Can tigers survive in human-dominated landscapes?

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A tiger is chasing monkeys. Rock art from the middle Bronze Age (approximately 3200 BP[1]) found in the Panna region of Madhya Pradesh state in India. This photo was taken in the Hinauta area of the Panna Tiger Reserve.

[1] BP = Before Present

1 General Introduction

1.1 Introduction

Tigers (*Panthera tigris* Linnaeus, 1758) are globally endangered wildlife species, and there are worldwide efforts to revive tiger populations (Goodrich *et al.*, 2015). The forests of India currently support over 60% of the world's 3890 wild tigers and they are therefore critical to the survival of the tigers in the future (WWF, 2016; Natesh *et al.*, 2017). Despite increased global efforts to recover tiger populations their revival has been slow (Nowell and Jackson, 1996). By 2009, in India the species numbers have hit a new low and they had become locally extinct in the Sariska and Panna Tiger Reserves (Panna TR) (Gopal *et al.*, 2010; Seidensticker *et al.*, 2010). An inquiry by the government into the factors leading to the extinction revealed poaching, lack of corridor connectivity to other tiger supporting sites, and mismanagement, as the main driving factors (Gopal *et al.*, 2010). In 2009, the Madhya Pradesh Wildlife Department, the government agency responsible for tiger conservation in the Madhya Pradesh state, started to reintroduce tigers into the Panna TR. One male tiger and five females from various tiger reserves in the region were systematically introduced between 2009 and 2014 to form the founder population in Panna TR (Sarkar *et al.*, 2016). These founder tigers in turn gave birth to more tigers and the tiger numbers were rising in Panna TR by the time I started my PhD study in 2013.

In October of 2013, I received a brief two worded email from Mr R. Sreenivasa Murthy, the Director of Panna TR, in India that said, "Call me". During that period I was working as a consultant in the tiger reintroduction project and also collecting data for my PhD. Knowing that an email of such brevity had to mean something much more important and urgent, I telephoned the Director. The Director informed me that "it has been raining here the past two days continuously". "P212[2] was seen walking steadily upstream of the river since yesterday. The tiger will soon move outside the park". In the background, I could hear the chatter of the director's staff trying to dispatch messages to the various field teams patrolling the Panna TR. The seriousness and urgency of the situation was discernible in their words and voices.

The tiger who was reported to be moving upstream was an approximately 24 months old young male. It was a second generation tiger[3] from the Panna tiger reintroduction project. Despite efforts to control the poaching and management inadequacies after the tiger reintroduction program, the director was concerned that the large cat would cross the boundary of the protected tiger reserve and move into the surrounding human-dominated

[2] P212: Is a unique identification number given to a radio collared tiger in Panna Tiger Reserve, India. The number reveals particulars of the individual tiger with respect to the tiger reintroduction project.

[3] First generation are the founder tigers and second generation are those born to the founder tigers

landscape. We discussed at length all the possible outcomes for the tiger, possible repercussions for the people who lived in the tiger's route and the preparedness required for the staff following the tiger.

We were aware that after crossing the boundary of the reserve, P212 would be entering the agricultural fields. In those areas, people lived and conducted their everyday lives, their livestock also grazed there and more importantly; this is where people and livestock accessed the river. In the past, other tigers may have used this route along the river as a natural corridor. It might have allowed them to move through the 40 kilometres of the human-dominated agricultural landscape that separated Panna TR and the forests of Pahadi in the east. However, since tigers are cryptic and impossible to follow without the aid of radio or satellite collars, their previous travels through this route remain unknown. However, P212 was fitted with a VHF radio collar that transmitted a signal at a coded bandwidth. The monitoring teams used this radio signal to follow the cat. The knowledge of the tiger's whereabouts was invaluable to my study, but it was also a conscious reminder that the large cat was loose amongst human population and this thought was unnerving.

I shared my views on the emerging situation with the director and recommended that the tiger should be allowed to continue its movement upstream. Since our staff followed the tiger, they could always intervene, if the need arose and then capture the cat. I believed that P212's actions would provide a unique opportunity to observe a dispersing wild tiger as it moves away from its natal area in a protected reserve and as it navigates through the different landscapes that lay in its path. Such insights would greatly contribute to the scientific knowledge of interactions that take place between tigers and the surrounding human-dominated landscape, when tigers move out of protected tiger reserves.

We also had reasons to worry. The politically sensitive tiger reintroduction project was already in the news, and various community groups discussed its real merit. At this precarious stage, P212 could be killed, if it attacked people, or if it tripped any one of the electric wires that are commonly strung out in agricultural fields to kill wild pigs or by a village mob, out of sheer fear and pumped up adrenaline. All these outcomes would have severe adverse consequences for the tiger reintroduction project, and there was also the danger of losing political support for the project, which was obviously undesirable. The director simultaneously consulted his superiors and colleagues in the Madhya Pradesh Forest Department and sought their advice. Eventually, a courageous decision was taken by the state wildlife department to allow the tiger to continue its journey through the human-dominated area. Around this time, news from the tiger teams was that the large cat had killed a domestic water buffalo grazing in the field. It fed on the water buffalo and remained to guard its kill. Villages came to know of the loss, and soon word spread that a tiger was moving through the area. As a first step, the reserve staff following the tiger compensated the owner on the spot for the loss. However, the commotion that followed disturbed the tiger from its kill, and the tiger abandoned it and moved further upstream. That same evening the tiger killed a cow. We knew that if the tiger was disturbed from its kill, it would only be forced to kill more animals. However, the presence of the reserve staff and their working elephants attracted attention and word quickly spread. To avoid further losses, we

had to communicate with the villagers and stop them from going to the river and to round up their livestock. Then again, we faced a dilemma. We were new to the area; we did not know the local villagers nor the lay of the land. However, we had to quickly and efficiently communicate with hundreds of people who lived in remote rural villages scattered across the area or risk chaos.

Based on a previous experience, we put a plan together. First, we made a list of local politicians[4] and on behalf of the tiger reserve invited them for an urgent meeting. In the meeting, following a preconceived plan, the director addressed the local leaders and informed them of the emerging situation. The director presented the following statement to them; *"The tiger is in your area and needs your help, and only you can help and no one else"*. With this, the administration of the ongoing event and responsibility to secure the tiger moved onto the shoulders of the local leaders. They were happy to take charge and quickly deliberated with their staff and summoned their cadres. Through them, they sent word to the headmen of various villages and summoned them for a meeting. The headmen, in turn, asked their teams and activated traditional beaters[5] (*Dand peethna*). Very soon drumbeaters were shouting announcements and communicating the instructions of their village headman. Villagers have been cautioned to stay away from the river and to corral their livestock. It took less than five hours for the local conventional network to spread the words of warning to tens of villages in the area. By the next morning, there were no people near the river, and most livestock were rounded up. The tiger could stay undisturbed near its kill, and by that evening, having had its fill, it moved on. That same night the big cat crossed the village areas along the river and safely moved into the forested hills of Pahadi, a non-protected corridor forest that connected with two other tiger reserves.

Historical tigers of Panna TR prior to the reintroduction and also those reintroduced, have had home ranges extending over the surrounding human-dominated landscapes (Chundawat *et al.*, 2016; Sarkar *et al.*, 2016). Documenting tiger space use and diet, while they are using such areas, could potentially reveal how tigers respond and behave when they encounter human activity. Human-tiger interactions and their coexistence prospects are relatively unstudied subjects and the radio-collared tigers of the reintroduction program presented a perfect opportunity to studying tigers as they moved in the human-dominated landscapes. Additionally, it would allow examining the people who lived and used the same areas. This unique opportunity to study people and tigers at the same time motivated me to develop a detailed and systematic approach to examine human-tiger coexistence in human-dominated landscapes.

1.2 The urgent need to study human tiger coexistence

The tiger is one of the world's most iconic mammals and, unfortunately, also one of the most endangered. According to the IUCN[6] global Red List, its status in the wild is

[4] Here local politicians are people's elected representatives called MLA's and M.P's.

[5] Beaters use drums to draw people's attention and shout out important news in rural villages of Madhya Pradesh, India.

Endangered. A 1998 global tiger population estimate approximated that 5000 to 7000 may still be alive in the wild (Goodrich *et al.*, 2015). But by 2017, there are as few as 3,890 tigers left, suggesting a rapid overall decline in tiger numbers (GTF 2017). Next, of the nine subspecies of tigers (Latest taxonomy under revision); *Panthera tigris tigris, Panthera tigris altaica, Panthera tigris amoyensis, Panthera tigris Corbetti, Panthera tigris sumatrae, Panthera tigris jacksoni, Panthera tigris sondaica, Panthera tigris virgata and Panthera tigris balica* the last three are already extinct in the wild and in zoo's (Goodrich *et al.*, 2015). Apart from experiencing substantial population declines, global tiger ranges have also contracted. The reduced numbers and isolation renders wild populations to inbreeding depression, poaching, and increased incidents of conflicts with human communities and makes tiger populations highly vulnerable to extinction (Kenne *et al.*, 2014; Wikramanayake *et al.*, 2004). Several decades of efforts in India to restore the tiger populations in dedicated tiger reserves have not increased their numbers and reveals the shortcomings of depending entirely on tiger reserve centric conservation (Damodaran 2007; Chundawat *et al.*, 2016). However, after the St Petersburg tiger conference and improved efforts, tigers numbers reportedly increased in some parks in India, Nepal and Russia (WWF, 2016). In India, as an alternative to the PA centric conservation, a more holistic conservation approach that includes both protected tiger reserves and the surrounding unprotected land units, all amalgamated into a large tiger landscape, is proposed by some authors (Gopal *et al.*, 2007; Ranganathan *et al.*, 2007; Walston *et al.*, 2010; Wikramanayake *et al.*, 2004). This approach is in line with the "ecosystem approach" adopted by the IUCN. It is envisioned that a large tiger landscape approach supports the ecological and genetic needs of the tigers and further ensures the functioning and well-being of an entire ecosystem benefiting people, tigers and so many other species (Lambeck, 1997; Perrings and Gadgil, 2003; Wikramanayake *et al.*, 2004). Such reasoning also provided the support in India for ambitious projects like the Panna Tiger Reintroduction Project.

The new landscape level tiger conservation approach that focuses on ecosystem functioning and human wellbeing is very attractive from a human standpoint. However, it involves extending tiger conservation to larger landscape units that include human-dominated multiple use forests and private lands. As many managers and conservationists have observed, the new plans are worthy but may be overambitious in their desire to succeed mainly because of the people who also live and use these landscapes and the potential conflicts with tigers (Dorresteijn *et al.*, 2016; Dickman, 2010; Kolipaka, 2017). However, attempting such ambitious goals has a justifiable merit, because tigers as top predators are also keystone species (Lambeck, 1997; Ripple *et al.*, 2014). Therefore the conservation of the tiger and their habitat may also ensure the conservation of hundreds of other floral and faunal species within the tiger landscape. Furthermore, if managed well, such a holistic conservation approach may have economic and ecological outcomes benefitting the well-being of the human communities that live within these proposed tiger landscapes (Balmford *et al.*, 2002; Perrings and Gadgil, 2003). Therefore, efforts to conserve the tigers in human-dominated landscapes are an opportunity to design and

[6] IUCN International Union for Nature Conservation

manage a broad landscape that meets the needs and requirements of many species and parties.

With a new strategy that takes into account both people and wildlife, in 2010, governments of the 13 tiger range countries endorsed the doubling of the number of wild tigers by 2022 (GTI, 2010). India, which is a signatory to the Global Tiger Initiative, supports nearly 60% of the world's wild tigers (Natesh *et al.*, 2017). The Indian authorities who created 48 protected tiger reserves for the species also plan to establish connected networks between the reserves and create safe movement corridors, buffer zones and multiple-use forests and ensure the persistence of the tiger species in the country (Gopal *et al.*, 2007). To integrate the people aspect into the tiger conservation planning, National Tiger Conservation Authority (NTCA) the government organisation that oversees tiger conservation in India, issued guidelines in 2007 to the tiger reserves in India to encourage coexistence (Gopal *et al.*, 2007). Two different management models are proposed, a *separation model*, where tigers are protected exclusively in core zones of tiger reserves separated from people and a *coexistence model* for areas outside the core zones. This new shift to coexistence is proposed at a time when the real prospects of people and tigers sharing a landscape are not entirely clear and fraught with suspicion of inevitable conflicts between local people and tigers (Treves and Karanth, 2003).

The worrying threat of human-tiger conflicts

The coexistence plans have their own merits, in terms of providing a future for large carnivores beyond the boundaries of the protected reserves and for simultaneously benefiting local communities through new work opportunities. Furthermore, it may lead to better maintenance of natural resources and tourism (Balmford *et al.*, 2002; Perrings and Gadgil, 2003; Walston *et al.*, 2010). The thorough understanding of the ability and willingness local communities to live alongside wildlife (coexist), especially with dangerous wildlife like tigers, is currently lacking (Athreya *et al.*, 2016; Carter and Linnell, 2016). For instance, it is well known that people fear large carnivores. In the emerging coexisting scenario, if people frequently encounter large carnivores like tigers or experience attacks, then such incidents could further instil fear and trigger panic and in response people may object to coexistence plans. Therefore, to address these inevitable people-carnivore interaction issues in a coexistence context, it is important to understand the relationship that local people have with their surrounding natural environment.

Similarly, local knowledge about wildlife and their behaviour have to be assessed. Peteriani and her colleagues show how lack of knowledge of wildlife may lead to people undertaking risk-enhancing behaviour (Penteriani *et al.*, 2016). Such behaviour could make people and livestock vulnerable to large carnivores in a coexistence scenario and it could jeopardise conservation efforts. In order to reduce the risk of human injuries and livestock losses in a coexistence area, it is critical to assess prevailing local knowledge on wildlife, people's husbandry practices and people's ability to prevent injuries and livestock losses (Abade *et al.*, 2014; Dickman, 2010; Game *et al.*, 2014; Logan *et al.*, 2014; Sogbohossou *et al.*, 2011; Tumenta *et al.*, 2013). Such understanding will help in comprehending the scale and types of interventions that may be needed for effective management.

In the same way, there has to be an increased understanding of the relatively less understood behavioural plasticity (adaptability) of tigers to adapt and persist in human-dominated landscapes (Athreya *et al.*, 2016; Carter and Linnell 2016). Tigers are wide ranging animals with large home ranges and high metabolic needs (Karanth *et al.*, 2004). Furthermore, tigers' space use is thought to be influenced by prey availability and prey densities (Goodrich *et al.*, 2010; Karanth and Sunquist 1995). For example; female tiger home ranges in prey-rich Chitwan National Park in Nepal is on average 20 km² (95% MCP), while in the dry forests of Panna TR in India female home ranges approximate 76 km² (95% MCP) (Sarkar *et al.*, 2016; Sunquist and Sunquist 2002). In low prey density Russian Far East home ranges are much larger at about 400 km² (95%MCP) (Goodrich *et al.*, 2010). Recent studies suggest that in most protected areas a scale mismatch between the tiger home range size and PA size exists (Chundawat *et al.*, 2016). As a result most tigers in protected areas also invariably move and use areas outside the protected area boundaries. Tigers are obligate carnivores and their diets require high amounts of protein (Erland *et al.*, 2011; Hayward *et al.*, 2011). In terms of metabolic requirements, Miller *et al.*, (2014) suggested that in the absence of human disturbance, a breeding female Amur tiger tigers needed 11.4 kg/day to avoid starvation. Non-reproducing adult male tigers needed 5.2kg/ day or 28.4 prey animals/ year and females needed 3.9kg/day or 18.2 prey animals/ year. In livestock dominated dry PAs of India tiger prey could include roughly 6 large domestic animals/ tiger/year (Chundawat *et al.*, unpublished). Within their home ranges in undisturbed areas, tigers kill a wide variety of prey species. Hayward and his colleagues compiled information on 3187 kills of tigers from across the tigers range and estimated that tigers most preferred prey species are wild pigs (Sus scrofa) and sambar deer (*Cervus unicolor*) (Hayward *et al.*, 2011). They also estimated that tigers preferred prey animals are in the 60 to 250 kg weight class and they killed animals proportional to their own weights. For instance, male tigers killed bigger male prey and the smaller females killed slightly smaller prey animals (Hayward *et al.*, 2011). However, most of the data that Hayward and his colleagues compiled comes from protected areas, where human presence and activities are restricted. For instance, their data do not show the contribution of livestock to tiger diet, which are common outside PA's.

In addition, tigers are ambush predators. Their activity is predominantly crepuscular and nocturnal and they rest during the day (Karanth and Sunquist 2000). In human-dominated landscapes, people carry out their daily activities during the day. They graze animals, they harvest fuel wood and gather forest products. They fish in water bodies and use areas near streams. The natural response of the tiger to such human activity and how it influences its spacing characteristics is not clear. Karanth and Sunquist (2000) propose that activity patterns of the tiger are driven primarily by prey activity patterns. Does this mean tigers in human use areas will change their activity patterns because of the presence of livestock during the day? Moreover, prey animals that solitary ambush predators like tigers kill are dependent on species-specific anti-predator behaviour (Karanth and Sunquist, 1985). This means that livestock either have to show adequate anti-predator responses to survive tigers, or people should guard their animals in such a way that makes it difficult for tigers to kill them. These insights into tiger spatial behaviour, such as its home-ranges, spacing characteristics, changes in space use and its diet are critical to plan effective conservation strategies outside PA's.

Finally, as Swan *et al.*, (2017) suggest the possibility of problem individuals (domestic animal killers or man eaters) and the unknown ecological drivers underlying problem individuals. All these known and unknown tiger related factors, raise doubts amongst conservationists and managers about the real prospect of tigers persisting outside PA's. Therefore, the knowledge on the ability of tigers and people to co-adapt and coexist are critical to secure tiger survival in human-dominated landscapes (Carter and Linnell 2016).

1.3 Large Carnivore Conservation Models

The current theoretical debate surrounding the conservation of large carnivores in the wild revolves around two key conservation models, the *separation model* and the *coexistence model*. The *separation model*, which conceptually evolved from the North American wilderness model, separates people and nature (Packer *et al.*, 2013). This model is based on the need to protect nature from the negative influence of people. The rationale behind this model is that large carnivores can successfully persist only in intensely managed protected areas or in remote uninhabited wilderness areas. The key underlying argument behind the *separation model* is that large carnivores and people will get into conflict, if carnivores move and use human-dominated landscapes. This reasoning is based on hard evidence of conflicts that have severely impacted human communities and large carnivore populations across the world and undermined their conservation (Treves and Karanth, 2003; Sogbohossou *et al.*, 2011). Packer *et al.*, (2013) analysed conservation efforts carried out on lions (*Panthera leo*) in 38 sites, with efforts ranging from 4 to 46 years. They reported that lion conservation efforts (predominantly in Africa) had better success in fenced protected areas with higher capital investments than in unfenced populations that required less capital investments. While this may be true in Africa, in Europe the coexistence approach to large carnivore conservation has proved successful (Chapron *et al.*, 2014). There is evidence that the four major European carnivores bears, wolves, lynxes and wolverines are recovering well in the coexistence landscapes of across Europe (Chapron *et al.*, 2014). The coexistence model follows a landscape- level conservation approach. Here, land sharing as opposed to land sparing (*separation model*) is seen as more appropriate to conserve large carnivores. Furthermore, the European example shows that conflicts are manageable under certain condition.

Both the *separation* and *coexistence* models for conservation have contextually proved successful and also failed in some cases. The next theoretical debate is on the approach to governance of conservation spaces, a key factor that influences success (Borrini-Feyerabend 2015). Four governance models that are also acknowledged by the International Union for Conservation of Nature (IUCN) are commonly practiced across the world to govern conservation spaces (Borrini-Feyerabend *et al.*, 2006). They are;

1) Governance by government (at various levels and possibly combining different institutions). Example, India.
2) Governance by various rights holders and stakeholders together (shared governance). (Proposed for managing wildlife outside PA's in India)
3) Governance by private individuals and organisations.
4) Governance by indigenous peoples and/or local communities

In Africa, we also find the loss of natural habitat of the lion populations outside protected areas and the challenges to deal with increasing conflicts triggered by people causalities and livestock losses (Bauer *et al.*, 2015). Furthermore, poor enforcement of regulations on hunting is leading to overharvesting of animals and the genetic isolation of lion populations (Bertola, *et al.*, 2011; Croes *et al.*, 2011). All these factors that negatively influence lion populations could be addressed cost effectively and more efficiently by fencing vast stretches of land and separating lions and people (Packer *et al.*, 2013; Bauer *et al.*, 2015). The success of such fenced protected areas is best seen in South Africa, where lion populations enjoy relative safety compared to other unfenced populations in Africa (Packer *et al.*, 2013; Bauer *et al.*, 2015). Not all authors agree on the decline of un-fenced populations (Riggio *et al.*, 2016). The drawback of fenced populations, as Packer, Creel report, is that most fenced areas are too small to sustain long term ecosystem processes (Creel *et al.*, 2013; Packer *et al.*, 2013). Others disagree and contend that lions in fenced populations represent a small portion of the overall lion population in Africa (Riggio *et al.*, 2016). Additionally, the challenges to generate the finances required for large scale fencing efforts and managing closed lion populations remains. The approach to governance of lion conservation areas in Africa on the other hand vary from country to country. South Africa, for instance has demonstrated that governance by private individuals and organisations works. In Kenya, the governance is mostly by the government. It appears that there is no one best model but various models and all of them have their own advantages and disadvantages.

In Europe, Chapron *et al.*, (2014) reported that coexistence models proved successful for brown bear, wolf, lynx and wolverine conservation. They attributed the success of coexistence to the large scale legal protection for the large carnivores. Next, the improved socio-economic development in Europe led to improved habitat quality. They also reported that large scale emigration of rural people to urban areas has led to carnivore recovery in rural landscapes of countries like Franc. Further, local contexts, cultural factors and effective regulatory practices have all made coexistence between large carnivores and people possible (Chapron *et al.*, 2014). In particular, the revival of traditional livestock protection measures such as using livestock guarding dogs, keeping livestock at night in corrals and employing herders to accompany animals have reduced livestock losses (Chapron *et al.*, 2014). These practices coupled with investments in new preventive techniques such as electric fences are considered as important factors which made coexistence between large carnivores and people possible (Chapron *et al.*, 2014). Some challenges still remain in Europe. Such challenges are concentrated in locations, where people's ability to adapt with carnivores and coexist have been lost. Furthermore, in areas where very intensive and highly commercial livestock production system exist, people are thought to conflict with large carnivores that returned to use the landscapes (Chapron *et al.*, 2014). The governance in Europe is mostly through shared governance (Chapron *et al.*, 2014).

In India, beginning in the early 1970s, conservation initiatives such as the enactment of the Indian wildlife Act (1970) and Project Tiger in 1972 helped in creating a large number of tiger reserves (PA's) (Johnsingh and Goyal, 2005; Walston *et al.*, 2010). The creation of these reserves and the governance by the forest departments proved successful in

increasing tiger numbers. However, by 1990, a gradual but steady decline in tiger numbers was observed in spite of continued efforts to protect them. During this period, many conservationists having realized the biological and ecological needs of the tiger in the wild shifted the focus of tiger conservation from protected reserve centric conservation to a landscape approach (Sanderson *et al.*, 2006; Wikramanayake *et al.*, 1998; Wikramanayake *et al.*, 1999).
After the St. Petersburg meeting and the 1st Asian Ministerial Conference on Tiger Conservation in 2010 and the conception of the Global Tiger Recovery Program, all tiger range countries acknowledged the need to double the tiger numbers by 2022 (Seidensticker, 2010). Thereafter, the government authorities in India officially started promoting tiger conservation at larger landscape units and with a coexistence agenda. Here, a hybrid model comprising the strict protection of protected tiger reserves that act as source pools (managed with a separation model) and networks of safe movement corridors and multiple use lands (administered with a coexistence model) are envisioned (Karanth and Gopal, 2005; Wikramanayake *et al.*, 2011). But, on the ground, the governance issue still remains unchanged with the government agencies mostly managing tigers outside PA's without actively involving local communities (Singh *et al.*, 2011).

India, with its rapidly developing economy, is still a developing country with a large financially underprivileged rural population. Rural inhabitants continue to depend on the forests for their subsistence. While India has the financial might and political willingness to conserve its biodiversity, it also has some of the challenges that are reported in Africa and Europe. For example, people causalities and livestock losses as reported from Africa are also common in India and create resistance to carnivore conservation efforts outside protected areas (Dhanwatey *et al.*, 2013; Rajpurohit and Krausman, 2000; Madhusudan, 2003). Poor enforcement of laws leading to widespread poaching by rural residents continues outside protected areas (Sharma *et al.*, 2014). Many of the factors that Chaperon *et al.*, (2014) mention for the success of coexistence of large carnivores like wolves and bears and people in the European context do not exist in India. For example, In India wide scale legal protection for wildlife exists but the poor enforcement of laws hinder desired results (Challender and MacMilla, 2014). The favourable socio-economic development, which lead to improved habitat quality in Europe do not yet exist in India. Millions of rural poor continue to directly depend on forests for their survival. Such direct dependence has led to intensive and unchecked use of natural resources that have degraded natural forests outside PA's (Davidar, *et al.*, 2010). On the other hand, like in Europe, local contexts and culture are still very relevant for tiger conservation outside PA's in India (Torri and Herrmann 2011). For instance, the animistic Indian religions are known for promoting a culture of tolerant and accommodating attitudes towards nature and animals (Bhagwat and Rutte 2006; Simaika and Samways, 2010). Additionally, rural inhabitants in India live in undeveloped areas, where wild animals are also found. It may be possible that rural people in India, influenced by their faith and their continuous need to adapt with local wildlife have developed ways to successfully coexist. However, there is scanty empirical evidence to suggest that people have successfully adapted to local wild animals. Further, people's ability to cope when large predator populations increase or when newly reintroduced carnivores appear, is not clear. If rural residents in India find it

difficult to adapt alongside reintroduced and increasing populations of large carnivores like tigers, they may create barriers to share land with such animals.

Recent studies by Natesh *et al.* (2017) revealed that the tiger population in North western India is not genetically diverse. They propose that this situation is because of loss of corridors that connect western populations with the Central Indian and South Indian populations. Fortunately, Central, Southern and North Eastern tiger populations in India are relatively more diverse (Sharma *et al.*, 2013). These studies reemphasise the importance of securing movement corridors that connect various source populations in India (Natesh *et al.*, 2017; Sharma *et al.*, 2013). However, my argument is that most of the existing corridors are human-dominated landscapes and the local people's willingness and tiger'' ability to adapt their ecological needs (space and prey) in lands used by humans are not clear. Under these circumstances, when there are a few known encouraging factors supporting coexistence and several unknown factors, it is hard to predict the outcome of the proposed tiger conservation outside protected areas. My study intends to contribute to developing understanding on the coexistence prospects of people and tigers in human-dominated landscapes.

1.4 Research Aim and Objectives

The main objective of my research is to understand the factors influencing human - tiger (*Panthera tigris tigris*) coexistence in human-dominated landscapes of India. The specific objectives of the study are;

1. To understand the factors that contributes to people's willingness and ability to share land with tigers.
2. To gain insights into the natural ability of tigers to coexist with people (under locally tolerable levels of conflict) in human use lands.

1.5 Hypothesis and Research questions

The hypotheses postulated in my study are,

Hypothesis 1:
It is hypothesised that rural people living within the tiger landscapes may have developed local coping strategies that will lower negative interactions with large carnivores like the tiger (Chapter 2).

Hypothesis 2:
It is hypothesised that factors such as financial gains from livestock and knowledge on carnivores will increase use of preventive livestock practices and decrease livestock losses to large carnivores (Chapter 3).

Hypothesis 3:
It is hypothesised that tigers will avoid areas where human use is intensive such as villages and water bodies in human dominated landscapes (Chapter 4).

Hypothesis 4:
It is hypothesised that the presence of feral livestock along with open –access grazing practices in human-dominated forests would increase the incidents of predation on livestock by tigers, even when wild prey are available (Chapter 5).

Four main research questions and several sub-questions have been defined to answer the main question, "Can large carnivores like tigers survive in human-dominated landscapes of India?" The first question is framed to enable the assessment of socio-cultural factors, such as, the influence of local people's practices and beliefs on conservation. The second question examines local livestock husbandry practices and its influence on livestock losses to predators. The third and fourth questions are framed to examine ecological factors like tiger space use and their diet in human-dominated landscapes.

Main questions pertaining to the socio-cultural dimension are:
1) How do people's practices and beliefs influence tiger conservation in multiple use forests?
Sub questions include:
- What are the local people's practices and what is their relationship with carnivore conservation?
- What are the beliefs and views of people on wildlife?
- What is the relationship between beliefs –practices and carnivore conservation?
- How is adherence to local beliefs and practices ensured?
- Are local practices sustainable?

2) What are the perceptions of local livestock owners on the factors that influence tiger predation of livestock in the multiple use forests?
Sub questions include:
- How is livestock husbandry conducted?
- What is the extent of livestock depredation?
- What are the preventive measures used to safeguard livestock from carnivores?
- What are the perceptions of livestock owners on the effectiveness of their preventive actions?
- What are the barriers to effective livestock husbandry?

Main questions pertaining to tigers are:
3) What is the space use of tigers in human use lands?
Sub questions include:
- Does tiger space use in the core zone and human-dominated buffer zone vary?
- How do tigers use space in areas of high human activity, like near villages and water bodies?
- What underlying factors influence variations in space use?

4) What is the diet of tigers in human use lands?

Sub questions include:

- What is general diet of tigers in Panna TR?
- What are the main prey species that tigers kill?
- How does predation vary between domestic and wild prey?
- Do predation rates vary within tigers?
- How is predation in core zone compared to the human-dominated buffer zone?
- How is predation in areas of high human activity like near villages and water bodies?
- What underlying factors influence predation rates?

1.6 The biosocial approach to this study

The framework of biosocial conservation science, which combines both the biological and social aspects surrounding conservation issues, such as in this study, is considered an efficient approach to study human - wildlife coexistence (Setchell *et al.*, 2016). For instance, as a practice, trained biologists always studied wildlife, but as wildlife became increasingly threatened, biologists started studying wildlife from a conservation perspective. However, biodiversity conservation issues constitute both the human dimension aspects and the wildlife aspects, and therefore, the threats to a species can be a social science subject as well a natural science subject (Green *et al.*, 2015; Setchell *et al.*, 2016). For this reason, this subject requires people with knowledge in several disciplines of sciences or inclusive communities of practitioners, including biological and social scientists who can integrate vastly different scientific disciplines and apply multiple approaches (Game *et al.*, 2014; Green *et al.*, 2015). In my study, I approach the examination of socio-cultural aspects such as people's religious beliefs on tigers, their local practices and livestock husbandry methods through an anthropological perspective. The tiger behavioural aspects such as, their space use and diet in human use areas, are examined from a biological perspective. I then synthesis all the findings to provide answers to my main research question: "Can large carnivores like tigers survive in human-dominated landscapes of India?"

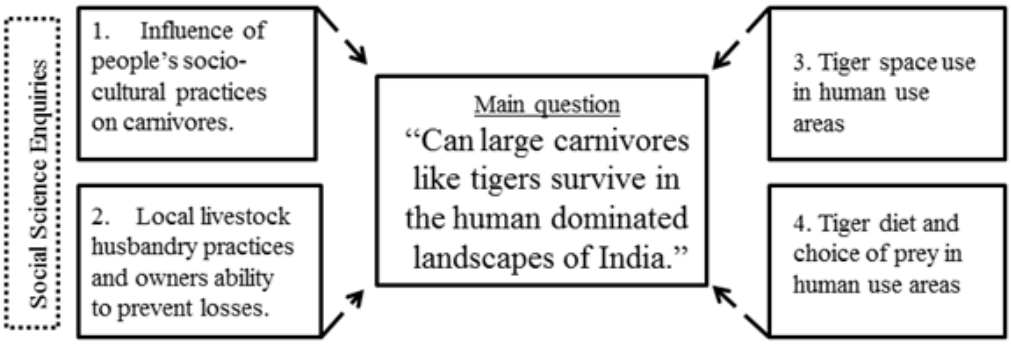

Figure 1.2: The social and natural science enquiries framed to address the main research question of my study "Can tigers survive in the human-dominated landscapes of India?"

The influence of the biosocial approach on the writing style and organisation of the chapters and sub-sections of this manuscript will be evident to the reader. This unorthodox writing style is because I did not wish to restrict the writing style to any one academic discipline but make this multi-disciplinary work interesting to both the social science and natural science readers. The flipside of this attempt is that the readers of the specific disciplines may find the style of the presentation unusual.

1.7 Study Area

This study was conducted in the human-dominated buffer zone forests of Panna TR, which is located in the Vindhya Hill ranges of Madhya Pradesh state of India (Fig. 2).

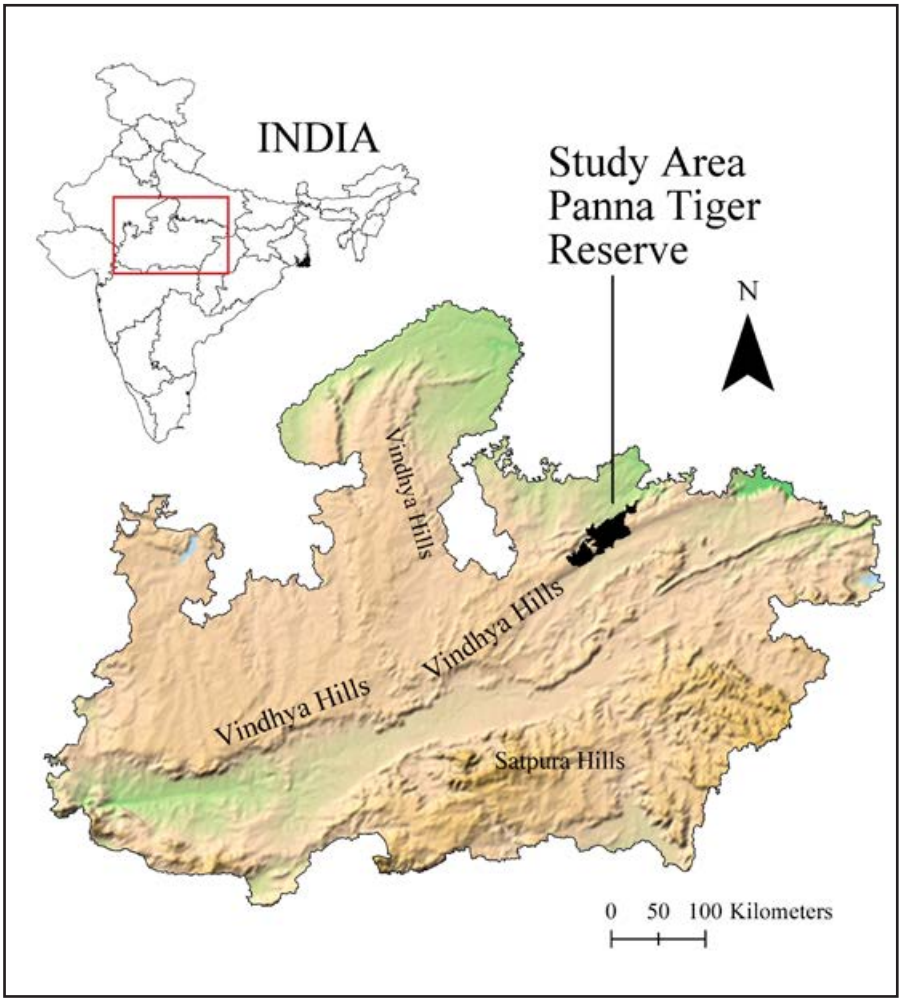

Figure 1.3 Panna Tiger Reserve (black) is shown in the Vindhya Hills of Madhya Pradesh State, India.

The Vindhya Hills are a broken chain of low hills with flat plateaued tops. There is fossil evidence of *Homo erectus* from 1, 50,000 years BP in the Vindhya Hills (Deegan 1995). Likewise, fossil evidence also reveals a broad range of currently living to extinct Jurassic wildlife in the region (Deegan 1995). The Vindhya Hills are frequently referred in the famous Indian epic Ramayana. The places, where Rama the main character in the epic supposedly travelled, are today major pilgrimage sites. In reality and in people's imagination, the Vindhya Hills are very diverse and support fascinating human cultures and wildlife. Rock art is widely found in Vindhya Hills and is known to date from 14000 BP to 1300 BP[7] (Lorblanchet, 1992; Walimbe and Schug, 2016). The drawings provide visual cues into ancient human cultures from three different time periods and provide insights into the relationship local inhabitants may have had with their surrounding natural environment. Additionally, residents living in the study area consider the local rock art as sacred and attach their own meaning to the pictographs and petroglyphs. Since understanding human-wildlife relationships is the central theme of my study, I will use the rock art found in the study area to set- the- ground for explaining the relations resident people may have had with the surrounding natural environment.

Some researchers believe that it may be hard to accurately date rock art in India, because of the existence of drawings from so many periods (ancient to present) on the same panel (Blinkhorn *et al.*, 2012). For overcome this difficulty, I adopt the chronology and interpretation that is commonly used from the extensively studied UNESCO world heritage site at Bhimbetika's[8] , which is in the Vindhya Hills south of the study area, as a benchmark to show the relationships ancient man had with his environment and the changes that transpired in the relations in time (Mathpal, 1984; Blinkhorn *et al.*, 2012).
The oldest rock art in the study area are large, one- dimensional, animal-shaped outlines filled with geometric designs. Interestingly, in this period human forms are not present in the rock art (Figures 1.4).

A second series of rock art, approximately dates between 12000 and 6000 BP, reflects in addition to animal pictures, human figures in hunting scenes posing with spears, bows and arrows. Here the drawings are generally smaller in size (10cm to 25cm in Panna) when compared to the older drawings shown in Figures 1.4. It is generally believed that such drawings give a glimpse into the Mesolithic hunter-gatherer lifestyles of the local communities (Deegan, 1995) (Figures 1.5)

The third phase, 4000 to 2500 BP comprise of drawings that show contact between rock shelter inhabitants and agriculture communities of the plains. Rock art from 2500 to 1300 BP supposedly shows dramatic changes, when it is compared to those of the past. In this period, animals are not seen alone but with human riders on them. Likewise, sketches of *yaksas*, the beneficent or malevolent spirits who are seen as the principal inhabitants of the forest appear as the first representations of the community's mythical world (Figure 1.6; Deegan 1995).

[7] BP is Before Present

[8] Bhimbetika is a UNESCO world heritage rock art site located in Vindhya Hill of Hoshangabad district, Madhya Pradesh state, India.

Figure 1.4 An example of what could have been the earliest rock art. Here the drawings are large (30 cm to 100 cm or more) and consist of one- dimensional, animal-shaped outlines filled with geometric designs. The photograph was taken near Akola village in the buffer zone of Panna Tiger Reserve.

Figure 1.5 Man hunting animals. These pictures were made in the Talgaon area of Panna Tiger Reserve.

Figure 1.6 The *Thakur baba* or headless horseman is a beneficent spirit of the forest. He is always drawn with a human shape but without a head.

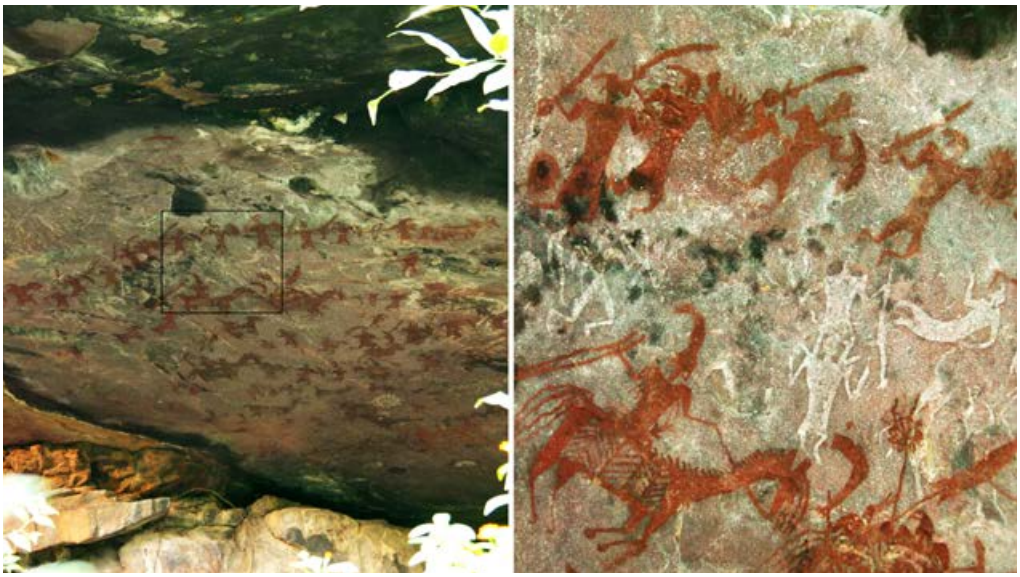

Figure 1.7 The drawing on the left is the larger panel and the one of the right is an enlarged section from the panel. Here, two armies are shown at war and both are accompanied by their spirit protectors who are drawn in white.

The last series of Rock art, possibly executed at end of the Raj Gond period in the 1500s, indicates the synthesis of forest and plains cultures through folk motifs of different topics and design. However, by clearly displaying these motifs of the physical and spiritual environments in rock art, the ancient local inhabitants seem to show the successful integration of their way of life, world views and the surrounding natural environment (Deegan 1995). It is unlikely that the current inhabitants are related to the ancient people, but they too just like ancient people integrate their way of life, world views and the surrounding natural environment (Kolipaka, 2015).

1.8 Study outline

This PhD dissertation is based on articles and it is divided into six chapters. The individual chapters have been published in several scientific journals. The articles are formatted to suit the layout style of this book but the content remains unchanged. While I am the main author in all the articles, they are all written in cooperation with several other co-authors. So the reader may find the use of words like “We” in chapters 2 to 5. The contributions of different co-authors are listed at the end of each chapter. References presented in the chapters are grouped and presented at the end.

Chapter 1 provides a background to the study, identifies the problems and the need for the study and lists the key research question.

Chapter 2 is a case study that examines how local people's practices and beliefs influence carnivore conservation in the study area. In India, religion and age-old cultures influence people's day to day life and practices. Studying the interconnected relationships between religion, people's practices and its influence on wildlife offers clues that may allow managers and conservationists to addressing complex conservation challenges in human-dominated landscapes. This study was published as a Journal article in the Journal of Human Ecology. 2015; 52(3): 192–207.

Chapter 3, The article, "Factors influencing livestock losses to predators in the multiple-use buffer zone of Panna Tiger Reserve, India." examines livestock owner's knowledge on carnivores, local husbandry practices and perceptions of livestock owners on the factors influencing predation by carnivores. In India, during 2015, citing religious reasons, an informal ban has been issued by Hindu nationalist groups on the sale of cows to slaughterhouses. Such mind-sets grounded in religion and backed by politicians, on a practical level, create difficulties for livestock owners to sell their animals. These restrictions have economic implications, make it difficult to remove excess animals and cause extra burden on owners and create complications for securing livestock from carnivores in shared spaces. (Unpublished article)

In Chapter 4, tiger space use in an area that is also used by people is examined. Here the focus is on understanding the natural responses of tigers to human presence and activities. Since the future tiger conservation strategy in India is heavily dependent on conserving tigers in human-dominated landscapes, this article provides insights on tiger's spatial behaviour, when using such human-use areas, and discusses management options. The article is published in Mammalia 2017. doi:10.1515/mammalia-2016-0126

Chapter 5 examines the diet of tigers in human-use areas. In the study area, livestock is freely grazed in the forests and wildlife also enters farmlands. My study examined tiger diet and predation in various parts of the human use areas, like near villages and near water bodies. The article is published in PloS one 12.4 (2017): e0174844.PloS one 12.4 (2017): e0174844.

Chapter 6 is the synthesis of Chapters 2, 3, 4 and 5 and provides theoretical and empirical evidences and explanations on the various questions and findings presented in each of the four chapters.