent of attacks on humans and livestock by the leopards and the extent of losses that people face due to leopard predation?
(iv) How does translocation of leopards, the most common management strategy used in India today, affect conflict levels?

CHAPTER 2. DENSITY OF LEOPARDS IN A HUMAN-DOMINATED LANDSCAPE

Leopards are distributed across India and many sites report severe conflict with large number of attacks on humans (Athreya et al. 2007). However peer reviewed scientific literature investigating the ecological and sociological drivers of human-leopard conflict are largely absent (Athreya et al. 2011). In this chapter, photographic capture-recapture techniques were used to assess the density of the two large carnivores, the leopard and hyaena (*Hyaena hyaena*), in a human-dominated landscape with density of more than 200 people/km². The total effort carried out was 1110 camera-trap days spanning over 179 km² in a 30 day period in November and December 2008. The density estimates were based on the conventional as well as the spatially-explicit capture-recapture analytical methods. Similar density estimates were obtained for leopards and hyaenas, at 5/100 km² each, which is higher or comparable to estimates obtained within protected areas in other countries (Spalton et al. 2006; Khorozyan et al. 2008; Balme et al. 2009; Gray & Prum 2011), and within some protected areas (Chauhan et al. 2005; Harihar et al. 2011) in India.

Ten other species of wild carnivores, including the vulnerable (IUCN category) rusty-spotted cat (*Prionailurus rubiginosus*), were photographed in the camera traps. This study found breeding populations, at relatively high density, of
leopards and hyaenas in the human-dominated landscape. It also highlights the need to also focus on the potential utility of human-use areas for the conservation of wild carnivores while taking into account important factors such as landscape, the ecology of the species, culture of the people and the interaction between humans and carnivore species because all these are likely to affect large carnivore persistence in such landscapes.

CHAPTER 3. DIET OF LEOPARDS IN A HUMAN-DOMINATED LANDSCAPE

The quantum of prey biomass available in the landscape is a key determinant of predator density (Carbone & Gittleman 2002, Karanth et al. 2004). Most studies that have quantified this relationship are from natural ecosystems where only wild prey is present whereas in human-use landscapes the biomass of domestic animals can be extremely high (Schaller 1983; Seidensticker et al. 1990; Mizutani 1999), especially in tropical countries where livestock rearing (or pastoralism) is an important source of livelihood for rural people. This potential food source for large felids is likely to affect their persistence outside protected areas and also influence the incidence of conflicts (Breitenmoser et al. 2005). For instance, Seidensticker et al. (1990) found that the biomass of domestic prey species was much higher outside the National Park and the leopards living at the edge of the Chitwan National Park in Nepal preyed largely on domestic animals compared to the leopards inside the Park.

In this chapter, the biomass of domestic animals in a human-dominated landscape has been estimated and examined in relation to the diet of the resident leopards. There is no report of wild ungulate presence from the study area and no evidence was obtained during the field-work. The biomass of domestic species was estimated from interview data obtained from 77 households and the leopard diet was assessed from the scats collected in the area. In all, 265 scats were collected over 238 km² of which 85 provided usable information on the leopard’s diet. The results indicate that 86.56% of the leopard’s diet consists of domestic animals, and the most common prey is domestic dog constituting 40% of the total
prey biomass. The biomass of domestic livestock present in a human-dominated landscape was found to be extremely high at 66,527 kg/km², which can theoretically support ten times the leopard density compared to what was obtained using photographic capture recapture. However, the leopards mainly attacked medium-sized domestic animals and not the adult cattle. Furthermore, domestic dogs and cats were seen to be more important dietary components compared to goats and calves, probably because the latter are protected by the farmers. Using Carbone & Gittleman’s (2002) regression equation relating prey biomass to predator density, it was found that the biomass of owned domestic dogs and cats alone can sustain the current density of leopards and hyaenas in the human-dominated landscape. Dogs are abundant in India (Hiby et al. 2011) and are likely to play a crucial role in maintaining leopard populations even in areas devoid of wild prey species. Thus this study provides for the first time, results on the prey species and the quantum of prey biomass available for a large felid, the leopard, in a human-dominated landscape.

CHAPTER 4. QUANTIFYING CONFLICTS BETWEEN LEOPARDS AND HUMANS IN WESTERN MAHARASHTRA CROPLANDS.

Human – large felid conflict is an issue of global concern because of the losses people face due to livestock predation, and attacks on humans by large felids (Inskip & Zimmermann 2009; Loveridge et al. 2010a). The retaliatory killing due to conflict is responsible for high rates of mortality of the large felids, most of which are highly threatened mainly due to anthropogenic reasons (Loveridge et al. 2010a). In this chapter, the level of conflict caused by leopards living in a human-dominated landscape with a density of more than 200 people/km² was studied.

Specifically, Forest Department records, and interview data from

(i) people who had filed claims for compensation,

(ii) randomly selected households and

(iii) a sample of migratory shepherds
were used to obtain information on the livestock losses due to leopard attacks. Generalised linear models (GLM) with binomial errors were used to address the following questions:

(i) What was the risk of losing a goat versus a calf among people who had filed for compensation? Cows were rarely attacked by leopards.
(ii) What variables affected the chances of a household facing a livestock predation event by leopards?
(iii) What affected the farmer’s attitude in terms of his wanting the leopard removed (or not) from the area?

Interview data and Forest Department records on compensation, report not a single human death by leopards in the 179 km² study area although rare accidental attacks on humans did occur. In the case of livestock losses, a total of 242 livestock were killed in three years in the study area between April 2006 and February 2009 whereas the mammalian livestock density in the study area was found to be ~400/km². As with leopards elsewhere, mainly medium-sized stock were attacked, with the probability of goats begin killed twice that of calves and almost no cows were killed. All the night time attacks on livestock occurred near houses, but no humans were attacked during the time of the livestock attack although people do try and save their livestock when they hear it cry out in the night. The results also indicate that leopards were not a major reason for mortality for goats but were for the owned domestic dogs. Furthermore the results indicate that ineffective protection and the presence of dogs is likely to increase the probability that a farmer will face a leopard attack on his livestock. Also, the probability that a farmer wants the leopards removed from his area increases if he has faced a previous attack on livestock. This is despite the presence of the Forest Department compensation system in the area.

Compensation is provided with the intention of making people more tolerant of their losses but is not seen to be effective system even in other countries (Kaczensky 1999; Frank et al. 2005; Marker & Dickman 2005; Nyhus et al. 2005;
Rabinowitz 2005; Azevedo & Murray 2007; Gusset et al. 2007; Inskip & Zimmermann 2009). Furthermore, a livestock has to die before the government assists the farmers and the death of a single animal can be a significant loss for the poor farmer. Thus it is recommended that the focus of state assistance should be proactive and focus on better protection of livestock.

The results of this research work questions the way in which the term ‘conflict’ is employed in the Indian context. The leopards are not attacking people even though both share the habitat at relatively high densities. Nor are people proactively killing leopards because of cultural tolerance on the one hand and exposure to severe legal penalties on the other. Furthermore, livestock losses are also much lower than one would expect given the high density of livestock and leopards in the landscape.

Conflict is defined as aggression between two species. At my study site where interventions are very low, the leopards are not attacking humans and people are not killing or trapping the leopards, the situation does not qualify as ‘conflict’. Instead, it can be conceptualized as a dynamic interaction, in which people and leopards have adapted to each other in ways that allow them to coexist with minimal conflict. This work highlights the need for reorientation of perception of conflict and for formulating proactive conflict preventive measures. It has applications in other ecological systems where large number of humans die due to large cat attacks and livestock losses are high due to ineffective protection.

CHAPTER 5. THE ROLE OF LEOPARD TRANSLOCATIONS IN CONFLICT MITIGATION: EFFICACY AND ALTERNATIVES
The earlier chapters deal with the ecology of leopards in a human-dominated landscape where interventions are minimal and conflict levels are not as high as we would expect. In this chapter, analysis of historical data obtained from the forest department on human-leopard conflict is used to identify the drivers of serious conflict. In Junnar Forest Division, a human-dominated irrigated landscape that adjoins the Ahmednagar district of Maharashtra a large scale
translocation programme was carried out where a large numbers of leopards were captured from human-use areas and released into adjoining forests. The patterns of conflict, especially attacks on humans, that followed the translocation intervention are assessed and the reasons for the same are discussed in this chapter. Capture of leopards from human-use areas and release in adjoining forests is the most common management strategy used in India even today.

In the densely populated Junnar district in Western Maharashtra, India, 28 leopards were captured in an area of $3828$ km$^2$ (with $239$ people/km$^2$) and released into forested areas at an average translocation distance of $39.5$ km ($\pm 1.8$ km SE), in 2001 and 2002. Eleven more leopards were relocated into these forests from other districts in the same period. By the end of 2002, these releases were stopped. Fifty seven leopards that were captured thereafter were translocated to other remotely located forests in Maharashtra.

Between 1993 and 2001, an average of 4 attacks on humans occurred each year and after the translocation exercise the average escalated to 17. Linear and logistic regression results show that (i) attack frequency on humans in the Junnar region increased following releases nearby and decreased when leopards were released far away, (ii) attacks on humans became more deadly when the number of leopards introduced from other districts increased, and (iii) attacks on humans were most likely to occur in regions where the largest number of leopards had previously been introduced from other areas. The difference is particularly striking compared to the previous year when the same leopards had lived without attacking people in the same area.

Possible behavioural explanations for the increased conflict could be increased stress, loss of fear towards humans during capture, spatial disorientation and upheaval of the social structure of an otherwise strongly territorial species such as the leopard, following release into a new area. These are factors that are rarely considered when translocating these animals. Also, the translocated leopard is forced to move through unfamiliar terrain, densely populated landscapes,
creating a potential for conflict. In a country like India where large carnivores share space with large numbers of humans, who are traditionally more tolerant, the focus should be on proactive methods that lead to a greater social acceptance of the presence of these carnivores while maintaining the lowest possible levels of conflict. The results of this work show that inappropriate intervention in a human-dominated landscape can have drastic effect on the welfare of not only leopards but also of humans.

CHAPTER 6. CONSERVATION AND MANAGEMENT OF LEOPARDS IN HUMAN-DOMINATED AREAS IN INDIA

The results of this research have direct bearing on managing human – leopard conflict in India. For the first time, evidence of a fairly high density of resident, breeding leopards living among high density of humans and subsisting entirely on domestic animals, particularly domestic dogs and cats has been obtained. The results of this work also show that an intervention that is biologically inappropriate can severely worsen conflict, with attacks on people commencing after the intervention, in this case large-scale capture and release of leopards. India has a high density of humans, livestock and the presence of a varied assemblage of wild carnivores inhabiting human-use areas therefore it is very important that any management intervention with the large cats, especially in and around human-use areas, has to be carefully planned because of the direct repercussions it could have on human lives. Using management interventions that are practiced in other countries such as culling/translocation, where typically human population densities are much lower, may not necessarily be relevant to Indian conditions.

However, there is good reason to be optimistic as the study also shows that high density of leopards can live among high density of humans without killing people or causing substantial livestock losses in relation to what is available. The results also find that effective livestock protection reduces losses and that the abundance of domestic dogs and cats forms a major prey base for leopards in a human-dominated landscape. This work shows that even though a compensation
procedure exists, following a livestock loss, the farmers tend to demand removal of leopards. Thus, it is crucial that the Forest Department assist people to better protect their livestock and prevent losses. This could also lead to a gradual phasing out of the compensation scheme and save substantial government resources in the long term as well as reduce livestock losses and foster a culture of increased tolerance for the large cats.