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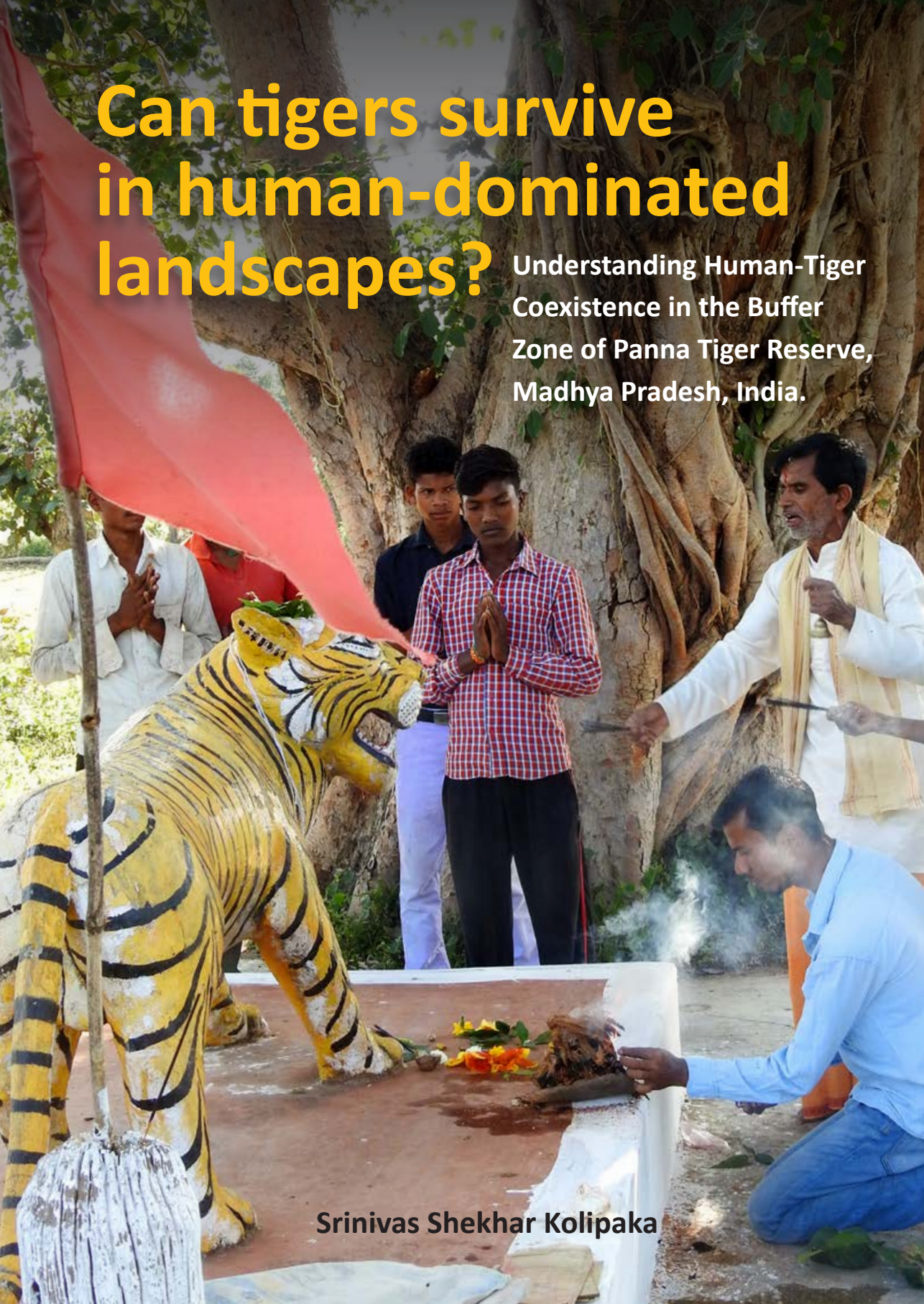
Can tigers survive in human-dominated landscapes?

Understanding Human-Tiger Coexistence in the Buffer Zone of Panna Tiger Reserve, Madhya Pradesh, India.



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Can tigers survive in human-dominated landscapes?

Understanding Human-Tiger Coexistence in the Buffer Zone of Panna Tiger Reserve, Madhya Pradesh, India.

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Prof. Dr. P. Pels, Leiden University

Contents

Terms used

Human-dominated landscapes:
In this study, the term human-dominated landscapes are referred to government-controlled non-protected forests or territorial divisions, where land use is predominantly anthropocentric.

Multiple-use lands:
Multiple-use forests or lands are managed to accommodate various uses on the same land. For example, in the buffer zones of the tiger reserve, livestock grazing by local communities and wildlife conservation are both pursued side by side. The term *shared lands* also means the same.

Tiger Reserves:
To protect the tiger, Indian government identified and declared several areas that are vital for the species continued survival as tiger reserves. These areas comprise of national parks, multiple use forests like Wildlife Sanctuaries and human-dominated non-protected forests (territorial divisions). In tiger reserves, the focus of management is on tiger conservation.

Panna Tiger Reserve:
Panna Tiger Reserve or Panna TR comprises a core zone, which is a national park or IUCN PA category II area (meaning areas secured exclusively for wildlife with human activities limited to non-consumptive tourism). Surrounding the core zone is a multiple use buffer zone which is an IUCN PA category IV area (meaning the area has villages, and it is permitted for residents to extract natural resources from the area).

Core Zone of a tiger reserve:
An area within the tiger reserve that is exclusively managed for wildlife. Here human influence is limited to non-consumptive tourism and all other human activities are prohibited by law.

Buffer Zone of a tiger reserve:
An area separating the core zone from the surrounding intensive land uses. The buffer zone is a multiple-use land and its creation is mandatory around the core zones of tiger reserves. However, these areas contain villages, and resident people extract natural resource for their consumption from the forests in the buffer zone. Developmental activities are restricted in these zones.

Cattle:
Cattle are colloquially referred as cows in India. The domestic cow of India belongs to the genus Bos. The female cow is kept for milk and males are used for ploughing fields. For religious reasons beef is not eaten by majority Hindus.

Domestic water buffalo:
These animals from the genus Bubalus are domesticated and widely used across India. Female buffalos are kept for milk and males are used for ploughing fields. Buffalo meat is widely consumed unlike beef.

Livestock:
A more general term for addressing all farm animals (cows, domestic water buffalo, goats, pigs, horses and donkeys).

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?"

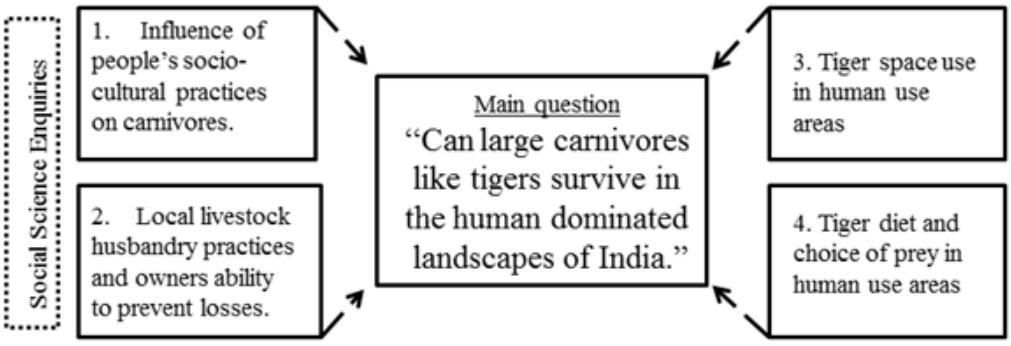

Figure 1.2: The social and natural science enquiries framed to address the main research question of my study "Can tigers survive in the human-dominated landscapes of India?"

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).

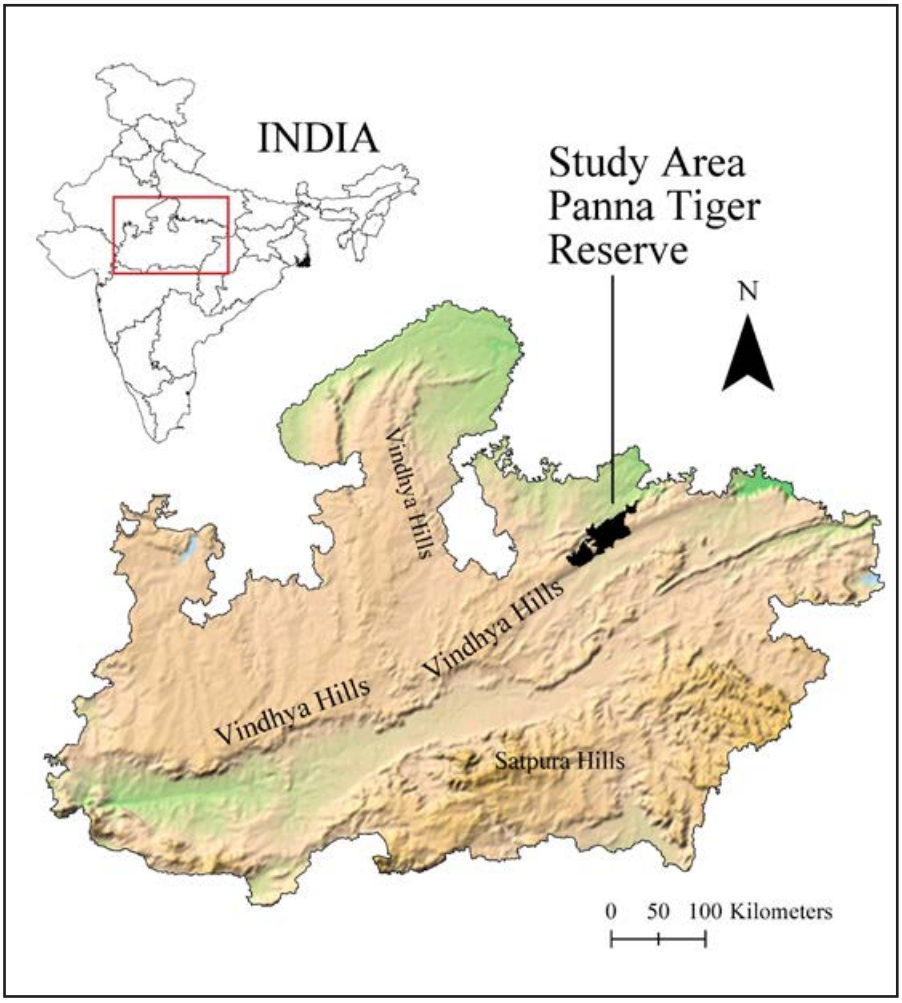

Figure 1.3 Panna Tiger Reserve (black) is shown in the Vindhya Hills of Madhya Pradesh State, India.

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.

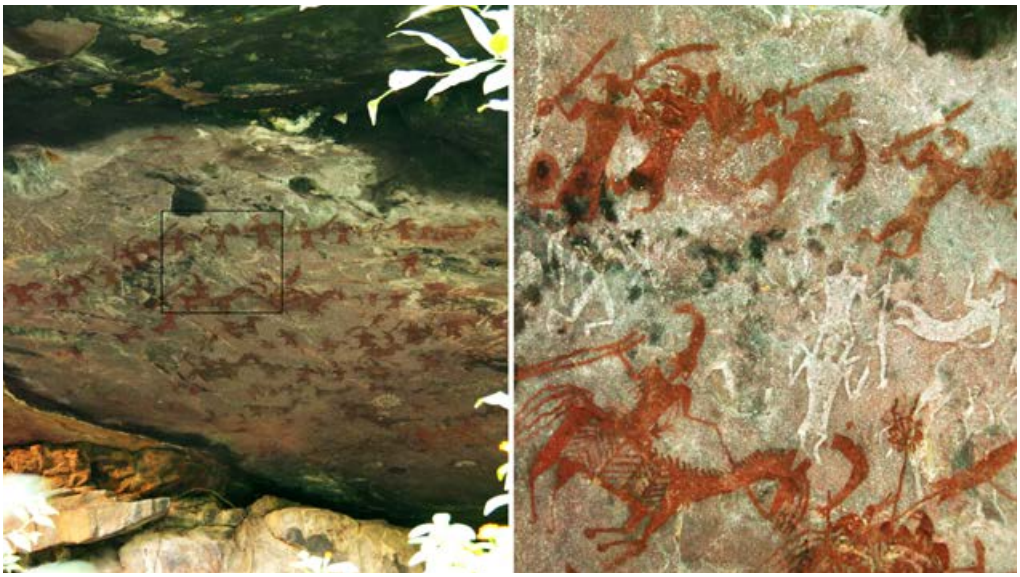

Figure 1.7 The drawing on the left is the larger panel and the one of the right is an enlarged section from the panel. Here, two armies are shown at war and both are accompanied by their spirit protectors who are drawn in white.

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.

Human figures in rock art.
This drawing was found in the
Panna Tiger Reserve, India.

2 The Influence of People's Practices and Beliefs on Conservation: A Case Study on Human-Carnivore Relationships from the Multiple Use Buffer Zone of the Panna Tiger Reserve, India.

Kolipaka, S.S., Persoon, G.A., De Iongh, H.H. and Srivastava, D.P., 2015.
Published in the Journal of Human Ecology, 52(3): 192-207 (2015)

Abstract

The case presented in this paper is a unique situation of livestock pastoralists, living in the buffer zone of Panna Tiger Reserve in India, displaying unusually high tolerance towards large carnivores in spite of frequent predation incidents. The researchers dissect the case, examine local people's practices and draw attention to factors influencing people's practices. Through interviews and personal observations the researchers collected detailed information on people's practices and the factors influencing such practices. They collected information on large carnivores near 29 villages in the buffer zone and looked at factors influencing their presence in these areas. Their findings reveal the play and working of several social factors that are instrumental in influencing people's tolerance and people's behaviours towards forests and wildlife and recommend that carnivore conservation projects focusing outside protected areas should critically assess the influence of such aspects on their conservation goals. And wherever applicable, find ways to innovatively model them into their conservation plans.

2.1 Introduction

In India and other parts of the world, wildlife species are known to frequently move beyond the boundaries of protected areas and persist in multiple use forestlands, private lands and human-dominated landscapes. Generally, these areas are under a variety of human land uses and accommodate village settlements and people's activities like livestock grazing, agriculture and also their recreation. It is widely accepted that when humans share space with wildlife, interactions are inevitable and some interactions have negative consequences for humans and for wildlife. Fearing conflicts and eventually

loss of people support for conserving wildlife outside protected areas there is a growing interest within conservation planners and practitioners to understand correlates that promote coexistence of people and wildlife. Examples include promoting coexistence in conservation plans for tigers and leopards in India, Jaguars in South America and wolves and bears in Europe (Wikramanayake *et al.*, 2011; Chapron *et al.*, 2014; Odden *et al.*, 2014; Rabinowitz, 2014).

Conserving wildlife outside protected areas especially endangered large carnivores like tiger, wolf and bear has always posed challenges. This is because large carnivores are known to attack people, create economic losses through predation on livestock, in some situations they are culturally undesirable, and some species also trigger fear within people (Athreya *et al.*, 2013; Chapron *et al.*, 2014; Goodale *et al.*, 2015). People are known to respond to these physical and psychological threats by retaliating on carnivores and carnivore conservation promoters. Human caused mortality of carnivores through direct killing of carnivores, keeping a blind eye to their poaching or decreasing support for their conservation are all reasoned to their decline globally (Wikramanayake *et al.*, 2011; Inskip *et al.*, 2013; Traves and Bruskotter, 2014; Rabinowitz, 2014; Madhusudan, 2015). Dissimilar to the above situations, there are also documented cases where local people show much restrain and tolerate large carnivores in spite of the threats they pose to human interests, allowing coexistence (Jones *et al.*, 2008; Chapron *et al.*, 2014; Goodale *et al.*, 2015; Vucetich *et al.*, 2015).

Since humans and their activities are inseparable features of the landscape outside protected areas, knowledge of the factors that enable coexistence of people and carnivores are always interesting to conservation planners. Literature on the subject of human-carnivore interactions indicates that people's tolerance of carnivores is a vital ingredient for carnivore survival outside protected areas (Traves and Bruskotter 2014; Yirga *et al.*, 2014). However, the factors motivating people's tolerance of carnivores are numerous and range from monetary factors to case specific contextual factors to social factors (Banerjee *et al.*, 2013; Chapron *et al.*, 2014; Traves and Bruskotter 2014). Further, it is also recognized that the factors influencing people's tolerance of carnivores are not straight forward but many, interrelated and whose functions and relationships are complex and not fully understood (Traves and Bruskotter 2014; Goodale *et al.*, 2015).

To further improve existing knowledge and understanding on the topic of human motivations to tolerate carnivores and also to elaborate on the interrelatedness and complexity of factors affecting human tolerance of carnivores, the researchers critically examined a case study of livestock pastoralists from the multiple use buffer zone of Panna Tiger Reserve. Uniquely, the pastoralists do not retaliate on large carnivores such as the tiger (*Panthera tigris*), leopard (*Panthera pardus*), grey wolf (*Canis lupus*) or sloth bears (*Melursus ursinus*) in spite of recurring livestock losses and threat of personal injury. Initial enquiries into this unique case revealed the existence and play of several social factors such as culturally grounded practices, their religious beliefs and norms influencing their livestock management practices and views on carnivores. Based on these initial cues the researchers set the focus and objectives to:

1. Examine and describe local livestock management practices drawing attention to factors influencing these practices.
2. Describe qualitatively the relationship between the factors and pastoralists tolerance of carnivores.
3. To analyse the sustainability of those factors exerting influence.

The researchers believe that such detailed dissection of a positive case of tolerance will improve the understanding on the nature and depth of influence of social factors on carnivore conservation outside protected areas.

2.2 Methods

Data presented in this paper is collected over a fouryear period between 2010 and 2014. A large amount of data was collected by the principal researcher, as part of his project to study tiger conservation in multiple use forests of India and unpublished information relevant for this paper is used from the same data set.

2.2.1 Study Area

This research work was carried out in the multiple use buffer zone forests of Panna Tiger Reserve in India (Fig. 1) located in north central Madhya Pradesh at longitude 79°556E to 80°273E and latitude 24°274N to 24°905N. The tiger reserve is spread over an area of approximately 1400 km², of which approximately 550 km² is demarcated as an inviolate core zone, where human activity is restricted and natural resource extraction is prohibited. The remaining 850 km² is a multiple use buffer zone, where local people have traditional rights called Nistar to extract forest resources.

The area has tropical climate with three distinct seasons. The hot summers are between March and June, wet season from July to October and the mild winter season from November to February. The annual rainfall is approximately 1100 mm. Monsoon rains are the only source of water for large areas of the park. The maximum day temperatures in summer reach 47°C and in winters the temperature can drop to 3°C during nights. Influenced by cyclones on the coasts, a few winter and summer showers are common in the study area (Mathai 1999). The terrain in the study area can be best described as hilly with flat plateaus and plains areas.

2.2.2 Local People Communities

A total of 42 villages with an estimated human population of 43,125 people live within the multiple use buffer zone of the Panna Tiger Reserve. Tens of villages are also located outside the periphery of the buffer zone. Extremely low levels of socioeconomic development characterise people in the area (Mathai 1999). Education and modern skills amongst local people are very low making their chances of employment almost non-existent. Domestic animal rearing and agriculture are common but only provide subsistence occupations for a majority of the local people.

Working, as daily wage labourers, collecting and selling fuel wood and non-timber forest products are important sources of income for a substantial number of people. Due to rapid increase in local population and division of lands across generations (father to son), most landholdings are small and are used exclusively for agriculture (Mathai 1999).

The major ethnic groups of the area are the Gonds (Rajgonds, Nandgonds and Saurgonds) and Khairuas among the tribes and the Yadavs among the nontribal (Mathai 1999). People representing 30 *jati's* (caste or tribe) are described in the study area. People typically live in mixed community villages with Hindu *jati*, *adivasi* (original inhabitant) and Muslim *jati*, people living together. There are also a few small forest villages, where all residents belong to a single *jati*. Local traditional practices such as worship of animistic spirits are actively practiced and reflect in daytoday life of local people in the study area. It is also common to see members from different *jati's* following comparable practices or having overlapping beliefs.

2.2.3 Carnivores in the Study Area

Over twenty terrestrial mammalian carnivores are recorded in Panna Tiger Reserve core and buffer zones. Large terrestrial carnivores (>20kg body weight) include the tiger (*Panthera tigris tigris*), leopard (*Panthera pardus fusca*), Indian wild dog or dhole (*Cuon alpinus*), wolf (*Canis lupus pallipes*), striped hyena (*Hyaena hyaena*), sloth bear (*Melursus ursinus*) and domestic dogs (*Canis lupus familiaris*).

2.2.4 Selection of Villages and Informants

The researchers wanted to include villages and people with varying geographic and demographic features in the final sample. Further, they wanted to collect information, which could be quantitatively and qualitatively analysed and support the key research objectives. Distance from core zone to the villages and size of the village were two criteria's the researchers used and selected 29 out of the 42 villages located within the buffer zone (Fig. 1). Five to ten households from each of the shortlisted villages were selectively sampled and a total of 255 households were finally interviewed. The researchers ensured that the interviewed households represented members from the diverse jatis in the villages, ensured that households keeping the three livestock types were included and also ensured that households who earned a livelihood from livestock and those who kept livestock purely for subsistence were also included.

2.2.5 Data Collection

To study the influence of local practices on large carnivores, the researchers focused on two livestock management practices: 1) Villagers practice of disposing dead domestic animal carcasses, and 2) Villagers practice of abandoning unwanted livestock. To establish the number of livestock carcasses near villages the researchers maintained records of domestic animal carcasses dumped outside, and the 29 villages included in the study for the whole of 2013.

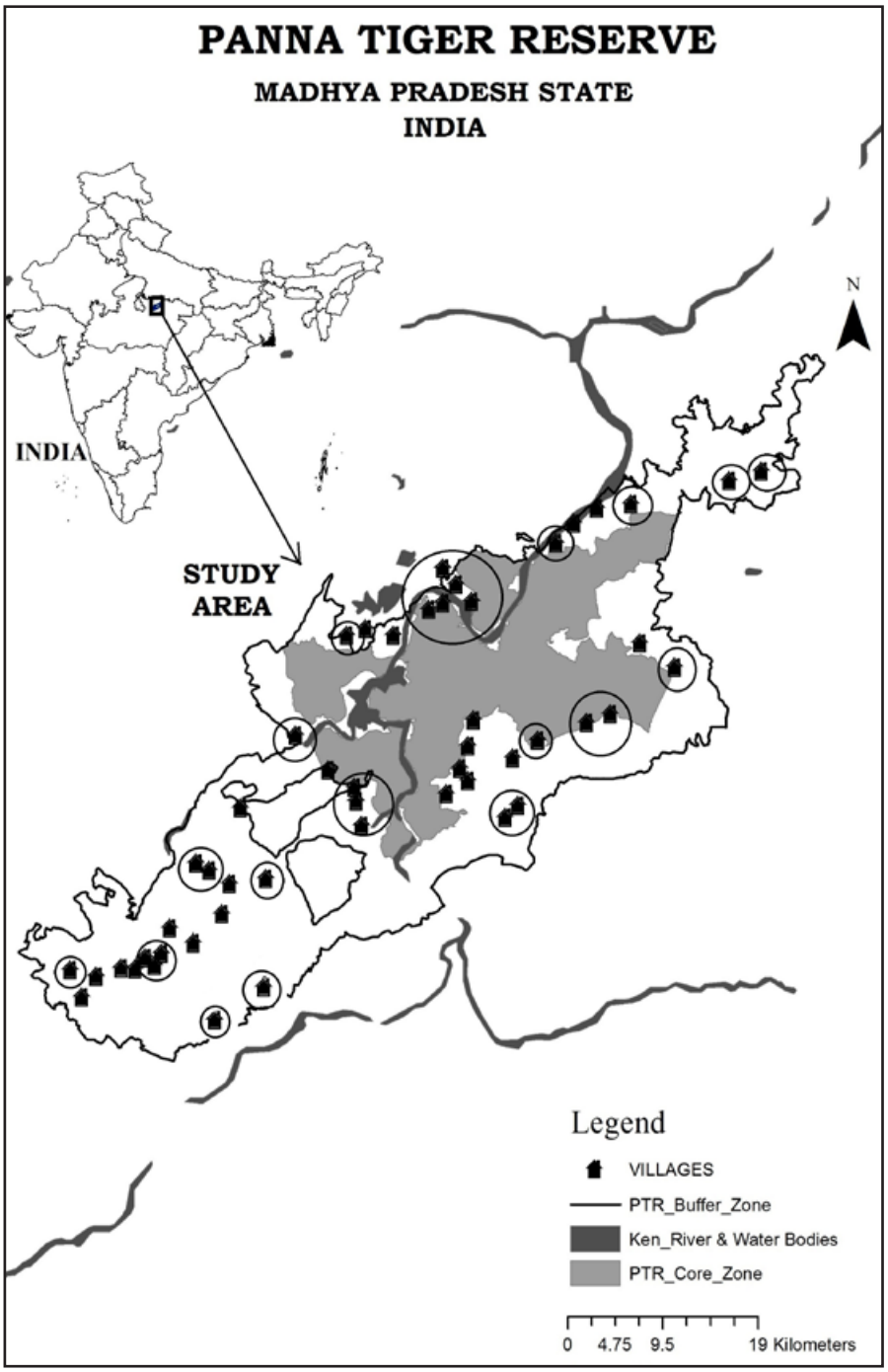

Figure 2.1. The dark grey area is the inviolate core zone and the adjoining areas with villages is the multiple use buffer zone of Panna Tiger Reserve. Data for this study was collected only from those villages with circles around them.

The researchers selectively set up photo camera traps (10 CuddyBack white flash photo camera traps) near carcasses to record presence of carnivores. To establish numbers of livestock killed by large carnivores, the researchers collected information on livestock losses from villagers (part of interviews) and also analysed records of livestock kills made by eight radio collared tigers monitored by reserve staff. To establish presence of carnivores around villages and in the buffer zone forests of the study area, the researchers incorporated relevant questions in the interviews and collected secondary information from villagers. The researchers crossed checked this information with detailed information collected by the principal researcher as part of his carnivore surveys in the region. All the collected information was collated and analysed to established links between availability of carcasses and presence of carnivores near villages.

To examine factors influencing people's perceptions of risk from carnivore's, questions relating to households socioeconomics, yearly livestock losses, perceptions and attitudes towards carnivores and park management, knowledge on carnivores, herding and corralling strategies were incorporated into the interviews and analysed. The researchers also made personal observations on 20 pastoralists by accompanying them on their day trips into the forests and kept notes of their behaviour at spirit sites, responses to carnivores, herding techniques and other aspects. Information from interviews and observations were collated and analysed to make meaning of pastoralists' perceptions of risk from carnivores and the same information was also used to assess interviewed pastoralists' adherence of religious norms, a social factor.

To collect information on the factors that influenced local livestock management practices, the researchers selectively framed questions and asked them during the informal interviews. As a first step, the questions were tested randomly on a few villagers. The collected information suggested that villagers linked their religious beliefs, cultural norms and aspects like convenience, and justified it to their practices. The researchers incorporated the different views in the final semi-structured interviews and informally interviewed 82 pastoralist households (out of the 255). Questions were designed to gather information on three main themes: 1) Local people's beliefs and norms towards the natural world, 2) benefits people derived as a result of their beliefs and norms, and 3) adherence and sustainability of existing practices. Interviews were informally conducted at homes of pastoralists and the checklist of themes ensured that all the topics and questions were covered. Information on sustainability was crosschecked with six spirit intermediaries on trends in continuity and erosion of beliefs.

The researchers noticed that people from lower ranking social classes (*jatis*) found it difficult to answer questions related to abandoning domestic animal or talking about presence of carcasses especially when there were onlookers from higher ranking *jati's*. So the researchers ensured that onlookers were not present while questioning households and also mixed sensitive topics into informal conversations.

2.2.6 Analysis

Qualitative data and quantitative data were separately analysed but combined to interpret and support arguments made in the discussion. The Thematic Content Analysis as explained by Bernard (2006) was used to analyse the qualitative interviews. The informants' responses such as their views and perceptions on the core topics were placed into predefined themes under each of the core topics. This ensured that the focus stayed on the core topics (practices, religious beliefs, cultural norms, and adherence). This also helped keep focus on the research objectives. Individual statements were given codes and some of them were quoted directly in the papers' text. Themes were linked and suitable quotes were selected to suit the thematic structure of the paper and explained. Quantitative information from carnivore data was analysed using a Microsoft Excel 2013 spread sheet and presented in the paper. (See Table1: The methods employed in this study to collect information).

Table 2.1: Summary of methods

S. NO.	METHODS	SOURCE	SAMPLE	PERIOD
1	Observations	Livestock pastoralists[1]	20	2013
2	Semi-structured Interviews	Households owning livestock	82	20132014
3	Pre-structured Questionnaire Survey	Spirit mediums Households owning livestock	6 255	 2013 to 014
4	Counts of Livestock Kills	Panna Tiger Reserve records	8 radio-collared tigers	2010 to 014
5	Carcass Counts	Villages forest fringe areas	29 sites	20132014
6	Presence/ Absence Surveys	Buffer zone	N.A	20122014

[1] Livestock pastoralists are those villagers who earn their livelihood from rearing livestock.

2.3 Results

2.3.1 Local Livestock Management Practices

The researchers present two local livestock management practices and show evidence of how the local practice are deeply entrenched in complex local culture and also how they also provide practical advantages to carnivores.

2.3.2 Practice 1: The Disposing of dead domestic animal carcasses near village forest fringes

Most villagers in the study area viewed cattle (cows and buffalos) as religious symbols and considered it a taboo to eat beef. Intentionally harming domestic cows, killing or trading in their skins was also considered a taboo and people abstained from such activities. Even

Muslims who generally had no religious taboo towards eating beef agreed to the views of the majority villagers and abstained from eating beef or trading in their skins in the study area.

In response to a question of how members from Muslim communities viewed cows and buffalos, a Muslim pastoralist replied, *"Muslims in this area stopped eating beef nearly 30 years ago. Not even buffalos. Beef is only available in Mahoba, which is 40 kilometres from here"*.

As a social norm, most interviewed villagers regarded touching dead animals as unclean or achuut (not to touch) and normally abstained from such acts. Instead, they depended on a traditional system, where in members from the *chamar jati* (tanner) handled and removed dead animals from villages. Chamars are considered very low *jati* (status group) and treated as untouchables in the study area. Their houses within a village are usually located at a distance from homes of other villagers and villagers do not accept drinking water or food from *Chamars*. These low social groups of villagers earn livelihoods by performing menial jobs. They operate in villages on locally agreeable conditions, in some villages they pay an annual fee to the village *panchayat* (administrative body) for removing carcasses, while in some they are paid and in others they perform a free service without any monetary transaction involved. *Chamars* pick up domestic animal carcasses, skin them and dispose remains at village-forest fringes. After the flesh from dead carcasses is scavenged by animals and birds, *chamars* also remove bones and supply them to the bone meal industry. Where *chamars* are not available, villagers personally remove carcasses and dispose whole carcasses far from human habitation. The interviewed *chamars* in the study area report increasing objections from local villagers to skin and trade in skins of dead animals following a state wide ban on beef products. The current practice of disposing carcasses near village forest-fringes is widely accepted by all social groups in the area and it is also adhered in areas adjoining the study area. Villagers from the forty two (42) villages in the study area keep over 45,000 cows. In the 29 surveyed villages 20,968 livestock (cows, buffalos and goats) were counted and villagers reported losses of 6.9 percent or 1455 livestock in 12 months of 2013. Parallel to this, the researchers also counted 209 domestic animal carcasses (cows 172, buffalo 16 and 21 full or partial skeletons) in varying stages of decomposition in the multiple use forests of Panna Tiger Reserve between September 2013 and August 2014. According to villagers, a certain number of livestock perish annually for various reasons. Disease, shortage of forage and water, and natural causes are reasoned as major killers and accounted for mortalities of forty three percent of dead cows, (53%) fifty three percent of buffalos and (55%) fifty five percent of goats. Predation by carnivores accounts for losses of (43%) forty three percent of dead cows, (32%) thirty two percent of buffalos and (33%) thirty three percent of goats. Villagers dispose dead carcasses near village-forest fringes and many carnivore species feed on these readily available carcasses.

Mortality of livestock reportedly occurs throughout the year with peak mortality occurring during summers and during the monsoon periods. During the hot summer months (April to June), livestock mortalities occur due to shortages in forage, exposure to the sun and

water scarcity. While predation by carnivores and disease related losses are highest during monsoon period (July to October).

Presences of at least two species of large carnivores were recorded within a 1.5 km periphery of each of the 29 surveyed villages suggesting that large carnivores were active near and around human settlements. The carnivore surveys indicate that large carnivores have a wide distribution in the Panna Tiger Reserve Buffer zone, in spite of severe degradation of habitat and presence of humans in the area. Distribution varied from species to specie with the hyena, jackal and sloth bear having the widest and most uniform distribution in the multiple use forests while the tiger, leopard, wolf, and dhole distribution was restricted to specific areas. Domestic dog presence was very commonly recorded in the study area and they made forays deep into the forests during day but retreated towards the village-forest fringes by nightfall, where they were very active. The evidence of all carnivores species (except sloth bears) feeding on domestic animal carcasses near village-forest fringes and in the multiple use forests strengthens the argument of links between the practice of dumping carcasses and use of such domestic animal carcasses by carnivores.

2.3.3 Practice 2: The Abandoning of Unwanted Cattle

Eighty percent (80%) of all households in the 29 surveyed villages owned cows. Majority of villagers kept cows for subsistence (milk and butter) and a few managed larger herds to earn a livelihood. However, buffalos and goats were maintained with an aim to earn a livelihood. Interviewed villages expressed both personal and social obligation to follow religious sanctions and social norms prohibiting sale of cows to slaughterhouses, selling their skins or eating beef. For most villagers, performing acts against their religious beliefs was personally confronting and they feared supernatural retribution and community disapproval.

Interviewed villagers revealed that they sometimes feel burdened to maintain excess and unwanted cows (as they cannot sell them to slaughterhouses) and voiced discontent on the increasing numbers of such unwanted animals in the villages. They expressed that they need help to decrease cow numbers but at the same time they vented helplessness in confronting the religious and social sanctions. Most interviewed villagers did not have answers when questioned about ways to control cow numbers. None of the interviewed villagers expressed willingness to take independent initiatives and all expected the reserve management to find a solution. Not willing to maintain larger numbers of cows and forced by sanctions not to dispose them, villagers disown and allow female animals that do not yielding milk, become old or sick and male calves to roam feral in the jungles of the study area.

The surveys reveal that feral cows that moved in the multiple use areas are vulnerable to predation by large carnivores. Feral cows in the multiple use forests originated from various sources. Their owners left behind thousands of cows when 10 villages were relocated from within Panna Tiger Reserve between 1990 and 2013. Such abandoned cows roam feral in the jungles and also produce young. Villagers living on the fringes of the multiple use buffer zone forests and those living insider the buffer zone too abandon

their unwanted cows and allow them to roam feral. Further, villagers who cannot afford the services of a *baredi* (community herder) allow cows to graze free, without herders, and such cows stray far into the multiple use areas. As a result, feral and free roaming cows abound in the study area and such cows fall frequent prey to large carnivores. Characteristically, of the 648 animals killed by 8 radio-collared tigers of Panna Tiger Reserve between 2010 and 2014, fifty one percent (51%) are livestock (243 cow and 35 buffalo). Out of the 243 cows killed by tigers 112 were males, 78 were females and 53 were young animals. This finding suggests that large carnivores like tigers actively predate on cows roaming in the Panna Tiger Reserve. Further, thirty one percent (31%), nineteen percent (19%) and sixty one percent (61%) of all livestock owners with cows, buffalo's and goats interviewed during this study experienced incidents of predation by large carnivores during 2013. This suggests that livestock, which is cared for and maintained by villagers, are also vulnerable to predation along with free roaming and untended domestic animals.

2.3.4 Religious Beliefs and Norms of Local People Towards the Natural World

The researchers found evidence that the beliefs and cultural norms that people held towards the natural world also influenced and guided some of their behaviours towards the natural world including wild animals.

Beliefs towards the Natural World

Interviewed villagers strongly believed that worshipping forest spirits and making pacts with them ensured their personal wellbeing. They also believed that it ensured the safety of their family and also their livestock. They believed that powerful forces (in streams, trees, rocks, animals, and sky) inhabit forests and that these forces can cause harm when they move through forests. For instance, a large branch of a tree may fall on their herd animals, or a sudden flash flood in the stream could drown a person, or a boulder may tumble out of the hillock and destroy everything in its path. Interviewed pastoralists believed that the spirits they worshipped have the power to safeguard them from the forces of the natural world. They therefore, made pacts with the spirits for their continued protection. For example, respondents were fully aware that large carnivores like tigers and wolves moved in the same forests that they also used. They were also conscious of the dangers that tigers and wolves could pose to their livestock. Yet, interviewed pastoralists choose to believe that as a result of the pacts they have with their spirit protectors, their spirit protectors exerted control on the natural world including the tiger and the wolf and ensure their safety. Most interviewed pastoralists also justified attacks and killings of livestock by tigers and wolves as acts sanctioned deliberately by spirits. They viewed such incidents as normal occurrences and reasoned that spirits were helping the carnivore survive. Some interviewed members justified attacks on humans as a punishment for wrongdoing. The below narratives capture the belief of a respondent.

"Tigers like humans also feel hungry. When hungry tigers make loud growls. Such growls are pleas to spirits to lead them to prey. Spirits then guide tigers to prey animals and permit them to make a kill. Tigers can never make kills without the support and permission of the spirits." (A pujari, a spirit ritual organizer)

Interviewed respondents believed that harming wildlife, even those that are potentially troublesome, was not their function. Yadav pastoralists for instance, revered the cow as their mother. Gond tribes viewed wild pigs, nilgai antelope, tiger amongst others as animals that were favourites to the forest spirits *Siddh baba, Masan baba and Badami baba*. They therefore, viewed the aforementioned animals belonged to the spirits and believed that harming them would result in retribution from the spirits. They also feared that hunting them would jeopardize their existing pacts with their spirit protectors, making them vulnerable to unforeseeable dangers. Some also believed that killing sacred animals would unleash retaliatory attacks by the animals upon them. Some respondents viewed that killing animals (such as the cow) that are sacred to some groups of people would lead to conflicts within people. For example, interviewed Muslim goat pastoralists disclosed that they stopped eating beef in their areas since the Hindus living there viewed the cow as a sacred animal. Similarly, the Hindu living in the area mutually respected the beliefs and values of Muslim community members. Interviewed people expressed that they chose to make collective decisions on sensitive issues and did not make independent decisions. They instead deliberated on the situation over a spirit ritual, consulted elderly members from their community and explored ways that were acceptable to majority of community members. The below narratives highlight the views and beliefs that respondents held towards animals.

"Badami baba is a very powerful forest spirit. Badami baba can summon the tiger by its ear. If a tiger repeatedly kills cattle or creates panic in villages, Badami baba can be requested to summon and tame the tiger." (A buffalo herder)

"Wolves should not be killed or harmed. Other wolves will unleash retaliatory attacks if their members are killed or attacked." (A Gond goat herder)

"Cows are holy animals and should not be harmed, killed or sold to slaughterhouses. Killing cows or selling their skins is therefore prohibited in the community and even evokes community disapproval and punishment on offenders. I fear my family and I may be face community exclusion if I supplied your project with buffalo calves or cow calves as bait to catch Tigers." (A Yadav pastoralist)

"The wild animals belong to the forest and it's the responsibility of the forest department personnel to control their animals. I am not going to kill them or harm them and evoke the department's wrath."

Influenced by the various cultural, popular and widely established beliefs, respondents abstained from harming or killing even bothersome animals.

Most interviewed pastoralists adhered to the religious and cultural norms that also had practical advantages to them. Adherence reduced risk of direct encounters with animals and discouraged risk taking that could jeopardize a pastoralist's safety and wellbeing.

Religious Norms and Taboos Towards Animals

Pastoralists adhered to many types of cultural norms and taboos that guided their behaviour towards the natural world and the animals in the study area. For instance, a goat herder disclosed that as a norm he did not venture out into the forests at night time. He believed that forces of the forests, that which could potentially harm are most active during the dark hours. So he avoided venturing into the forests during the dark hours and waited till daybreak to take animals into the forests. He also returned home from the forest before it got dark. Most pastoralists as a general rule followed this norm. By adhering to such a norm directly translates into a positive advantage to those who adhere, meaning, those respondents adhering to the abovementioned norm avoid forays into the forests in the crepuscular (dawn and dusk) and nocturnal hours when most carnivores are active and visibility in the forest is minimum. By adhering to the norm, respondents are knowingly or unknowingly minimizing their risk of encountering animals or other dangers that lurk in dark in forests.

Another social norm commonly adhered by Yadav pastoralists demanded that livestock and pregnant animals should not be left to stay on their own in the forests. Such a situation would automatically allow spirits to summon tigers or other animals to predate on those animals. Therefore, if a situation arose, as a norm, the entire community took the responsibility to look for missing animals. Adherence to the above social norms has positive consequences for pastoralists. They gave extra attention and safeguarded pregnant and young animals and as a unit they collaboratively searched for lost and missing animals. Here, adhering to norms also reinforced collaboration amongst pastoralists and ensured community support if a person needed help thus reducing the risk of losing vulnerable animals to carnivores and even livestock thieves.

2.3.5 Enforcement of Norms

Traditional local institutions and self-regulation both ensured enforcement of norms amongst interviewed pastoralists. The researchers observed that young children were actively engaged in religious ceremonies from a young age. On special occasions they were also treated as gods and adults in turn worshipped children. One important and costly offering that villagers made to their spirit protectors as part of their pacts was to feed young girls (*Kanya Bhoj*), and this was regarded as esteemed offerings to spirits. In many ways, the children were introduced to local religious belief systems from an early age and mistakes made by children were normally overlooked and treated as acceptable. However, oversights by adults evoked within individuals, a fear of supernatural retribution or feelings of imminent damage from unknown sources. Sometimes the community imposed fines and even harsher community disapproval for breaking norms. Most respondents viewed that adhering to norms was normal behaviour, it reduced dangers and kept spirits satisfied and therefore was to their own benefit. All interviewed religious intercessors (n=6) reported observing an increasing trend in the numbers of villagers involved in the traditional belief system. They however felt that the younger generation, influenced by other worldly distractions, may temporarily lose interest in traditional beliefs but returned back to the traditional beliefs when they became adults.

2.3.6 Perceptions About Risks From Carnivores

The interviews revealed that the pastoralists' awareness and knowledge about wildlife was influenced by their own physical location, that is, areas in which they moved within the buffer zone. They had greater knowledge on animals that directly threatened them and their livestock (in real life and metaphorically), and those species that are easily visible than those that are cryptic, elusive or wholly nocturnal. For example, pastoralists herding goats and grazing on the flat plain areas of the buffer zone regard the wolf as a problem carnivore and report that it attacked their animals even in broad daylight. They however do not see the wolf as a threat to their own personal safety. The same goat herders revealed high familiarity with tigers (locally referred as *Nahar and Sher*) and leopards (*Sher and Duranga*) but they did not perceive them as threats to their animals or personal safety. Further, only forty six percent (46%) of the interviewed pastoralists (N=255) could accurately identify tigers from leopards from photographs shown to them. An even smaller number could verbally describe differences accurately. A very small percentage of interviewed pastoralists (2%) acknowledged seeing tigers or leopards in real life. The above information suggests that pastoralists had high awareness on animals like wolves that were present and posed direct problems to their livestock. However, they had little knowledge on cryptic carnivores like tigers and leopards, which are not easily visible and avoid open plains, where pastoralists frequent. These factors most likely ascribe to the difference in their knowledge on species.

Based on interviews, the researchers assessed that a large majority of the interviewed (79%) did not view tigers as a problem species. Only twenty one percent (21%) of the pastoralists viewed tigers as a threat, of which nineteen percent (19%) viewed them as threatening to large domestic animals. All pastoralists herding buffalos had high awareness about tigers, but only a small percentage (18%) of them actually experienced loss from predation in 2013. The variations in perceptions of pastoralists on tigers are likely because of infrequent predation by tiger on buffalo. Tiger presence and distribution in the study area is restricted to certain patches of the multiple use buffer zone area (Fig. 1) and not the entire area. Hence, livestock losses from tigers were also restricted to some areas only and not experienced by all the pastoralists. Further, even within those areas with known tiger presence there were no incidents (historic or recent) of human deaths from tigers. The cryptic nature of tigers and the non-existent human fatalities from tigers may be the reason for the low one percent (1%) fear amongst pastoralists that tigers would kill humans.

Forty four percent (44%) of the interviewed pastoralists viewed leopards as threatening to large domestic animals and three percent (3%) also felt that they were threatening to goats and calves of cows and buffalo. Pastoralists did not see leopards as risk to human life. All (100%) pastoralists with goats were familiar with wolves and seventy one percent (71%) of them viewed them as threatening to goats and calves of cows and buffalo. A very small percentage (3%) saw them as threatening to larger domestic animals and very few respondents (1%) saw them as threatening to human life. Pastoralist's views suggest their high familiarity with some species and they readily see differences in the threat wolves

and leopards pose to their safety and livestock. Pastoralists with goats also reported avoiding thickly vegetated forest patches fearing leopards and tigers and stuck to the open patches where visibility was greater. In some areas of the study, the pastoralists reported that wolves were locally extinct as a result of intense modification of open forest to suit agriculture.

Fifty two percent (52%) of interviewed pastoralists viewed that sloth bears were dangerous to human safety as they attacked people and therefore the most threatening of all carnivores in the study area. However, at the same time forty seven percent (47%) of interviewed pastoralists also did not view sloth bears as a threat. This difference in opinion is in spite of the wide distribution of sloth bears in the area. Attacks by bears on humans are not common in the study area but a few cases (8 in 2013) are reported every year. However, awareness about bears is high and so people are on vigil for bears when they move in forests. According to the pastoralists, bears are unpredictably aggressive when they have small cubs around them. Pastoralists did not see sloth bears as threatening to livestock but only to personal safety.

All interviewed pastoralists articulated deep knowledge on potential risks from individual large carnivores (tigers, leopards, wolves, sloth bears, jackals) to their personal safety and their livestock. Some interviewed pastoralist's revealed specialized knowledge on some species resulting from their experiences. For instance, their familiarity with leopards was very unique, as they classed leopards into three different groups using a local reference system. This classification was based on leopard body size and the size and type of livestock they killed. These included, Duranga (a large male leopard capable of killing adult cows and buffalo), tenduva (smaller adult female leopards or young males that killed smaller cows and their and calves) and cheetri (dog sized spotted cat that kills poultry and goats). All interviewed pastoralists were fully conscious that carnivores feed on carcasses dumped near villages and those in the multiple use forests. Very few (1%) of the interviewed expressed fear of large carnivores to their personal safety. They reasoned that this was because there was enough wild prey for carnivores to eat in the forest including free roaming livestock. They also viewed that eating humans was not interesting to carnivores and were fully conscious that humans were no match for the strength of a tiger, leopard or a wolf. Pastoralists expressed that wolves were more easily visible and could be scared away by throwing stones and or by screaming. Ninety percent (90%) of interviewed pastoralists viewed hyena and jackal as nonthreatening species. A small percentage of the interviewed pastoralists (16%) viewed jackals as threat to personal safety.

The researchers' personal observations on pastoralists revealed that negative perceptions and attitudes of interviewed pastoralists towards carnivores did not translate into negative responses on carnivores. The researchers found no evidence to suggest that the pastoralists on whom they made detailed personal observations (n=20) attempted to kill or consciously remove carnivores to decrease risk of predation on their livestock during the study period. All interviewed pastoralists viewed that occurrence of dangerous wildlife in the forests was normal and explicitly regarded harming or killing wildlife near spirit sites as a religious offence. The researchers found no evidence during the study to suggest

that pastoralists broke commonly held norms. Figure 2 lists the pastoralists' views on carnivores based on their perception of the species.

2.4 Discussion

2.4.1 Significance of Local Practices to Carnivore Conservation

Results of my study indicate that local people's practices have practical advantages for carnivore species. In the multiple use buffer zone forests of Panna Tiger Reserve, the people's extractive activities especially fuel wood extraction and unchecked grazing by livestock significantly reduce the quality of the habitat available for wild herbivores, which are natural prey for large carnivores. However, because of the widespread nature of local livestock management practices like dumping of dead livestock carcasses and allowing unproductive and unwanted[9] animals to roam feral. Additionally, poor corralling facilities for cows and people's lenient cow herding strategies all these practices create opportunities for large carnivores to kill domestic animals in the buffer zone. The researchers claim that the local people's livestock management practices are one of key governing factors influencing the presence and wide distribution of large carnivore species throughout the multiuse buffer zone and near villages. Valeix *et al.*, (2012) report of observing similar behavioural adjustments and adaptations by their study lions in Africa to feral domestic animal movements. Lions reportedly move more frequently into areas where feral livestock occur. Yirga *et al.*, (2012) also report a similar case of hyenas adapting to human food sources and coexisting alongside people in Ethiopia, and Athreya *et al.*, (2013) report of leopards adapting and thriving in large swaths of sugarcane fields with no natural forests in the vicinity, in Maharashtra state of India. The researchers suggest that large carnivores in Panna buffer zone too are displaying similar adaptability to living in the buffer zone by taking advantage of the prevailing human conditions such as, low direct retaliation by people, lenient livestock management practices and readily available food sources in the buffer zone.

While the above illustrates how some people practices have positive outcomes for large carnivores and also the ability of some large carnivore species to take advantage of people's practices, the findings also reveal that pastoralists in Panna show high adaptability to living alongside large carnivores. Such adaptability to live along carnivores is driven by many, interlinked factors and each of the factors is elaborated to highlight its specific influence. For example, pastoralists feel reassured by their faith in their spirit protectors and experience a sense of security from powerful forces in the forests including wild animals. Nelson, Singh, Vucetich, Woodhouse and many others have reported this motivating function of religious beliefs on believers and that such belief systems are commonly practiced, even today, in many traditional societies across the world (Nelson, 1974; Singh, 2012; Vucetich *et al.*, 2015; Woodhouse *et al.*, 2015).

[9] In the study area old, sick and those animals that do not yield milk are seen as unproductive animals. Cow and buffalo bulls and male calves are seen as unwanted. These animals are generally abandoned and not looked after by owners.

Further, pastoralists in Panna adhere to cultural and religious norms towards forests and wildlife that by coincidence or conscious design reduce direct human impacts and also interactions with wildlife. For example, fearing retaliatory attacks from spirit wolves pastoralists do not scheme to exterminate wolves they instead chase them away.

Another factor is the pastoralists' superior traditional ecological knowledge on wildlife and their habits and their awareness of the wide distribution of large carnivores in the buffer zone. Pastoralists are familiar with local wildlife from a very early age. They accompany their parents on herding trips and sometimes they are also given independent charge to guard livestock. Such knowledge and awareness about animals coupled with traditional norms that lower interactions between people and carnivores and their religious beliefs that provide psychological respite from the dangers of living alongside carnivores, all contribute to the feeling of lowered risk from carnivores, which are enabling the observed high tolerance of carnivores in Panna buffer zone. However, as cautioned by many researchers negative interaction with carnivores leading to loss of human or livestock losses exceeding tolerable limits could change the people's responses towards carnivores and may provoke unwarranted actions towards carnivores.

2.4.2 Factors Influencing Tolerance of Pastoralists

The findings suggest that pastoralists and livestock owners display high tolerance towards large carnivores in spite of the dangers carnivores pose to their personal safety and that of their livestock. The researchers explain the observed tolerance within pastoralists as an outcome of several internal and external factors that collectively (but not necessarily in equal proportions) exert their influence influencing people's beliefs, perceptions, attitudes, behaviours and their perceived risks from carnivores and ultimately their responses towards carnivores. *Internal factors* are explained as intrinsic benefits and practical advantages that pastoralists experience from their religious beliefs, by adhering to cultural norms and following traditional practices. *External factors* are those real time contextual experiences. For instance, a fatal animal attack on a human that is frequently recollected by villagers or a violent conflict with authorities (man-man conflicts) that is still fresh in the minds of people.

2.4.3 Internal Factors

Interviewed pastoralists disclosed several intrinsic benefits they experience from their religious beliefs and adhering to norms, which allow them to cope with stressful situations in their lives. For instance, on one occasion, a tiger killed a few buffalos belonging to a pastoralist. The pastoralist, when questioned, interpreted the event as a coordinated event that took place with the approval of higher order spirits. He did not blame the tiger but instead shrivelled into a state of submission and blamed himself for allowing the buffalos to stray into the forest at night-time and accepted the killing by the tiger as a coordinated event, directed by the supernatural. Pastoralists regard the tiger as a powerful beast symbol both in a real world sense and also as a metaphoric (spirit) that inhibits the forests and that, which can influence their life. As also reported by other

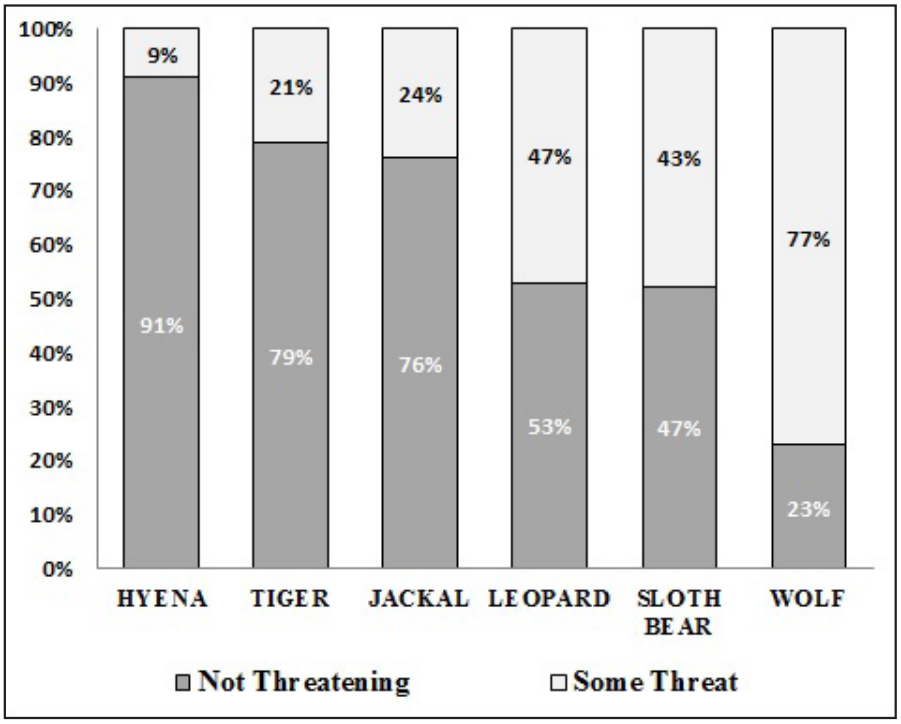

Figure 2.2 The dark grey areas represent those who do not view carnivores in the study as a threat. The areas in white represent those who see a degree of threat from the species.

researchers, pastoralists in Panna believe that their spirit protectors have the power to both ensure human wellbeing and also to punish them (Buchler *et al.*, 1980; Boteroa *et al.*, 2014; Sidky, 2010). In the above described incident, the pastoralist viewed the killing of his buffalos by the tiger as an incident directed by the supernatural, beyond the mortals' ability to control. He also viewed the event as a punishment for leaving buffalos over the night in the forests, which according to him was a breach of norms. Many researchers including Woodhouse and Singh, report observing people in their study areas constructing similar meanings to events, events that are formidable, and overwhelming (Singh, 2012; Woodhouse *et al.*, 2015). Pastoralists also viewed that events such as natural calamities, disease outbreaks, large predators and sometimes events that are difficult to comprehend are controlled by the supernatural. Many researchers including Woodhouse and Singh, report observing people in their study areas constructing similar meanings to events, events that are formidable, and overwhelming (Singh, 2012; Woodhouse *et al.*, 2015).

Pastoralists in my study disclose experiencing personal benefits from their religious beliefs and norms. For instance, the economically poor pastoralists had no alternatives but to move and use forests for their livelihood in spite of knowing that dangerous wildlife roam the forests. According to them, their belief in their spirit protectors and the pacts they make with them for their safety creates a state of mind, where they experience feelings

of decreased anxiety, loss of fear to travel alone in forests, and loss of fear from the forces of the forests. These feelings that pastoralists experience are intrinsic in nature and the interviewed could clearly verbalize these benefits. Existence of such intrinsic benefits from religious beliefs have been acknowledged and also reported by many scholars (Nelson, 1974; Johnson, 2005; Boteroa, 2014; Goodale *et al.*, 2015). The importance of these intrinsic benefits when they are perceived through the mental lenses of economically backward rural communities like those in the study area, where communities are exposed to vagaries of nature, face persistent threats and have little or no social security provided by the state, are profound. Interviewed pastoralists are internally aware of the benefits of adhering to their religious beliefs and following norms and also fear losing this security if they act against the beliefs or norms. The fear of retribution, also reported by several researchers, is likely holding pastoralists in the study area from taking actions that can jeopardize their relations with their spirit protectors (Buchler *et al.*, 1980, Horne, 2003; Jones *et al.*, 2008; Boteroa *et al.*, 2014; Woodhouse *et al.*, 2015). Such actions consciously taken or unintentional sometimes are also known to have benefits to natural world (Jones *et al.*, 2008; Dudley *et al.*, 2009; Dominguez *et al.*, 2010).

Interviewed pastoralists also consciously maintained favourable relations with the reserve authorities. They however viewed wildlife as the property of the reserve and hence its management their responsibility. On questioning them about their willingness to take actions against problem animals, they readily pointed fingers at the reserve authorities blaming them for not managing their carnivores efficiently and refused to take any personal initiatives. Here, the conflicts with authorities over animals and the loss of rights to herd animals, a material requirement for the pastoralists is most likely the underlying reason for their tolerance for carnivores.

2.4.4 External Factors

The study reveals that real life contextual events experienced by pastoralists also influence their views, perceptions and attitudes towards large carnivores. For instance, many interviewed pastoralists (79%) do not view the tiger as a threat to human life. Many of them (51%) instead viewed the sloth bear as a greater threat. These variations in risk attributed to different animals are likely because of the following reasons. In the Panna study area; there are no known records of tiger attacks on humans in the last 30 years. On the other hand, human injuries from sloth bear attacks are more common. Secondly, according to the interview data, very few villagers ever encountered a tiger in real life but people encounter bears more often and are known to frequent village fringes frequently to feed on fruits of domesticated trees. Thirdly, tiger distribution and presence is restricted to certain patches of the reserve area and not the entire reserve area. On the other hand, bears have a wider distribution than tigers. Lastly, tigers are more cryptic and difficult to encounter than bears. As also pointed out by Goodale *et al.*, (2015), these real life encounters and negative experiences are most likely influencing the pastoralists' perception of higher risk from sloth bears to human life than from tigers.

The study also reveals that pastoralists have proficient knowledge of local carnivore species and their habits. The researchers also found links that such knowledge was greater on species that either threatened their livestock, their personal safety or those species that are visible. Pastoralists also consciously weighed and chose strategies that worked best to reduce livestock losses. For instance, pastoralists chatted in the evenings and discussed animal sightings and made travel plans. Pastoralists knew about wolves, they viewed them as a threat to goats and young cow and buffalo calves and they felt that wolves were not a threat to their personal safety. Personal observations also revealed that pastoralists were very knowledgeable about wolves and their habits and adopted strategies that minimized losses from wolves. For example, some pastoralists used dogs for early warning against wolf attacks. Some pastoralists were aware that tigers and leopards were more cryptic and less visible than wolves. Hence, they consciously avoided patches with dense vegetation and thus avoided tigers and leopards. As also pointed out by Traves and Burskotter (2014), the pastoralists' knowledge, their ability to find solutions and mitigate losses all contribute to shaping their tolerance of large carnivores.

The researchers also found evidence that pastoralists took calculated risks and tolerated some of the threats posed by carnivores. For instance, pastoralists were dependent on the multiple use forests for their livelihoods as there were no alternative grazing grounds in the vicinity. They therefore consciously weighed the practical benefits of using the government administered buffer zone forests and tolerated inconveniences from wildlife and avoided acts such as killing or injuring problem animals and restrained acts that could jeopardize their rights to use the areas. Such conscious decision making by rural pastoralists was also observed by Banerjee *et al.*, (2013) in their study in Gujarat State of India.

2.4.5 Adherence to Practices

Observations on pastoralists suggest that their adherence to religious and cultural norms was both widespread and also sustainable. Interviewed pastoralists viewed that adherence was not imposed on to them but it was in the personal interest of individuals to adhere or choose not to adhere. Pastoralists viewed non-adherence resulting in two different outcomes. For example, breaking social norms such as killing selling religious symbols like cows to slaughterhouses had larger community level repercussions. In these contexts enforcement was through local institutions. Secondly, breaking norms grounded in individual belief were more individually confronting, and here enforcement was through self-regulation. As also observed and reported by many researchers, local people in the study area experienced an obligation to follow culturally acquired norms because people believed that their actions influenced their wellbeing (Horne, 2003; Johnson, 2005; Botero *et al.*, 2014). Therefore, adherence of norms was in an individual's personal interest.

Pastoralists also experienced practical advantages from adhering to their religious, social and behavioural norms. For instance, a social norm discourages human presence in the forest areas after the jackals start howling (basically night-time). Another social norm commonly adhered by pastoralists prohibits livestock to be left unguarded in forests at

night-time. Influenced by such norms people help each other find lost or missing domestic animals. Factually, people who follow these norms benefit from reduced interactions with dangerous wildlife (which are most active in the crepuscular and nocturnal hours), and community members share an obligation to help each other search for missing livestock or those that stray too far. Such direct practical benefits resulting from following social norms may be the reason behind the high adherence of norms observed within local communities in the study area. Such practical advantages, as also observed in studies by Horne, are most likely motivating people's self-regulation of norms (Horne 2003). One interviewed pastoralist's narrative is particularly relevant to showcase the extent to which local people think and construct meaning of the retaliatory powers of their spirit protectors.

"Hunting of wild animals in our area stopped a long time ago. The forest guards here are very strict and do not spare anybody who hunts wildlife. Even the Thakur community members (local elite class) stopped hunting pigs and deer as a result. May be it is the spirits in the form of forest guards who are protecting animals from being killed."

2.5 Conclusion

Assessing the people's practices outside protected areas is important for conservation managers because as reported in this paper, sometimes local practices may not necessarily be conscious acts of local people to safeguard wildlife but could have ancillary effects with positive or negative outcomes for conservation. Likewise, local belief systems and norms associated with spirit sites like prohibitions on hunting may appear irrelevant and inadequate if one looks at the small geographic size of the sites. However, the widely prevalent and locally acceptable practices, the vital locations of spirit sites near valuable resource points like sources of springs, near streams, and the high numbers of adherers of the belief system are significant for conservation and cannot be overlooked.

The research raises questions about the role of non-monetary motivators to solicit people's support for conservation. In countries like India, where religion and culture still continue to influence people's daily lives and practices, it would be futile to attempt change in local practices without considering the underlying mechanisms in which the practices are grounded. This is particularly relevant to conservation outside protected areas, a known complex endeavour. The study illustrates ways to dissect and clearly visualize the social factors that sometimes sustain scenarios like coexistence. However, clever and replicable ways to embed the findings into projects still remain unclear and will need work.

If policymakers in India were to take my study seriously, they might want to look at ways to collaborate with local level institutions and also involve local villagers and religious leaders on conservation projects. Building bridges with local communities and local institutions is very relevant because existing practices recorded in the study area are likely to stay in use at least for the medium term in spite of all the modernization taking place in India.

2.6 Recommendations

To Managers: As a result of conducting this research, the researchers propose that addressing the human dimension aspects is an inseparable part of carnivore conservation in multiple use and human-dominated landscapes. This means carnivore conservation in multiple use forests or human-dominated areas necessitates the need for a robust understanding and expertise in dealing with the human dimension aspects.

Issues related to the human dimension of wildlife can have socio-political repercussions. Therefore, if managers do not have the means or expertise, sometimes just being aware of the situation is better than actually trying to do something that could have counterproductive outcomes. The fact that nonfinancial motivators also play a large role in people's behaviour towards carnivores does not mean known financial motivators like compensations should be ignored.

Acknowledgements

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Drawing of a bull. Humped cattle are common cattle breeds in the Indian subcontinent. This rock art was found near Udla village, buffer zone of Panna Tiger Reserve.

3 Factors Influencing Livestock Losses to Predators in the Multiple-use Buffer zone of Panna Tiger Reserve, India.

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(In Prep)

Abstract

Despite having seemingly excellent local knowledge on carnivores and using preventive strategies, livestock owners using the multiple-use buffer zone forests of Panna Tiger Reserve in India experienced high livestock losses to large carnivores. The underlying human factors behind such failure to control losses needed examination. Through informant interviews and observations we collected quantitative and qualitative data on local knowledge, livestock management strategies and resident livestock owner's perceptions on the factors creating barriers to lowering losses. We used Generalised Linear Models (GLM) and qualitative ethnography to analyse factors influencing livestock losses. Our findings do support our assumptions that proper knowledge of carnivores and use of preventive strategies lowered losses but did not prevent reoccurrence. Deep-rooted socio-political factors surrounding livestock and ineffective land use regulations in government forests compelled resident livestock owners to tolerate unproductive and free-roaming cattle and lenient herding practices. These external factors created barriers for resident livestock owners to manage their animals well and made livestock vulnerable to large carnivores. Further, the prevailing situation reduced cow and buffalo trade that once flourished in the area and removed the incentive to look after domestic animals. Importantly, the external influences prevented residents to take actions to improve the situation. We conclude that the ability of people to manage their livestock in a conservation area may be determined by the local socio-political factors as much as it depends on their own ability to safeguard their animals.

Keywords

Pastoralists; Livestock predation, Outside Protected Areas; Shared landscapes; India

3.1 Introduction

The pastoral Gond[10] tribes live in villages located inside the buffer zone of Panna Tiger Reserve (Panna TR), Madhya Pradesh State, India. Lakhan Gond and his people have

[10] Gond tribes are a majority, forest dwelling people of Central India. They commonly rear goats.

always grazed their domestic animals in these forests. Around 8 p.m. one December evening in 2013 a meeting was arranged to take place in Lakhan's hut and soon after dinner several herders gathered, some bringing their children. Some of the visitors sat by the open fire, while some stood. Customarily, Lakhan's family passed a sizeable plastic plate containing beetle nuts, cardamom, cloves, beedis (local cigarettes) and aniseed amongst the visitors. People picked from the assortment and by joining their palms together complimented the family by saying "Jai Mata"[11]. Soon a shepherd spoke up, and rest went quiet. He started to narrate the events of his day in the forest. *"The narha (stream) next to Siddh Baba (spirit site) is flowing fast and is still knee-deep, he continued. The stepping-stones are all high and allow easy crossing." "I also crossed a group of forest guards monitoring the radio-collared tigers near ganja pahadi (bald hill) with their tracking antenna. They said the Sher (tiger) was resting in the stream at the foot of the hill". "Any news of the thieves who stole the Yadav's[12] buffalo?"*, Asked another shepherd. A voice from the shadows said, *"The Yadav's suspect cattle rustlers from Katni". "According to them, this was the third incident this season in their village".* There was silence for a second, and someone asked, "*Did anyone see the bhigna (wolf)?"* Lakhan Gond and the two herders who accompanied him saw a pair of golden jackals and a group of six long-billed vultures on a cow carcass, two chinkara antelopes, a nilgai antelope and a pack of village dogs stalking an animal in the bushes. No one saw or heard the wolves that day. Soon the conversation turned to a pestering hoof rot that infected the commercially valuable village goats. After the quick exchange of news and information, the herders discussed grazing routes for the following day. There was a unanimous agreement to avoid using the waterhole below the *ganja pahadi* until the tiger moved away. Those who decided announced their routes, greeted others a good night and slowly walked away into the darkness towards their huts.

It is widely reported that in shared landscape effective livestock management practices lower vulnerability of stock to carnivore predation (Ogada *et al.*, 2003; Pimenta *et al.*, 2017; Tshering and Thinley, 2017; Tumenta *et al.*, 2013; Van Bommel *et al.*, 2007). In this article, we examine a case study from Panna Tiger Reserve (PTR), where Lakhan and his people experienced livestock predation from carnivores regardless of their seemingly solid local knowledge on carnivores and using precautionary measures. This case is compelling from the local people perspective for multiple reasons. Firstly, the resident livestock owners are economically deprived earning as little as 523 US $ or 31,389 Indian Rupee per annum (Bahuguna, 2000; NIC, 2017). They may be highly reliant on their livestock for their livelihoods and may not endure repeated losses. Secondly, in the absence of village grazing lands, government forest lands may be their only option for grazing livestock (Mathai, 1999). The social conflicts as a result of economic losses and a lack of alternative land for grazing are worrisome. From a wildlife conservation perspective, in Panna TR, Bengal tigers (*Panthera Tigris tigris*) became locally extinct in 2008 and were reintroduced in 2009 (Gopal *et al.*, 2010). Subsequent conservation efforts ensured that the numbers of tigers and other wildlife increased. The multiple use lands that Lakhan and his people

[11] "Jai maata" – To the glory of the divine feminine spirit (maata), is a common used good-wish phrase by Gond tribes.

[12] Yadav's are Hindu pastorals who rear cows and buffalos and consider the bovines their gods.

use are also critical for the future survival of the expanding wildlife. If left unaddressed, the current livestock predation by carnivores could trigger conflicts with local communities and pose a threat to the well-intended government efforts to secure tigers outside reserves. This precarious situation compels managers and conservation proponents to find solutions for the losses.

The objective of this article is therefore to make the factors influencing livestock predation in the buffer zone of Panna Tiger Reserve explicit. Firstly, we quantified the extent of annual losses experienced by residents to understand the range of causes and scale of such losses. Second, we analysed possible factors influencing predation. Within this we specifically examined;

A. Since, several authors showed that lack of precautionary measures could increase predation rates of livestock by large carnivores (Abade *et al*., 2014; Pimenta et al., 2017; Tshering and Thinley 2017; Tumenta et al., 2013; Van Bommel et al., 2007). We examined the effectiveness of local preventive strategies to minimise losses. Here, we checked for variability in use of preventive strategies and their effects on different livestock species. Since the resident livestock owners have low incomes, we assumed that the higher their dependence on their stocks for revenue, the higher would be the likelihood of them using preventive measures. We hypothesised that the use of preventive strategies would decrease predation risk.
B. We questioned Lakhan and people's local knowledge of carnivores, another critical aspect affecting predation (Khorozyan *et al*., 2017; Logan *et al*., 2014). We examined their ability to accurately identify local carnivores and their knowledge on the habits, and risks from carnivores to different livestock types. We hypothesised that inadequate understanding of carnivores and their behaviour would increase predation risk.
C. We examined livestock owner's individual perceptions of factors influencing loss. Drawing from an earlier study of Kolipaka *et al*., (2015). We specifically re-examined livestock owner's views on the effect of income from livestock on their choice of using or not using preventive strategies. We also questioned the consequences of regional socio-cultural cultural practices such as the ban on selling cattle to abattoirs and the local cultural practice of abandoning untenable cattle to livestock owners living in the buffer zone. The sensitive nature of the examined topics means that people seldom discuss these topics but try to adapt and the influence of these issues on livestock losses are overlooked (EPW 2017; Santoshi, 2016; Ghosh, 2017). The discussion describes the factors affecting livestock predation and management options.

3.2 Methods

3.2.1 Study Area

This research work was conducted in the multiple-use buffer zone forests of Panna Tiger Reserve in India. The reserve is located in North-central Madhya Pradesh at longitude

79°556E to 80°273E and latitude 24°274N to 24°905N. The protected tiger reserve is approximately 1400 km² and has a core zone and a multiple-use buffer zone surrounding the core. Other government-controlled forest lands, agricultural lands and villages extend beyond the periphery of the tiger reserve (Kolipaka *et al.*, 2015).

3.2.2 People's Use Of Forest Land

People from 42 villages and practising traditional ways of life live inside the buffer zone. The resident villagers (43,125 people) have customary rights called Nistar to access forests and extract forest resources (Kolipaka *et al.*, 2015). Additionally, several tens of thousands of people also live on the periphery of the reserve and access the buffer zone forests. Residents and outsiders' use the forests on a daily basis. They graze livestock, collect fuelwood and extract forest products like tree raisin, wild gooseberries (*Amla*), wild mushrooms, and honey. They also visit religious sites located in the area.

3.2.3 Local People Groups and Their Livestock

People belonging to 30 different caste and ethnic groups, practising Hinduism, Islam and tribal religions, coexist in the study area (Kolipaka *et al.*, 2015). Local people have animistic beliefs and consider several domestic and wild animals including the cow, nilgai antelopes, peacocks, monkeys and snakes sacred. They restrain from harming, killing or eating them. Livestock keeping is standard in the area, and resident villagers commonly keep house cows, domestic water buffalo and goats (Mathai, 1999) The small milk yielding native varieties of cows provide mostly for sustenance. The fat rich buffalo milk, on the other hand, is sold. Milk from a single buffalo can earn the owner approximately 100 US $ (5000-7000 Indian Rupees) per month. Goats are sold for meat and make about 30 US$ (2000 Rupees) for a 10-kilogram male goat.

In the study area and the broader region around it, religious prohibitions on eating, culling or selling cows and buffalo to slaughterhouses exist (Ghosh 2017). Politically motivated vigilantes, thugs and community-enforced norms ensure that bans are in place (Dosanjh, 2017). Additionally, local cultural customs like *Anna Pratha*, where livestock owners choose to abandon scores of cattle during drought years into the forests, rather than see them die of thirst or hunger, prevail (Santhoshi 2016). Prohibitions on the sale of cows and buffalo to abattoirs have decreased their economic value, and livestock owners are compelled to let excess, unwanted and unproductive animals to roam free and feral (Kolipaka *et al.*, 2015). Thousands of such animals move inside the Panna Tiger Reserve and are available prey for local carnivores (Kolipaka *et al.*, 2017a).

3.2.4 Wildlife in Human-Use Areas

The presence of several large carnivore species including, the tiger (*Panthera tigris tigris*), leopard (*Panthera pardus fusca*), Indian wild dog or dhole (*Cuon alpinus*), wolf (*Canis lupus pallipes*), striped hyena (*Hyaena hyaena*), sloth bear (*Melursus ursinus*), and domestic dog

(*Canis lupus familiaris*) are reported outside PTR (Kolipaka *et al.*, 2015). Additionally, wild pig (*Sus scrofa*), nilgai antelope (*Boselaphus tragocamelus*), sambar deer (*Rusa unicolor*) and cheetal deer (*Axis axis*), are also recorded in the human-dominated landscapes of the PTR buffer zone (Mathai, 1999).

3.2.5 Data Collection

Data used in our study were collected as part of a broader effort aimed at understanding the survival of the endangered tiger species outside protected areas of India between 2009 and 2015. Table 1 presents the summary of data collection methods. Wherever possible, interviews have been recorded on a digital Dictaphone (Phillips Voice Tracer 600) and some of the respondent disclosures are quoted directly in the text of this article. We accompanied herders and while out in the field examined their knowledge of animal tracks, burrows and examined kills. We used explicit photographs of animals and using vernacular names tested respondent's ability to identify carnivores accurately. We also checked their local knowledge on the spatial and temporal aspects of animal movements and predation incidents and their preventive strategies. To assess the accuracy of the responses we crosschecked respondent's answers on predation with the data we collected independently on large carnivores (Kolipaka *et al*., 2017a).

Table 3.1: Summary of Methods

S. NO.	METHODS	TYPE OF INFORMATION	SOURCE	SAMPLE	PERIOD
1	Pre-structured Questionnaire Survey	• Socio-Economics • Livestock Husbandry Practices • Livestock Losses	Households owning livestock	255	2013-2014
2	Ethnomethodology	• Local cultural factors surrounding livestock, • Bans on sale of cows • Factors influencing the use of government land.	Households owning livestock (from within the 255)	82	2013-2014
3	Herder Observations	• Livestock herding techniques • Preventive measures against local carnivores	[1] Herders (from within the 255 interviewed households)	40[3]	2013-2014
4	Observations	• Corralling practices[13]	Households owning livestock	255	2013-2014

[1] Herders were accompanied to the forests on 78 occasions. [13] Corrals and enclosures are used synonymously in the article.

3.2.6 Data Analysis and Statistics

The wide range of enquiries allowed us to collect both qualitative and quantitative information. This information is analysed for each of the two research objectives and synthesised. The explanations are presented with the intent to provide a detailed, in-depth description of everyday life and practice, a "thick description", based on the idea of an interpretive theory of culture, used within the context of describing the factors affecting livestock losses.

Treatment of quantitative data: To test the effect of the "importance of income from livestock" on preventive strategies and predation rates, we used Generalised Linear Models (GLM) with "Importance of Cows, buffalos and goats to income" as a response variable. Independent variables included the use of dogs, herders, corrals, entire stock with each household, total loss per family in one year and loss from predation in one year. We also checked for two-way interactions between some of the presumably related independent variables. Then, following a systematic removal process, we removed all non-significant interactions and keeping only the significant variables in the final model. Next, we used predation as a response variable and used the same preventive measures as independent variables. The selected models are shown in the online supplement and Appendix 2.

Treatment of qualitative data: Perception data collected from the interviews with households were administered informally, and during the interviews, we asked respondents their opinions on three topics. These included 1. Local socio-cultural practices influencing livestock husbandry practices. 2. The effect of prohibitions on the sale of cows and 3. The influence of current land use regulations on livestock grazing in government lands. Here, our goal is to arrive at an understanding of a particular phenomenon from the perspective of those experiencing it. Only 82 of the 255 respondent households participated in the extended discussions. Time and their willingness to discuss the sensitive topics influenced respondents' participation. Since local culture is the focus of our enquiry, the philosophical background that traditional culture is inherent within respondents has not been overlooked.

Like a PRA (Participatory Rural Appraisal) exercise, we made a flowchart of respondents perceptions during the interviews and drew the trajectory of the influences to understand relations between the external forces and livestock losses. This allowed us to refine the specifics of each theme and the overall story that the analysis tells, generating clear definitions and names for each theme. Next, we identified themes relevant to the research objectives and re-questioned respondents. For example, one respondent household expressed *that the local cultural practice of dumping dead cattle carcasses near the village-forest fringes in the study area attracted carnivores close to villages* (Figure 1). Next, they expressed the advantages and unwanted impacts of the disposal practice (right-hand side of Figure 1). One of the commonly stated adverse effects was that dangerous wild carnivores came close to villages. When asked how to reduce this, they provided solutions and perceived barriers to change. Here, we considered both the latent and manifest content in the responses, which further allowed us to choose between manifest (developing categories) and latent contents (developing themes). We then included these incrementally in the next stage of questioning and similarly in the analysis that allowed us to construct vivid, compelling extracts.

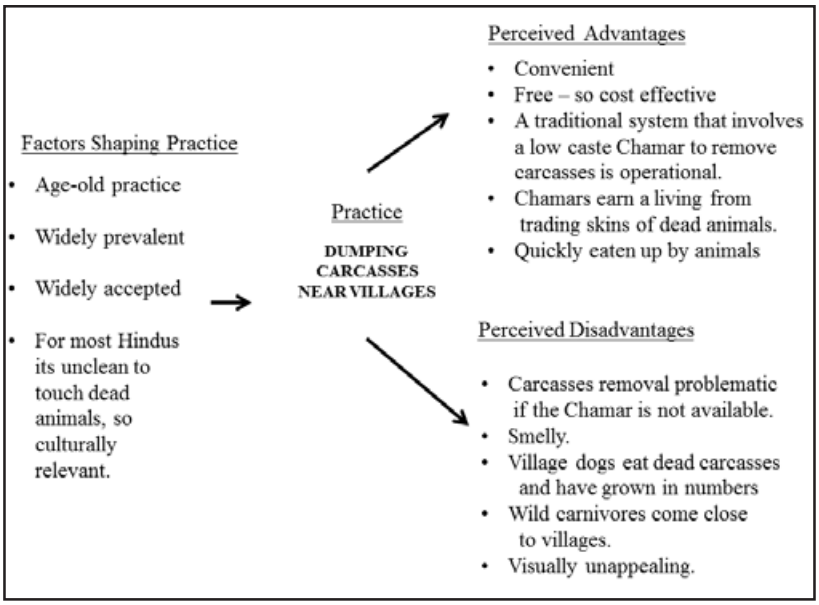

Figure 3.1 Factors shaping the local practice of dumping livestock carcasses near villages fringes and the resident livestock owners perceived advantages and disadvantages of the practice.

3.3 Results

The relationship between respondent's local knowledge and use of preventive measures and livestock losses were examined. Also, the influence of income from livestock on the use of preventive measures, and the impact of socio-political factors and land use regulations on local livestock practices were examined.

3.3.1 Livestock and Losses

According to the respondents, forty (40%) percent of households in the study area raised domestic animals (cows, buffalos and goats). Cows were the most commonly tended animals and 83% of the 255 interviewed households owned an average of 5.5 (SD 9.68) cows per household. People profited from the protein in the milk and from cow dung, which is the standard cooking fuel and used in-house maintenance. Buffalos and goats provided direct incomes through milk and meat respectively. Forty-two (42%) percent of the interviewed households kept buffalos and 65% goats with an average of 5.5 (SD 4.29) and 14.2 (SD 12.50) animals per household.

Livestock Losses: Sixty (60%) percent of the interviewed households reported livestock losses occurring from disease, predation, theft or accidents during a one-year period between 2013 and 2014 (Table. 2). Diseases caused the highest mortality amongst livestock and accounted for losses of 55% for cows, 52 % for buffalos and 55% for goats during the study period. Predation by carnivores ranked second followed by theft and

accidents (Table.2). Affected owners of buffalos and goats lost an average annual income of 250 US $ (15,000 Indian rupees) and 110 US $ (6500 Indian rupees) respectively to carnivores alone and valuable protein from cow milk.

Table 3.2. Livestock losses experienced by 255 interviewed households resulting from disease, predation, theft and accidents during a one-year period between 2013 and 2014 in Panna Tiger Reserve Buffer Zone.

LIVESTOCK	FAMILIES WITH COWS (n=Total livestock with households in 2013-14)	HOUSEHOLDS WHO REPORTED LOSSES (n=Livestock killed in 2013-14)	DISEASE (N)	PREDATION (N)	THEFT (N)	ACCIDENT (N)
Cow	212 (1422)	116 (385) (Mean = 2.75; SD = 1.96)	172 (Mean=2.75; SD=7.2) S	162 (Mean = 2.46; D = 0.72)	37 (Mean = 2; SD = 0.58)	14
Buffalo	106 (586)	41(83) (Mean = 1.6; SD=0.56)	43 (Mean = 1.5; SD= 0.4)	24 (Mean = 1.6; SD=0.28)	10 (Mean = 1.2; SD=0.21)	6
Goat	168 (2388)	144 (847) (Mean = 4.62; SD= 4.36)	462 (Mean = 2.60; SD= 0 .97)	286 (Mean = 3.3; SD= 1.5)	86 (Mean = 4.3; SD= 0.68)	13

3.3.2 Factors investigated for influencing livestock losses

Local Ecological Knowledge on Carnivores

Residents accurately identify most wildlife species and their awareness of the threats from various species was also high (see Figure. 3). The exception was on nocturnal species like honey badger (ratel) and Indian pangolin.

Location of Attacks:

According to the respondents, a significant proportion of cow, buffalo, and goat (71%, 92%, and 90%) predation incidents occurred when the animals were out in the forest. Only 7 incidents (3 cows and 4 goats) of predation while the animal was in an enclosure were reported during our study period. Overall, 94% of the goat owners knew the precise location of the predation incidents, but only 50% of cow and buffalo owners knew such details.

The Timing of Attack:

According to the respondents, 34% of cows were attacked or killed between dusk and dawn and only 10% during the daytime. Additionally, 56% percent of cow owners were not aware of the time of attacks or kills. In the case of domestic buffalo, 57% of predation incidents took place between dusk and dawn, 9% during the day and 34% were now aware of the time of the incident. In goats, 72 % of attacks or kills occurred during the day, 15% at night time and only 13% of goat owners did not know the time of the attack.

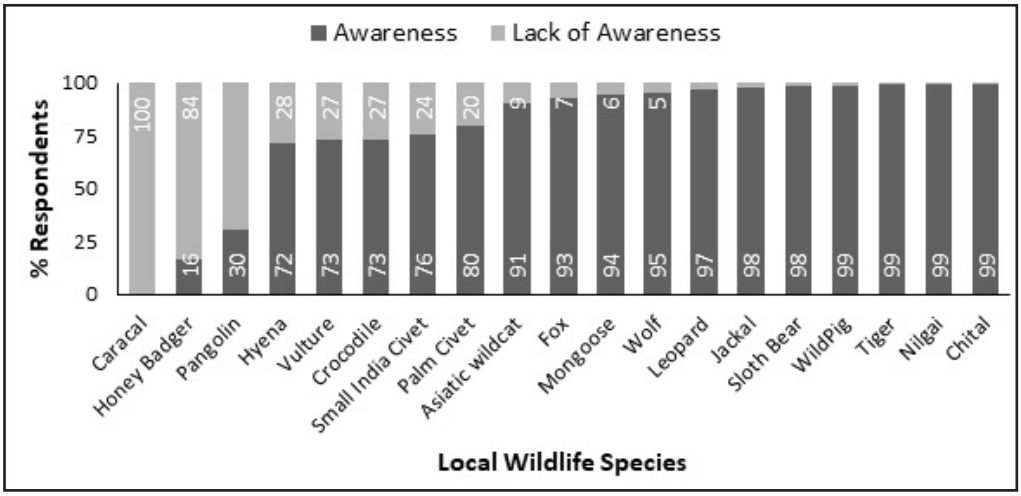

Figure 3.2 Awareness (dark grey) on the threats from carnivores was high amongst resident pastoralists.

Carnivores Responsible for Livestock Predation:

According to respondents, wolf, village dog, leopard, tiger and occasionally dhole were the leading killers of livestock. According to the respondents, tigers were responsible for 20% of the cows and 30% of the buffalos killed during the study period. Leopards were held responsible for killing 50% of the cows, 33% of the buffalos (mostly calves) and 21% of the goats. Wolves and village dogs were help responsible for losses of 30% of cows, and 79% of goats in the buffer zone of PTR. Overall, respondents could not identify the predator in 21% of cow and buffalo attacks and 3% of goat kills

Respondent's views and choice of preventive measures:

According to the respondents, all herders (100%) conducted grazing only between dawn and dusk, and avoided forests during low light. In the evenings, following their return from grazing, all herders gathered and discussed daily events and consciously made decisions on future grazing routes. They felt that this practice reduced predation considerably. Fifty percent (50%) of herders did not view that further increase in herding efforts could decrease predation rates. Herders believed that local dog breeds were good for the warning but not to frighten carnivores. They also felt that dogs attracted carnivores like leopard and wolves. While these were the reasons for the low usage of dogs for protection, 47% of interviewed herders also believed that having good guard dogs could reduce predation. Making loud noises and calling livestock while grazing was a commonly used deterrent to warn carnivores of human presence. 31%, 35% and 43% of the interviewed cow, buffalo and goat owners expressed satisfaction with the effectiveness of this method of deterrence. Use of sticks and stones was also common deterrent to scare off carnivores. However, only a small percentage of herders (12%) got convinced of its effectiveness. The materials used to build enclosures for animals and fencing fields varied between respondents. Goat enclosures located in the open forests or near the fringe of villages comprised of hardy thorns and thorny shrubs all mixed and piled to

form an impenetrable barrier. These structures were roughly two meters in height, and the majority of the inspected goat enclosures were of proper construction capable of preventing predators and thieves from entering the corral. When the stock size was small goats were also enclosed within the house compound. Buffalos and valuable cows were also confined within the complex of the owner's house. According to the respondents, confining animals at night time also prevented theft of animals (Appendix 1). Overall, only a tiny percentage (<3%) of predation incidents occurred near the corrals and respondents did not see a need for improvement in corral construction and expressed satisfaction with the effectiveness of their existing structures. Protection of forest spirits is another commonly sought measure to reduce losses of domestic animals, but less than 20% felt that this could further reduce real predation. Overall, 30% of herders did not respond when asked to "think of other new ways to prevent losses from predation".

Reasons For Low Retaliating On Carnivores:
According to the respondents, a majority (91%) of the interviewed respondents mentioned "Fear of getting into trouble with forest department personnel" for tolerating carnivores. A small percentage (7% and 2%) also expressed that "It was wrong to kill animals" and that "The spirits would be annoyed", as reasons for not retaliating (Appendix 1, Tab.5).

3.3.3 Use of Preventive Measures
The most common preventive measures used to safeguard domestic animals from carnivores were herders accompanying herds, use of guard dogs and use of corrals. The preventive measures used by owners to protect cows, buffalo and goats varied. For instance, use of enclosures to secure buffalo and goats after grazing was common. Cows, on the other hand, stayed outside the enclosures. Likewise, herders accompanied 79% of buffalos and 97% of goats while grazing in comparison to 64% of cows. The use of dogs to protect animals was observed in only 34% of respondents.

Income from livestock increased use of preventive measures. Generalised Linear Model (GLM) showed an interaction between the stock size and presence of herders influencing income. The size of stock significantly impacts the importance of livestock for income (for all three domestic animal species; $P = 0.0018$) and deployment of herders (only cows ($P=0.0013$) and buffalos ($P<0.001$)). The larger the size of the stock, the more valuable livestock became for income. Additionally, if herders accompanied cows and buffalo while grazing such stock contributed more to income. (Here, the effect of the presence of the shepherds on income is two-directional.)

Preventive measures decreased predation rates. There was a significant interaction between the size of the stock and presence of herders influencing predation rates. The number of predated livestock increased significantly with the size of stock for all cows, buffalo and goats (Cows: $P<0.001$, Buffalo: $P=0.00192$, Goat: $P=0.0362$). Predation rates were significantly lower in cows (not for buffalos and goats) when herders were present ($P<0.001$). Further, distance from the village to the forest also showed a significant relationship with predation $P<0.001$). The numbers of cows predated were higher at closer distances to the forest and the further away from the village from the forest edge the

lesser cows predated. For instance, with every 1000 m increase in distance from the forest to the village, there is statistically speaking, half a cow less predated. Predation of buffalo and goats, on the other hand, was not significantly related to distance. The presence of dogs and total losses (from disease, theft, accidents) did not significantly relate to predation rates (Chapter 3, Appendix 2).

3.3.4. Perceived factors shaping predation

Respondent disclosure revealed significant influence of local cultural practices, politically backed prohibitions on cattle and lack of preferential land use rights to residents as the three major indirect factors affecting respondents ability to control livestock losses in the study area.

Local cultural practices:

According to the respondents, *Anna Pratha* is an old and familiar local practice. The local Hindu groups revere the cow as a sacred animal but when they are challenged by calamities such as droughts and sickness in animals and cannot tend to their stocks they prefer to abandon cows and bulls into the forests rather than see them die. As a result, thousands of abandoned cows and bulls roam feral in the study area. "*The villagers from Ajaygadh pushed 2000 unwanted cows and bulls this summer into the forests*", said one respondent. "*With periodic droughts in this region, the practice of Anna Pratha has become more common and widespread in the Bundelkhand area*", he said. "*These abandoned animals will compete with our valuable cows for grazing and water*," According to the respondent's, large carnivores killed the surplus feral cows and bulls in the forests, and when their valuable animals use the same areas, they too become vulnerable to the

Figure 3.3 Lenient herding makes cows vulnerable to predation by large carnivores like a tiger in multiple-use lands. Photo Source: Anshuman Kumar

carnivores. Responding to a question on "*Can you round up and remove such unwanted cows from the forests?*" A Yadav caste respondent explained, "*We belong to the family of Krishna[14], and the cow is our mother. I would rather prefer to see it die in peace in the forests than seeing it die in front of my eyes*."

Politically backed prohibitions:

Hindus in the study area believe that the cow is sacred and consider it a sin to eat beef. The ruling right-wing Hindu party is in power for nearly two decades in the state of Madhya Pradesh. Their stay in power allowed them to impose an informal ban on cow slaughter and prohibition on the sale of cows to abattoirs. In 2015, the same Hindu right-wing party became a majority government in India. Respondents viewed that since the new government came into power, the informal prohibitions on cows also extended to buffalos. Further, the enforcement of prohibitions by local vigilante groups has become more stringent. In response to one of our questions, "*Would you sell us a buffalo calf for use in our tiger research?*" A Yadav buffalo herder said, "*The community will kill me if I sell you a buffalo calf to bait tigers*". "*The villages will also target my family and may expel them from the village*". Respondents expressed that prohibitions on selling cattle have disturbed the normal functioning in communities. "*the Yadavs threatened the Chamar family in our village, and they left. Currently, we do not have help to remove dead animals. Sometimes carcases of animals killed in road accidents stay untouched and stinking for days. Villagers bear the stench but do not touch them*," said one respondent. "Animal attacks on cattle increased since the tigers have been reintroduced", said one respondent. "T*here are so many unproductive cattle in the forest, and the tigers are taking advantage of them. At the same time how could you blame the tiger, it is not its fault that the cattle are there. I wish these feral animals were removed and sent away to a ghosala[15]*", he concluded. Respondents expressed that because of the prohibitions, there are currently more cows in the villages and in the forests then there were 20 years ago. All respondents failed to visualise a solution to reducing the number of cows or taking the matter into their hands. The fear of the cow-vigilantes and the increased community retaliation was reasoned for their inability to make decisions. They expected the park authorities to make decisions both on cattle and wildlife issues. "*It is their park and their animals*", said one respondent.

Ineffective land use regulations and preferential rights

All respondents were aware that the core zone of the Panna Tiger Reserve was a prohibited area for grazing and that the buffer zone forests was for multiple-uses. All respondents believed that the park authorities had full legal control to restrict their use of the multiple-use buffer zone. None of the interviewed respondents was knowledgeable on their legal right to access the government forests as described in Forest Rights Act 2006[16]. According to the respondents, poor regulations are restricting the systematic use of buffer zone forests. "*Anybody can come, aap ajo (you come), nobody will stop you. People from*

[14] Krishna the Indian god is believed to be the king of Yadavs pastoralist. The cow is therefore sacred to them.

[15] Ghosala is a care centre for abandoned cows. Several ghosalas accommodating hundreds of cows are situated around the study area.

[16] Forest Rights Act 2006 gives solemn right to all forest dwelling communities to access forests for meeting their natural resource requirements. The act does not distinguish between protected and non-protected forests.

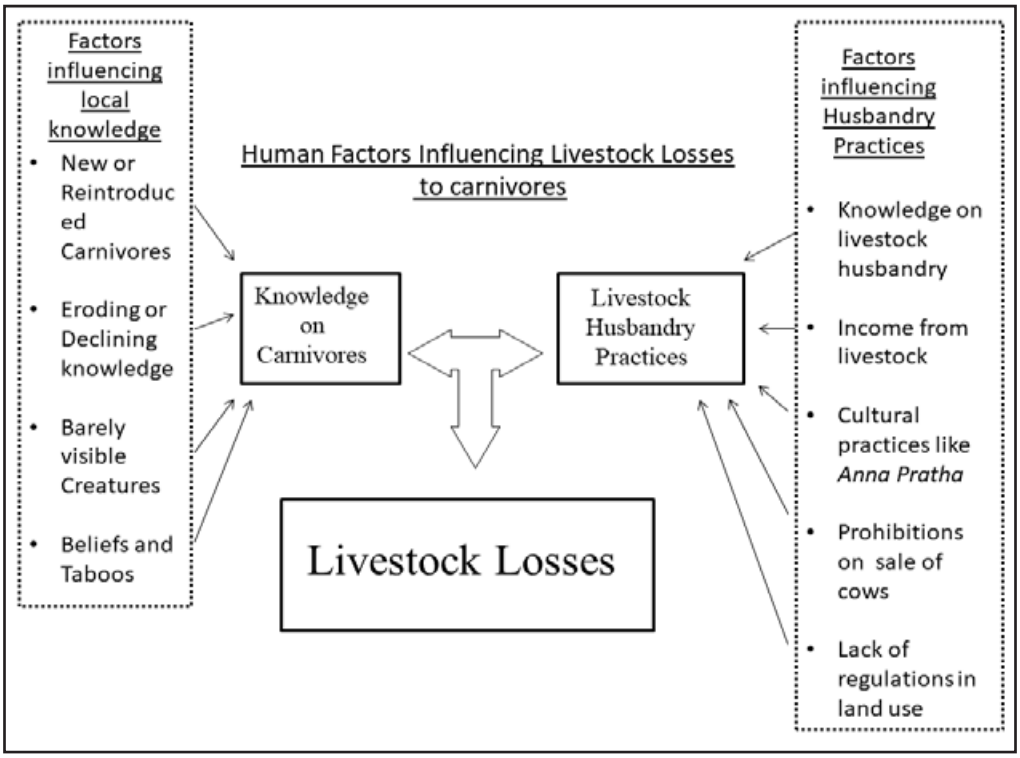

Figure 3.4 Schematic diagram showing the external factors that could affect people's local knowledge and livestock husbandry practices in the buffer zone of Panna Tiger Reserve, India.

as far as Khajuraho town come to fish in the river" said one respondent. Respondents expressed that outsiders allow cattle to graze freely without herders and enabled them to stay in the forests for prolonged periods. Because they had no exclusive land use rights, they could not stop or regulate their use while in government forests. They felt that as residents in the buffer zone they should be given preference over non-residents to access buffer zone forests. When asked, why do you choose to be part of the buffer zone? The most common responses suggested that respondents expected increased monitory benefits from being part of the buffer zone. "*We are going to get a good price on our land when the park authorities propose relocation of villages*," said one respondent.

3.4 Discussion

3.4.1 Local socio-political factors influencing livestock losses

Our findings revealed that resident livestock owners had good local ecological knowledge on large carnivores in their areas. They changed preventive measures for various livestock stages and for different livestock species. Significantly higher efforts were made to

safeguard buffalos and goats but not cows. Those owners who used preventive measures lost significantly lesser animals than those who did not. This findings supported the well-established understanding that preventive measures and excellent local knowledge on carnivores enable livestock owners to reduces the loss of livestock to predators (Ogada *et al*., 2003; Timenta *et al*., 2017; Tshering and Thinley 2017; Tumenta *et al.*, 2013; Van Bommel 2007). However, we found that several obscured factors reduced the ability of owners to manage their stock well and kept losses relatively high than in other comparable parts of India. For example, despite high awareness of the threats from carnivores some owners were selective in their use of preventive measures. Income from livestock influenced such differential treatment. Likewise, local socio-political factors increased the presence of unwanted and feral animals in multiple use forests and also compelled respondents to stock more livestock than they needed. Also, lack of exclusive land-use rights for resident livestock owners in the buffer zone forced them to tolerate the lenient herding practices of non-residents. Based on our empirical findings we agree with Eklund et al., (2017) that preventive measures and knowledge may reduce predation rates but may not stop all predation incidents. As our study shows, factors like income from livestock, age old cultural practices, political influence that deterred people to take actions and ineffective land use regulations, in an interlinked manner may influenced local livestock husbandry practices and people's own ability to control losses.

Absence of income from cows

Cows did not earn income to resident owners, but goats and buffalo did. The lack of revenue reduced people's use of preventive measures for cows. Our findings support the results of Banerjee *et al*., (2013) from Gir forests in the Gujarat State of India that economic incentives motivate herding practices. In Gir forests the local pastoralists tolerated lions killing their buffalos because they earned more money from the local park management's compensation scheme. A majority of cows owned in our study area were little milk yielding native varieties. Most people kept these cows for milk and used their dung as fuel. They did not earn incomes. The native cow types were hardy animals and could withstand the harsh local conditions and did not need tending. So residents continued keeping them and benefited, even in a small way, without having to spend time or effort in their upkeep.

We found a relationship between stock size and preventive methods used. Owners who depended on their cows for income also kept more cows than those who did not depend on animals for income. Further, owners with larger stocks also benefited (economically) if they used preventive measures such as deploying shepherds. Finally, those who did not use precautionary measures lost more animals to predators than those who did. These findings show how income from cows influenced the stock size, use of preventive measures and losses. The segment of people who lost more animals were those who earned their income from labour work. They kept cows for sustenance use, to supplement their weak earnings. This group of residents did not earn enough income to hire shepherds. The effect of the stock size on the owner's ability to employ shepherds, as predicted by our GLM model in two-directional. This is interpreted as, people could afford shepherds because the livestock they owned generated enough

money to afford the services of shepherds. Unfortunately, people holding large stocks (they also earned income) and those who used preventive measured also suffered high losses from predation. Such undiscerning losses are because; since all residents grazed their livestock in the same forests and the differential treatment by some affected all. This relationship shows that in multiple use landscapes that are also used by large carnivores, when a portion of the stock is secured, and rest is allowed to graze free, the portion that is secured is also likely to become vulnerable to predation. The next discussion is on interconnected effects of socio-political influence on livestock husbandry practices.

Socio-political influences

The disclosures of the livestock owners suggest that the external socio-political factors are essential stimuli and create barriers for livestock owners. For example, cultural practices such as Anna Pratha encouraged people to abandon untenable cows into the forests. Similarly, the lack of land use regulations in government forests encouraged resident and non-resident villagers to pursue lenient cow herding practices such as, not using herders and allowing cows to graze unguarded and not using night time enclosures. In our study area, people do not eat beef. Further, the ban on selling cows to abattoirs and the low milk yielding cows, all these factors have lowered the commercial value of native varieties of cows. Our findings in Panna are dissimilar to those reported by Bhatia *et al.*, (2017) who studied the influence of religious beliefs of Muslim and Buddhist pastoralists towards snow leopard in Ladhak, Kashmir. In Ladhak, they found that income from livestock was a stronger influencer on attitudes of people towards snow leopards than religion (Bhatia *et al*., 2017). We found the opposite to be true in Hindu respondents in Central India, who despite their weak economic status are unable to exploit the surplus cows in their areas because of local religious norms towards cows and the political support for such views. This situation created an excess of unwanted native varieties of cows and bulls that did not have any commercial value in villages. As a result, large numbers of livestock were allowed to move freely in the forests, and such animals became ready prey for large carnivores (Kolipaka *et al*., 2015). In Panna, the complex interactions between the social (beliefs, religion and cow protection) and natural systems (multiple-use forests, predators), like observed in several other contexts in the world, are of significance (Adhikari 2016; Abade et al., 2016; Madden, 2004).

While the above mentioned complex interactions were at play, residents in the buffer zone villages expressed helplessness to control the external socio-political influences and poor land use regulations that affected them. On-one-hand they experienced livestock losses, and on-the-other-hand, they could not respond to the overwhelming forces fuelling such losses. This situation is explained by Cutter (2003) through his vulnerability science framework as those circumstances that put people and places at risk and *those conditions that reduce the ability of people and places to respond to environmental threats*. Ghate et al.(2013b) also support our findings., and they demonstrated through their field experiments that people become vulnerable to external threats when they lacked the power to control their natural resources.

3.4.2 Management Option

Livestock is integral to people's welfare and well-being in most rural areas of the world including India (Herero *et al.*, 2010). Therefore, livestock's presence in rural landscapes and government-controlled forests will carry on, typifying such lands. To conserve carnivores in areas that are also used by livestock, it is essential to find ways to decrease livestock losses or risk losing people's support for carnivore conservation. With the current Hindu conservative government in power, the existing socio-political situation surrounding sacred animals in India are likely to continue (Teltumbde, 2015). Next, its influence on people and their livestock practices in the study area will likely remain. While this situation may advantage carnivores in multiple use areas through readily available domestic prey animals (Kolipaka *et al.*, 2017a), it is liable to exert economic burden on those residents who depend on livestock for livelihoods (Teltumbde, 2015). Under these circumstances, soliciting local people's support for carnivore conservation will be difficult.

Fortunately, the high local knowledge and good familiarity on wildlife amongst resident livestock owners will not require the need for costly and hard-to-execute awareness and educational campaigns. Further, local knowledge may be a reliable source of information to refocus local conservation efforts. For example, during our interactions with livestock owners, we became knowledgeable about the predatory nature of the wolf and free-roaming village dogs, which caused more livestock losses than the tiger, leopard and the dhole combined in the study area. This finding is significant for tiger conservation in multiple use forests because wolf and village dogs caused more losses of commercially valuable goats, unlike tigers or leopards that killed more commercially low-value cows (Appendix 1-Table 3). Next, the residents are satisfied with the usefulness of their preventive strategies against predators. They do not see the current predation resulting from their lack of knowledge of carnivores or their inability to use preventive methods. They feel helpless to tackle the interlinked socio-political and lack of rights in government-controlled forests, which exposed them to vulnerability. Since the support of the local people is critical for large carnivore survival in multiple use forests and outside protected areas, the reserve management may have to address the local concerns. For example, issuing exclusive user rights to residents who live inside the buffer zone, will empower and encourage the 43,125 people of 42 resident villages to come together and stand up against the non-residents. Issuing preferential user rights may stimulate residents defining their grazing lands and impose stricter grazing regulations that check undesired livestock grazing practices. Empowering local communities as Ghate *et al.*, (2013b) showed through their field experiments will allow better natural resource management by the communities when such communities have the power over their resources. Further, conservation advocates, through their networks and contacts, must find platforms to address the currently paralysed discussion on excess and unwanted livestock bothering rural people. I use the metaphor of an entangled knot. By addressing the issues the reserve managers will help loosen up some of the strands from the entangled knot[17], knot being the complex interlinked effects of the socio-political situation, which create barriers for residents. By

[17] Knot is a metaphor.

loosening the knot, the highly knowledgeable and adaptable residents will be in a position to better protect their livestock from predators.

3.5 Conclusion

Our study provides novel insights into various external factors that can influence livestock husbandry practices and keep livestock losses high. This is despite livestock owners having excellent local knowledge and using preventive strategies to safeguard their animals. Reserve managers and tiger conservation groups cannot overlook the interlinked effects of income, socio-political factors and ineffective land use regulations on livestock husbandry practices in a shared landscape. We feel that the external forces exerting pressure on resident owners may be too complicated for them to solve on their own and they may need the reserve management's help. We conclude that the ability of people to manage their livestock in a conservation area may be determined by the external factors as much as it depends on their ability to safeguard livestock.

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Writing- original draft: SSK.
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An adult female tiger. Female tigers play an important role in a reintroduction program by producing and raising the cubs needed to build the population.

4 New insights into the factors influencing movements and spatial distribution of reintroduced Bengal tigers (*Panthera tigris tigris*) in the human-dominated buffer zone of Panna Tiger Reserve, India

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Abstract

The influence of tiger-specific (sex, age group), environmental (seasons, photoperiod) and anthropogenic (human use regimes) factors on the movements and spatial distribution of tigers using the human-dominated buffer zone of the Panna Tiger Reserve, India was studied. Generalised linear mixed models were used to test the significance of the relationships between the covariates influencing tiger presence. We report that tiger-specific factors – age group (generation) and sex – and environmental factors – seasons and day/night – significantly explain the observed variations in tiger use of the human-dominated buffer zone. For instance, second-generation tigers (sub- adults) spent 40% of their time in the human-use areas, compared to 10% spent by first-generation tigers (adult). When in human-use areas, sub-adult tigers approached areas near villages and spent 30% less time in areas close to water than adult tigers. Our study concludes that, in addition to tiger-specific factors, human factors, including livestock practices and peoples' activities, influence tiger behaviour and their use of shared spaces. These unchecked human practices may lead to increased negative tiger-human interactions and restrict tigers from exploiting the resources in multiple-use areas.

Keywords: Central India; human-carnivore interactions; multiple-use forests; reintroduced tigers.

4.1 Introduction

In many countries, large carnivores persist in relatively small protected areas that are surrounded by multiple-use forests and human-dominated landscapes (De Fries *et al.*, 2005, Boitani *et al.*, 2007, Chundawat *et al.*, 2016, Santini *et al.*, 2016). Animals living in such environments frequently move beyond the protected boundaries to search for prey, to establish new territories, or to look for mates (Boitani and Powell, 2012). This inevitably

results in contact with human communities and increased predation by carnivores on domestic livestock or attacks (Woodroffe and Ginsberg, 1998, Dickman *et al.*, 2013, Miller *et al.*, 2016). When people experience such losses, they retaliate (Woodroffe and Ginsberg, 1998, De Fries *et al.*, 2005, Wikramanayake *et al.*, 2011, Santini *et al.*, 2016). It is well established that human factors, including human-carnivore conflicts, contribute significantly to the decline of carnivore species outside the protected areas (Wikramanayake *et al.*, 2004, De Fries *et al.*, 2005, Boitani *et al.*, 2007, Dickman *et al.*, 2013). The tiger is a conservation priority and there are several approaches to recovering tiger populations across the world (Johnsingh and Madhusudan, 2009, Walston *et al.*, 2010). India's National Tiger Conservation Authority has established 48 tiger reserves or genetic source pools across the subcontinent (http://projecttiger.nic.in). Projects like this secure breeding sub-populations and create networks of source pools (Hanski, 1998, Wikramanayake *et al.*, 2004, Johnsingh and Madhusudan, 2009).

The Panna Tiger Reserve (PTR) in India is one such genetic source pool. The state Forest Department initiated a tiger reintroduction programme in 2009 after local tigers became extinct due to poaching (Gopal *et al.*, 2009, Sarkar *et al.*, 2016). Following successful breeding, tiger numbers in PTR increased from six founder animals to over 30 individuals between 2009 and 2014 (Sarkar *et al.*, 2016). Currently, the Forest Department aims to create and strengthen safe areas across the larger landscape and secure the tiger species outside the reserves (Gopal *et al.*, 2009, Wikramanayake *et al.*, 2011).

Like most tiger reserves, the PTR is an isolated, protected area surrounded by multiple-use forests and human-dominated landscapes. In the PTR, the home ranges of male and female tigers are larger than the average ranges in other parts of India (Chundawat *et al.*, 2016, Sarkar *et al.*, 2016). These large ranges and the relatively small size of the protected area lead to a mismatch between the space needed for tigers and the available protected area (Chundawat *et al.*, 2016). Consequently, tigers, including the breeding females, which are vital to the survival of the source pool, frequently move outside the protected area (Chundawat *et al.*, 2016, Sarkar *et al.*, 2016). Moreover, new tigers also enter the PTR and sometimes dispersing males, unable to find suitable habitat outside, also return to the PTR (Chundawat *et al.*, 2016), shifting tiger territories and changing their social organisation. These new insights into the factors shaping tiger territoriality show that tiger territoriality is very flexible. The dynamic territories of tigers, the protected area-home range (hereafter, PA-home range) mismatch, the frequently changing social organisation and the increasing numbers of tigers within the PTR, all suggest that some portion of the current PTR tiger population will recurrently move and use areas outside the reserve. This finding compels tiger researchers and conservation managers to find ways to ensure tigers' persistence in shared spaces outside protected areas (Carter and Linnell 2016). In this article, we expand further on the subject of tigers and humans sharing a landscape and examine a case of very high frequency (VHF)-radio-collared tigers from the PTR tiger reintroduction programme using the human-dominated buffer zone.

The current understanding of tigers in India is based on protected areas, where human activity is restricted (Athreya *et al.*, 2014). Knowledge of how tigers use areas outside the

protected areas is not available and creates uncertainty regarding the tigers' use of forests with human presence and activity. For example, it is not clear whether tigers will approach areas near to the villages or avoid them. There is evidence in a study of African lions by Oriol-Cotterill *et al.*, (2015) in Laikipia, Kenya that they show avoidance behaviour towards human settlements and roads. Moreover, it is not certain, how tigers will respond to human activity near shared water bodies that are important both for tigers and the local communities, or whether all tigers respond similarly or if the use of space varies among tigers. My study addresses the knowledge gap on tigers' responses to shared landscapes. Such understanding could lead to improved management of multiple-use landscapes both for the benefit of the tiger and the people using the areas.

In this study, we focus on tiger space utilisation in areas with known human activity and identify variations in use among tigers. We have defined two main research questions:

1. Do tigers use multiple-use buffer zones differently from core areas, in particular human settlements, waterholes?
2. How does the presence of tigers in multiple-use areas change over time?

The VHF data from radio-collared tigers was grouped into sex and age categories and estimates the percentage use of spaces with known human activity. Next, we examined how space use varies with changes in tiger sex, age group, seasons, day and night, near water and in time.

4.2 Materials and methods

4.2.1 Study area

This research was carried out in the PTR located in north central Madhya Pradesh, India. The reserve has a surface area of 1645 km^2 and is divided into two management units: a core zone (550 km^2) and a multiple-use buffer zone (1095 km^2) (Figure 1). Human activity and natural resource extraction are restricted in the core area. In the buffer zone, 43 villages with over 40,000 people and 42,000 livestock live and depend on the forest resources (Kolipaka *et al.*, 2015).

The tiger reserve is in the western Vindhya Hill ranges, which is part of a broken chain of narrow but elongated highlands and plateau escarpments and multiple-use forests that extend to the north and to the south. The tiger reserve is approximately 30 km at its widest (range 10-30 km) and approximately 100 km long.

The terrain is hilly with flat plateaus and undulating plains (Karanth *et al.*, 2004). The vegetation is predominantly savannah-type woodland-grassland habitat and mixed forests. Bamboo grows on the slopes.

Rainwater from the hills flows through numerous streams that cut through the open areas and eventually flow into the Ken River, the largest water source in the area. Due to

the hilly topography, rapid drainage and the short rainy season, the availability of surface water is limited during the summer (Gopal *et al.*, 2009).

4.2.2 Tiger reintroduction programme

In 2009, two adult female tigers, T1 and T2, were introduced into the Panna Tiger Reserve, followed by a male tiger T3 in November 2009. Subsequently, three more female tigers T4, T5, and T6 were phased into the reserve. Table 1 and Sarkar *et al.*, (2016) provide details of the founder tigers (hereafter referred to as first-generation tigers) and their descendants.

4.2.3 Tiger location fixes

All first-generation tigers introduced into the PTR are mature adults (Table 1) fitted with radio collars. Sarkar *et al.*, (2016) published detailed information on the collars and collaring procedure used at PTR. Teams comprising three to six trained monitoring staff, working in 8 h shifts, monitored the collared tigers with handheld VHF receivers. They recorded and reported the data to the manager to facilitate decision-making. Radio collars were subsequently fitted to the second-generation sub adult tigers aged between 18 and 24 months. More generations of tigers had been born in PTR by the end of our study but not all tigers were radio-collared (Figure 2). In this article, the word generation refers to sub-adult tigers.

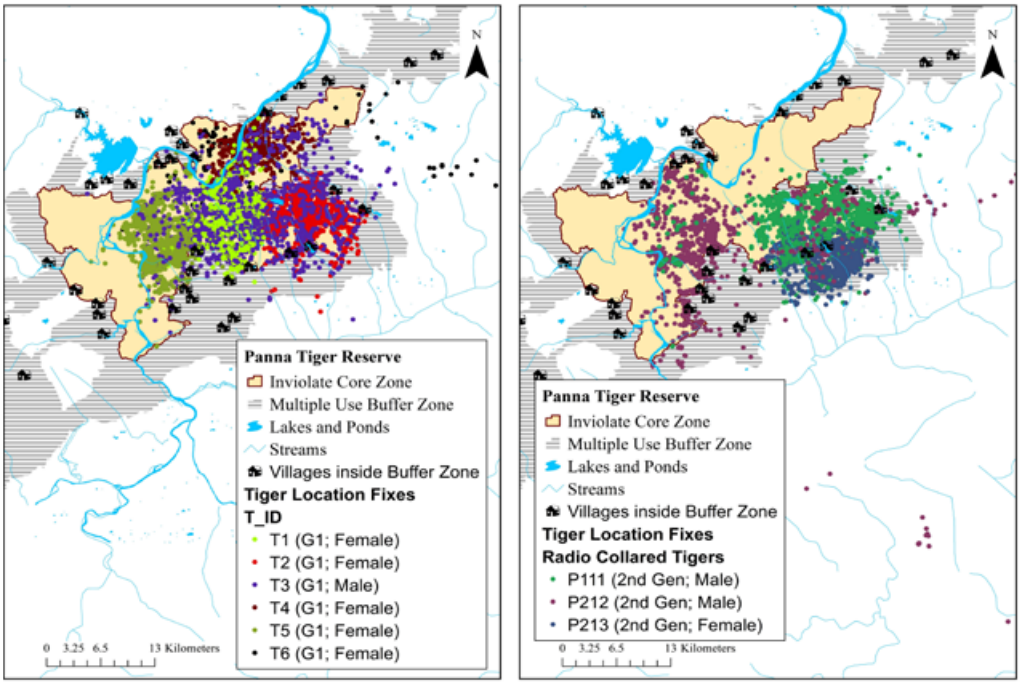

Figure 4.1 VHF radio collar location fixes of six Generation 1 (left) and three Generation 2 tigers (right) for the year 2013 in the Panna Tiger Reserve.

Table 4.1: Histories of the nine radio collared tigers from the Panna tiger reintroduction program that are included in this study.

TIGER ID	SEX	GENERATION	LITTERS BORN AS OF 2014	ORIGIN	YEAR BORN (B) OR REINTRODUCED (RE)	AGE WHEN FIRST COLLARED	TOTAL GPS FIXES (IN YEARS)	STATUS AS OF JANUARY 2016 ANALYSED
T1	♀	1	3	Bandhavgadh National Park	2009 Re	C. 7	31487	Alive
T2	♀	1	4	Kanha National Park	2009 Re	C. 7	18922	Alive
T3	♂	1	NA	Pench National Park	2009 Re	C. 7	35835	Alive
T4	♀	1	2	Kanha National Park	2011 Re	C. 7	19333	Dead
T5	♀	1	1	Kanha National Park	2011 Re	C. 7	18985	Dead
T6	♀	1	1	Pench National Park	2011 Re	C. 7	1590	Alive
P212	♂	2	NA	Born in Panna	2010 B	C. 1.8	15146	Dead
P213	♀	2	1	Born in Panna	2010 B	C. 1.8	15809	Alive
P111	♂	2	NA	Born in Panna	2010 B	C. 1.8	18933	Alive

Generation 1, adult tigers when introduced; Generation 2, sub-adults when introduced; NA, not applicable.

4.2.4 Human use of buffer zone forests

Residents access forests daily to graze their livestock, collect fuel wood and extract non-timber forest products both for subsistence and as a source of income. Livestock rearing is common and consists mainly of cows, buffalos and goats (Kolipaka *et al.*, 2015).

4.2.5 Three distinctive human-use areas

We identified regions with high human activity within the buffer zone and examined tiger use and variations in tiger presence within three areas (Kolipaka *et al.*, 2015).

4.2.6 Human-dominated buffer zone

The tiger reserve area has two management zones, a core zone and a multiple-use buffer zone (Figure 1). The core zone is an inviolate area within the tiger reserve, where human presence and activities are strictly regulated. This zone is fully secured against wildlife and approximately 15% is open for non-consumptive, vehicle-based tourism. The buffer zone, on the other hand, includes villages and accommodates peoples' activities. We examined

tiger use of the buffer zone and hypothesised that some tigers – probably sub-adult tigers – most likely influenced by the territoriality of the dominant adults in the core zone and the PA-home range mismatch (Chundawat *et al.*, 2016), will use the human-dominated buffer zone more.

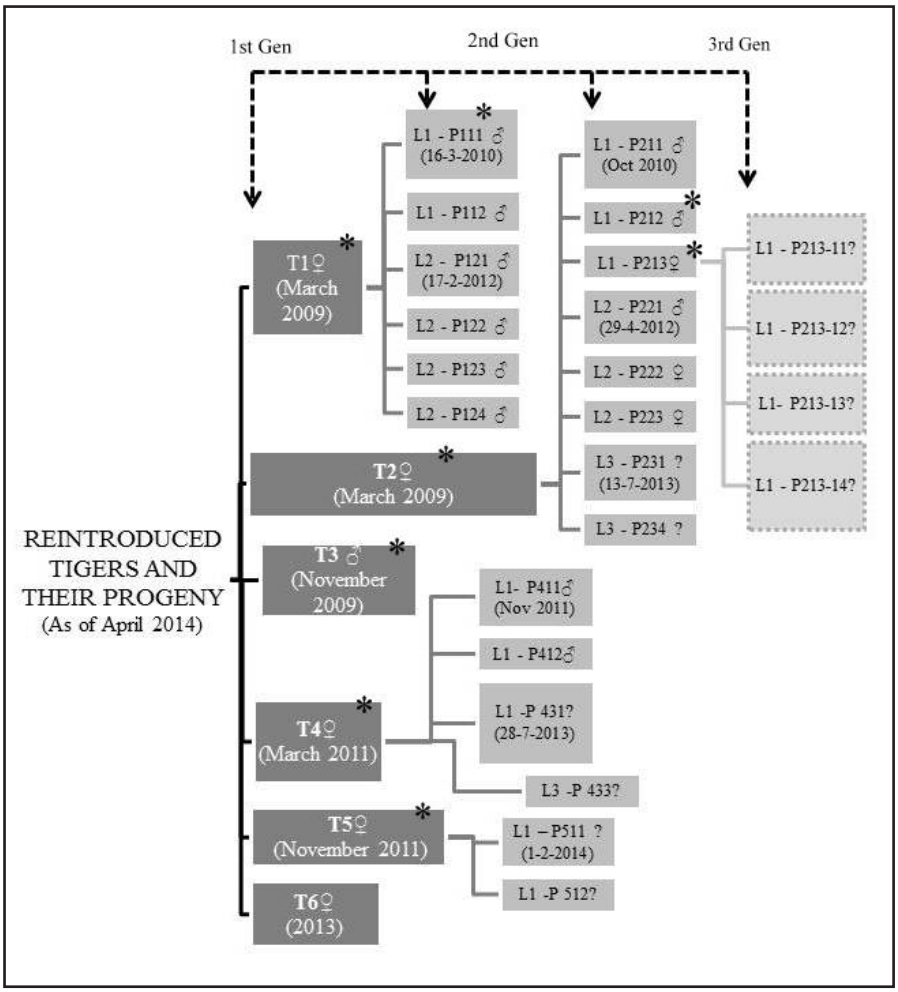

Figure 4.2 The first generation of reintroduced tigers T1, T2, T3, T4, T5 and T6 and the progeny born subsequently in the Panna Tiger Reserve as of April 2014. The dates indicate reintroduction and dates of birth. L, litter number; (?), sex unknown; (*), collared tigers and VHF location data included in this study.

4.2.7 Near villages

In an earlier study, we estimated that during daytime (7:00 h–17:00 h), people of all age groups actively move and use areas within a 2 km radius of villages (Kolipaka *et al.*, 2015) to conduct their daily activities and for resource collection. We examined tiger presence and use of areas near villages located in the buffer zone to gain an understanding of how

tigers respond to such human activity. We hypothesise that tigers avoid areas close to the villages due to the high human presence and activity.

4.2.8 Near water bodies

The availability of water in the buffer zone varies greatly across the seasons. In an earlier study, we recorded that, during daytime, herders and their livestock frequently access water bodies and habitually stay close to water (Kolipaka *et al.*, 2015). Their presence and activity were high within 250 m on either side of the water bodies. We hypothesised that tigers failed to utilise resources in areas where human presence and livestock activity is high. We therefore examined tiger presence near water in the human-use areas.

4.2.9 Statistical analysis

We conducted our final analysis on nine radio-collared tigers (three and six animals) and analysed 5 years of tiger VHF locations between 2010 and 2014 (see Table 1). We examined tiger presence in the three distinctive human-use areas and compared the percentage of tiger presence in these regions with the human-dominated buffer zone and the core area. Within the buffer zone, we examined the 2 km distances from villages and 250 m on either side of the water bodies. Since the high human-use areas are equivalent in size to the areas outside, it is possible to make a comparison between the two. The decision to measure presence inside or outside human-use areas necessitated the use of binary response variables in the analysis. We expected that tiger presence in the human-use areas would vary in relation to tiger-biological and ecological attributes treated as independent variables. For the first analysis, we included generation (first generation = adults and second generation = sub-adults), sex (male/female), seasons (summer, rainy, winter), day (7 am–6 pm)/night (6 pm–7 am) and year (2010–2014, continuous). We included two additional independent variables in the 2nd and 3rd analysis: zone (core/buffer) and livestock grazing areas (inside/5 km outside the village). Hourly tiger location fixes are naturally correlated, i.e. the spatial location of a tiger at a point in time is related to the spatial location in the next 1 h. We arbitrarily selected two location fixes for each day to create a random element to the data, as suggested by Oriol- Cotterill *et al.*, (2015). We randomly picked a daytime location fixed (5 am–5 pm) and one fix for night-time locations (6 pm - 6 am). All analyses were performed using SPSS ver. 23 (IBM Corp 2014) with the proportion of tiger fixes within the three predefined human-use areas as dependent (response) binary variables, using generalised linear mixed models (GLMM) with binomial logistic regression link function. Since we restricted data to nine tigers (30% of the population), we treated individual tigers as a random effect. That is, we treated the effects of this random variable as a random sample of the effects of all the tigers in the PTR. In the mixed-effects model (GLMM), sex, age group (generation), season, day/night, year (continuous), zone and 5 km buffer were treated as main effects and as two-way interactions. To examine trends (over time) in tiger presence, we used “year” as a continuous predictor. Adequate model fits ensure stepwise removal of non-significant ($p < 0.05$) two-way interactions and we optimised the model based on all main effects and only those two-way interactions that

were significant (see Supplemental Appendices 1, 2 and 3 for coefficients and the model selection procedure). We present Akaike Information Criterion (AIC) of our final model fits to explain suitability of the best fit model.

4.3 Results

4.3.1 Presence of tigers in human-dominated buffer zone

Variations in the presence of tigers in the core zone and the human-dominated buffer zone are presented in the regression Table 2. In the best fit model (AIC 84,042.759, accuracy 81.8%), four out of five main effects and six two-way interactions are significant (Table 2; see also Supplemental Appendix 1 for regression coefficients). The important interactions are described below.

Table 4.2: Binomial logistic regressions of variables (main effects) and interactions between variables explaining tiger presence in the multiple use buffer zone of the Panna Tiger Reserve.

VARIABLES AND INTERACTIONS	F	DF1	DF2	SIG
Corrected model	18.276	14	16,452	P<0.000
Generation	14.159	1	16,452	P<0.000
Sex	1.450	1	16,452	P=0.229
Season	28.170	2	16,452	P<0.001
Day/ Night	85.085	1	16,452	P<0.001
Year	46.608	1	16,452	P<0.001
Generation & Day/Night	26.191	1	16.452	P<0.001
Generation & Year	26.732	1	16,452	P<0.001
Sex & Day/Night	6.937	1	16,452	P=0.008
Sex & Year	24.815	1	16,452	P<0.001
Seasons & day/night	3.743	2	16,452	P=0.024
Seasons & year	20.203	2	16,452	P<0.001
Significance is determined at $p < 0.050$; greater values are not considered significant.				

The presence in the buffer zone of second-generation tigers is 40%, which is about four times higher than for first-generation tigers. In this area, all tigers showed a higher nocturnal presence compared to the diurnal presence (temporal variation in presence). However, the nocturnal presence was twice as high as the diurnal presence among first-generation tigers and less pronounced in the sub-adult second-generation tigers (interaction: generation * day/night, $p < 0.001$, Table 2; Supplemental Appendix 4A). There is also a significant interaction between variables sex and day/night (Table 2). Male and female tigers showed no variation in their nocturnal presence in the buffer zone. However, during the daytime, female tiger presence was higher in the buffer zone than male tiger presence (interaction: sex * day/night, $p = 0.008$, Supplemental Appendix 4B).

Tiger presence in the buffer zone varied seasonally, with a significantly higher presence during the rainy and winter seasons and significantly lower presence in the summer. During the rainy and winter seasons, temporal variation in tiger presence (nocturnal to the diurnal difference in presence) was also low. In the summer, overall tiger presence in the buffer zone was low, but tigers maintained a higher temporal variation. Their night-time presence was greater than during the day (interaction: season * day/night, $p = 0.024$, Supplemental Appendix 4C). Over a period of 5 years, all tigers showed a decreasing trend, over time, in terms of presence in the buffer zone (Figure 3D, coeff: −0.307, $p < 0.001$). This decrease is much stronger among second-generation tigers (coeff: −0.281, $p < 0.001$) than among first-generation tigers. Between sexes, male tigers show a continuing trend in terms of presence (coeff: −0.242, $p < 0.001$), unlike female tigers. There were no significant changes in tiger presence between seasons, with a higher tiger presence in the winter and rainy seasons than during the summer months (coeff: 0.339, $p < 0.001$; Table 2).

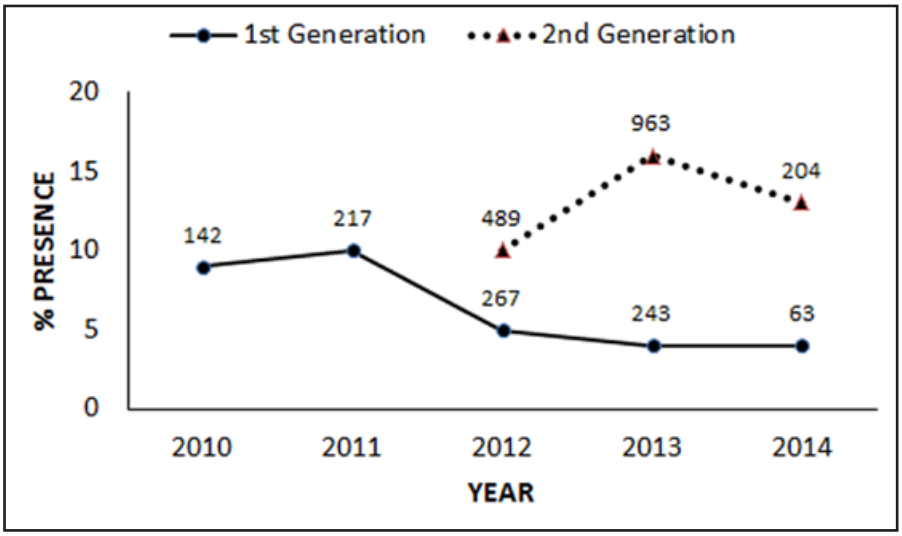

Figure 4.3 The change in first- and second-generation tiger presence near villages that transpired over a 5-year period between 2010 and 2014 in PTR. (N, randomly sampled tiger VHF location fixes).

4.3.2 Presence near villages

Table 3 presents the results of the statistical analysis of the presence of tigers near villages. This analysis focuses on the tiger use of areas where human presence and activity is very high. In the best fit final model (AIC 87.393,131, accuracy 84.5%), three out of the six main effects and eight two-way interactions are significant (Table 3, see also Supplemental Appendix 2 for regression coefficients). The important interactions are described below.

Table 3: Binomial logistic regression of variables (main effects) and interactions between variables explaining tiger presence within 2 km of the villages located in the buffer zone of the Panna Tiger Reserve.

VARIABLES AND INTERACTIONS	F	DF1	DF2	SIG
Corrected model	43.542	18	16,448	P<0.001
Generation	1.104	1	16,448	P=0.293
Sex	2.849	1	16,448	P=0.091
Seasons	19.755	2	16,448	P<0.001
Day/Night	0.939	1	16,448	P=0.333
Year	16.843	1	16,448	P<0.001
Zone-cl	5.585	1	16,448	P=0.018
Gen & Seasons	3.658	2	16,448	P=0.026
Gen & Year	57.214	1	16,448	P<0.001
Gen & Zone_cl	243.769	1	16,448	P<0.001
Sex & Season	3.389	2	16,448	P=0.034
Sex & Year	19.150	1	16,448	P<0.001
Sex & Zone_cl	56.145	1	16,448	P<0.001
Season & Year	10.416	2	16,448	P<0.001
Year & Zone_cl	10.574	1	16,448	P=0.001

Three out of the six variables are not significant on their own but significant as interactions. Significance is determined at $p < 0.050$; values greater are not significant. The variables generation and sex interact significantly with seasons (Table 3). Second-generation tiger presence near villages is considerably higher than the presence of first-generation tigers (interaction: generation * zone, $p < 0.001$, see Table 3; Supplemental Appendix 4D). The presence of sub-adult tigers near villages was consistently greater than that of first-generation tigers in all three seasons and throughout the study period. Between sexes, male and female tigers were equally present near villages and did not show any sex-biased difference in their presence (interaction: sex * zone, $p < 0.001$, see Table 3; Supplemental Appendix 4E). The difference between males and females was in the location of their presence. Female tiger presence was higher near those villages that are very close to the core zone, while male tiger presence was also high near villages that were far from the core area. Moreover, this difference in presence between the sexes was consistent and significant for all the three seasons (Table 3). Second-generation tigers and male tigers showed significantly higher presence near villages during the rainy season; this decreased marginally during the winter months and was least in the summer season (interactions generation * season, $p = 0.026$; Table 3; Supplemental Appendix 4F); (interactions sex * season, $p = 0.034$; Table 3; Supplemental Appendix 4G). The tiger presence near villages changed gradually over the 5-year study period. The first-generation tiger presence near the villages decreased further but the decline in second-generation tiger presence was very gradual and continued to be higher than the first-generation tigers (coeff: 0.467, $p < 0.001$). Between sexes, male tigers showed a stronger declining trend than females in terms of presence over time near the villages (Male: coeff: −0.254; $p < 0.001$; Figure 4). Within seasons, tigers continued to show a significantly higher presence

near villages during the rainy and winter seasons and this presence decreased to the lowest levels during the summer months (summer: coeff: 0.316, $p < 0.001$; Figure 5).

4.3.3 Presence near water bodies

Table 4 presents the results of the statistical analysis of the presence of tigers near water bodies. This analysis focuses on tiger presence near water bodies used by people and livestock. In the best fit final model (AIC 80,937.956, accuracy 83.6%), three out of seven main effects and seven two-way interactions are significant (Table 4, see also Supplemental Appendix 3 for regression coefficients). The important interactions are described below.

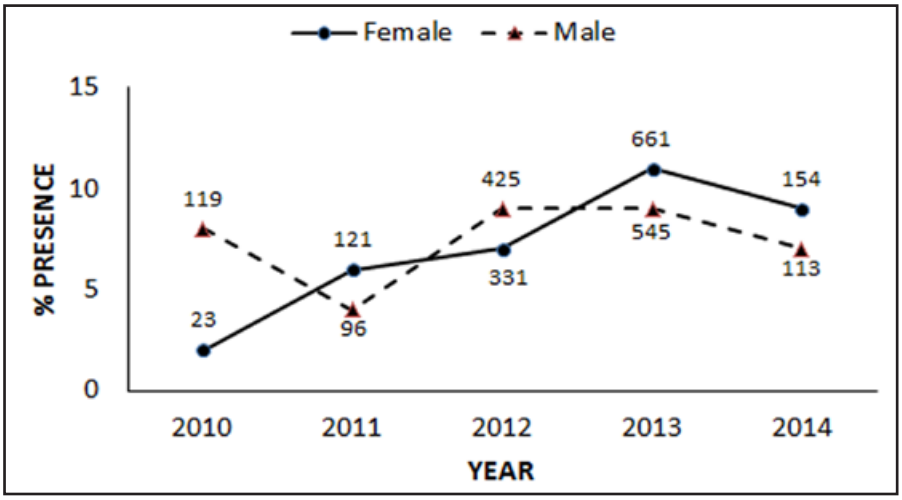

Figure 4.4 The change in the male and female tiger presence near the villages that transpired over a 5-year period between 2010 and 2014 in PTR. (N, randomly sampled tiger VHF location fixes).

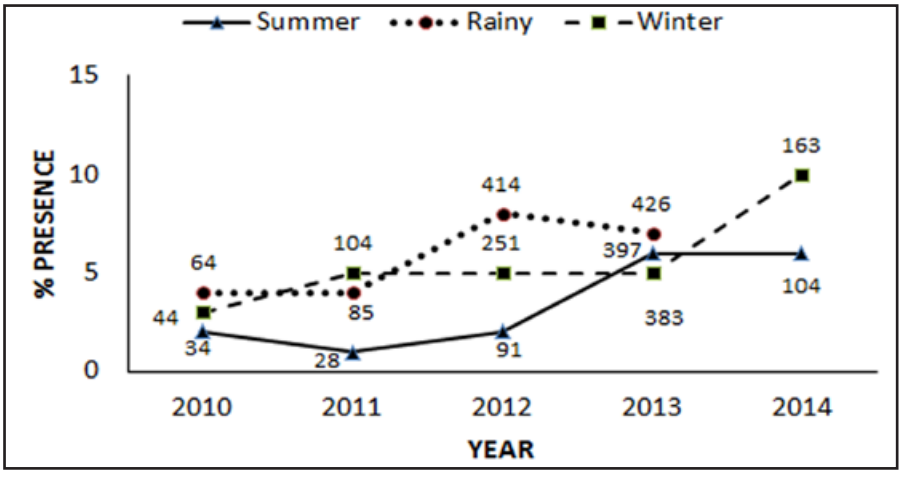

Figure 4.5 The seasonal change in tiger presence near the villages that transpired over a 5-year period between 2010 and 2014 in PTR. (N, randomly sampled tiger VHF location fixes).

Table 4.4: Binomial logistic regression of variables (main effects) and interactions between variables explaining tiger presence within 250 m of water bodies and in livestock herding areas.

VARIABLES AND INTERACTIONS	F	DF1	DF2	SIG
Corrected model	11.587	18	16,449	P<0.001
Generation	1.842	1	16,449	P=0.175
Sex	1.386	1	16,449	P=0.239
Season	8.547	2	16,449	P<0.001
Day/Night	3.403	1	16,449	P=0.065
Year	0.837	1	16,449	P=0.360
Zone_cl	4.461	1	16,449	P=0.035
Points_in_ 5k_buffer	7.736	1	16,449	P=0.005
Gen & Seasons	14.278	2	16,449	P<0.001
Gen & Year	7.226	1	16,449	P=0.007
Sex & Season	6.379	2	16,449	P=0.002
Sex & Year	14.158	1	16,449	P<0.001
Sex & Zone	11.370	1	16,449	P=0.001
Sex & Points in 5km buffer	10.049	1	16,449	P=0.002
Seasons & Zone	3.032	2	16,449	P=0.048

Seasons (as the main effect) and six interacting variables significantly explain tiger presence near water and livestock grazing areas. Significance is determined at $p < 0.050$; greater values are not significant.

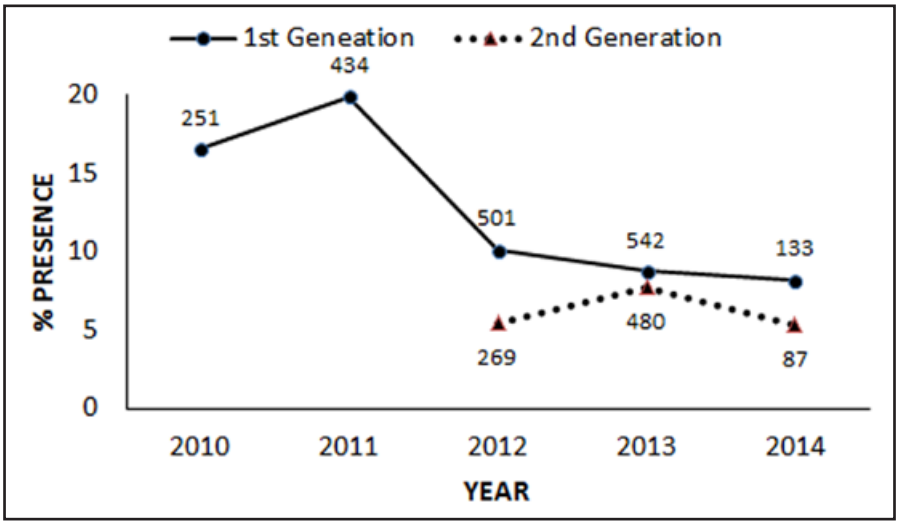

Figure 4.6 The seasonal change in the first- and second-generation tiger presence near water bodies that transpired over a 5-year period in PTR between 2010 and 2014. (N, randomly sampled tiger VHF location fixes).

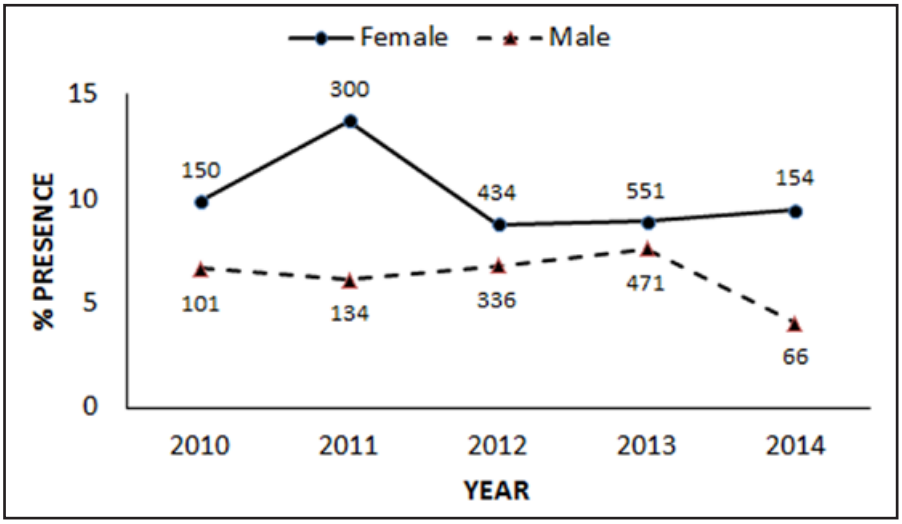

Figure 4.7 The change in the male and female tiger presence near the water bodies that transpired over a 5-year period in PTR between 2010 and 2014. (N, randomly sampled tiger VHF location fixes).

VHF-radio-collared tigers spent 25% of their time at locations close to water. Tiger presence near water was the highest during the summer months and declined over the rainy and winter seasons. This seasonal difference in presence near water did not change while tigers were in the core zone or the buffer zone (Supplemental Appendix 4L). However, we observed age related differences among tigers and their presence near water. Male and female second generation tigers that used the buffer zone spent considerably less time near water during the summer (interactions generation * season; $p < 0.001$; Table 4; Supplemental Appendix 4H) and (interactions sex * season; $p = 0.001$; Table 4; Supplemental Appendix 4K) this reduced presence of tigers near water while in the buffer zone did not change over the 5-year study period ($p = 0.007$; Figure 6). When tigers used livestock grazing areas, at a 5 km distance around the villages, their presence near water was also low (interaction sex * 5 km circle; $p = 0.002$; Table 4; Supplemental Appendix 4J).

4.4 Discussion

We examined variations in tiger presence in areas with high human presence and activity. We discussed the observed variations and focussed on the implications for tiger conservation in human-use areas. Our analysis shows that between 2009 and 2014, as tiger numbers grew in the Panna Tiger Reserve from six founder animals to over 30 animals, tiger presence also increased in the adjacent human-dominated buffer zone. The increase was most pronounced in second-generation tigers or sub-adults in comparison to first-generation adult tigers. This outward expansion of sub-adult tigers from the protected core zone of the PTR into the adjacent human-use areas is most

likely because of intraspecific competition with the dominant tigers and the need for younger tigers to disperse from their natal areas and establish their territories (Goodrich *et al.*, 2010). These are naturally occurring tiger behaviours and when they occur in a small-sized protected area like the PTR, where tiger home ranges are relatively larger than the available space within the protected area (Chundawat *et al.*, 2016), tigers inevitably move into the adjacent buffer zones and the unprotected landscape beyond the PTR. We found remarkable differences between groups of tigers in the use of the shared spaces. The group of sub adult tigers used the shared spaces both during the day, when human and livestock activity was high and at night, when such activity was low. In comparison, the group of adult, first-generation tigers revealed a higher nocturnal presence, showing temporal variation in their use (Supplemental Appendix 4A). Temporal partitioning by tigers while using human-use areas is reported by Carter *et al.*, (2012) from their studies in Nepal. Such use of shared spaces when human activity is low may decrease confrontation with people. However, our analysis demonstrates that some, but not all tigers have the opportunity for temporal partitioning. In the PTR, it is the dominant adult tigers that show greater temporal partitioning while using human-use areas compared to sub-adult second generation tigers.

We also noticed that tigers dispersing through the human-dominated landscapes rested close to the villages during the day, most likely because they did not have other options. Both male and female sub-adult tigers approached areas near the villages much more than adult tigers. People conduct their daily activities near villages and village cows congregate unguarded in these areas at night (Kolipaka *et al.*, 2015). There is also an abundance of unguarded domestic prey in the PTR as a result of domestic cow management practises (Srivastava 2014, Kolipaka *et al.*, 2015). As a result, tigers are increasingly killing livestock (Kolipaka *et al.*, 2017b). Moreover, the forced removal of a sub-adult third-generation tigress from a village in the buffer zone in 2016, as evidenced by newspaper reports (TOI, 2016), demonstrate the negative consequences of sub-adult tigers engaging in livestock raids close to the villages. The sub-adult tiger presence near the villages peaked to 16% during 2012 and showed a slow decline in 2013. We cannot comment on whether their presence further declined as we only have 2 years of data on sub-adult tigers. We can speculate that the initial increase in presence near the villages may be a result of chance encounters of sub-adult tigers with villages while establishing new territories. Further, lenient local grazing practices (Srivastava 2014, Kolipaka *et al.*, 2015) and the seasonally changing vegetation near the villages may provide the cover tigers need when hunting for prey near villages without being detected. Our studies on tiger diet in the buffer zone of the PTR reveal that sub-adult tigers and adult male tigers kill greater numbers of domestic prey animals, even in areas where wild prey is available (Kolipaka *et al.*, 2017a). However, our studies do not reveal any significant increase of tiger kills in the neighbouring villages. In fact, tigers are known to be wary of people and avoid encounters with humans (Karanth and Gopal 2005).

We also offer an alternative explanation for the sub-adult tiger presence near villages using the “concept of naivety” amongst young carnivores (Kojola *et al.*, 2016). Kojola *et al.*, (2016) observed that young, sub-adult wolves approached areas close to human

settlements much more frequently than adults during the initial dispersal periods from the natal pack. However, with age, they changed this behaviour and avoided villages. The initial increase and subsequent decrease in sub-adult tiger presence near villages, especially among younger male tigers, may be due to the "naivety" of the sub-adult tigers. This decrease, however, should not be confused with the natural decrease that comes with the readjustment of home ranges as tigers age. Future research should focus on this "naivety hypothesis" in young tigers as they could become vulnerable to conflicts while in human-use areas. The reduced conflicts as a result of complete, partial, or even temporal avoidance of areas close to villages can have positive consequences for tiger survival. We see the decrease in tiger presence, over time, near villages in the PTR as a positive sign. While we know the risks to livestock from tigers using the areas near villages, the risks to human life and safety from tigers cannot be ascertained in this study because there have been no reported tiger attacks on people in the PTR. The low number of human attacks may also be a result of the high awareness amongst residents about carnivores and the prevailing traditional norms that regulate the presence of people (not domestic cows) in the forests of PTR after dark (Kolipaka *et al.*, 2015). In contrast, tiger attacks leading to injuries and even deaths of people are frequent in the buffer zone of the Bandhavgarh Tiger Reserve, which is just 300 km away from the PTR (Pers Comm: R. Sreenivasa Murthy). This difference is most likely as a result of people's awareness about tigers and people's use of shared areas. We hypothesise that a combination of factors, including peoples' practices, environmental factors, distribution of prey in the areas and the individual characteristics of tigers (sub-adult/adult, male or female) are better predictors of tiger presence near villages than one single factor. Overall tiger presence in the buffer zone also decreased during our 5-year study period. The observed initial increase and subsequent decrease in overall tiger presence in human-use areas are most likely because of dynamic shifts in individual tiger territories. As sub-adult tigers grow in age, some of them may reclaim territory and readjust their home ranges (Goodrich *et al.*, 2010, Chundawat *et al.*, 2016) and use less of the buffer zone. However, this change did not last long in PTR. A new, third generation of tigers was added to the population and new, sub-adult tigers moved into the human-use buffer zone and continued using areas near villages (TOI, 2016).

4.4.1 Tiger presence near shared water bodies

As expected, tiger presence near water bodies in the PTR was significantly higher in the hot summer months than during the winter and rainy seasons. Overall, tigers spent a quarter of their time in areas near water. Their prominence near water suggests the importance of this habitat to tigers. Recent ex-situ studies on tigers indicate that tigers benefit in several ways from access to water, including improved self-grooming, biological functioning through immersion, affiliative behaviours, ability to hide and beneficial interactions with their surroundings (Biolatti *et al.*, 2016). Tigers using the buffer zone spent less time near water during the summers than tigers using the core area. Tigers also spent less time near water when they were present in the livestock grazing areas. This situation did not improve during the study period (Figure 7). Tigers that moved further away from the periphery of the core zone are affected more than those that remained close, in this case, mostly sub-adult tigers and male tigers. We understand from the studies

on African lions that human and livestock activities in shared areas restrict lions from exploiting the resources in these places (Oriol-Cotterill *et al.*, 2015). We suspect that tigers in the PTR are also impacted by such human factors while using areas with human activity.

4.5 Concluding remarks and recommendations

In tiger reserves like the PTR, which are surrounded by human-dominated landscapes, the likelihood of sub-adult tigers and dispersing tigers using human-use areas is high. It is encouraging that adult tigers that breed and add offspring to the source pool – vital from a conservation perspective – show temporal partitioning while using human-use areas. However, sub-adults tend to approach villages readily, creating challenges for management. Over time, there was a decline in this behaviour. Second-generation tigers also reorganised their territories, and there was an overall decline in tiger presence in the buffer zone during our study period. However, a third generation of tigers was born in the PTR and they recolonised the human-use areas. This recurring pattern of new, sub-adult tigers moving into human-use areas is likely to continue. At this stage, it is unclear whether the presence of tigers in human-use areas increases risks to human safety or tiger survival, but higher livestock losses do occur. We give due warning in this regard that, left unaddressed, this situation has the potential to increase conflict between humans and tigers. To manage tigers in source pools like the PTR, which are surrounded by human-use landscapes, managers must invest in long-term conservation programmes aimed at encouraging changes to people's practices in such landscapes. This includes the use of corrals for cows, discouraging free grazing and dumping dead animal carcasses within designated areas and not in forests. The abovementioned activities are not compatible with multiple-use and will encourage tigers to kill unguarded livestock and approach the villages. By regulating people's use of the forests, the risks to people and livestock from tigers can decrease. Further, it will allow tigers to use water and feral cows within shared landscapes to their advantage. Finally, monitoring of sub-adult tigers that readily use areas near villages and marginal lands will be integral to tiger survival in human-use areas.

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Author Contributions

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Investigation: SSK.
Methodology: SSK WLMT HHI.
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Validation: SSK WLMT MZ HHI GAP.
Visualization: SSK WLMT MZ.
Writing- original draft: SSK.
Writing- review and editing: SSK WLMT HHI GAP.

A rock in shade is a day time resting spot for this sub-adult tiger and its mother. This photograph was made in the Talgaon area of Panna Tiger Reserve.

5 Wild versus domestic prey in the diet of reintroduced tigers (*Panthera tigris*) in the livestock-dominated multiple-use forests of Panna Tiger Reserve, India

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Abstract

Grazing livestock in openly accessible areas is a common practice in the multiple-use forests of India; however, its compatibility with the reintroduction of tigers to these areas requires examination. Here, we investigated the diet of tigers in a livestock-dominated multiple-use buffer zone of the Panna Tiger Reserve, India. We hypothesised that the presence of feral cows, along with open-access grazing practices in multiple-use forests, would increase the incidence of predation on livestock by tigers, even when wild prey are available. We used generalised linear models to test whether predation of livestock versus wild animals was influenced by (1) the sex and age class of tigers, (2) season, and (3) the distance of prey from the core-zone boundary of the reserve. Overall, sub-adult tigers and male tigers killed more livestock than wild prey, even when wild prey was available. In the winter and rainy seasons livestock were killed in higher numbers in the buffer zone than in summers, this may be because of the seasonally changing livestock herding patterns in the area. Further, with increasing distance from the core-zone boundary, all tigers killed more livestock, possibly because livestock were more easily accessible than wild prey. Our results show that open-access and unregulated livestock grazing is not currently compatible with large carnivore conservation in the same landscape. Such practices will lead to an increase in negative tiger-human-livestock interactions. In conclusion, we suggest the need to encourage locals to corral valuable cows, leaving feral/unwanted livestock for tigers. This simple strategy would benefit both local inhabitants and tiger conservation in the multiple-use forests of India.

5.1 Introduction

The successful conservation of carnivores outside of protected areas is hindered by human carnivore conflicts associated with livestock predation and attacks on humans (GTI, 2012). In many countries, livestock provide stable livelihoods and sustenance for people (Herrero

et al., 2013). However, when large carnivores inhabit the same landscapes that are also used by livestock, carnivores inevitably encounter and prey upon on livestock, as well as presenting a potential threat to people. Ultimately, the magnitude of livestock losses and ability of people to cope with such losses shapes their willingness to share the landscape with carnivores (Thirgood *et al.*, 2005; Thorn *et al.*, 2012). Therefore, it is essential to minimize the incidence of predation where possible and ensure human safety to manage and successfully protect threatened carnivores in shared landscapes.

There are approximately 3000 tigers (*Panthera tigris*) left in the wild, and their numbers are still declining, despite sustained conservation efforts (GTI, 2012). There are global efforts to safeguard the future survival of this iconic species in the wild. The forests of India support over 50% of the world's remaining wild tiger population; thus, these areas are important for the future survival of tigers. At present, wild tigers mostly inhabit protected tiger reserves in India, where human presence and activities are limited (Miller *et al.*, 2015). However, to safeguard their future, networks of corridors have been proposed between tiger reserves, allowing free movement of tigers among protected areas, and access to a larger landscape with suitable habitat for population recovery (Waltson *et al.*, 2010).

India retains large tracts of government-controlled forests that extend beyond most protected tiger reserves. Within these forests, economically poor rural people pursue traditional livelihoods, collecting forest produce, such as fuel wood, fodder, timber, resins, fruits, and roots, in addition to grazing their livestock (Talwar and Gathe, 2003). For example, the per capita income of people living in the Panna district of Madhya Pradesh, India, where the Panna Tiger Reserve (PTR) is located is 523 US $ (or 31,389 Indian Rupees) (NIC 2017). The rural people living in the 42 villages in the buffer zone of the PTR keep approximately 25,000 cows, 5000 domestic buffalo and 15,000 goats (Srivastava, 2014). Cows are mostly kept for sustenance and provide vital protein in the form of milk to rural residents. Buffalo can be purchased for 500 US $/individual (or 30,000 Indian Rupees) and reared for its high-fat milk, which is sold. Goats are bred for meat, and are valued at approximately 30 US $ (2000 Indian Rupees) for a 10 kg male goat. Local people have traditional rights to access multi-purpose forests, with their activities mostly controlled through informal community-level norms rather than regulated by formal government authorities (Kolipaka *et al.*, 2015).

However, the park management body has no control on how many cows, whose cows, or where the cows are grazed in the buffer zone forests. Such unchecked grazing in multiple-use forests by local communities and poor regulation of forest use is widespread in India. People's use of forests can have both costs and benefit for carnivores using the same area (Banerjee *et al.*, 2013; Kolipaka *et al.*, 2015; Kuiper *et al.*, 2015; Linnell *et al.*, 1999; Sharma *et al.*, 2015). For instance, poor livestock husbandry practices increase their vulnerability to predation (Kuiper *et al.*, 2015; Linnell *et al.*, 1999; Miller *et al.*, 2015; Rajaratnam 1999). Furthermore, the unchecked and unregulated use of forests decreases the quantity and quality of habitat available for wildlife (Ramakrishnan *et al.*, 1999; Erb *et al.*, 2016) and local communities (Erb *et al.*, 2016). Consequently, poor regulations in

shared landscapes make it difficult to enforce sustainable natural resource management that also benefits wildlife (Talwar and Ghate, 2003). On the other hand, people's practices could also have positive benefits on carnivores. For instance, over 2,500 cows perish each year from disease, predation, and seasonal extreme weather conditions in the 42 buffer zone villages of the PTR (Srivastava, 2014). Villagers dump cow carcasses at the village-forest fringes, where they are easily accessible as carrion for many carnivores (Kolipaka *et al.*, 2015). Striped hyenas (*Hyaena hyaena*), village dogs (*Canis familiaris*), wild pigs (*Sus scrofa*), jackals (*Canis aureus*), and raptors (e.g., vultures) opportunistically feed on these carcasses and thrive (Kolipaka *et al.*, 2015). Large carnivores, like leopards, persist in highly modified farmland by killing available wild and domestic prey, like pigs and dogs (Athreya *et al.*, 2013). Wolves (*Canis lupus*) also survive in the heavily degraded forests of central and western India by predating and scavenging on available wild and smaller domestic animals (Jethva and Jhala, 2004). However, it remains unclear to what extent tigers exploit livestock in multiple-use zones, and to what extent tigers might be dependent on domestic animals to expand into habitat beyond the boundaries of protected areas (Athreya *et al.*, 2013). Yet, such information is required because the Indian authorities plan to extend tiger conservation to create corridors beyond the reserves into these tracts of forests that are widely used by local communities.

The endangered tiger is a conservation dependent species (GTI, 2012). From the perspective of recovering the tiger population, tigers need to expand beyond the confines of the protected reserves to maintain a strong gene pool and avoid local extinctions of the source population (Kenney *et al.*, 2014). Therefore, both male and female tigers need to survive when outside protected reserves to facilitate population recovery. Here we investigate the case of tigers from PTR, where they became locally extinct during 2008 and were reintroduced into the same livestock dominated environment in 2009. The growing population of reintroduced tigers enter the adjoining multiple-use buffer zone where thousands of livestock graze, along with over 9000 feral cows (Chundawat *et al.*, 2008; Kolipaka *et al.*, 2015; Sarkar *et al.*, 2016). With this, the compensations paid for livestock losses by PTR management are also increasing (see the compensations records presented in (S3 Table). Tigers prey on large and intermediate bodied prey animals Bagchi *et al.*, 2003; Hayward *et al.*, 2012; Kerley *et al.*, 2015; Reddy *et al.*, 2004; Sankar and Johnsingh, 2002). Thus, understanding how people and tigers interact in this landscape might provide conservation planners with important management insights for tiger conservation in livestock dominated landscapes. We hypothesised that the presence of feral cows, along with open-access grazing practices in multiple-use forests, would increase the incidence of predation on livestock by tigers, even when wild prey are available.

We examined kill data belonging to a group of radio-collared tigers inhabiting the PTR and we collected tiger scats in the multiple-use forest. We used generalised linear models to test the wild and domestic prey killed in relation to: (1) sex and age of tigers, (2) season, (3) the distance from the core-zone boundary of the reserve, and (4) water bodies. We expect our results to provide insights on livestock predation and management options to reduce tiger predation on livestock and facilitate the coexistence of people and tigers in multiple-use landscapes.

5.2 Methods

5.2.1 Ethics statement

Field data collection permits were issued by the Chief Wildlife Wardens Office of Madhya Pradesh Forest Department, India to S. S. Kolipaka. Permit Number: 4029/9-6-2015. Data on tiger kills was obtained from the records of Panna Tiger Reserve, issued to S. S. Kolipaka under a mutual agreement. Permit Reference: Proceedings of the meeting 02.06.2014".

5.2.2 Study area

Our study was carried out in the PTR (24° 274' N to 24° 905' N latitude; 79° 556' E to 80° 273' E longitude), which is a protected area that is located in the Bundelkhand region of north-central Madhya Pradesh, India. The reserve covers a 1645 km area and is divided into two management units, a core zone and a multiple-use buffer zone (Fig 1). The core zone is 550 km, while the buffer zone is 1095 km. Human activity is restricted and natural resource extraction is prohibited in the core zone, whereas the buffer zone is a multiple-use zone. The tiger reserve is approximately 30 km at its widest (range: 10 to 30 km) and approximately 100 km in length (Fig 1), and is surrounded by multiple-use and human-dominated lands.

5.2.3 Traditional livestock management practices

Human presence and activity is high up to a 2 km distance from the centre of the villages during the daytime (07:00 to 17:00), with activity dropping between dusk to dawn (17:00 to7:00). Water is a scarce resource in the study area, with reliable water bodies being limited. Consequently, people must share the same water bodies with their livestock and wildlife. Herders graze livestock up to a distance of 5 km from the village centre, with travel distances being highest during winter and rainy season to access good grazing sites and to keep cows away from crops in the fields. This reverses in the summer months when temperatures get extremely hot and because livestock can also graze in fallow agricultural fields in villages. We examined the response of tigers using the buffer zones to these conditions near villages and water bodies.

5.2.4 Distribution of livestock in the PTR

The presence and distribution of livestock in PTR are influenced by local husbandry strategies and prevailing cultural practices (Kolipaka *et al.*, 2015; Santhoshi 2016). Consequently, livestock that graze in the forests of the PTR buffer zone are grouped into three categories: (1) feral cows, (2) cows that are owned but are not economically valuable, e.g., for commercial milk production (3) valuable buffalos and goats that are economically valuable, e.g., for milk and goats for meat. First feral cows, both females and males. Second, owned native cows, lacking village grazing lands, villagers drive several thousands of cows to graze in the forests of PTR, mostly during the winter and monsoon farming seasons. Such cows graze in the forests unaccompanied by herders during the day

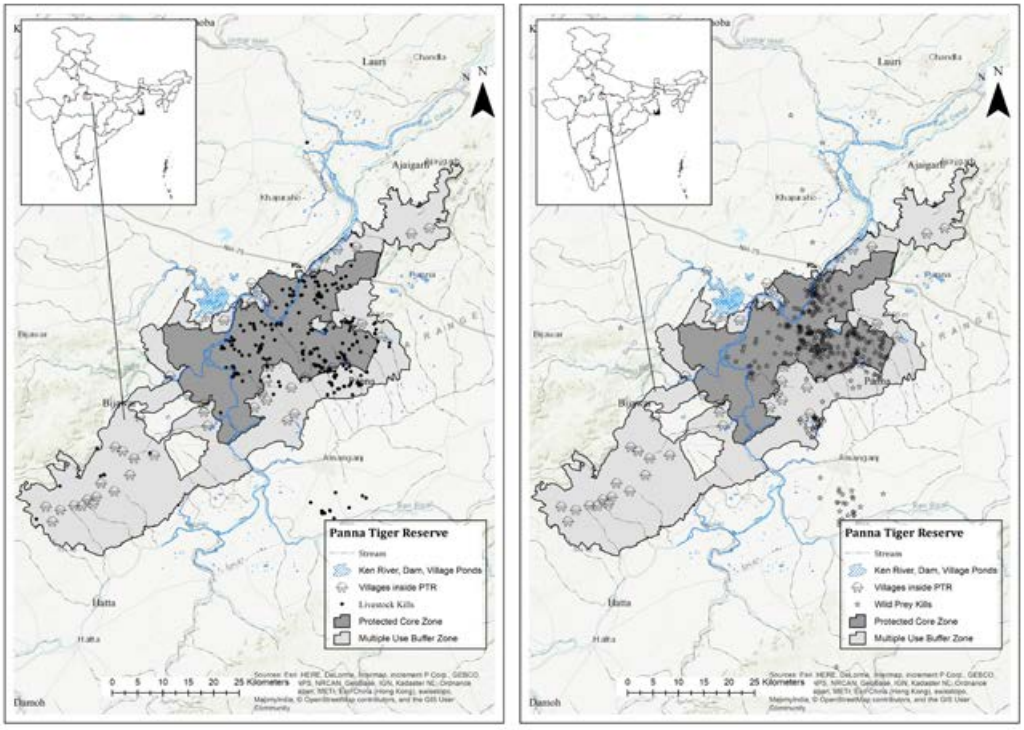

Fig 5.1 Map of the study area, the Panna Tiger Reserve. The dots (left) and stars (right) represent the spatial location of livestock and wild prey animals killed by 9 radio-collared tigers between 2009 and 2014.

and aggregate near the village fringes at night. Most native varieties of cows do not yield sufficient milk; thus, they are not considered economically valuable by villagers. Yet people keep them because of religious sanctions that prohibit selling cows to tanners (Kolipaka *et al.*, 2015). Third, valuable livestock that provide livelihoods for people, including milk yielding cows, and buffalos and goats. These valuable animals are herded during the day and are corralled at night.

5.2.5 Study tigers

Over 20 terrestrial mammalian carnivores have been documented in the core and buffer zones of the PTR. Large terrestrial carnivores (>20 kg body weight) include the tiger, leopard, Indian wild dog or dhole (*Cuon alpinus*), wolf, striped hyena, sloth bear (*Melursus ursinus*), and domestic dog (Chundawat and Sharma, 2008). The tigers are part of a reintroduction project that commenced in 2009. Six founder tigers, which were reintroduced between 2009 and 2013 (5 ♀ and 1 ♂), and 4-second generation tigers (1 ♀, 3 ♂; born between 2010 and 2011). All 6 founder tigers and 6 of their offspring have been fitted with VHF radio collars by reserve authorities. Details of this equipment are provided by Sarkar *et al.*, (2016). PTR tiger monitoring teams working in three 8-h shifts

followed radio-collared tigers each day using a handheld VHF antenna between 2009 and 2014. The teams were tasked with recording the spatial locations of the tigers on an hourly basis. Following the signals from the transmitters, members from the monitoring team located individual tigers and homed-in. Tigers spent considerable time near carcasses and, whenever opportunity permitted, members from the team visually inspected kills after the animals left the carcass, recording details about the kill. Monitoring teams successfully recorded large bodied animal carcasses, but most of the carcasses of intermediate and smaller sized prey were either dragged deep into the thickets or were completely eaten by the tigers. Since we were more interested in livestock kills, the collected dataset provided sufficient information that was also reliable. The collected data were manually recorded into books maintained separately for each tiger and, where possible, photographs were taken. Recorded information on kills included the spatial locations of the kill, prey species, age group, and sex of prey. A small percentage (3%) of the kills could not be identified to the species level because carcasses were destroyed too much during the kill and subsequent feeding. Such information was excluded from the final analyses.

5.2.6 Categorisation of tiger kills

We classified potential mammal prey into 3 size-based categories: large (>150 kg), intermediate (20±149 kg), and small (<19 kg). Potential large sized prey animals included the sambar deer (*Rusa unicolor*), nilgai antelope (*Boselaphus tragocamelus*), domestic cow (*Bos taurus*), and domestic water buffalo (*Bubalus bubalis*). Potential intermediate sized prey included the young of sambar deer, nilgai and cows, chital deer (*Axis axis*), wild boar, chinkara antelope (*Gazella bennettii*), and four-horned antelope (*Tetracerus quadricornis*). Potential small-sized prey included the plains grey langur (*Semnopithecus entellus*), the domestic pig, goat, and domestic dogs (IUCN, 2015).

5.2.7 Analysis of scats

We collected tiger scats from the buffer zone during 2015 to investigate the presence of small prey that might be poorly represented by kill data. Since scats and kills were from different years, we did not include scats analysis here, but we did use the findings to support kill data as a validation technique. For details, see Table A in S2 Table.

5.2.8 Statistical analysis

We considered depredation rates (domestic versus wild) in relation to 3 landscape characteristics: management zone (core versus buffer zones), within and beyond 2 km of villages, and within and beyond 250 m of water sources. In the first analysis, prey (domestic or wild) was the dependent variable, while zone (buffer/core), generation (first generation = mature adults; second generation = young adults) and sex (male/female) of tigers, and season (summer, rainy, winter) were included as independent variables. In the second analysis, we included “Distance”, which was the distance from the core zone boundary to kill location and ªnear villagesº (inside/outside 2 km of villages, which are high human density areas) as independent variables. In the third analysis, we used

"water" and "near water" (inside/outside 250 m of water body) as the independent variables (rather than those of village). All analyses were performed using generalised linear models (GLMs) in R 2.12.0 (R Core Team 2013). Adequate model fits were ensured by the stepwise removal of non-significant (significance $p < 0.05$) three-way and two-way interactions. We optimised the model based on all main effects and by only using the three -way and two-way interactions that were significant (See S1 Table for coefficients and the model selection procedure).

5.3 Results

5.3.1 General diet

Our final analysis included 627 kills from 10 tigers (6 ♀ and 4 ♂) collected over a 5-year period between 2009 and 2014. Tigers primarily preyed on large and intermediate sized wild and domestic prey animals in the PTR (Table 1). Wild prey represented 54% of all kills made by tigers, while domestic prey animals represented 43%. Sambar deer represented 70% of all wild prey that were killed. Cows represented 87% of all livestock killed (Table 1). Small sized prey animals (like reptiles, birds, and mongoose) represented <5% of the tiger diet, and were better represented in tiger scats compared to carcass counts; however, large prey were also predominant in scats. As a result, scat analysis was used only used to validate the presence and quantity of small prey in the tiger diet.

Table 5.1. Wild and domestic prey species killed by 10 radio-collared tigers in the core and the multiple-use buffer zones of the PTR between 2009 and 2014.

Prey Species	Prey Type	Average body weight of prey (Kg)	Body size category	Total Kills	% Kills	Kills in BZ	% Kills in BZ
Cow (Feral + Domestic)	D	150	L	243	37.56	86	51.8
Sambar Deer	W	136	L	245	37.87	52	31.3
Nilgai	W	182	L	49	7.57	15	9.0
Domestic Buffalo	D	150	L	35	5.41	0	0
Sloth bear	W	70	In	2	0.31	0	0
Leopard	W	45	In	3	0.46	0	0
Cheetal deer	W	47	In	21	3.25	1	0.6
Wild Pig	W/D	45	In	29	4.48	4	2.4
Dog	D	20	In	0	0	**	**
Goat	D	10	S	1	0.15	**	**
Reptile	W	2	S	0	0	**	**
Bird	W	2	S	1	0.15	**	**
Mongoose	W	1.5	S	0	0	**	**
Unrecognised		NA		18	2.78	8	4.8
Total				647	100.00	166	100.0

D = domestic; W = wild; L = large (>150 kg); In = intermediate (20–149 kg); S = small (<20 kg); BZ = buffer zone;
(**) = Represented by scats only and not kills (see supplement for more details); The average weight of the domestic cows and buffalos is less as they are native varieties and have a small structure compared to dairy cattle.

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5.3.2 Predation in relation to the core and buffer zone

Livestock represented 57% of prey animals killed by tigers in the multiple-use buffer zone. In comparison, 40% of animals killed in the core zone were domestic. Male tigers killed a higher percentage of livestock in both the zones (66% and 79% in the core and buffer zone, respectively) than female tigers (29% and 39% in the core and buffer zone, respectively) (Fig 2; Table B in S2 Table). However, a similar proportion of male and female domestic prey was killed in the core and buffer zones (Fig 2). There was seasonal variation in the number of domestic prey animals killed by tigers in the core and buffer zones. In the core zone, tigers killed a higher percentage of domestic prey animals (66%) during the summer months, with this percentage dropping in the rainy and winter seasons. In the buffer zone, this situation was reversed, with tigers killing more domestic prey animals during the winter (73%) and rainy season (59%), and fewer in the summer (Fig 3).

5.3.3 Predation incidents near areas of high human activity in the buffer zone

Twenty-five percent of all kills made by tigers were within 2 km of villages. In these areas, tigers killed both domestic (52%) and wild animals (43%). However, proximity to villages was not statistically significant for predation, whereas distance from the core zone was significant (S1 Table). The predation of livestock increased with increasing distance from the core zone boundary to areas in the buffer zone (Table E in S2 Table). Male tigers killed more (N = 57) livestock than females (N = 39) up to a distance of 10 km from the core zone.

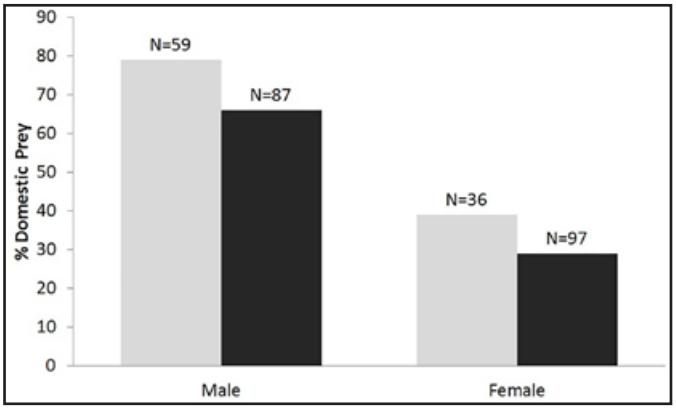

Figure 5.2 Percentage of livestock killed by male and female tigers in the core (black bars) and buffer (grey bars) zone of the PTR between 2009 and 2014. There was a significant interaction between sex * zone (df = 2, $p < 0.05$), with similar proportions of livestock being killed in core and buffer zones by males and females.

At 10 km beyond the core zone, males and females killed similar proportions (Male (N = 27), Female (N = 28) of livestock (Fig 4). Tigers killed more livestock with increasing distance from the core zone during the rainy and winter seasons. The proportion of domestic animal kills in each season differed for each distance group from the core (Fig 5).

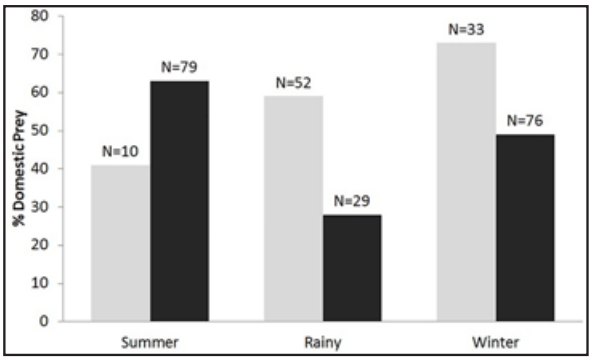

Figure 5.3 Percentage of livestock killed in the core zone (black bars) and buffer zone (grey bars) of the PTR by tigers during different seasons. There was a significant interaction between seasons * zone ($p = < 0.001$), with the proportion of livestock killed in the buffer being highest during the rainy season.

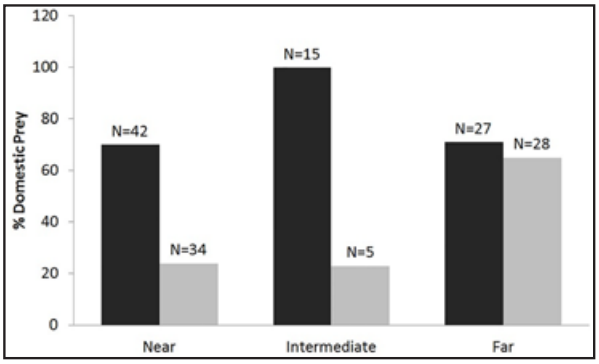

Figure 5.4 Percentage of livestock killed by male (black bars) and female (grey bars) tigers increased with distance from the core zone of PTR. At >10 km distance from the core zone, males and females killed livestock in similar proportions, with this result being statistically significant ($df = 2$, $p = < 0.001$).

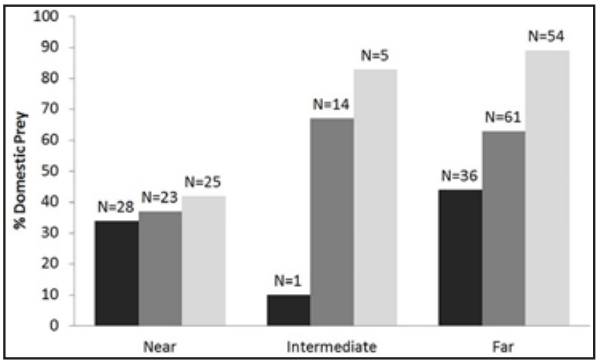

Figure 5.5 Percentage of livestock killed by tigers during the summer (black bars), rainy (dark grey bars), and winter (light grey bars) seasons with increasing distance from the core zone. The proportion of livestock killed doubled at >2 km distance from the core during the rainy and winter seasons ($df = 4$, $p = 0.006$), but remained low during the summer.

Twenty-nine percent of prey killed by tigers was near water (<250 m of water). Domestic and wild prey represented 45% and 52% of kills, respectively. However, there was no significant difference in the incidence of predation at <250 m and >250 of water bodies.

5.4 Discussion

This study demonstrated that tigers primarily fed on large-bodied prey, including both domestic and wild animals. Livestock were preferentially preyed upon with increasing distance from the protected core zone. Of note, female tigers primarily fed on wild prey when closer to the core zone, whereas male tigers targeted both domestic and wild prey. However, the proportion of domestic prey killed by males and females in core and buffer zones was comparable. Furthermore, seasonally changes in the distribution of livestock, reflecting seasonal variation in practices and livestock management, influenced the predation rate of livestock by tigers in the core and buffer zones. Our results demonstrate that open-access livestock grazing is not currently compatible with large carnivore conservation in the same landscape. However, our results also provide important information that could help reduce negative tiger-human-livestock interactions in the livestock-dominated buffer zone of the PTR.

5.4.1 Prey items of tigers

Supporting previous studies, the tigers in the livestock-dominated PTR primarily preyed upon large and intermediate sized prey species (Bagchi *et al.*, 2003Karnath and Sunquist, 1995; Kerley *et al.*, 2015). It is likely that our estimates based on kills alone underestimate the contribution of intermediate and small-sized prey, as demonstrated by our scat analyses (see supplementary material), and should be interpreted with caution. Our independent analysis of tiger scats validated that large animals represented the largest component of prey items; however, more small prey items were detected using this technique. Sambar deer and cows represented the wild and domestic prey animals, respectively, that were primarily killed by tigers, supporting the results of previous studies Chundawat *et al.*, 1999; Sankar and Johnsingh, 2002). Unlike cows, buffalos tend to be accompanied by herders in our study area and are corralled at night (Kolipaka *et al.*, 2015). The better herding and corralling practices extended to buffalos might explain the low losses of buffalo in comparison to cows. Our results show that the contribution of livestock to the diet of tigers was much higher in our study area compared to other geographically similar sites, where livestock is also predominantly found (Chundawat *et al.*, 2004; Reddy *et al.*, 2004). However, similar levels of livestock predation have been detected for lions (*Panthera leo*) in similar livestock dominated habitats of western India (Banerjee *et al.*, 2013). The high predation of livestock by tigers in our study area is probably because of local livestock management practices. For instance, villagers follow a traditional practice called Anna Pratha. In this practice, villagers that cannot fend for their cows during periods of stress (such as droughts) release their animals to fend for themselves or allow them to die out of sight (Santoshi, 2016). As a result, thousands of feral cows and herder less domestic cows move inside the reserve area (Chundawat and Sharma, 2008).

5.4.2 Predation in relation to the protection zones

Overall, distance from the core zone boundary significantly explained the predation of domestic prey animals. More livestock were killed in the buffer zone than in the core zone of the PTR. The large number of wild animals killed near the core zone boundary was because of the availability of wild prey in these areas, and also because wild prey frequently raid crops in agricultural fields near peripheral areas (Karanth *et al.*, 2012). Of note, more livestock were killed in the core zone during the summer, and vice versa during the rainy and winter seasons. Locally prevailing ecological conditions shape the movements of tigers (Chundawat *et al.*, 2016) and livestock in the core and buffer zone, and probably influence predation rates. During the hot summer months, herders do not move their herds far from villages. They also allow livestock to graze on low-quality forage that is available in fallow agricultural fields. In comparison, feral and un-herded cows move into the core zones to access better grazing and water sources. These movement patterns are reversed during the rainy and winter seasons.

Tigers, especially males, killed more livestock with increasing distance from the core zone boundary (up to 10 km), supporting that reported by Karanth and Sunquist (1995). In contrast, female tigers killed more wild prey animals than domestic prey animals in the Core zone. Female tigers might preferentially target wild prey because they raise their young in the core zone and tend to have smaller home ranges than males. Thus, females probably choose areas that are far from human activity and where they are more likely to encounter wild prey. In contrast, males and young tigers move further afield and encounter more domestic prey.

5.4.3 Predation in relation to villages and water bodies

Unexpectedly, predation near villages and water bodies in the multiple-use buffer zone was not significant. In other words, the incidence of tiger predation did not appear to increase near villages or water bodies, due to the presence of livestock. This result was interesting, especially because the presence of tigers was significantly high near villages but low near water bodies in the buffer zone, at least based on our unpublished data of the spatial movement patterns of tigers. However, the high presence of tigers did not translate into more killings. Our findings show that tigers spend considerable time near villages. It is likely that tigers are attracted to villages by people's activities (such as dumping cow and buffalo carcasses near village fringes), un-corralled cows aggregating near villages at night, wild prey entering agricultural fields, and the presence of water bodies near village peripheries. However, as observed for lions in Kenya Oriol-Cotterill *et al.*, (2015), tigers might not be able to fully utilise the available resources near villages or water bodies, where human presence and activity are high, while still continuing to use other parts of the human-dominated landscape. For instance, our study showed that livestock were preyed upon in greater numbers in other parts of the buffer zone and not necessarily near villages.

5.4.4 Management suggestions

Our study showed that local practices, leading to the presence of livestock (feral and owned) throughout the multiple-use area, exhibit both costs and benefits to tigers using such areas, supporting the findings of Sharma *et al.*, (2015). Livestock are important to people's culture, livelihood, and well-being in India, as well as in most rural areas of the world. Consequently, livestock grazing will continue to remain a major land-use type in multiple-use landscapes, characterising such landscapes. Therefore, it is important to develop ways to decrease the predation of livestock by carnivores requiring conservation in multiple-use landscapes. Our results clearly show that free-for-all livestock grazing is not compatible with large carnivore conservation in the same landscape. Such practices will cause negative tiger-human livestock interactions to increase, particularly as the government is implementing initiatives to increase the size of the tiger population (Wikramanayake *et al.*, 2011). From the management perspective, this issue generates the need to consider new management options for tiger conservation in multiple-use landscapes. For instance, if the observed livestock management practices are widespread and commonly practised by thousands of people (like in the study area), attempting large-scale changes to people's practices is not a viable option. Instead, reserve management must innovatively model certain local practices to suit tiger conservation. For instance, as observed in the study area (Kolipaka *et al.*, 2015), many rural societies have traditional belief systems and norms that regulate their use and movement in forests. Likewise, people also have taboos towards hunting wild animals like nilgai and pigs that are potential prey of tigers (Kolipaka *et al.*, 2015). These traditional practices reduce direct encounters between people and dangerous wildlife, including tigers, and also safeguard the prey of tigers (Kolipaka *et al.*, 2015). By incorporating some of these traditional practices into management plans, managers might be able to retain existing levels of low interactions between people and tigers. Furthermore, not all livestock predation incidents generate conflict with humans. Tigers might actually be providing a service to local communities by predating and regulating feral and unwanted animals. For instance, educational programs could be used to inform local communities about how tigers target prey items to encourage them to corral valuable cow and buffalo and leave feral/unwanted livestock for tigers. Local communities could establish ways to separate valuable village cows and buffalos from feral and unwanted cows and buffalos by means of tattoos or markings. In addition, fenced grazing zones could be set up for valuable livestock, restricting their movement in the forests. This simple strategy would benefit both local people and tiger conservation in the multiple-use forests of India, Particularly in light of managers planning to implement corridors to connect protected areas to increase the gene flow among tiger populations.

5.5 Conclusions

This study provides novel insights into the prey choice of tigers in a human-dominated landscape with potential overlap between wild and domestic animal prey. While tigers were more likely to prey upon livestock with increasing distance from the core protection zone, we found no evidence that tigers kill more prey animals near villages or near shared water bodies. Thus, feral and free-roaming village cows and buffalos represent key targets for some tigers. In conclusion, for tigers to persist in multiple-use landscape, concepts that incorporate the needs of both wildlife and people must be implemented, rather than unregulated free-for-all land use.

Supporting information found in the on-line repository

S1 Table. Coefficients for analysis (1) Zone, (2) Village, (3) Prey age, (4) Prey Sex, (5) Water and (6) Scat and Kill.
S2 Table. Details of data analysis.
S1 Fig. Compensation amounts paid to livestock owners by PTR management between 2009 and 2014.
S1 Text. Climate, geography, vegetation and the practice of Anna Pratha in the study area.

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A tiger is worshiped by a group of villages near Bandhavgadh tiger reserve, Madhya Pradesh. (Photo by Vijaybhan Singh)

6 Synthesis: Human-tiger coexistence

6.1 Introduction

Tiger conservationists have long supported the notion that the tiger's (*Panthera tigris*) future survival in the wild is dependent on its ability to successfully coexist with humans outside protected areas (Sanderson *et al.* 2006; Walston *et al.* 2010; Wikramanayake *et al.* 2011). The tiger is on the IUCN Red List of Threatened Species and its current population is mostly restricted to isolated protected areas of Asia and Russia (Goodrich *et al.* 2015; IUCN 2017). Most protected areas, on their own, are not sufficient to support the large home ranges and high metabolic needs of the tiger and sustain a viable population (Ramakrishnan *et al.* 1999; Chundawat *et al.* 2016). As an alternative solution, tiger conservation is envisaged in larger landscapes comprising connected networks of protected reserves, multiple-use forests and private lands (Karanth and Gopal 2005; Ranganathan *et al.* 2007; Wikramanayake *et al.* 2011). However, people also live and use lands in the proposed tiger landscapes, and so the tiger must share the same lands and available resources to survive successfully. There is a general belief that the tiger's presence outside protected areas is a recipe for disaster. This is because, people and tigers compete for the same resources, and tigers can attack people and kill their livestock (Madhusudan 2003, 2015). Such negative interactions are thought to trigger people-tiger conflicts and create barriers to tiger conservation efforts (Woodroffe *et al.* 2005; Karanth *et al.* 2012). For these reasons, the ability of people and tigers to co-adapt and coexist is critical for their successful conservation in shared lands (Carter and Linnell 2016). In my study, titled 'Can large carnivores survive in human-dominated landscapes of India?', I investigated the mechanisms that allow people and tigers to successfully co-adapt and coexist in human-dominated lands and used both social science and natural science approaches to study such adaptation. The methodologies adopted to assess the human dimension aspects in this study were ethnography, respondent interviews and observations and they are grounded in values-belief-norm theory (Stern *et al.* 1999). Taking this approach allowed me to develop understanding about the interlinked sociocultural, political and economic factors shaping and influencing local people's views, attitudes, behaviour and practices relevant for coexistence with tigers. By contrast, the tigers were studied by assessing their spatial behaviour using VHF radio collars and by using carcass counts and faecal hair samples collected from human-use areas to review their diet. The combined information is then synthesised and presented to answer the main questions raised in my study:

1) How do people's beliefs and practices influence tiger conservation?
2) What factors influence tiger predation of livestock?
3) How do tigers use space in human-dominated lands?
4) What is the diet of tigers in such shared areas?

My study reveals that people and tigers can share space and coexist with minimal conflict. The principal mechanism underlying the observed coexistence scenario is the ability of humans and tigers to co-adapt, and it is two directional. Such co-adaptation includes:
1) people's ability to cope with the psychological fear of the tiger.
2) People's capacity to avert personal injuries and prevent losses of valuable livestock.
3) The ability of tigers to use space and find suitable prey in human-use lands with minimal conflict.

This chapter examines coexistence in the context of theory and empirical findings and looks at both the human dimension and the ecological aspects relating to the tiger and how these are associated with *co-adaptation* in shared lands. The first section outlines a sociocultural perspective that serves as a framework for examining research findings relevant to coexistence. Notably, the conceptual perspective postulates human adaptation rather than separation from dangerous animals. In line with this position, the second and third sections present conceptual and research findings on people's adaptation to the fear of the tiger and real threats (human attacks and livestock kills). The fourth section discusses the conceptual arguments and empirical research findings related to tiger responses to human presence and activity in an area: avoidance responses, spatial and temporal shifts in activity and finding prey. The final section considers research that would further expand our understanding of drivers of coexistence and suggests research approaches that may shed empirical light on the co-adaptation of people and tigers for successful coexistence.

6.2 A sociocultural perspective on the fear of living with dangerous animals

In some societies, tigers are viewed as godly, spiritual and mystical creatures and evoke feelings of fear within people that is comparable to people's fear of the divine, of the supernatural, of God (Hiltebeitel 1978; Canda 1981; Bakels 1994; Mao 2009; Heneise 2016). In others, people fear the tiger as an animal that attacks people and kills livestock and regard it as a problematic animal capable of creating panic, disrupting normalcy and causing death (Carter *et al.* 2012b; Miquelle *et al.* 2005). While most humans fear the real and the metaphorical tiger and view it as a powerful animal capable of killing a person, there are variations in the way people construct the meaning of the source (instigator) of the fear and the event (attack). While some see the threat as a supernatural manifestation that they have little or no control over, others see the threat as a natural one, i.e. a flesh-and-blood tiger (Bakels 1994; Carter *et al.* 2012b).

People's fear of the tiger is natural and innate. Ulrich (1993), in his study on *biophobia*, meaning 'the fear of living things', suggests that the human feeling of fear for objects in the natural world is inherent. This natural fear is interpreted as an evolutionary mechanism that may have assisted in human survival. Ulrich (1993) suggests that *biophobia* has its grounding in genetics and evolutionary theories and may have developed within people because of negative information or unpleasant past experiences with

dangerous animals. Examples are the natural human aversion to potentially dangerous animals such as crocodiles and snakes, dangerous predators or avoiding forests after darkness.

Other arguments for the human fear of dangerous carnivores (relevant for coexistence), as reported by Chapron *et al.* (2014) and Pilgrim *et al.* (2008), are based on people's disconnect with nature and their fear of economic repercussions. Agrarian societies, semi-urban and urban societie, for example, have distanced themselves from the wilderness and may have lost the adaptation to coexist with dangerous wildlife (Chapron *et al.* 2014). Furthermore, those communities who are highly dependent on their livestock or have changed their animal husbandry practices to new production structures are not willing to tolerate losses from tigers (Chapron *et al.* 2014). Here, the economic consequences and potential harm to people are overpowering, and people perceive the tiger as a pest. Ultimately, the natural fear, loss of adaptation to coexisting and the fear of economic losses all evoke feelings of fear and hostility towards the tiger and people are known to respond to such threats by retaliating or objecting to tiger conservation in areas they use.

Based on my findings, I agree with Bhagwat and Rutte (2006) and Simaika and Samways (2010) that, in many prevailing societies, traditional cultures are still intact and continue to shape the way people live in harmony with nature, including the tiger. Authors such as Berke *et al.* (2000) and Gadgil *et al.* (2003) also refer to the untapped potential of local ecological knowledge within rural communities. As my study shows, local cultures that promote harmony with nature and support the transfer of ecological knowledge from one generation to the next, most likely, support relatively tolerant attitudes towards nature and wildlife. Like the spirit sites that I mentioned in Chapter 2, Ulrich (1993) in his study of *biophobia*, drew attention to the temples people construct for worshipping snakes in India. The psychological impact of worshipping and conducting rituals to snake gods or the spirits of tigers is thought to be a coping process and reduces anxieties associated with a dangerous creature. In Chapter 2, I also elucidate, by way of a case study, how local beliefs and norms guided people's use of forests and shaped their attitudes and behaviours towards wildlife. For instance, residents, over the years, built numerous spirit sites scattered throughout the forests and believed that powerful spirits rest near those sites. They believed that wild animals would not harm them or their livestock while they were near such sites and may be experiencing the placebo effects of the belief-in-faith that Kohls *et al.* (2011) and Vance (2016) described. The forest trails they used frequently crossed these spirit sites, and the proximity to the sites instilled a sense of security in most people while moving in the forests. To ensure the continued protection of the spirits, people periodically stopped near sites and made sacrifices and offerings. They rested near sites, but did not disturb the character and sanctity of these places. Their actions have multiple implications: First, they reduce anxieties about dangerous animals while in the forest. Second, people showed high tolerance of animals as they believed animals were also protected by the spirits. Third, people followed the community norms near spirit sites and did not pollute these areas. As my results show, the wide scale of these local practices in my study region, coupled with the practical and intrinsic benefits people derived from

their practices, influenced their willingness to coexist. These arguments, which I describe in Chapter 2, are undeniable and highlight that some communities have developed and currently maintain traditions and local institutions that guide their interaction with the natural world and foster coexistence.

In addition to beliefs and norms influencing perceptions of fear, my findings also show that resident livestock owners encountered animals frequently and, at the same time, exhibited high levels of local ecological knowledge about carnivores and their habits. My findings support those of Roskaft *et al.* (2003) and Loe and Roskaft (2004), i.e. that the negative experiences and lack of knowledge about wild animals increased perceived fear of these animals in humans. For instance, between 2009 and 2013, the management of the Panna Reserve recorded six fatal attacks by sloth bears on people. In contrast, there have been no recorded attacks by tigers in the last 20 years in the study area. I explained in Chapter 2 how my survey findings on the threat perceptions of local livestock owners showed that people viewed the sloth bear as a greater threat and a more dangerous animal to human safety than the tiger. Seventy per cent of the interviewed households did not see the tiger as a threat. Similarly, greater familiarity and knowledge about the habits of the wolf influenced people's perceptions that the wolf is a threat to livestock and not human safety.

Thus, there are divergent views on factors that shape people's interactions with nature and fear of the tiger. The fear that people have of the tiger need not necessarily translate into a confrontation with the tiger or oppose people promoting tiger conservation. There is substantial evidence that rural communities living within the proposed tiger landscapes in India still follow traditional ways of life and their local cultures, practices and local knowledge provide functional support that helps them cope with the fear of the tiger (Kolipaka *et al.* 2015). Such mechanisms are often referred to as a traditional conservation ethic in literature and are known to have favoured wildlife in India (Berkes *et al.* 1995; Berkes *et al.* 2000). Therefore, the arguments suggesting that fear alone will create permanent barriers to all tiger conservation outside protected areas are not convincing.

6.3 Findings on people's ability to avert personal injuries and prevent livestock losses

The most convincing current arguments against people's ability to cope with the real threat of the tiger come from the reasoning that tigers can attack people and kill livestock. What if tigers are reintroduced into areas where they are currently extinct? What if people have lost their coping mechanisms? For instance, "Elephants and tigers kill one human a day in India," reported India's *Hindustan Times* on 1 August 2017. Tigers killed 92 people and elephants 1052 between April 2014 and July 2017 (Times of India 2017). It is true that large carnivores like tigers, leopards and lions are capable of killing humans. The losses of livestock to large carnivores are also common and high. The general apprehension of conservationists and managers is that human attacks and livestock losses will reduce people's tolerance of wildlife and could trigger retaliatory behaviour towards dangerous

or potentially threatening wildlife. This line of reasoning goes on to suggest that people cannot cope when exposed to new scenarios or when they encounter unfamiliar situations, like newly reintroduced tigers.
Many researchers contradict this reasoning. The view that biological conditioning, learnings derived from cultural practices and local ecological knowledge allow people to avert personal injury has received broad support.

6.3.1 Biological and cultural conditioning developed to avert injuries from wild animals

An important aspect of averting injuries is that, in many existing cultures, people have developed ways to avoid dangerous situations. According to the research findings of biophobia, upon examining human cognitive responses to potentially harmful situations, Ulrich and his colleagues found that exposure to negative feedback and negative experiences make people defensive to potential hazards. Such conditioning allows people to adapt and increase human survival (Ulrich 1993). For example, Jones and colleagues reported that, in Madagascar, the local social norms prohibited people from killing taboo lemurs and other carnivores, even when such animals were perceived as evil and dangerous (Jones *et al.* 2008). Here, by removing the interest in the animal, people limited their interaction, avoided them and potentially saved themselves (irrespective of whether lemurs are dangerous or not). Similarly, widely held beliefs in forests spirits discouraged people in my study area from using forests after dark. The practical advantages of this widely held belief system come from the pacts that people make with their protector spirits. For instance, the protection of spirits is ensured only when certain norms are not violated. Therefore, people strictly adhere to rules and avoid forests at night-time. Avoiding nights in the forest decreases direct encounters with dangerous animals like the tiger, which is most active in the crepuscular and nocturnal hours (Chapter 4). Here, the cultural conditioning leads to the conscious or not-so-conscious acts of people and allowed them to maintain spatial and temporal separation from tigers, thus reducing risks. Ulrich (1993) explains this as cultural and biologically prepared learnings, which might provide communities with efficient ways of adapting to dangerous situations. People, influenced by their conditioning, try and avoid dangerous situations, in a defensive manner, without actually having to have direct and dangerous encounters. This line of reasoning is also applicable to contexts where communities have lost their coping mechanisms or where carnivores are newly reintroduced. In Chapter 1, I described four incidents that took place during my project work, in which I reported people's responses to the presence of a tiger. In all the examples, local communities organised themselves and supported the authorities to ensure the safe movement of the tiger through human-dominated areas and avert a crisis. Initially, the sudden and unannounced arrival of the tiger into human-use areas created panic within local communities. However, there were creative ways to solve these crisis situations, and the anxiety within community members was reduced when local religious leaders intervened in one incident, when local politicians took the lead in another, when locally influential landlords extended support and when local government officers got involved in the fourth. Here, the presence and leadership of the right people influenced the behaviour of the community as a whole. According to Ullrich (1993), when incidents such as a tiger in a human-dominated area take place,

the telling and retelling of such incidents involving the tiger and the ways in which it was tackled when it was in the area, lays the foundations for communities to learn and adapt to future situations.

6.3.2 Local knowledge on carnivores

Knowledge about local carnivores and their habits can reduce the risks of injuries in the event of an encounter. Brown and Conover (2008) compiled information on the responses of people when attacked by bears, wolves and pumas and report that knowledge about the animals influenced people's responses during encounters and saved lives during attacks. Their findings show that there is no single best way to escape injuries during attacks, rather there are many ways to avoid harm. A goat herder from my study area shared his encounter with a tiger (Figure 6.2). One day, as the man was walking home alone from the forest, he encountered a tiger sitting in the middle of the forest path. He recollected his first thoughts on seeing the tiger, "I am seeing a spirit tiger and the spirit will not harm me." He looked at the tiger and realised that the animal was resting. He stopped walking and folded his palms in respect and asked the tiger to spare him. He then slowly walked backwards, without making eye contact, and only then turned around and continued walking. This way, he increased the distance between the tiger and himself and escaped.

Figure 6.2 A goat herder showing the posture of the tiger he encountered.

Here, the cultural conditioning that the tiger is a spirit and that it will not harm the herder and the knowledge and presence of mind to slowly walk away, thus increasing the distance between the tiger and him, saved the herder's life. Penteriani *et al.* (2016) showed in their research on the causes of attacks on people that risk-enhancing behaviour by people lead to most (over 50 per cent) carnivore attacks in America. Such risk-enhancing behaviour included teasing animals, getting too close to animals and leaving children on their own, and all prompted attacks. Their research also showed the indirect effects of risk-enhancing

behaviour and how it led to attacks, i.e. accidentally walking into animals or encountering animals with cubs or pet dogs attracting large carnivores. Overall, the risks of attack are attributed to people's lack of knowledge about carnivores and the resulting risk-enhancing behaviour. As reported by Van der Ploeg and his colleagues, lack of knowledge can also mislead third parties, such as policymakers. In the Philippines, policymakers declared the endangered local crocodile species a dangerous pest while, in reality, people who shared the rivers with the crocodile have learnt to move in groups, use the rivers in designated areas and avoided the crocodile successfully (Van der Ploeg *et al.* 2011). In such cases, the importance of communication and education is emphasised.
There are also local cultures that discourage risk-taking and promote learning. In my study area, Yadav pastoralists adhere to a community norm where members are obliged to help those whose cows or buffalo are missing. The Yadavs believe that if livestock are left to wander in the forests at night-time, the spirits of the forests (including the tiger) have a right to prey upon them. So, community members help each other search for missing animals. Such norms have possible risk-averting consequences. By moving in groups, they decrease their chances of being attacked by animals and increase their chances of finding missing livestock. Furthermore, following local customs, children are taught these local practices and about the risks from carnivores from a young age. Such cultural conditioning and knowledge foster naturally risk-aversive behaviour and are favourable for coexistence.

6.3.3 Averting threats to livestock

Carnivores have killed livestock since time immemorial and at least since humans began domesticating animals. Based on this assumption, it is likely that, through the ages, humans may have tried and explored ways to decrease losses from predators. My results provide proof of this and I agree with other researchers who claim that good knowledge of carnivores and preventive strategies enable owners to reduce livestock losses (Wolf – Ogada *et al.* 2003; Wolves, bears and pumas – Pimenta *et al.* 2017; Lion – Tumenta *et al.* 2013). In my study area, local livestock owners, well-versed in the activity patterns of tigers and wolves, avoided dense forests and grazing between dusk and dawn. Instead, they grazed animals during daytime. Additionally, following an old, customary practice, they held daily evening meetings and discussed animal sightings and local news about carnivores. The combination of local knowledge and local practices allowed herders to consciously avoid grazing in risky areas. According to Carter and Linnell, (2016) knowing this natural ability of local communities to co-adapt with large carnivores and the circumstances that foster such adaptation is vital for coexistence between people and tigers.

Preventive strategies do not always work, and livestock predation persists in many contexts despite people's efforts (Khorozyan *et al.* 2017). I had similar observations and I described in Chapter 3 how contextual social circumstances sometimes promoted lenient livestock husbandry practices and increased risk of predation. Pimenta *et al.* (2017) observed that carnivore attacks in Portugal were higher when free-ranging livestock husbandry systems were adopted. This is confirmed by my results and in both cases owners did not accompany herds. Herds were grazed in communal lands and forest lands and animals were never corralled at night. In comparison, losses were much

lower in husbandry systems where people personally grazed animals and confined them to enclosures after dark. Here, a third dimension, the socio-political situation, created barriers for livestock owners, and livestock losses continued. For instance, my study reveals that socio-political factors surrounding sacred cows in the region encouraged people to abandon unwanted cows in the forests. As a result, commonly, large carnivores preyed on such abandoned animals and sometimes also valuable livestock. The highly contextual situation of my study did not impact livelihoods directly because a majority of the people kept cows for sustenance use only. However, the indirect impact, as local Yadav pastorals revealed, is the decreasing dependence on livestock as a choice of livelihood amongst traditional pastoralists. This shows that there was some adaptation by people and I agree with Traves and Bruskotter (2014) that economic livestock losses alone did not result in any direct retaliatory killings of carnivores. These finding are not only relevant for tigers, but have been observed in contexts where tigers, jaguars, wolves, lions, and bears are present, all of which are potentially dangerous for livestock and contribute to economic losses worldwide (Traves and Bruskotter 2014).

Then again, as Treves and Bruskotter (2014) evidenced, social factors can influence people to poach animals. Such poaching could be for consumption and for trade. Poaching, though a critical and widely recognised threat to tigers outside protected areas and to meeting the 2022 'double-the-tiger' population goal, is not as a result of human-tiger conflicts (Miquelle *et al.* 2005; Wikramanayake *et al.* 2011). For this reason, it is not the focus of my study. As shown in this section, the not so obvious and previously unknown insights into the complex nature of issues shaping livestock losses necessitates the need to understanding the exact nature of the local contexts in order to address livestock predation issues. For instance, Yirga and his colleagues revealed that situations like disease and theft sometimes caused more livestock losses than predators in their study area in Kenya (Yirga *et al.* 2014). I report similar findings and in both cases people followed local practices, accompanied herds, used enclosures at night-time and kept dogs for warning. People were highly satisfied with their preventive measures against predators and felt that factors other than predation were more of a concern. This finding shows that people's prioritisation of threats can vary depending on the locally prevailing contextual factors and the threats predators pose may not necessarily be at the top of their lists.

6.3.4 Adapting to newly introduced carnivores

People's ability to adapt to newly reintroduced or recovering large carnivores may be problematic (Chaperon *et al.* 2014). I agree with this, but also provide evidence in Chapter 1 that people can adapt to new scenarios. In my study area, which is a protected, dry, deciduous forest landscape, tigers naturally occur in low densities (Karanth *et al.* 2004). Additionally, larger stretches of the reserve, including stretches of the newly created buffer zone, are not suitable[18] for tigers (Chundawat *et al.* 1999). As a result, tiger presence and movement in the area is low. However, after the reintroduction of tigers

[18] Unsuitable because large stretches are flat grasslands, which are non-habitat for tiger and also because human overuse of the landscape has rendered the areas inappropriate.

and the subsequent conservation efforts, tiger numbers increased in the core zone and buffer zone and, as I describe in Chapter 4, currently tigers are present in areas that they have not previously used. Herders using the buffer zone areas encounter people monitoring tigers, tiger tracks and signs, and experience livestock losses more often than they have in the past. While there is a high general awareness about tigers, as I describe in Chapter 3, there are herders who do not have the practical knowledge on averting tigers because of their infrequent previous encounters. For instance, goat herders using the buffer zone areas commonly encountered wolves but not tigers. They have developed local grazing strategies that safeguarded their animals against wolves. For instance, they graze their goats in more open areas and avoid thick forest. They throw stones and shout and use sticks to scare wolves. While small-sized goats are not natural prey for the tiger, the strategies that herders use to prevent wolf attacks may not safeguard them against an ambush predator like the tiger. Furthermore, it may also expose them to the risk of tiger attack. While this situation may sound discouraging, I described in Chapter 3 how goat herders periodically asked the tiger monitoring teams about the locations of tigers and consciously avoided such areas. This natural ability of people to adapt to the presence of the new predator should be seen as a positive indication of individuals' adaptation to the emerging new scenario and supports the theory of Ulrich and his colleagues that communities learn (Ulrich 1993). Management strategies should recognise these favourable cues that people give out (more details on the role of the reserve management in the recommendations section 6.3.1). Parallel to this, as I show in my findings in Chapter 2, local herders who are now wary of the personal danger that the large and relatively unknown tiger may pose, started making enquiries about how to make pacts with the spirit of newly reintroduced tigers. The disclosure of a buffalo herder presented in Chapter 2 captures the advice given by the locally trusted spirit intermediary. "Badami baba is a mighty forest spirit. Badami baba can summon the tiger by its ear. If a tiger repeatedly kills domestic animals or creates panic in villages, Badami baba can be requested to summon and tame the tiger." These examples illustrate ways in which local people practically and psychologically try to adapt to the newly reintroduced tigers in their environment. However, only time will tell if people's adaptation is complete.

6.3.5 Summary of Findings: The human dimension

To summarise briefly, my findings support the view that, in many communities, people's beliefs, their cultural practices and local knowledge extend support to cope with their naturally occurring psychological fear of the tiger. Their coping mechanisms, which are embedded in their faith, religious beliefs and practices, are a compelling motivator that allow people to access and use forests with potentially dangerous animals. Furthermore, their cultural practices and knowledge of carnivores provide them with the support to make conscious decisions and avert risk-enhancing behaviours and saves them during encounters.

Research findings also suggest that livestock losses can be reduced by using preventive strategies. However, there is also evidence that preventive strategies may not always work or eliminate losses from occurring. Several factors, including socio-political factors, lack of knowledge and ability of carnivores to adapt to precautionary measures, may create

barriers to preventing losses. Findings indicate that communities naturally learn to adapt and re-adapt to changing scenarios. Such adaptation is likely to encourage adaptation and coexistence with the newly reintroduced or recovering carnivores in human-use areas. At the same time, in heavily modified systems, where people are not willing to adapt or where social factors do not allow people to change, it may be unrealistic to promote large carnivores. Research also suggests that people may not always retaliate if they lose animals and that there may be other underlying social factors or human-human conflicts that trigger retaliation. Furthermore, communities using livestock for sustenance, or where social situations lead to excess livestock, or where people are accustomed to predation incidents, show natural tolerance in the form of acceptance of loss as a natural event. My study concludes that, from a human perspective, there is adequate evidence that, contextually, people can adapt and coexist with tigers. My focus in the next section is on the ability of tigers to adapt in human-use areas.

6.4 Tigers in human-dominated landscapes

My research data does not support my third hypothesis – that tigers will totally avoid areas where human activity is high (Chapter 4). But my data does support my fourth hypothesis – that the presence of feral cattle along with open-access grazing practices in multiple use forests increases the incidents of predation on all livestock by tigers, even when wild prey are available (Chapter 5). My findings suggest that the radio-collared tigers of Panna Tiger Reserve exhibited high behaviour plasticity and adapted their activity patterns to human use and activity in the study area. They avoided areas when human activity was high, but approached villages and water bodies when human activity lowered. Several authors suggested that such behavioural plasticity exhibited by large carnivores as a response to changes in their environments may increase their chances of survival in human-dominated landscapes (Miquelle *et al.* 2010; Rabinowitz and Jr. 1986; Rabinowitz 2014). My findings on the tiger's natural adaptation to human activities are new and will increase the current understanding of tiger-human coexistence in human-dominated landscapes. However, the natural adaptability that I refer to is a biological measure of adaptability and not an absolute indicator of tigers' survivability in human-dominated lands. For this reason, the results of my study should be interpreted with caution and should not be a basis for setting targets for projects, such as the 2022 'double-the-tiger-numbers', which is a social and political target.

I subscribe to the definition of the 'habitat of a carnivore', as proposed by several researchers, that clearly considers the resources that contribute to an animal's fitness while depicting its habitat (Mitchell and Hebblewhite 2012). Based on this definition, carnivores can successfully persist in an area only when they achieve a niche that involves access and selection of resources and the conditions that improve their survivability and successful reproduction (Mitchell and Hebblewhite 2012). Areas where they achieve successful survival and reproduction are called source habitats for carnivores and in India, most tiger source habitats are already protected tiger reserves (Karanth and Gopal 2005; Wikramanayake *et al.* 2011). According to Watkinson and Sutherland (1995) and

other authors, the areas that carnivores use but where their survival is low and their reproduction is decreased are sink habitats (Mitchell and Hebblewhite 2012; Watkinson and Sutherland 1995). By this definition, my study area, which is the newly established human-dominated buffer zone of the Panna Tiger Reserve and the multiple-use forests extending beyond the reserve are *sink habitats* for tigers (Chundawat *et al.* 1999). Since the proposed networks within the tiger landscapes in India comprise both *source habitats* and *sinks* and which are also spatially interconnected, I examined tiger responses to some of the most common human activities seen in such interconnected spaces.

Based on the empirical findings of my study, I reported that my study tigers exhibited a high behavioural plasticity to the various human activities and did not readily conflict with people as generally thought. The most convincing current arguments against the tiger's ability to survive in human-dominated lands come from the reasoning that tiger survival may be limited by human activities and that they may become prone to conflicts with people and livestock (Das 2015; Goodrich *et al.* 2011; Gubbi *et al.* 2016). This line of reasoning suggests that tiger and human coexistence is incompatible and interactions with people will either make them vulnerable or confrontational. As a solution, more protected spaces are proposed by some authors (Gubbi *et al.* 2016). I found that there is little empirical evidence in published literature on tigers' natural ability to adapt to various human activities in human-dominated landscapes and coexist. It is true that when large carnivores like tigers move into human-dominated areas interactions with people are inevitable. It is also true that for a solitary, territorial and obligate predator like the tiger, the resources available in an area such as availability of water, vegetative cover and prey, contribute directly to its fitness (Gour *et al.* 2013; Hayward *et al.* 2012; Karanth and Sunquist 1995). Also, the direct conflicts with people as result of tiger attacks and livestock kills, matter (Goodrich *et al.* 2011; Das 2015). However, the scanty empirical evidence on the ability of the tigers to adapt to human activity is concerning.

6.4.1 Tiger activity patterns

I found that tigers shifted their activity patterns and moved in human-dominated landscapes at night-time, when human activity lessened. They also approached close to villages and used the same water bodies at night that people intensively used during the day. Additionally, tigers made shifts in activity patterns responding to the seasonal temperature variations. In the hot, summer months their presence in human-dominated landscapes increased at night-time. The low vegetation in summers, restricted water bodies and prey that are not active in the heat of the day may have influenced tiger behaviour. In Chapter 2, I showed how this summertime activity pattern of tigers changed in the rainy season and winter months. In rainy and winter seasons, their presence in human-dominated areas increased during the day. This may be because daytime temperatures became more ambient, vegetative cover and water is not scarce and prey become more active during the day. Several large carnivore researchers have showed how lions, brown bears, leopards and spotted hyena demonstrated high behavioural plasticity and adapted their activities to human presence and activities in their environment (Athreya *et al.* 2013; Carter *et al.* 2012; Kojola *et al.* 2016; Martin *et al.* 2010; Oriol-Cotterill

et al. 2015; Yirga *et al.* 2012). For example, Martin *et al.* (2010) reported that brown bears temporally adjusted their activity patterns in human-use areas and only used such areas when human activity lessened. Similar temporal adjustments in activity to human presence have been reported in lions, tigers, leopards and wolves (Athreya *et al.* 2013; Carter *et al.* 2012; Oriol-Cotterill *et al.* 2015; Kojola *et al.* 2016). In Chapter 4, I described how some tigers using the core zone areas moved into the adjoining human-dominated buffer zone areas at night-time when human activity decreased and moved back into the core zone during the day. At the same time, some of my study tigers did not have the possibility to retreat to the core zone and remained in the buffer zone. But they did not show any significant increase in their daytime activity. My findings are consistent and support those of Carter *et al.* (2012) who showed that in Chitwan, Nepal, tigers avoided human areas during daytime, most likely because of disturbance caused by fuel wood collectors and the low vegetative cover caused by over grazing. Contrasting findings are reported by Naha *et al.* (2016) who showed that their study tigers were also active during the day, most likely influenced by local contextual factors, such as absence of livestock rearing, low persecution by residents and the availability of their main prey (Cheetal deer are diurnal). In my study, I did not find any age-group and sex specific variations in activity patterns. These evidences of behavioural plasticity through spatial and temporal shifts in activity indicate that tigers are capable of adapting their activity patterns to the finer-scale changes in human, prey and environmental conditions within their areas. The next topic is the tiger use of areas where human activity is concentrated.

6.4.2 Tiger presence near villages and water bodies

I found that tiger presence near villages and near water bodies in human-dominated areas was high. However, I observed age-group biased variations in tiger presence in these areas with younger tigers using these areas more than adults. My findings support the findings of Kajola *et al.* (2016) who reported that, in Finland, their radio-collared younger wolves, most likely influenced by their naivety, approached villages more frequently than mature wolves. My study on tigers is the first to claim that young tigers behave differently from adult tigers in human-use areas. For example, while all my study tigers approached villages in their environment (showing greater avoidance during day when human activity peaked), the younger tigers were much more present near villages than adult tigers. However, this changed over time and with age (and most likely experience) when their presence near villages decreased. I see this decrease as a natural shift and it is supported by the findings of Kajola *et al.* (2016) who also observed a similar natural decrease in the presence of their study wolves near villages over time. As Figure 3 shows, my study tigers rested close to people's homes in areas where human density and activity was low and were even present during the daytime. This behaviour was not exhibited near villages where human density was high, as also reported by Kojola *et al.* (2016). The ability of tigers to stay unnoticed near some villages may also be dependent on vegetative cover, fewer village dogs and ambient daytime temperatures. The ability to use minimal vegetative cover and yet stay unnoticed may be very useful for those tigers travelling through human-dominated lands or younger animals exploring new territories. My findings support those of Carter *et al.* (2012) and Miquelle *et al.* (2005) who showed that tigers may avoid areas in human-

dominated landscapes if such cover is absent or when human disturbance increased. This understanding of the tiger's ability to use and also avoid spaces with changing conditions near villages can be helpful for planning village peripheries in coexistence scenarios. Otherwise, as I showed in Chapter 2, people's livestock husbandry practices, which provide readily available food near villages, may attract tigers closer to settlements and the younger tigers may be drawn more than the adults because of their naivety about the risks associated with approaching villages.

In Chapter 5, I described how, during my five-year study, I did not find any evidence that tigers, young or adult, targeted animals near villages. In spite of large congregations of cows near village peripheries, tigers did not kill more animals near villages than in other parts of the human-dominated area. It appears that not all visible and abundant prey is available for tigers to exploit. I support the line of reasoning of Nilsen *et al.* (2012) who showed that prey abundance alone does not necessarily contribute to availability, and that availability is a function of several factors, including: abundance, prey-antipredator behaviour; cover, human activity, village dog and others. In my study area, the village cows that congregated near villages may have attracted both young and adult tigers closer to villages, but this did not result in more killings of cows than in other areas. It is likely that the cows had good group vigilance and may have proved difficult to capture. Based on my findings, I agree that tigers will be drawn to villages, but disagree with the argument that tiger presence near villages increases predation of livestock compared to other places in the human-dominated landscape.

Figure 6.3 A dispersing male tiger (in the yellow box) rests close to a human settlement during the day. The tiger may be advantaged by the ambient daytime temperatures and vegetative cover in the study area during overcast days in the winter (November to February). Photo R. Sreenivasa Murthy.

6.4.3 Tiger presence near water bodies

My study findings show that tigers do not avoid using water bodies in the human dominated landscapes. However, their effective use of such water bodies decreased in comparison to those in the undisturbed core zone. I support the findings of Biolatti *et al.* (2016) whose experiments on captive tigers have shown that access to water improves tiger well-being. Tiger well-being, as I explained in Chapter 4, could comprise several factors, including their ability to stay unnoticed, regulate body temperature, and avoid biting ticks (Biolatti *et al.* 2016). Tigers are often found near water, so the existence of a functional relationship has long been known (Chundawat *et al.* 2016); however, empirical data and evidence on how much tigers depend on water in the wild has been lacking. For example, Naha *et al.* (2016) reported that tigers using the waterlogged mangrove forests of the Sundarbans avoided swimming across long channels of water, but readily crossed small distances and accessed land. My studies reveal for the first time that in water scarce, dry landscapes, when human disturbance near water bodies is minimal, tigers spend nearly 25 per cent of their time near water (Chapter 4). Such access to water bodies may have allowed them to cope with high summer temperatures (exceeding 45C) in my study area. I agree with Biolatti *et al.* (2016) that tigers need water to regulate body temperatures. In my study area, their need for water bodies to regulate heat may have decreased in winter and rainy seasons, most likely due to changes in ambient local temperatures. Such decreases in temperature may have allowed some of them to explore further afield in the human-dominated areas, despite low access to water bodies. Here, their ability to move in areas far from reliable water bodies is noteworthy and should be seen as behavioural plasticity, though, as Biolatti *et al.* (2016) showed, it may have some overall negative impact on tiger well-being. Additionally, my findings (Chapter 4) show that younger tigers and adult males moved further away from reliable water bodies in the human-dominated areas and not the adult females and females with cubs. As a result, younger animals and males were more exposed to vulnerability than female tigers. Furthermore, I found no evidence that tigers killed more domestic or wild animals near water bodies than in areas far from water. This was in spite of a high presence of domestic and wild prey animals near water bodies in the study area. While more future research is needed to understand the finer details of the functional relationship tigers have with water, I feel that tigers in human-dominated areas do not target prey exclusively near water. Such targeted killings could reveal their presence to people and increase prey vigilance near water and, consequently, they may lose a precious opportunity to stay close to water bodies.

6.4.4 Tiger predation of livestock

My study findings show that, when livestock were available, all tigers killed more of such animals even when wild prey was available. However, age-group and sex specific variations in predation rates show that younger animals and male tigers killed more livestock than female tigers. For these categories, predation rates did not vary for human-dominated areas and the protected core zone. However, for females it did and they killed more livestock only when they were far from the core zone in the human-dominated landscape.

I agree that tigers are obligate carnivores and I support the explanation of Nilsen *et al.* (2011) that the prey available to a carnivore is not purely a function of abundance, but also includes prey-anti-predator behaviour, differential vulnerability of prey in different lifecycles, seasonality and more. In Chapter 5, I described that male tigers and sub-adult tigers killed more livestock than female tigers. However, the proportion of wild to domestic animals killed remained comparable between all age groups and sexes. I support the explanation of Karanth and Sunquist (1995) that male and young tigers most likely killed more numbers of domestic animals because of their frequent encounters with such animals (influenced by their wide-ranging movement patterns). Further, I also agree with Karanth and Sunquists' explanation that the relative ease of killing domestic animals, in comparison to wild prey, may have played a role in younger tigers killing such animals (Karanth and Sunquist 1995). In my study area, this may have helped younger tigers to use and survive in a disturbed landscape, where preferential wild prey is sparse. Female tigers, on the other hand, killed more wild prey animals than domestic prey animals in the core zone of the study area. I explained in Chapter 3 that female tigers might have preferentially targeted wild prey because they raise their young in the core zone and tend to have smaller home ranges than males. Thus, females probably choose areas that are far from human activity and where they are more likely to encounter more wild prey.

I do not support the argument of Karnath *et al.* (2004), and several other authors, that from a tiger conservation perspective, wild prey species are essential to the tiger's persistence (Chundawat *et al.* 1999; Miller *et al.* 2015; Ramakrishnan *et al.* 1999). However, I do support Karanth *et al.* (2012), and other authors, who argue that human-tiger conflicts have a complex nature and that they can jeopardise tiger conservation. I believe that a habitat outside protected areas of India cannot be realised without livestock in it. From a biological perspective, and based on my findings on tiger adaptability to prey in human use areas, I contradict the general understanding that wild prey species are essential to the tiger's persistence. Metabolically, domestic animals, such as water buffalo and cows, provide all the proteins, lipids and fats required for an obligate carnivore like a tiger. New understanding on large carnivore diets as shown by Athreya *et al.* (2016) and Yirga *et al.* (2013) reveals that large carnivores like leopards and spotted hyenas can thrive in human-dominated lands without wild prey and totally adapt to locally available prey species. Such understanding on tigers is lacking and often supressed by arguments that it is impossible for tigers to survive without abundant wild prey.

In Chapter 5, I described how, as the distance from the core zone of my study area increased, all tigers, irrespective of their age-group and sex differences, resorted to killing more domestic animals. Furthermore, male tigers also preferentially targeted male prey animals (especially male domestic animals), but smaller female tigers killed both male and female domestic animals in similar proportions, suggesting that the predator-prey body weight ratio as explained by Hayward *et al.* (2012) and Miquelle *et al.* (2010) may have a role in a tiger's choice of prey. I agree with Nielsen *et al.* (2012) that the availability of domestic animals to tigers in my study area is not purely because domestic animals are in abundance in this location; but, as I described in Chapters 2 and 3, the presence of male feral domestic animals is a consequence of local people's practice of abandoning unwanted animals in the forests. Tigers killing such unwanted animals should be viewed as a natural, finer-scale local adaptation, which is also socially acceptable. Furthermore,

Figure 6.4 Omnivorous by nature, wild pigs commonly feed on domestic animal carcasses in the study area. They, in turn, are also prey for the tiger. Photo by Shukru Kumal.

livestock is also eaten by other carnivores like wild pigs (Figure 4), which, in turn, are prey for tigers in human-dominated landscapes.

My findings contradict the general notion that livestock predation by tigers is always conflict-prone (Karanth *et al.* 2004). I reason, based on the evidence provided in the above paragraphs, that when feral and not-so-commercially-valuable livestock are available in an area and when local people's wildlife acceptance capacity, as explained by Decker and Purdy (1998), is favourable, conflicts do not occur. Moreover, tigers did not kill more domestic animals in areas intensely used (near villages and water bodies) by people. So the problem animal situations, like those proposed by Swan *et al.* (2017), did not occur in my study area and, therefore, are not applicable in this context. I believe that the local circumstances surrounding livestock are unique in my study area and quite different from those commonly mentioned with regard to Nepal or other parts of the world. I also believe that there may be more such areas in India, where tigers can exploit domestic animals without the threat of conflicts with humans. Realistically, the social and economic costs of removing socially and politically sensitive domestic animals from forests in India are very high (Chapter 3). It is certainly worth exploring the natural decline that tigers and other large carnivores can, together, bring about by suppressing lower trophic levels, especially on unwanted and feral domestic animals populations, without the nuance of the

socio-cultural and political complications (Dorresteijn *et al.* 2015). Based on the empirical findings of my study, I believe that the latter is hugely advantageous and practical to the tiger and the local communities.

6.4.5 Summary of findings: Tigers in human-dominated landscapes

Tigers have long fascinated humans, and people have been observing and studying their behaviour since ancient times. While there is a general acknowledgement amongst present day tiger conservationists and managers that tigers are adaptable animals, their real ability to adapt to human activities in human-dominated landscapes is largely unknown. This lack of knowledge has resulted in a general belief that all tiger-human interactions lead to confrontations and eventually conflicts and, therefore, coexistence is incompatible. My study shows that tigers have a higher natural ability to adapt to some of the most common human activities, such as people's presence, their husbandry practices and use of water bodies, than generally expected. They adapted their activities, showed higher tolerance to changes in land use, tolerated human activity near water bodies and adapted to a diet of locally available but suitable prey (including livestock) and still continued to use space and resources with minimal conflict (acceptable to local communities). This adaptation is not unidirectional, but rather two-directional with the human dimension aspects also playing an important role in the tiger's successful adaptation. For this reason, the described findings are specific (contextual) to the Panna Tiger Reserve and the adjoining areas and may not be directly comparable to contexts in other areas. In other areas, the composition of the local people, their beliefs and practices, their local knowledge on tigers, adaptation ability and tiger characteristics will vary. Therefore, the findings must be interpreted keeping in mind the local human and tiger contexts. In chapters 4 and 5 I also listed a series of contexts where tigers may naturally fail to adapt. For instance, age related issues such as naivety in young animals made young tigers take risks and approach villages and use areas where they have little or no access to water bodies. Likewise, male tiger's, just like young tigers, killed more livestock even when wild prey were available. Tiger's use of water bodies also varied. Undoubtedly, they are able to access water bodies better in the core zone where human disturbance was minimal that in the buffer zones. In spite of these differences, attacks on people were not reported during the five-year study period or previously. I believe that this may be because of local factors unique to the study area. In other areas, other permutations and combinations of people-tiger factors influence outcomes. As shown in Chapters 2 and 3 and section 6.3, human factors create barriers for tigers and reduce their ability to exploit human-dominated landscapes to their advantage. However, based on my study, I believe that focussed and small improvements in human use of the landscape, with the intention of sharing space with tigers, will allow the naturally adaptive tiger to use resources to their advantage and survive in human-dominated landscapes.

6.5 Recommendations

Based on the empirical findings of my study I propose a number of recommendations for wildlife managers and conservation organisations. Following these recommendations will allow them to support tiger-human coexistence in human-dominated landscapes.

6.5.1 For Managers

The findings of my study reveal that the successful conservation of large carnivores such as tigers outside protected areas depends on both on people and tigers. Therefore, without understanding these bio-social and interlinked influences the real factors influencing coexistence will not become clear.

Tackling the social complexity

The sheer numbers of people, the diverse ethnic groups, different cultures and people with varying worldviews all these issues will pose challenges to any manager who wishes to address people aspects in India. Therefore I recommend the following:

Take local practices seriously

My study shows that, in rural India, local people developed many local practices. These practices have both positive and negative influences on large carnivore conservation goals. First, an assessment of the impact of the local practices should be conducted. For example, as shown in Chapter 2, the local practice of dumping domestic animals carcases and allowing unwanted cows to roam feral in the Panna landscape have a positive influence on local large carnivore distribution. While at the same time they could increase interactions between large carnivores and people near villages. In this scenario, managers would benefit by innovatively adapting the positive aspects of the practices while trying to carefully avoiding the negative aspects and adapting them into conservation plans. For example, vulture conservation in France and Nepal are proving to be successful for the recovery of endangered vultures when local livestock herders revert back to age-old practices of leaving dead carcasses for the birds. Of course, management must find ways to eliminate dog packs and the spread of diseases into wild populations. I feel strongly that managers should not try and reinvent the wheel in this regard. Locally prevailing practices can be adapted innovatively to solve some of the most common conservation challenges.

Adapting management practices to local contexts

Defining a scale is very important for conservation interventions. Based on the empirical evidence from my study, it is increasingly clear that most situations are contextual and cannot be readily extrapolated to the large landscape in totality. This means that one-size-fits-all approaches will fail. This is because with changes in local social, cultural and political settings, changes in knowledge on carnivores and changes in local economic factors, people's abilities and willingness to live with carnivores changes. For example, in Chapter 3, I described that local people in my study area have a high awareness of tigers, have good local knowledge to avert accidents and injuries and they also take preventive measures to safeguard valuable livestock. This situation is contextual to study

area because of the local people groups. The local gond tribes and yadav pastoralist have unique practices. They have good local knowledge of the forests and on local carnivores and they believe and worship forest spirits. In this described context, managers need not focus on awareness campaigns or start training local people in new husbandry practices. People are already aware of such issues and have good practices in place. Instead, managers should focus on the land-use regulations in territorial forests and buffer zones or deal with local politicians who are politicising cows with religion and creating barriers for livestock owners wanting to remove unwanted and excess cows from the landscape. Managers should hold meetings with local politicians to highlight the interconnected effects of their political strategies and solving local conservation problems. Managers should incentivise residents with special land-use rights which will automatically motivate residents and give them the right to control unchecked grazing by non-resident outsiders.

The need to involve social scientists

The diverse and complex social aspects are not readily visible for the untrained eyes to see. My study shows that the social conflicts surrounding natural resource use are an integral part of human societies and can only be addressed by a deep understanding of local contexts. This line of thinking is supported by many authors (Dickman 2010; Madden and McQuinn 2014; Redpath *et al.* 2017). This means that managers may need the help of social scientists who, in turn, must engage with local people and develop understanding on local cultures and practices and the interlinked nature of influences. When this information is subsequently communicated with the managers, managers will have the information to make decisions. In a populated and culturally diverse country like India, the recommendation is for managers to involve social scientists to guide them to identify and address the complex social factors influencing tiger conservation.

Promoting the umbrella effect of tiger conservation

Human-dominated landscapes outside PA's in India are known sink habitats for tigers. This means that the current biodiversity holding potential of these overexploited lands is low and therefore these lands do not contribute to human wellbeing in any substantial way. By promoting tiger conservation into these lands the government managers are also promoting the conservation of biodiversity in these lands. Since conserving the tiger has an umbrella effect and will improve the biodiversity in the area which will ultimately be useful for local people and their wellbeing, the reserve management should promote sustainable use of natural resources and conservation of biodiversity. These interlinked effects of conserving the tigers are known to the knowledgeable local people living in my study area. However, if managers become aware of these linkages and together with local communities if they can collaborative plan the use of multiple-use government forests with an aim to improving biodiversity in such lands. Such lands would benefit local people and tiger conservation efforts.

6.5.2 Conservation agencies

Conservation needs in human-dominated landscapes are many and infinite. However, the need to focus on achievable and financially feasible targets is highlighted. The nature of

people's issues, which are set in local cultural practise and habits, and the scale of such practices may be overwhelming in the India context. So, conservation organisations may have to engage people with special skills to tackle problems to tackle herder-less grazing practices. As shown in Chapter 3, the factors influencing the use of herders while grazing animals include the economics underlying livestock keeping, perceptions of local people regarding threats from carnivores, cultural practices and practices grounded in habit and ease of doing. Moreover, the land-use regulations and laws governing grazing encourage herder-less grazing in territorial forests. Conservation organisations may not get to the bottom of the problems unless these deep-rooted issues are understood. Organisations may also be overwhelmed by the diverse nature of influences and conflicts between the diverse rights and stakeholder groups. In the end, there is a very high risk of organisations with good intentions making mistakes and actually creating barriers to conservation. Given the complexity of issues and the need to engage with diverse rights and stakeholders, conservation organisations must have trained staff.

Support the development of paraecologists

Local issues cannot be taken up without involving local people. As I explained in a co-authored publication, a paraecologists is "a professional with local knowledge, being largely trained on the job in one or more fields of ecological science. He or she contributes to scientific research and local capacity development as well as enhances communication between local and scientific communities" (Schmiedel *et al.* 2016). Conservation organisations may benefit from involving local people and developing their capacity to contribute to local projects. In addition, involving trained local people to engage with their own communities and promote conservation has several benefits. First, an internalised approach will largely eliminate organisations from directly getting involved with local communities and their innumerable complications. The example of WWF-India and their attempt to bring change to the children of pardhi hunting tribes is a well-known example. Panna Tiger Reserve was experiencing a crisis as a result of local hunting tribes who set up snares and traps to catch wild animals for bush-meat. WWF-India, along with the Panna Reserve management, conceptualised an idea to adopt children of the pardhi tribes and raise them in a boarding school. The well-intended intention was, if children of pardhi tribes were exposed to a different way of upbringing they may abandon their traditional way of life and become part of the new modern India. By adopting this approach WWF aimed to eradicate the practice of trapping and hunting by traditional communities from its roots. With great reluctance, the generally secretive and cautious pardhi parents allowed their children to be raised in a hostel. The initiators were, however, not prepared for the complexities that followed and the responsibility of changing the way of life of an entire group of pardhi children. Furthermore, they experienced a shortfall in the resources that were needed for the project. Failing to generate resources and realising the long-term nature of the engagement, the well-intended program was stopped five years after its initiation to the dissatisfaction of the parents. This brings us to the second recommendation.

The need to involve trained local people in surveys and collecting data

Social factors influencing carnivores cannot be understood without collecting information.

As my study shows, information collected from people on their herding practices or perceptions on livestock kills or knowledge on local wildlife or ethnographic accounts of cultural practices, all explain their relevance for coexistence. Currently, the reserve management and their staff collect census data on tigers and other wildlife from Protected Areas. Information from people is almost never collected. Firstly, such work is very cumbersome and needs trained manpower. Furthermore, there is need for continuous and different types of information from areas outside PA's to aid management. Often, the government reserve staff are not trained in such data collection work and the authority of forest departments may have limitations in collecting data from local people. This complex and the periodic need to collect data from local people could be undertaken by conservation organisations. However, they must innovatively involve local people in such work, as suggested in recommendation 1.

The need to support local innovation

Local people have developed ways to deal with problem animals. This local innovation cannot be overlooked. For example, people have developed vegetative fences with local thorn bushes and shrubs that deter wild herbivores and livestock from entering fields. Sometimes, this approach may not stop pigs or monkeys that can dig the ground or climb over the fences. In these cases, the old methods should not be abandoned as they serve several other purposes, but new innovation that could address monkeys and pigs should be integrated into the existing structures. In 2017, WWF Netherlands launched an interesting programme in line with the Global Tiger Initiative's goal of doubling the global tiger numbers by 2022. They launched an online open challenge focussed on engineers, scientists, conservationists and others to develop implementable prototypes for mitigating human-wildlife conflicts. The winners would get a 30,000 euro grant to develop their prototype into a full-fledged system that could be implemented at a tiger conservation site. Similarly, conservation organisations should encourage such innovation within local communities to find solutions for their wildlife problems and solutions for their daily needs. Promoting such thinking and innovation will help local communities to come up with locally suitable solutions instead of waiting for external agencies to intervene.

6.5.3. Future research needs

Based on my study, I propose future research topics that will shed more understanding on managing coexistence in human-dominated landscapes.

Human dimension research

1. While the social factors that influence people's ability to support wildlife conservation are clear, modelling them into implementable strategies is still uncertain. For example, my study shows that local religious leaders and intermediaries who are part of spirit worshipping are a big influence on the views people construct of nature and wildlife. However, future research (action research) is needed to find ways to successfully involve religious and faith leaders to support conservation.
   Question: Are there simple and effective ways to involve local faith leaders to support large carnivore conservation efforts?

2. Developing locally relevant financial and non-financial motivators to support conservation. Compensations for crop loss and livestock kills, insurance schemes for livestock, rehabilitation of villagers and eco-tourism are some of the different ways in which financial instruments are used to solicit the support of people to live alongside or tolerate dangerous animals and create more space for wildlife. But, as my study shows, there are several non-monetary motivators grounded in faith, cultural, pride, practical and intrinsic dependence, as shown in Chapter 2, that also instil a desire within people to protect nature and tigers. Research is needed to explore more non-financial motivators and also to find ways to implement them as conservation strategies. Questions include, what are the non-monetary motivators that promote tolerant attitudes towards large carnivores in the landscape? What are the practical and intrinsic benefits that people derive from holding such views? How can this understanding be modelled into conservation plans?
3. Research that captures the processes that take place within communities as people try and cope or fail to cope when large carnivores move into their areas. Such research will shed more understanding on how communities organise themselves or fail to do so when carnivores expand into their areas.

Wildlife Research

1. My study describes behavioural plasticity of tigers to some of the common human activities in my study area, like shared water bodies, unchecked livestock grazing and people's movements in the areas during the day. Such plasticity of tigers to various other forms of human activities has to be explored. Since human activities are numerous, first, an assessment must be conducted of the potentially problematic activities, such as night-time lights, noise, extent of wire snares and foot traps by local hunters and loss of vegetative cover due to over grazing and its impact on tigers' use of space.

   As a second step, thresholds of such plasticity, another key insight that was beyond the scope of my study, essential to reducing intensity of human use in the areas, must be under taken. Only when these thresholds become clear, conservationists will be able to address human issues and when human activity becomes an overbearing disturbance to tigers becomes evident. Till such time, all human activities appear to be disturbances, which is not true.
2. My study shows that tigers readily use livestock in an area and such killing many not always lead to conflicts with local communities. This tolerance of tigers killing livestock is based on the fact that, in my study, tigers killed more unwanted and feral animals. But ways to separate unwanted and valuable animals are not yet clear. Future research should focus on wildlife management issues and ways to separate valuable and not-so-valuable animals in order to assess losses to people. For example, using ear tags, or paint markers or tattoos. Without such understanding, all livestock killed will appear to be valuable animals, which is not the case.
3. Wild prey abundance in human-dominated landscapes could not be assessed in this study. Since abundance on its own is not an indicator of availability to the tiger, prey abundance (including conflict-free livestock), prey-anti-predator behaviour, differential vulnerability of prey at different lifecycles and risk of disease from livestock are

all unknown. These factors, which impact tigers in human-dominated landscapes, should be studied. Research into these topics is needed to secure stepping stones and sanctuary areas, which are human-dominated landscapes but could become potential future source habitats for tigers.

By interacting with local communities I was able to understand their relationship with the local wildlife.
Photo: Sushil Sharma

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Chapter 3 Appendix 1: Respondent Knowledge On Carnivores

Table 1. Locations of domestic livestock killed by carnivores in the buffer zone forests of Panna Tiger Reserve during 2013-14.

	COW			BUFFALO			GOAT		
Location	Owners affected (n)	Livestock losses (n)	% Losses	Owners affected (n)	Livestock losses (n)	% Losses	Owners affected (n)	Livestock losses (n)	% Losses
Within a village or a corral in a village	1	1	1	0	0	0	3	6	2
At village - forest edge	8	20	12	1	2	8	4	6	2
In the forest	46	115	71	15	22	92	95	258	90
In cattle camps	2	15	9	0	0	0	1	6	2
In a field located inside the forest	1	1	1	0	0	0	2	5	2
Do not know exact location	1	10	6	0	0	0	1	5	2
Total	**59**	**162**	**100**	**16**	**24**	**100**	**106**	**286**	**100**

Table 2. Time of carnivore attacks on domestic livestock in buffer zone of Panna Tiger Reserve buffer zone during 2013-14.

	COW			BUFFALO			GOAT		
Timing	Owners affected	Animals killed	% killed	Owners affected	Animals killed	% killed	Owners affected	Animals killed	% killed
Dawn	3	3	1	0	0	0	9	9	3
Day Time	11	22	10	3	6	10	35	70	24
Dusk	14	42	20	5	15	26	46	138	48
Night time	7	28	13	3	12	21	11	44	15
Don't know	24	120	56	5	25	43	5	25	9
Total	**59**	**215**	**100**	**16**	**58**	**100**	**106**	**286**	**100**

Table.3. Carnivores responsible for livestock losses in the buffer zone of Panna Tiger Reserve during 2013-2014.

	COW			BUFFALO			GOAT		
Species	Owners affected	Animals killed	% killed	Owners affected	Animals killed	% killed	Owners affected	Animals killed	% killed
Tiger	7	14	9	3	3	13	0	0	0
Leopard	15	45	28	3	4	17	0	22	8
Wolf	8	16	10	2	3	13	5	214	75
Jackal	0	0	0	0	0	0	80	0	0
Slothbear	0	0	0	0	0	0	0	0	0
Hyena	0	0	0	0	0	0	2	3	1
Leopard, wolf	8	25	15	2	2	8	10	30	10
Tiger, wolf	2	4	2	1	2	8	1	1	0
Tiger, leopard	5	20	12	1	2	8	0	0	0
Wolf , jackal	1	4	2	1	3	13	2	7	2
Don't know	13	34	21	3	5	21	6	9	3
Total	**59**	**162**	**100**	**16**	**24**	**100**	**106**	**286**	**100**

Table.4. Livestock owner views on current mitigation strategies that could further reduce levels of livestock depredation by carnivores in the buffer zone of Panna Tiger Reserve, India.

	PERCEPTIONS ON EFFECTIVENESS OF MITIGATION STRATEGIES								
	ON COW			ON BUFFALO			ON GOAT		
Mitigation Strategy	No Effect	Yes	% Yes	No Effect	Yes	% Yes	No Effect	Yes	% Yes
Shepherds accompany herds	123	89	42	56	50	47	101	67	40
Presence of dogs	193	19	9	97	9	8	147	21	13
Making Noise	147	65	31	68	38	35	95	73	43
Using a stick	188	24	11	93	13	15	138	30	18
Good corrals	206	6	3	103	3	3	161	7	4
God only can help	175	37	17	87	19	18	144	24	14
Cannot think of other options	146	66	31	74	32	30	127	41	24

Table.5. Reasons for not retaliating against carnivores as expressed by interviewed households living in the buffer zone of Panna Tiger Reserve.

Reason for high tolerance	Respondents (N)	%
1= Fear of forest department	232	91
2= Moral and ethical reasons	4	2
3=Fear of animals	19	7
Total	**255**	**100**

Chapter 3: Appendix 2: Final selected GLM models

Analysis 1: Importance of Livestock to Income

glm (ImpLI~HerdC:CT+HerdB:BT+GT)

anova(model4)

Analysis of Variance Table

Response: ImpLI

	DF	SUM	SQ MEAN	SQ F VALUE	PR(>F)
GT	1	0.8629	0.86293	9.8689	0.001884 **
HerdC:CT	2	1.1806	0.59029	6.7509	0.001396 **
HerdB:BT	2	2.6360	1.31799	15.0731	6.619e-07 ***
Residuals	249	21.7725	0.08744		
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

> summary(model4)

Call: lm(formula = ImpLI ~ HerdC:CT + HerdB:BT + GT)

Residuals:

MIN	1Q	MEDIAN	3Q	MAX
-0.5619	-0.1820	-0.0240	0.1449	0.6662

Coefficients:

	ESTIMATE	STD. ERROR	T VALUE	PR(>|T|)
(Intercept)	0.367853	0.028553	12.883	< 2e-16 ***
GT	0.004115	0.001116	3.688	0.000277 ***
HerdC0:CT	-0.005611	0.003197	-1.755	0.080442 .
HerdC1:CT	0.002151	0.001676	1.283	0.200643
HerdB0:BT	-0.001510	0.011706	-0.129	0.897500
HerdB1:BT	0.026131	0.004800	5.444	1.25e-07 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

Residual standard error: 0.2957 on 249 degrees of freedom

Multiple R-squared: 0.1769,

Adjusted R-squared: 0.1604

F-statistic: 10.7 on 5 and 249 DF,

p-value: 2.481e-09

Analysis 2: Predation on cows

glm(CowP~HerdC*CowsH+Dist, fam="poisson")

> anova(model5, test="Chi")

Analysis of Deviance Table

Model: poisson, link: log

Response: CowP

Terms added sequentially (first to last)

	DF DEVIANCE	RESID.	DF RESID.	DEV	PR(>CHI)
NULL			211	513.95	
HerdC	1	0.740	210	513.21	0.389505
CowsH	1	150.514	209	362.70	< 2.2e-16 ***
Dist	1	10.517	208	352.18	0.001183 **
HerdC:CowsH	1	20.558	207	331.62	5.785e-06 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

> summary(model5). Call: glm(formula = CowP ~ HerdC * CowsH + Dist, family = "poisson")

Deviance Residuals:

MIN	1Q	MEDIAN	3Q	MAX
-2.3538	-1.0497	-0.9697	0.1320	5.1539

Coefficients:

	ESTIMATE	STD. ERROR	Z VALUE	PR(>|Z|)
(Intercept)	-0.2832048	0.2271603	-1.247	0.212501
HerdC1	0.0659030	0.2121545	0.311	0.756077
CowsH	0.0558831	0.0053981	10.352	< 2e-16 ***
Dist	-0.0006169	0.0001813	-3.403	0.000666 ***
HerdC1:CowsH	-0.0294097	0.0058657	-5.014	5.34e-07 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

(Dispersion parameter for poisson family taken to be 1)

Null deviance: 513.95 on 211 degrees of freedom

Residual deviance: 331.62 on 207 degrees of freedom

AIC: 494.79

Number of Fisher Scoring iterations: 6

```
> tapply(CowP,HerdC,mean)
        0         1
0.8181818 0.7111111
> tapply(CowP,DogsC,mean)
        0         1
0.6187050 1.0000000
> cor(Dist,CowP)
[1] -0.1376552
> cor(Dist,CowP/CowsH)
[1] -0.1360985
> plot(Dist,CowP/CowsH)
```

Analysis 3: Predation on Buffalo

glm(BufP~HerdB*BT+Dog+dist, fam=”poisson”)

anova(model4, test=”Chi”)

Analysis of Deviance Table

Model: poisson, link: log

Response: BufP

Terms added sequentially (first to last)

	DF DEVIANCE	RESID.	DF RESID.	DEV	PR(>CHI)
NULL			105	94.526	
HerdB	1	1.1195	104	93.406	0.290016
BT	1	7.2382	103	86.168	0.007137 **
Dog	1	0.1396	102	86.028	0.708675
dist	1	0.0227	101	86.006	0.880145
HerdB:BT	1	0.2534	100	85.752	0.614672
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					

Analysis of Deviance Table

Model: poisson, link: log

Response: BufP

Terms added sequentially (first to last)

	DF DEVIANCE	RESID.	DF RESID.	DEV	PR(>CHI)
NULL			105	94.526	
BT	1	7.9352	104	86.590	0.004848 **
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					

> summary(model5)

Call: glm(formula = BufP ~ BT, family = “poisson”)

Deviance Residuals:

MIN	1Q	MEDIAN	3Q	MAX
-1.1592	-0.6445	-0.5450	-0.5226	3.4430

Coefficients:

	ESTIMATE	STD. ERROR	Z VALUE	PR(>|Z|)
(Intercept)	-2.07481	0.31061	-6.680	2.39e-11 ***
BT	0.08386	0.02601	3.224	0.00127 **
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				

(Dispersion parameter for poisson family taken to be 1)

Null deviance: 94.526 on 105 degrees of freedom

Residual deviance: 86.590 on 104 degrees of freedom

AIC: 127.26

Number of Fisher Scoring iterations: 6

```
> tapply(BufP,HerdB,mean)
        0         1
0.1363636 0.2500000
> tapply(BufP,Dog,mean)
        0         1
0.2191781 0.2424242
> plot(BufP,BT)
> plot(BT, BufP)
> cor(dist,BufP)
[1] -0.00302079
> plot(dist, BufP)
> cor(dist,BufP/BT)
[1] -0.01255683
> plot(dist,BufP/BT)
```

Analysis 4: Predation on Goats

glm(GoatP~HerdG*GT+Dog+dist, fam="poisson")
anova(model4, test="Chi")
Analysis of Deviance Table
Model: poisson, link: log
Response: GoatP
Terms added sequentially (first to last)

	DF DEVIANCE	RESID.	DF RESID.	DEV	PR(>CHI)
NULL		167	410.48		
HerdG	1	0.850	166	409.63	0.35655
GT	1	66.216	165	343.41	4.041e-16 ***
Dog	1	2.537	164	340.88	0.11120
dist	1	0.092	163	340.79	0.76204
HerdG:GT	1	3.058	162	337.73	0.08033
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

> model5<-step(model4)
Start: AIC=634.65
GoatP ~ HerdG * GT + Dog + dist

	DF	DEVIANCE	AIC
- dist	1	337.80	632.72
	<none>	337.73	634.65
- Dog	1	340.54	635.46
- HerdG:GT	1	340.79	635.70

Step: AIC=632.72
GoatP ~ HerdG + GT + Dog + HerdG:GT

	DF	DEVIANCE	AIC
	<none>	337.80	632.72
- Dog	1	340.57	633.49
- HerdG:GT	1	340.88	633.80

> anova(model5, test="Chi")
Analysis of Deviance Table

Model: poisson, link: log
Response: GoatP
Terms added sequentially (first to last)

	DF DEVIANCE	RESID.	DF RESID.	DEV	PR(>CHI)
NULL		167	410.48		
HerdG	1	0.850	166	409.63	0.35655
GT	1	66.216	165	343.41	4.041e-16 ***
Dog	1	2.537	164	340.88	0.11120
HerdG:GT	1	3.079	163	337.80	0.07931
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

> summary(model5)

Call:
glm(formula = GoatP ~ HerdG + GT + Dog + HerdG:GT, family = "poisson")

Deviance Residuals:

MIN	1Q	MEDIAN	3Q	MAX
-2.9607	-1.5887	-0.2580	0.4952	4.6194

Coefficients:

	ESTIMATE	STD. ERROR	Z VALUE	PR(>|Z|)
(Intercept)	-0.93848	0.80295	-1.169	0.2425
HerdG1	0.97627	0.80605	1.211	0.2258
GT	0.10333	0.04934	2.094	0.0362 *
Dog1	0.20377	0.12158	1.676	0.0937
HerdG1:GT	-0.08561	0.04937	-1.734	0.0829
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

(Dispersion parameter for poisson family taken to be 1)
Null deviance: 410.48 on 167 degrees of freedom
Residual deviance: 337.80 on 163 degrees of freedom
AIC: 632.72
Number of Fisher Scoring iterations: 5

```
> tapply(GoatP,HerdG,mean)
       0       1
1.200000 1.717791
> tapply(GoatP,Dog,mean)
       0       1
1.583333 1.916667
> plot(GoatP,GT)
> plot(GT, GoatP)
> cor(dist,GoatP)
[1] 0.0008056237
> plot(dist, GoatP)
> cor(dist,GoatP/GT)
[1] -0.0533146
> plot(dist,GoatP/GT)
```

Chapter 3: Appendix 3:
Open ended questions used to probe respondents perceptions on predation

Questions

1. What is your opinion on the current ban of sale on beef and cows and buffalos?
   What may be the implications to your community as result of the ban?
   What will happen to the excess animals that cannot be sold?
   What may be the positive or negative impacts of excess cattle in villages? Explain
   Will it impact your economically? Explain
   How will it impact your use of the forest land?
   How will these unwanted cattle impact your own valuable cattle?
   If you are inconvenienced by the bans what are your options?
   If you took any actions to reduce cows how will your community members respond? Explain

2. What do you think of Anna Pratha?
   What will happen to the excess animals? Explain
   What are the positive and negative outcomes do you see from this practice? Explain
   How may it impact your economically?
   How will it impact your use of the forest land?
   How will these unwanted cattle impact your own valuable cattle?
   If you are inconvenienced by this practice what are your options? Explain
   What do you think of the carcasses that are dumped at the village-forest edges?
   If you took any actions to reduce cows how will your community members respond? Explain

Flow chart of perceived reasons underlying predation

Figure 1: Practice of dumping carcasses

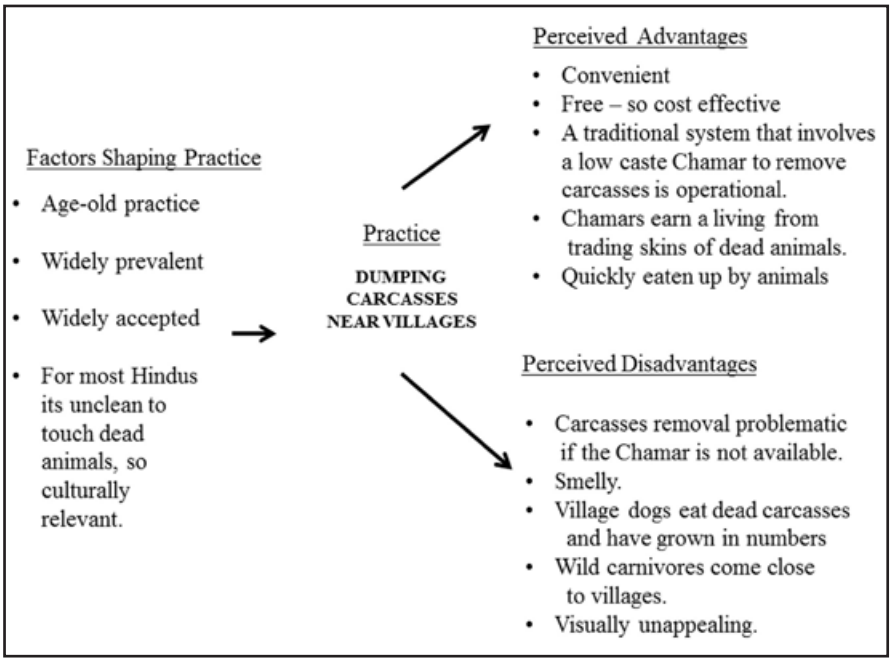


Figure 2: Land use regulations and the perceived advantages and disadvantages

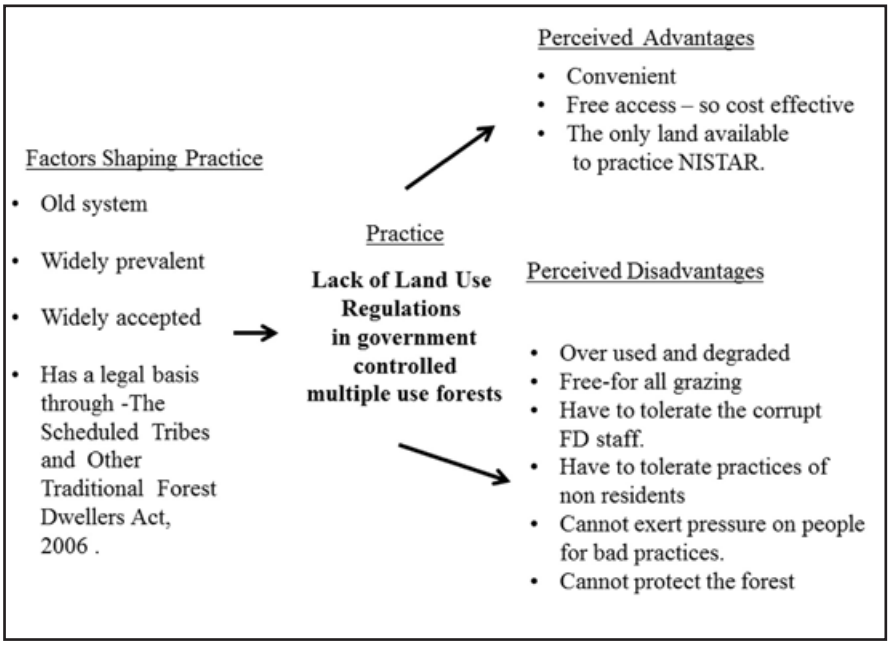


Figure 3: Perceptions on the cultural practice of Anna Pratha

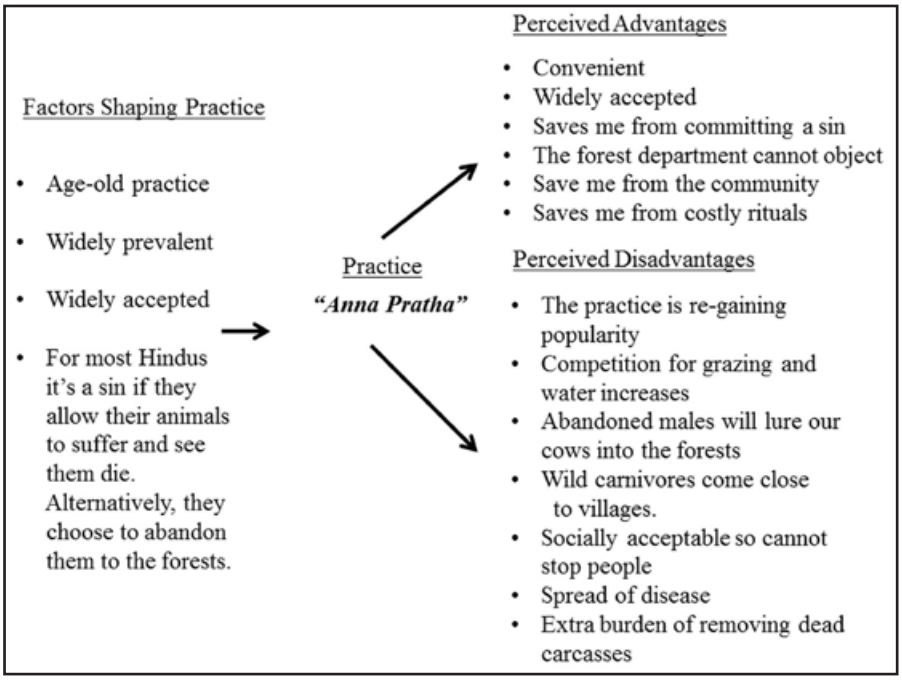
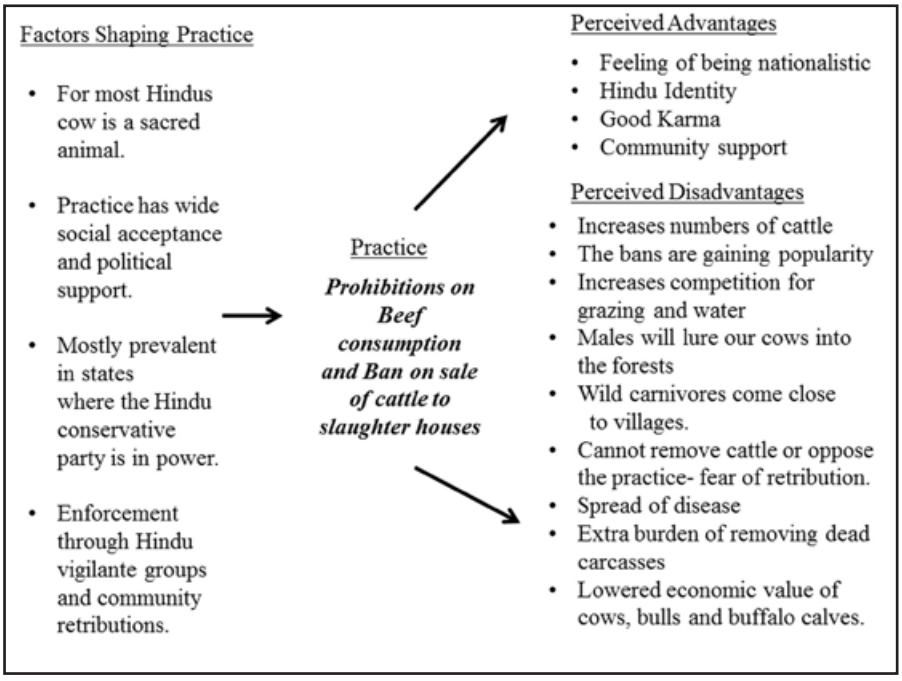


Figure 4: Perceptions on the prohibitions on selling domestic animals to slaughter houses



Chapter 4: Appendix 1: Coefficients of first analysis 'Zone' (core zone versus buffer zone)

Model term	Coefficient	Standard error	T	Sig	95% Confidence interval	
					Lower	Upper
Intercept	1.058	102693.887	0.000	1.000	-201290.071	201292.187
gen=2	1.529	102693.887	0.000	1.000	-201289.599	201292.658
gen=1	-1.052	102693.887	-0.000	1.000	-201292.181	201290.077
sex=m	-1.838	0.741	-2.483	.013	-3.290	-0.387
sex=f	-0.065ª					
seasons=w	-0.041	0.173	-0.238	.812	-0.381	0.298
seasons=s	-1.216	0.204	-5.965	.000	-1.616	-0.816
seasons=r	0ª					
day_night =1	-0.414	0.101	-4.118	.000	-0.611	-0.217
day_night =0	0ª					
y_con	-0.307	0.051	-6.010	.000	-0.407	-0.207
[gen =2]*[day_night=1]	0.459	0.090	5.118	.000	0.283	0.635
[gen =2]*[day_night=0]	0ª					
[gen =1]*[day_night=1]	0ª					
[gen =1]*[day_night=0]	0ª					
y_con*[gen=2]	-0.281	0.054	-5.170	.000	-0.387	-0.174
y_con*[gen=1]	0ª					
[sex=m]*[day_night=1]	-0.235	0.089	-2.634	.008	-0.410	-0.060
[sex=m]*[day_night=0]	0ª					
[sex=f]*[day_night=1]	0ª					
[sex=f]*[day_night=0]	0ª					
y_con*[sex=m]	0.242	0.049	4.981	.000	0.147	0.337
y_con*[sex=f]	0ª					
[seasons =w]*[day_night=1]	-0.056	0.102	-0.551	.582	-0.256	0.143
[seasons =w]*[day_night=0]	0ª					
[seasons =s]*[day_night=1]	-0.290	0.111	-2.616	.009	-0.507	-0.073
[seasons =s]*[day_night=0]	0ª					
[seasons =r]*[day_night=1]	0ª					
[seasons =r]*[day_night=0]	0ª					
y_con* [seasons=w]	0.056	0.051	1.107	.268	-0.043	0.155
y_con* [seasons=s]	0.339	0.058	5.842	.000	0.225	0.453
y_con* [seasons=r]	0ª					

Probability distribution binomial; link function logit; coefficient is set to 0ª because it is redundant.

Chapter 4: Appendix 2: Coefficients of second analysis 'near villages'.

Model term	Coefficient	Standard error	T	Sig	95% Confidence interval	
					Lower	Upper
intercept	-1.922	4,035	-0.476	.634	0,000	398,395
gen=2	0.623	0,452	1.378	.168	0,769	4,527
gen=1	0ª					
sex=m	0.174	0.436	0.399	690	0,506	2,796
sex=f	0ª					
seasons=w	-0.343	0.213	-1,610	.108	0.467	1,078
seasons=s	-1.666	0.260	-6,400	.000	0,113	0,315
seasons=r	0ª					
day_night =1	0.046	0.047	0.969	.333	0.954	1,148
day_night =0	0ª					
year_con	-0.189	0.062	-3.029	.002	0.732	0.935
zone_cl=1	1.016	0.195	5.210	.000	1,885	4,050
zone_cl=0	0ª					
[gen=2]*[seasons=w]	-0.347	0.129	-2.682	.007	0.548	0.911
[gen=2]*[seasons=s]	-0.131	0.141	-0.924	0.356	0.665	1.158
[gen=2]*[seasons=r]	0ª					
[gen=1]*[seasons=w]	0ª					
[gen=1]*[seasons=s]	0ª					
[gen=1]*[seasons=r]	0ª					
y_con*[gen=2]	0.467	0.062	7.564	.000	1.414	1.801
y_con*[gen=1]	0ª					
[gen=2]*[zone_cl=1]	-1.869	0.120	-15.613	.000	0.122	0.195
[gen=2]*[zone_cl=0]	0ª					
[gen=1]*[zone_cl=1]	0ª					
[gen=1]*[zone_cl=0]	0ª					
[sex=m]*[seasons=w]	0.270	0.114	2.359	0.018	1.047	1.639
[sex=m]*[seasons=s]	0.267	0.128	2.080	0.036	1.016	1.679
[sex=m]*[seasons=r]	0ª					
[sex=f]*[seasons=w]	0ª					
[sex=f]*[seasons=s]	0ª					
[sex=f]*[seasons=r]	0ª					
y_con*[sex=m]	-0.254	0.058	-4.376	.000	0.692	0.869
y_con*[sex=f]	0ª					
[sex=m]*[zone_cl_=1]	0.766	0.102	7.493	.000	1.760	2.628
[sex=m]*[zone_cl_=0]	0ª					
[sex=f]*[zone_cl_=1]	0ª					
[sex=f]*[zone_cl_=0]	0ª					
y_con*[seasons=w]	0.049	0.065	0.751	.453	0.725	1.192
y_con*[seasons=s]	0.316	0.075	4.238	.000	1.185	1.588
y_con*[seasons=r]	0ª					
y_con*[zone_cl=1]	0.187	0.058	3.252	.001	1.077	1.350
y_con*[zone_cl=0]	0ª					

Probability distribution binomial; link function logit; coefficient is set to 0ª because it is redundant.

Chapter 4: Appendix 3: Coefficient of third analysis 'near water'.

Model term	Coefficient	Standard error	T	Sig	95% Confidence interval	
					Lower	Upper
intercept	-1.797	1.296	-1.386	.166	-4.338	0.744
gen=2	-0.327	0.539	-0.606	.544	-1.384	0.730
gen=1	0ª					
sex=m	0.005	0.511	0.011	.991	-0.996	1.007
sex=f	0ª					
seasons=w	0.694	0.083	8.338	.000	0.531	0.857
seasons=s	0.977	0.081	12.038	.000	0.819	1.136
seasons=r	0ª					
day_night =1	-0.083	0.045	-1.845	.065	-0.171	0.005
day_night =0	0ª					
y_con	-0.146	0.029	-4.986	.000	-0.203	-0.088
zone_cl=1	0.505	0.122	4.151	.000	0.266	0.743
zone_cl=0	0ª					
points in 5km buffer=1	0.020	0.067	0.292	.771	-0.112	0.152
points in 5km buffer =0	0ª					
[gen=2]*[seasons=w]	-0.647	0.130	-4.964	.000	-0.902	-0.392
[gen=2]*[seasons=s]	-0.575	0.131	-4.373	.000	-0.832	-0.317
[gen=2]*[seasons=r]	0ª					
[gen=1]*[seasons=w]	0ª					
[gen=1]*[seasons=s]	0ª					
[gen=1]*[seasons=r]	0ª					
y_con*[gen=2]	0.181	0.067	2.688	.007	0.049	0.313
y_con*[gen=1]	0ª					
[sex=m]*[seasons=w]	-0.284	0.118	-2.402	.016	-0.516	-0.052
[sex=m]*[seasons=s]	-0.422	0.119	-3.546	.000	-0.656	-0.819
[sex=m]*[seasons=r]	0ª					
[sex=f]*[seasons=w]	0ª					
[sex=f]*[seasons=s]	0ª					
[sex=f]*[seasons=r]	0ª					
y_con*[sex=m]	0.171	0.045	3.763	.000	0.082	0.260
y_con*[sex=f]	0ª					
[sex=m]*[zone_cl_=1]	-0.406	0.120	-3.372	.001	-0.642	-0.170
[sex=m]*[zone_cl_=0]	0ª					
[sex=f]*[zone_cl_=1]	0ª					
[sex=f]*[zone_cl_=0]	0ª					
[sex =m]*[points in 5km buffer =1]	-0.319	0.101	-3.170	.002	-0.517	-0.122
[sex = m]*[points in 5km buffer =0]	0ª					
[sex =f]*[points in 5km buffer =1]	0ª					
[sex =f]*[points in 5km buffer =0]	0ª					
[seasons=w]* [zone_cl = 1]	-0.158	0.139	-1.141	.254	-0.430	0.114
[seasons=w]*[zone_cl = 0]	0ª					
[seasons=s]* [zone_cl=1]	-0.364	0.148	-2.460	.014	-0.654	-0.074
[seasons = s]* [zone_cl=0]	0ª					
[seasons = r]* [zone_cl=1]	0ª					
[seasons = r]*[zone_cl=0]	0ª					

Probability distribution Binomial; Link Function Logit; Coefficient is set to 0ª because it is redundant.

Chapter 5: S1 Table:
Coefficients for analysis (1) Zone, (2) Village, (3) Prey age, (4) Prey Sex, (5) Water and (6) Scat and Kill.

(1) Zone

Response: Prey (Wild/Domestic)

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.76420	0.50003	3.528	0.000418 ***
zone2	-1.52174	0.48181	-3.158	0.001587 **
sex2	-2.97532	0.56127	-5.301	1.15e-07 ***
gen2	-0.09017	0.35606	-0.253	0.800076
seasS	-1.65467	0.53472	-3.094	0.001972 **
seasW	0.89834	0.48014	1.871	0.061344 .
zone2:sex2	1.28178	0.52350	2.448	0.014346 *
zone2:seasS	2.12970	0.60457	3.523	0.000427 ***
zone2:seasW	-0.14699	0.56326	-0.261	0.794117
sex2:gen2	2.02289	0.52670	3.841	0.000123 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

(2) Village

Response: Prey (Wild/Domestic)

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)
NULL			49	155.968	
dist	2	22.686	47	133.282	1.185e-05 ***
sex	1	46.801	46	86.481	7.857e-12 ***
gen	1	8.629	45	77.852	0.0033079 **
seas	2	10.660	43	67.191	0.0048438 **
dist:sex	2	14.917	41	52.275	0.0005766 ***
dist:gen	2	12.794	39	39.480	0.0016664 **
dist:seas	4	14.310	35	25.171	0.0063700 **
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

(3) Prey Sex

Response: Prey sex

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)
NULL			39	61.974	
Sex	1	10.5341	38	51.440	0.0011719 **
seas	2	6.1064	36	45.334	0.0472072 *
domwild	1	5.1283	35	40.205	0.0235382 *
sex:domwild	1	12.1229	34	28.083	0.0004981 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

(4) Prey Age group

Response: Age group

	Resid.	Df	Resid.Dev	Df	Deviance	Pr(>Chi)
sex:gen:domwild	2	22	15.0122	-1	-5.4274	0.01982 *
sex:gen:zone	2	22	13.4381	-1	-3.8533	0.04965 *
sex:seas	2	23	18.9911	-2	-9.4063	0.009066 **
gen:seas	2	23	16.5089	-2	-6.9242	0.03136 *
domwild:seas	2	23	18.0732	-2	-8.4885	0.01435 *
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1						

(5) Water

Response: Prey (Wild/Domestic)

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)
NULL			43	194.605	
Zone	1	14.094	42	180.511	0.0001739 ***
sex	1	80.130	41	100.381	< 2.2e-16 ***
gen	1	13.989	40	86.392	0.0001839 ***
seas	2	12.929	38	73.463	0.0015575 **
zone:sex	1	0.314	37	73.149	0.5754047
zone:gen	1	7.398	36	65.752	0.0065304 **
zone:seas	2	17.643	34	48.108	0.0001475 ***
sex:gen	1	10.172	33	37.936	0.0014259 **
sex:seas	2	1.701	3	36.235	0.4272070
gen:seas	2	0.714	29	35.521	0.6997409
zone:sex:seas	2	3.282	27	32.240	0.1938148
zone:gen:seas	2	6.494	25	25.745	0.0388828 *
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

(6) Fisher exact test comparison scat and kill

```
> x<-as.matrix(c(43,20,12,162,5,0))
> dim(x) <-c(3,2)
> x
[,1] [,2]
[1,]    43  162
[2,]    20    5
[3,]    12    0
> fisher.test(x)
Fisher's Exact Test for Count Data
data:  x
p-value = 1.227e-14
alternative hypothesis: two. Sided
```

Chapter 5: S1 Text:
Climate, geography, vegetation and the practice of Anna Pratha in the Study area

The study area has a tropical climate with three distinct seasons. The hot summer occurs between March and June, the wet season occurs from July to October, and the mild winter occurs from November to February. The daytime temperatures during the summer months exceed 45 °C, whereas the temperature drops to 3°C at night during winter. Annual rainfall is approximately 1100 mm, with the monsoon rains providing the principal source of water for large areas of the region [18]. Winter and summer showers are influenced by cyclones [9]. Rainwater from the hills flows through numerous streams and drains into the Ken River, the major water body in the area.
The terrain and vegetation in the reserve is hilly, with flat plateaus on the top and undulating plains on either side of the hills. Due to the hilly topography and quick drainage, the availability of surface water is a limiting factor throughout the entire area when the rains stop. Low water availability also shapes the vegetation in the area.
The reserve supports predominantly dry deciduous vegetation. On the plains, savannah grassland-woodland forests with short grasses and open thorny woodlands occur. In some areas, dry mixed and monotonous forest occurs. Bamboo grows mostly on the slopes.

Over 12,000 cattle left to fend for themselves in parched Bundelkhand
http://www.hindustantimes.com/india-news/over-12-000-cattle-left-to-fend-for-themselves-in-parched-bundelkhand/story-lIs0F2ACm5V4PSG1hoiHdI.html
Jun 08, 2016 14:31 IST

Neeraj Santoshi
Hindustan Times, Bhopal

In 37 villages, nearly 90% of the 14,000 cattle were abandoned by drought-affected villagers. (HT Photo)

Unable to manage water and fodder for their cattle, scores of farmers in the drought-hit districts of Bundelkhand have released over 12,800 domestic animals this summer so far to fend for themselves, says a recent survey.
In the Bundelkhand region, it is a tradition called 'Anna Pratha' according to which people release their animals to fend for themselves or die away from their sight.
Hari Gaikwar, a farmer from Tikamgarh's Tanga village, couldn't bear to see his cows slowly dying of hunger and thirst before his own eyes. So he did the 'Anna Pratha' — like many others.
According to the survey conducted in 66 villages in three worst drought-hit districts of Bundelkhand — Tikamgarh, Sagar and Chhattarpur — there is no water left for cattle in 56% of the villages. In 37 villages, nearly 91% of the 14,000 cattle were released by helpless villagers. Hundreds of cattle have died, say the locals, while activists say the famine has already set in for the cattle.

LEFT TO DIE

District	Surveyed villages	Cattle population	Cattle released	% of cattle released
Chhattarpur	32	4,500	4,105	91
Sagar	14	2,500	2,025	81
Tikamgarh	20	7,000	6,674	95
TOTAL	**66**	**14,000**	**12,804**	**91**

"In utter desperation, I released my five cows, two calves and one bull as I couldn't arrange water or fodder for them. I couldn't see them suffering before my own eyes. Only I know what it feels like when you see your cows leaving…", said Gaikwar.

Sarika Sinha, regional manager of Action Aid MP, said the survey, which was conducted in April-May by Janpahal, a network of NGOs working in the drought-affected areas, Tikamgarh-based Madhya Pradesh Aapda Nivaran Manch and Action Aid, made them realise that famine-like conditions had already set in for domestic animals.

According to this survey, water was not available for cattle in 47% of the surveyed villages in Chhattarpur district, while in Tikamgarh district, the percentage of such villages was 45 %. Sagar district was the worst as 93% of the surveyed villages did not have water for the domestic animals.

Director animal husbandry Dr RK Rokde said he will ask his field staff in Bundelkhand to give him a report about the ground reality. "Many farmers in Bundelkhand release their cattle in summers. There is a tradition. But such a high figure is unusual. I will have to check with my staff. If the situation is alarming, we will take necessary steps," he said.

S1 Figure: Compensation amounts paid to livestock owners by PTR management between 2009 and 2013.

S.No	Year	Human Deaths		Human Injuries		Livestock kills	
				Number	Rupees	Number	Rupees
1	2009	0	0	13	66026	37	116000
2	2010	0	0	23	117200	42	125000
3	2011	0	0	27	73740	56	222500
4	2012	0	0	4	34677	83	312500
5	2013	0	0	6	23029	138	441600
	Total				314692		1217600

Source : Panna Tiger Reserve Office, 2015

(1 US$ = 60 Indian Rupees)

Chapter 5: S2 Table: Details of Data Analysis

Table A

Percentage (%) of kills and frequency of occurrence (% FO) of prey items found in tiger scats showed the contributions of wild (W) and domestic (D) prey animals to the diet of tigers in the Panna Tiger Reserve. The 647 kills (2009 to 2013) and 56 scats (2015) were grouped into three size-based categories ((L) large, (In) intermediate, and (S) small) to demonstrate the relative contribution of prey size and prey type to the diet of the tiger.

	Prey species and prey weight	Prey kills (2009-2014)		Frequency of Occurrence (FO) of prey items in scats (2015)	(% FO)
Prey size category and type	(Average body weights in kg)	Core + Buffer Zone		Buffer Zone	
		N	%	FO	%
L – WP	Sambar(136)	245	37.9	14	17.5
L – WP	Nilgai (182)	49	7.6	7	8.8
L – WP	Leopard (50)	3	0.5	**	**
L – WP	Sloth bear (70)	2	0.3	**	**
L – WP	Subtotal wild prey	299	46.3	21	26.3
L – DP	Cow (150)	243	37.6	22	27.3
L – DP	Buffalo(150)	35	5.4	**	**
L – DP	Subtotal domestic prey	278	43.0	22	27.3
In- WP	Chital (47)	21	3.2	8	10.0
In- WP	Pig (45)	29	4.5	8	10.0
In- WP	Subtotal wild prey	50	7.7	16	20.0
In – DP	Dog (20)	**	**	2	2.5
In – DP	Goat (10)	1	0.2	2	2.5
In – DP	Subtotal domestic prey	1	0.2	4	5.0
S – WP	Reptile (2)	**	**	7	8.8
S – WP	Bird (2)	1	0.2	4	5.0
S – WP	Mongoose (1.5)	**	**	1	1.3
S – WP	Subtotal wild prey	1	0.2	12	15.1
	Unrecognised	18	2.8	5	6.3
	Total	**647**	**100**	**80**	**100**

Overall = Core zone + Buffer Zone;
Prey size: L = Large; In = Intermediate, and S = Small
Prey type: WP = Wild prey animals, DP = Domestic prey animals
Prey killed: (N) = Number of kills; (%) = Percentage contribution
Average body weight of an individual prey in kg (Sankar and Johnsingh, 2002)
FO = Frequency of Occurrence (% FO) = Percent of all scats containing each prey item
** = No values

Table B

Wild (w) and domestic (d) animals and the percentage of domestic (d%) animals killed by male and female tigers in the core and buffer zones of the Panna Tiger Reserve, India, between 2009 and 2013.

	MALE TIGER			FEMALE TIGER			TOTAL		
ZONE	**w**	**d**	**d%**	**w**	**d**	**d%**	**W**	**d**	**d%**
Buffer	16	59	79	56	36	39	72	95	57
Core	44	87	66	232	97	29	276	184	40
Total	**60**	**146**	**71**	**288**	**133**	**32**	**348**	**279**	**44**

Table C

Wild (w) and domestic (d) animals and the percentage of domestic (d%) animals killed by tigers in the core and buffer zones during the summer (march to june), rainy (july to october), and winter(november to february) seasons in the Panna Tiger Reserve, India, between 2009 and 2013.

	SUMMER			RAINY			WINTER			TOTAL		
ZONE	**w**	**d**	**d%**	**w**	**d**	**d%**	**W**	**d**	**d%**	**w**	**d**	**d%**
Buffer	24	10	41	36	52	59	12	33	73	72	95	52
Core	124	79	63	73	29	28	79	76	49	276	184	39
Total	**148**	**89**	**38**	**109**	**81**	**43**	**91**	**109**	**55**	**348**	**279**	**44**

Table D

Wild (w) and domestic (d) animals and the percentage of domestic (d%) animals killed by male and female tigers belonging to the first and second generations in the Panna Tiger Reserve, India, between 2009 and 2013.

	FIRST GENERATION			SECOND GENERATION			TOTAL		
SEX	**w**	**d**	**d%**	**w**	**d**	**d%**	**W**	**d**	**d%**
Male	21	50	70	39	96	71	60	146	71
Female	275	99	27	13	34	72	288	133	32
Total	**296**	**149**	**33**	**52**	**130**	**71**	**348**	**279**	**44**

First generation tigers are 6 founder tigers reintroduced between 2009 and 2013.
Second generation tigers are those that are born to the founder tigers starting from 2011.

Table E

Wild (w) and domestic (d) animals and the percentage of domestic (d%) animals killed by male and female tigers at different distances (near, intermediate, far) from the core zone of Panna Tiger Reserve, India, between 2009 and 2013.

	NEAR			INTERMEDIATE			FAR			TOTAL		
SEX	**w**	**d**	**d%**	**w**	**d**	**d%**	**w**	**d**	**d%**	**w**	**d**	**d%**
Male	18	42	70	0	15	100	11	27	71	29	84	74
Female	109	34	24	17	5	23	15	28	65	141	67	33
Total	**127**	**76**	**39**	**17**	**20**	**54**	**26**	**55**	**68**	**170**	**151**	**80**

Near = Less than 2km; Intermediate = 2 to 10 km; Far= Over 10km

Table F

Wild (w) and domestic (d) animals and the percentage of domestic (d%) animals killed by first and second generation tigers at different distances (near, intermediate, and far) from the core zone of the Panna Tiger Reserve, India, between 2009 and 2013.

	NEAR			INTERMEDIATE			FAR			TOTAL		
GENERATION	**w**	**d**	**d%**	**w**	**d**	**d%**	**w**	**d**	**d%**	**w**	**d**	**d%**
First Gen	105	47	31	17	4	19	13	7	35	135	58	30
Second Gen	22	29	57	0	16	100	13	48	79	35	93	73
Total	**127**	**76**	**37**	**17**	**20**	**54**	**26**	**55**	**68**	**170**	**151**	**47**

Near = Less than 2km; Intermediate = 2 to 10 km; Far= Over 10km

Table G

Wild (w) and domestic (d) animals and the percentage of domestic (d%) animals killed by tigers during the summer, rainy, and winter seasons at different distances (near, intermediate, far) from the core zone of the Panna Tiger Reserve, India, between 2009 and 2013.

	NEAR			INTERMEDIATE			FAR			TOTAL		
SEASON	**w**	**d**	**d%**	**w**	**d**	**d%**	**w**	**d**	**d%**	**w**	**d**	**d%**
Summer	54	28	34	9	1	10	9	7	44	72	36	33
Rainy	39	23	37	7	14	67	14	24	63	60	61	50
Winter	34	25	42	1	5	83	3	24	89	38	54	59
Total	**127**	**76**	**37**	**17**	**20**	**54**	**26**	**55**	**68**	**170**	**151**	**47**

Near = Less than 2km; Intermediate = 2 to 10 km; Far= Over 10km

Table H

Male (MP) and female (FP) prey animals and percentage males (MP %) within wild and domestic prey animals, predated by male and female tigers in the Panna Tiger Reserve, India, between 2009 and 2013.

	WILD PREY			DOMESTIC PREY			TOTAL		
SEX	**MP**	**FP**	**MP%**	**MP**	**FP**	**MP%**	**MP**	**FP**	**MP%**
Male	43	5	89	73	53	58	116	58	67
Female	115	103	53	60	60	50	175	163	51
Total	**158**	**108**	**59**	**133**	**113**	**54**	**291**	**221**	**57**

Table I

Number of male (MP) and female (FP) prey animals and the percentage of male prey animals (MP%) predated on by tigers during the summer, rainy, and winter seasons in the Panna Tiger Reserve, India between 2009 and 2013.

SEASONS	MP	FP	MP%
Summer	120	75	62
Rainy	93	68	58
Winter	79	78	50
Total	**292**	**221**	**57**

Table J

Young (Y) and adult (A) prey animals and the percentage of adult prey animals (A%) predated on by first and second generation male and female tigers in the core and buffer zones of the Panna Tiger Reserve, between 2009 and 2013.

		CORE			BUFFER			TOTAL		
GENERATION	**SEX**	**Y**	**A**	**A%**	**Y**	**A**	**A%**	**Y**	**A**	**A%**
First Gen	Male	8	51	86	1	7	88	9	58	87
	Female	27	246	90	4	50	93	31	296	91
Second Gen	Male	9	53	85	12	47	80	21	100	83
	Female	1	15	94	9	19	68	10	34	77
Total		**45**	**365**	**89**	**26**	**123**	**83**	**71**	**488**	**87**

Table K

Young prey animals (Y), adult prey animals (A) and the percentage of adult prey animals (A%) within domestic and wild prey animals that were predated on by first and second generation male and female tigers in the Panna Tiger Reserve, between 2009 and 2013.

		WILD			DOMESTIC			TOTAL		
GENERATION	**SEX**	**Y**	**A**	**A%**	**Y**	**A**	**A%**	**Y**	**A**	**A%**
First Gen	Male	0	17	100	9	41	82	9	58	87
	Female	12	216	95	19	80	82	31	296	91
Second Gen	Male	2	23	92	19	77	80	21	100	83
	Female	0	10	100	10	24	71	10	34	77
Total		**14**	**266**	**95**	**57**	**222**	**80**	**71**	**488**	**87**

Table L

Adult (A) and young (Y) prey animals and the percentage of adult (A%) prey animals from within wild and domestic prey that were predated on by tigers in the summer, rainy, and winter seasons in the Panna Tiger Reserve, India, between 2009 and 2013.

	WILD PREY			DOMESTIC PREY			TOTAL		
SEASON	**A**	**Y**	**A%**	**A**	**Y**	**A%**	**A**	**Y**	**A%**
Summer	120	1	99	75	14	84	195	15	93
Rainy	80	6	93	62	19	77	142	25	85
Winter	66	7	90	85	24	78	151	31	83
Total	**266**	**14**	**95**	**222**	**57**	**80**	**488**	**71**	**87**

Table M

Adult (A) and young (Y) prey animals and the percentage of adult (A%) prey animals predated on by tigers in the core zone and buffer zones during the summer, rainy, and winter seasons in the Panna Tiger Reserve, India, between 2009 and 2013.

	CORE ZONE			BUFFER ZONE			TOTAL		
SEASON	**A**	**Y**	**A%**	**A**	**Y**	**A%**	**A**	**Y**	**A%**
Summer	167	14	92	28	1	97	195	15	93
Rainy	81	9	90	61	16	79	142	25	85
Winter	117	22	84	9	9	79	151	31	83
Total	**365**	**45**	**89**	**26**	**26**	**83**	**488**	**71**	**87**

Table N

Adult (A) and young (Y) prey animals and the percentage of adult (A%) animals predated on by male and female tigers during the summer, rainy, and winter seasons in the Panna Tiger Reserve, India, between 2009 and 2013.

	MALE TIGER			FEMALE TIGER			TOTAL		
SEASON	**A**	**Y**	**A%**	**A**	**Y**	**A%**	**A**	**Y**	**A%**
Summer	56	5	92	139	10	93	195	15	93
Rainy	47	13	78	95	12	89	142	25	85
Winter	55	12	71	96	19	83	151	31	83
Total	**158**	**30**	**84**	**330**	**41**	**89**	**488**	**71**	**87**

A VHF radio collar is attached to this adult female tigeress. The tiger monitoring teams using a tracking antenne gather the coded signal from the collar and use it to know the location of the tiger.

Summary

Can tigers survive in human-dominated landscapes? Understanding Human-Tiger Coexistence in the Buffer Zone of Panna Tiger Reserve, Madhya Pradesh, India.

Keywords

Tiger (*Panthera tigris tigris*), human-tiger interactions, human-dominated landscapes, beliefs and local practices, local ecological knowledge, livestock predation, tiger space use, tiger diet, India.

The tiger (*Panthera tigris*) is one of the world's most iconic carnivores for conservation. This status is because tiger populations throughout their range have reduced and continue to decline despite continued global efforts to save them. In 2010 the Global Tiger Initiative (GTI) meeting that took place in St. Petersburg, Russia, the governments of all 13 tiger range countries pledged to invest resources and contribute to doubling tiger numbers by 2022. This global effort may be the last chance to save the species from extinction.

The forests of India support nearly 60% of all the tigers in the world. However, India also has a large economically deprived rural population, and people rely heavily on the forests and forest resources for their survival and livelihoods. Conserving the tiger in India has vast benefits for these rural communities. If tigers, as keystone predators and focal species are conserved, such conservation will ensure forest protection and ecosystem functioning. Secure ecosystems will, in turn, protect many other species and also provide ecosystem services to the people living in the area. Following this line of reasoning, the Indian government has committed resources and created 48 tiger reserves, which are the critical source habitats for tigers in India. However, the Indian tiger conservation strategy, based on the metapopulation concept, is reliant on connecting various isolated protected areas capable of supporting only small numbers of tigers with the adjoining multiple use forests and private lands. If successfully implemented, the connected tiger landscape will adequately support a genetically diverse and ecologically viable population of wild tigers and also keep the ecosystem functioning of the landscape intact. The most significant challenge in realising this new vast landscape for tigers is to integrate the areas used by people into the landscape and create one coexistence landscape suitable for both people and tigers. I was motivated by the immediate and foreseeable challenges in realising a coexistence landscape and conceived this study.

There are many sceptics within tiger conservation groups and government managers who believe that promoting large carnivores in human use areas will lead to conflicts with people. Their scepticism is based on the fact that tigers, when they move in shared landscapes, are capable of attacking people and killing livestock. As a response, people will conflict and respond by killing tigers or opposing coexistence plans. Addressing conflicts is, therefore, one of the primary objectives of Global Tiger Recovery program, a global initiative to increase tiger numbers. There are also those who support the idea to promote tiger conservation outside protected areas. However, I feel that currently human-tiger coexistence prospects in India are poorly understood. My thinking is based on the fact that there is a scarcity of systematic studies on human-tiger coexistence scenarios. Most published information on human-tiger coexistence are intellectualised scenarios and assumptions of tiger behaviour from studies conducted in protected areas. In protected areas of India, human presence and activity are restricted, and therefore the full-scale human influence on the tiger habitat and tiger response to such influence are underrepresented. Further, historically and to the present tiger conservation efforts in India have mostly focussed protected areas and their management and have rarely aimed outside the protected areas or involved local people. So apart from human injuries and livestock losses other facets of the relationship people may have with tigers is poorly understood.

Rural citizens in India have always lived alongside wildlife and have developed ways to cope with the threats and dangers large carnivores like tigers pose. If people could not deal with dangerous animals, they would have killed all threatening wildlife species by now. However, that is not the case, and wildlife continues to survive alongside people in many parts of India. Firstly, not having a clear understanding of people's ability to coexist with the tiger may mislead conservationists and managers to take a position that people's presence and activities will pose a persistent threat to tigers and its future survival in such lands, and oppose coexistence plans. Secondly, it is irresponsible to blindly promote tiger conservation in human-dominated lands without an in-depth understanding of local people's ability to cope. Thirdly, reliable information on tiger space use, diets or any other facet of their behaviour in human-dominated landscapes is scarce. These knowledge gaps on people, tiger's and their abilities to co-adapt and coexist make up my study. Chapter's two to five describe each of the four investigations I conducted and chapter six provides a synthesises to the central question of my study, "Can tigers survive in the human-dominated landscapes?".

In chapter 2, an analysis of a unique situation of livestock pastoralists displaying unusually high tolerance towards large carnivores despite frequent predation incidents is presented. Firstly, I used ethnography to describe people's religious beliefs and local practices, and next, I analysed how these factors shaped the relations people had with tigers. Respondent interviews and personal observations allowed collection of detailed information, which were then qualitatively analysed. The findings revealed that residents had strong beliefs in forest spirits. They made pacts with their spirit protectors and firmly adhered to community norms that promoted risk-avoidance behaviours. These interconnected factors provided people with the psychological and practical advantages to

cope with large carnivores and decreased negative interactions. Further, widely prevalent age-old livestock husbandry practices like dumping cow carcasses near village fringes and abandoning unwanted cattle into the forests to roam free provided readily available food for several large carnivores in the region. The vast scale of these cultural practices in the area and the traditional conservation ethic exhibited by local people, positively influence the presence of large carnivores including the tiger.

In Chapter 3, I showed how despite having seemingly excellent local knowledge on carnivores and using preventive strategies, resident livestock owners of Panna Tiger Reserve, India experience high livestock losses to large carnivores. The underlying reasons behind such uncontrollable losses were examined. Through informant interviews and observations I collected quantitative and qualitative data on local knowledge, livestock husbandry and residents perceptions of factors influencing losses. I used Generalised Linear Models (GLM) and qualitative data from informant interviews to analyse and explain factors affecting losses. The findings do support the assumption that good knowledge of carnivores and the use of preventive strategies lowered losses but did not eliminate them entirely. Socio-political factors surrounding livestock, for example, prohibitions on the sale of cows to abattoirs and lack of exclusive land use rights in the buffer zone created obstacles for resident people living in the buffer zone to remove feral and free-roaming cattle of non-residents from the forests. Further, it compelled residents to graze their valuable stock in the same areas, which made their valuable livestock more vulnerable to predation by large carnivores. At the same time, residents also found it difficult to oppose the socio-political prohibitions on cows and buffalos and contradict the practices of non-residents. This case study shows that some communities have the local knowledge, and they invest in preventive measures. However, sometimes, the external socio-political influences and unfavourable land use rights create barriers for local people to manage their livestock well.

In chapter 4, I show the effects of tiger-specific (sex, age group), environmental (seasons, photoperiod) and anthropogenic (human use regimes) factors on the movements and spatial distribution of tigers using the human-dominated buffer zone of the Panna Tiger Reserve. Generalised Linear Mixed Models (GLM) were used to test the significance of the relationships between the covariates influencing tiger presence. The findings show that tiger-specific factors like age group, sex and environmental factors like seasons and day and night significantly explained the observed variations in tiger use of the human-dominated buffer zone. For instance, sub-adult tigers spent 40% of their time in the human-use areas, compared to 10% spent by adult tigers. When in human-use areas, sub-adult tigers approached areas near villages and spent 30% less time in areas close to water than adult tigers. Our study concludes that tigers try and adapt to human use, but the degree of adaptation is linked to experience (nativity hypothesis), meaning younger tigers may show minor adaptation than adults to human influences. If human activities, including livestock practices and people's land use remain poorly regulated in a landscape, such activities may negatively impact some tigers for example, through increased livestock predation leading to conflicts. Next, they may also restrict tigers from exploiting the resources like water bodies in the landscape.

In chapter 5, open access livestock grazing, which is a common practice in the multiple-use forests of India and its compatibility with the reintroduction of tigers is discussed. Here, I focus on the diet of tigers in livestock-dominated areas. The hypothesis was that the presence of feral cattle, along with open-access grazing practices in multiple-use forests, would increase the incidence of predation on livestock by tigers, even when wild prey is available. Generalised Linear Models (GLM) were used to test whether predation of livestock versus wild animals was influenced by (1) the sex and age class of tigers, (2) season, and (3) the distance of prey from the core-zone boundary of the reserve. Overall, sub-adult tigers and adult male tigers killed more livestock than wild prey, even when wild prey was available. In the winter and rainy seasons, livestock was killed by tigers in higher numbers in the buffer zone than in summers. This difference may be explained by the seasonally changing livestock movement patterns in the area. Further, with increasing distance from the core-zone boundary, all tigers killed more livestock, possibly because livestock were more readily available than wild prey. The findings of my study show that open-access and poorly regulated livestock grazing is not currently compatible with large carnivore conservation in the same landscape. Such practices lead to an increase in adverse tiger-human-livestock interactions. In conclusion, I suggest that it may benefit tigers and people if people corralled valuable cattle, leaving feral and unwanted livestock for tigers. This simple strategy would help both local inhabitants and tiger conservation in multiple-use forests of India.

The overall conclusion of my study is that in many rural communities of India people have developed ways to co-adapt and coexist with large carnivores such as tigers. My study demonstrates that the observed adaptation is two directional with tigers also showing natural adaptability to adapt to the human use of the landscape. These findings on the natural ability of people and tigers to co-adapt are new. Based on these new findings, the argument that tigers and people will readily conflict when they interact is not supported. People's ability to cope with large carnivores may not be restricted to my study area alone and may be more common in India than previously thought. Therefore the findings of this study are also relevant to other tiger supporting landscapes of India.

In my study, I demonstrated how local people could cooperate in situations of crisis and support tiger conservation. I believe that similar willingness to support tiger conservation would also be found in other parts of India. On the other hand, some circumstances can undermine the ability of people to adapt. For instance, external socio-political pressure preventing the removal of unwanted cows from the landscape created barriers for local herders to manage their stocks well. In such situations, where local people cannot act, they may need the support of the reserve management and conservation organisations.

Tigers, in response to human presence and activity, exhibited avoidance behaviour, spatial and temporal shifts in their activity patterns and successfully found prey. The few exceptions were the younger tigers that found it more challenging to adapt to human use areas in comparison to the mature adults and may become vulnerable. Interestingly, with age, they changed and avoided human-use areas like other adult tigers. These findings on young tigers are new. Because young tigers are naturally more risk-taking, they require

continuous monitoring while in human-use areas till they grow up. Second, when livestock was freely available in the landscape, tigers readily killed them. Such killing should not be seen as negative because the tigers, during our study period, did not show any signs of being problem animals such as prolific cattle killers or man-eaters. Further, the availability of livestock was because of prevailing local practices and predation by tigers did not lead to conflicts. Tigers feeding on unproductive male animals and abandoned livestock were favouring people. Those who lost valuable animals also knew the circumstances responsible for their losses. These include the presence of feral cattle in the landscape, prohibitions on the removal and sale of cows and buffalos and lack of land use rights. Additionally, people suffered more significant losses from disease and theft. So, local people did not consider predation on its own as the most significant issue.

Based on my research, I conclude that people living in the rural areas of India practice religions, embrace cultural values and carry out age-old practices that promote a tolerant conservation ethic. Their way of life, with or without their conscious actions allows them to share their landscape and the resources in it with the wild animals that also inhabit the landscape. Next, the national pride that a considerable part of world's tigers survives in India will continue to motive Indian politicians, government managers and urbanites to support tiger conservation efforts in India. Tiger conservation efforts outside protected areas can produce both positive and negative social impacts for local communities and resource users. For this reason, it is necessary to understand and adaptively manage the social impacts of tiger conservation over time. Such focused intervention will improve social outcomes, improve local support and increase the overall effectiveness of tiger conservation efforts.

If India fails to protect the tiger, it is clear that not only the natural landscape but also the human landscape will be more impoverished. However, there is enough evidence for optimism that tigers and people can contextually coexist. The coexistence that I showed in my study is naturally occurring, and traditional institutions, age-old beliefs and community norms ensure the adherence to facets governing coexistence. Further, there is evidence of sustainability within the observed local practices. If modern-day tiger conservationists can skilfully integrate some of the encouraging old-ways of rural people who have always coexisted with the tiger, I believe that modern India despite its vast population and challenges can successfully ensure the survival of the tiger.

Samenvatting

Kunnen tijgers overleven in door mensen gedomineerde landschappen? Naar een beter begrip van de co-existentie van mens en tijger in de bufferzone van Panna Tiger Reserve, Madhya Pradesh, India.

Trefwoorden

Tijger (*Panthera tigris tigris*), mens-tijger interacties, mens-gedomineerde landschappen, geloofsvoorstellingen en lokale praktijken, lokale ecologische kennis, vee-predatie, ruimtegebruik, tijgerdieet, India.

De tijger (*Panthera tigris*) is een van 's werelds meest iconische carnivoren voor natuurbehoud. Dit dier heeft deze status omdat tijgerpopulaties in het algemeen zijn afgenomen en blijven dalen, ondanks de aanhoudende en wereldwijde inspanningen om de tijger te behouden. In 2010 beloofden de regeringen van alle 13 tijgerlanden tijdens de Global Tiger Initiative (GTI) bijeenkomst in Sint-Petersburg (Rusland), om middelen te investeren en bij te dragen tot een verdubbeling van de tijgeraantallen in het jaar 2022. Deze wereldwijde inspanning kan de laatste kans zijn om de soort voor uitsterven te behoeden.

De bossen van India ondersteunen bijna 60% van alle tijgers in de wereld. India heeft echter ook een grote economisch achtergestelde plattelandsbevolking en mensen zijn voor hun overleving en levensonderhoud in hoge mate afhankelijk van deze bossen. Het behoud van de tijger in India heeft grote voordelen voor deze plattelandsgemeenschappen. Als tijgers, als keystone-roofdieren, worden beschermd, zorgt deze bescherming tevens voor instandhouding van bossen en voor goed functionerende ecosystemen. Goed functionerende ecosystemen zullen op hun beurt vele andere soorten beschermen en ook ecosysteemdiensten leveren aan de mensen die in het gebied wonen. In navolging van deze redenering heeft de Indiase overheid middelen beschikbaar gesteld en 48 tijgerreservaten gecreëerd, die de kritieke habitat vormen voor tijgers in India. De strategie voor de instandhouding van de Indiase tijger, die is gebaseerd op het concept van een meta-populatie, is echter afhankelijk van het verbinden van verschillende geïsoleerde beschermde gebieden die slechts kleine aantallen tijgers kunnen ondersteunen, met aangrenzend land dat in particulier eigendom is en met bossen die voor meerdere doeleinden gebruikt worden (multiple-use forests). Als deze strategie succesvol wordt geïmplementeerd, kan een 'tijgerlandschap' van onderling verbonden gebieden een genetisch diverse en ecologisch levensvatbare populatie van wilde tijgers

dragen en zal ook het ecosysteem van dit landschap intact blijven. De belangrijkste uitdaging bij het realiseren van dit nieuwe uitgestrekte landschap voor tijgers is om daarin de gebieden die door mensen worden gebruikt te integreren en zodoende een landschap te creëren dat zowel voor mensen als tijgers geschikt is. Ik was geboeid door de grote uitdaging om bij te dragen aan het realiseren van zo'n type landschap en bedacht deze studie.

Binnen organisaties die zich inzetten voor het behoud van de tijger en binnen de overheid zijn er veel sceptici die geloven dat het promoten van grote carnivoren in gebieden die ook door mensen worden gebruikt tot conflicten zal leiden. Hun scepsis is gebaseerd op het feit dat tijgers die zich in gedeelde landschappen bewegen, mensen kunnen aanvallen en vee kunnen doden. Als reactie daarop zullen mensen tijgers doden of plannen voor co-existentie van mensen en tijgers tegenwerken. Het aanpakken van conflicten is daarom een van de primaire doelstellingen van het Global Tiger Recovery-programma, een wereldwijd initiatief om het aantal tijgers te vergroten. Er zijn ook mensen die het idee ondersteunen om het behoud van tijgers buiten beschermde gebieden te bevorderen. Ik ben echter van mening dat de vooruitzichten voor deze co-existentie van mens en tijger in India slecht worden begrepen. Ik denk dat er een tekort is aan systematische studies die bestaande of experimentele scenario's voor deze co-existentie van mens en tijger beschrijven. Het grootste deel van de publicaties over de co-existentie van mens en tijger bestaat uit intellectualistische scenario's en veronderstellingen over het gedrag van tijgers, die zijn afgeleid van onderzoeken die zijn uitgevoerd in beschermde gebieden (nationale parken). In deze beschermde gebieden zijn de menselijke activiteiten beperkt en daarom is in deze publicaties ondervertegenwoordigd welke invloed mensen hebben op de habitat van tijgers en wat de reactie van tijgers op een dergelijke invloed is. Verder hebben historisch gezien en tot op heden de inspanningen voor het behoud van tijgers in India zich voornamelijk gericht op beschermde gebieden en op het beheer daarvan. Inspanningen om tijgers te beschermen in India zijn zelden gericht op het landschap buiten beschermde gebieden of op de betrokken lokale bevolking. Afgezien van menselijke verwondingen en het verlies van levens door tijgers, zijn andere aspecten van de relatie tussen mensen en tijgers, slecht begrepen.

De rurale bevolking in India heeft altijd samen met wilde dieren geleefd en manieren ontwikkeld om met de gevaren die grote carnivoren zoals tijgers opleveren, om te gaan. Als mensen niet met gevaarlijke dieren konden omgaan, zouden ze inmiddels alle bedreigende soorten in het wild hebben gedood. Dat is echter niet het geval, en wilde dieren leven nog steeds samen met mensen in veel delen van India. Het gebrek aan kennis over het vermogen van mensen om naast de tijger te leven, kan natuurbeschermers en managers misleiden. Ze kunnen veronderstellen dat de aanwezigheid en activiteiten van mensen een permanente bedreiging vormen voor tijgers en dus voor hun toekomstige overleving en plannen voor co-existentie tussen mensen en tijgers tegenwerken. Evenzo is het onverantwoord om het behoud van tijgers in door mensen gedomineerde landschappen blindelings aan te moedigen zonder een diepgaand inzicht in het vermogen van lokale mensen om het hoofd te bieden aan de mogelijke gevaren die daarmee gepaard kunnen gaan. Aan de andere kant is betrouwbare informatie over het ruimtegebruik

door tijgers, hun diëten of elk ander facet van hun gedrag in door mensen gedomineerde landschappen schaars. Deze kennislacunes over mensen en tijgers en hun vermogen om naast elkaar te bestaan, vormen de aanleiding van mijn studie. De hoofdstukken twee tot en met vijf beschrijven de vier deelonderzoeken die ik heb uitgevoerd. Hoofdstuk zes geeft een synthese van de centrale vraag van mijn studie: “Kunnen tijgers overleven in door mensen gedomineerde landschappen?”.

In hoofdstuk 2 wordt een analyse gepresenteerd van een unieke situatie van veehoeders die een ongewoon hoge tolerantie vertonen ten opzichte van grote carnivoren, ondanks frequente predatie-incidenten. Ten eerste heb ik op etnografische wijze de religieuze overtuigingen en lokale praktijken van mensen beschreven. Vervolgens analyseerde ik hoe deze factoren vorm gaven aan de relaties die mensen hadden met tijgers. Interviews met respondenten en persoonlijke observaties maakten het verzamelen van gedetailleerde informatie mogelijk, die vervolgens kwalitatief werd geanalyseerd. De bevindingen onthulden dat bewoners sterke overtuigingen hadden in bosgeesten. Ze hebben in veel gevallen een verbond gesloten met hun spirituele beschermers en ze hielden zich strikt aan de normen van de gemeenschap die risicomijdend gedrag bevorderen. Deze onderling verbonden factoren verschaften mensen de psychologische en praktische voordelen om de risico’s die gepaard gaan met grote carnivoren het hoofd te bieden en negatieve interacties met grote carnivoren te beperken. Verder zijn er de wijdverspreide en eeuwenoude praktijken in het houden van vee zoals het dumpen van karkassen van koeien aan de rand van het dorp en het achterlaten van ongewenst vee in de bossen om vrij rond te zwerven. Dit vee is direct beschikbaar voedsel voor verschillende grote carnivoren in de regio. De enorme schaal van deze culturele praktijken in het gebied en de traditionele ethiek van natuurbescherming van lokale mensen hebben een positieve invloed op de aanwezigheid van grote carnivoren, zoals de tijger.

In hoofdstuk 3 heb ik laten zien dat eigenaars van vee in Panna Tiger Reserve in India, ondanks het hebben van uitstekende lokale kennis over carnivoren en het gebruik van preventieve strategieën, grote verliezen aan dieren door grote carnivoren ervaren. De onderliggende redenen achter dergelijke oncontroleerbare verliezen werden onderzocht. Door interviews en observaties verzamelde ik kwantitatieve en kwalitatieve gegevens over lokale kennis en veehouderij en over de percepties van bewoners van Panna Tiger Reserve van factoren die van invloed zijn op deze verliezen. Ik heb Generalized Linear Models (GLM) en kwalitatieve gegevens van informanten gebruikt om factoren die verliezen beïnvloeden te analyseren en te verklaren. De bevindingen ondersteunen de veronderstelling dat goede kennis van carnivoren en het gebruik van preventieve strategieën verliezen van vee hebben verminderd, maar niet volledig hebben kunnen voorkomen. Socio-politieke factoren met betrekking tot vee, zoals het verbod om koeien te verkopen, en het ontbreken van exclusieve landgebruiksrechten creëerden barrières voor lokale mensen om onproductief en vrij zwervend vee van buitenstaanders uit de bossen te halen, terwijl zij genoodzaakt zijn om hun waardevolle dieren in hetzelfde gebied te laten grazen. Deze situatie maakt het waardevolle vee kwetsbaar voor predatie door grote carnivoren. Tegelijkertijd vonden mensen het moeilijk om zich tegen de externe socio-politieke druk te verzetten en op te treden tegen zwervend vee van buitenstaanders.

Deze case study laat zien dat sommige gemeenschappen over de lokale kennis beschikken om verliezen van vee te voorkomen en dat zij investeren in preventieve maatregelen. Desondanks vormen externe socio-politieke invloeden echter barrières voor de lokale bevolking om hun vee goed te beheren.
In hoofdstuk 4 laat ik de effecten zien van tijgerspecifieke factoren (geslacht, leeftijdsgroep), milieufactoren (seizoenen, regenperiode) en antropogene factoren (menselijke gebruiksregimes) op de bewegingen van tijgers in de door mensen gedomineerde bufferzone van Panna Tiger Reserve. Gegeneraliseerde lineaire gemengde modellen (GLM) werden gebruikt om de significantie van de relaties tussen de co-variabelen die de aanwezigheid van tijgers beïnvloeden, te testen. De bevindingen tonen aan dat de waargenomen variaties in tijgergebruik van de door mensen gedomineerde bufferzone grotendeels kunnen worden verklaard door tijgerspecifieke factoren zoals leeftijdscategorie, geslacht en omgevingsfactoren zoals seizoenen en dag en nacht. Sub-volwassen tijgers brachten bijvoorbeeld 40% van hun tijd door in gebieden die door mensen werden gebruikt, terwijl dat voor volwassen tijgers slechts 10% was. In gebieden die door mensen werden gebruikt, begaven sub-volwassen tijgers zich in gebieden in de buurt van dorpen en brachten ze 30% minder tijd door in gebieden dicht bij water dan volwassen tijgers. Deze studie concludeert dat tijgers zich proberen aan te passen aan menselijk gebruik, maar de mate van aanpassing gekoppeld is aan ervaring (geboortehypothese), wat betekent dat jongere tijgers slechts een beperkte aanpassing kunnen vertonen aan menselijke invloeden vergeleken met volwassenen dieren. Als menselijke activiteiten, waaronder de manieren om vee te houden en landgebruik, slecht worden gereguleerd, kunnen deze een negatieve invloed hebben op sommige tijgers (door verhoogde roof van vee, wat resulteert in conflicten) en kunnen tijgers worden beperkt in het gebruik van hulpbronnen in het landschap zoals water.

In hoofdstuk 5 behandel ik het onderwerp van vrije begrazing en de verenigbaarheid van deze praktijk met de herintroductie van tijgers. Vrije begrazing is een veel voorkomende praktijk in de bossen in India. Hier lag de focus op het dieet van tijgers in door vee gedomineerde gebieden. De hypothese was dat de aanwezigheid van vrij lopend, verwilderd vee, samen met lokale praktijken van vrije begrazing in bossen die voor meerdere doelen worden gebruikt, de predatie van vee door tijgers zou vergroten, zelfs wanneer wilde prooidieren beschikbaar zijn. Gegeneraliseerde lineaire modellen (GLM) werden gebruikt om te testen of de predatie van vee versus wilde dieren werd beïnvloed door (1) het geslacht en de leeftijdsklasse van tijgers, (2) het seizoen en (3) de afstand van de prooi tot de grens van de kern van het beschermd gebied Panna Tiger Reserve. Over het algemeen doodden sub-volwassen tijgers en volwassen mannelijke tijgers meer vee dan wilde prooidieren, zelfs wanneer wilde prooidieren beschikbaar waren. In de winter en in het regenseizoen werd een grotere hoeveelheid vee in de bufferzone gedood dan in de zomer. Dit verschil kan verklaard worden door de seizoensafhankelijke bewegingspatronen van het vee in het gebied. Daarnaast doodden alle tijgers meer vee in toenemende afstand van de grens van de kernzone van het beschermd gebied, mogelijk omdat vee vaker beschikbaar was dan wilde prooidieren. De resultaten van mijn onderzoek laten zien dat de praktijk van vrije begrazing en aanwezigheid van niet-gereguleerde grazende dieren momenteel niet verenigbaar zijn met het behoud van

grote carnivoren in hetzelfde landschap. Dergelijke praktijken leiden tot een toename van problematische interacties tussen tijgers en mensen. Samenvattend stel ik voor dat het ten goede kan komen aan tijgers en mensen als mensen waardevol vee omheinen, en verwilderd of ongewenst vee voor tijgers achterlaten. Deze eenvoudige strategie zou zowel de lokale bevolking helpen als een gunstig effect hebben op de bescherming van tijgers in bossen in India die voor meerdere doeleinden gebruikt worden.

De algemene conclusie van mijn studie is dat in veel plattelandsgemeenschappen van India mensen manieren hebben ontwikkeld om zich aan te passen aan en samen te leven met grote carnivoren zoals tijgers. Mijn studie laat zien dat de waargenomen aanpassing in twee richtingen gaat , waarbij tijgers ook een natuurlijk aanpassingsvermogen vertonen om zich aan te passen aan het menselijk gebruik van het landschap. Deze bevindingen over het natuurlijke vermogen van mensen en tijgers om zich aan te passen, zijn nieuw. Deze nieuwe bevindingen weerleggen de opvatting dat tijgers en mensen gemakkelijk met elkaar in conflict komen. Het vermogen van mensen om met grote carnivoren om te gaan, is misschien niet alleen beperkt tot mijn studiegebied maar komt in India mogelijk vaker voor dan eerder werd gedacht. Daarom zijn de bevindingen van deze studie ook relevant voor andere landschappen in India waar tijgers voorkomen.

In mijn studie heb ik laten zien hoe lokale mensen in crisissituaties kunnen samenwerken en het behoud van tijgers konden ondersteunen. Ik geloof dat een soortgelijke bereidheid om het behoud van tijgers te ondersteunen ook in andere delen van India te vinden is. Aan de andere kant kunnen sommige omstandigheden het vermogen van mensen om zich aan te passen ondermijnen. Externe socio-politieke druk die het verwijderen van ongewenste koeien uit het landschap verhindert, creëerde bijvoorbeeld barrières voor lokale herders om hun vee goed te beheren. In dergelijke situaties, waar lokale mensen niet kunnen handelen, kunnen ze de steun van het management van een beschermd gebied en van natuurbeschermingsorganisaties nodig hebben om de externe druk te weerstaan.

Tijgers vertonen vermijdingsgedrag en ruimtelijke en temporele verschuivingen in hun activiteitspatronen in reactie op de aanwezigheid en activiteiten van mensen. De weinige uitzonderingen hierop waren jongere tijgers, die het moeilijker vonden om zich aan te passen aan gebieden die door mensen worden gebruikt in vergelijking tot volwassen dieren. De jonge dieren werden daardoor mogelijk kwetsbaarder. Interessant is dat hun gedrag met de leeftijd veranderde en zij gebieden die door mensen worden gebruikt gingen mijden, net zoals andere volwassen tijgers. Deze bevinding over jonge tijgers is nieuw. Omdat jonge tijgers van nature meer risico's nemen, moeten ze continu worden gecontroleerd terwijl ze zich in gebieden bevinden die door mensen worden gebruikt, totdat ze volwassen zijn. Ten tweede, wanneer vee in het landschap vrij voorhanden is, doden tijgers dit vee gemakkelijk. Dit soort gedrag moet niet worden gezien als negatief omdat de tijgers tijdens onze onderzoeksperiode geen tekenen van het gedrag van 'probleemdieren' vertoonden, zoals het grootschalig doden van vee of het gedrag van mens-eters. Verder leidde predatie door tijgers niet tot conflicten. Tijgers voedden zich met onproductieve mannelijke dieren en verlaten vee, hetgeen gunstig is voor mensen. Diegenen die waardevolle dieren verloren, waren zich bewust van de omstandigheden die daartoe leidden. Dit zijn bijvoorbeeld de

aanwezigheid van verwilderd vee in het landschap, een verbod op het verwijderen van koeien en buffels en een gebrek aan exclusieve landgebruiksrechten. Bovendien leden mensen meer significante verliezen door ziekte van hun dieren of door veediefstal. Lokale mensen beschouwden roofdieren dus niet als het belangrijkste probleem.
Op basis van mijn onderzoek concludeer ik dat mensen die op het platteland van India wonen, religies praktiseren, culturele waarden omarmen en eeuwenoude praktijken uitvoeren die een tolerante beschermingsethiek bevorderen ten opzichte van wilde dieren. Hun manier van leven stelt hen in staat om hun landschap en de hulpbronnen daarin te delen met wilde dieren die ook in datzelfde landschap leven. Vervolgens zal de nationale trots dat een aanzienlijk deel van de tijgers in India overleeft, de nationale politici, regeringsmanagers en stedelingen blijven motiveren om de inspanningen voor de bescherming van de tijger te ondersteunen. Deze inspanningen om de tijger ook buiten beschermde gebieden te beschermen kunnen zowel positieve als negatieve sociale gevolgen hebben voor lokale gemeenschappen. Om deze reden is het noodzakelijk om de sociale effecten van het behoud van tijgers in de loop van de tijd beter te begrijpen en te monitoren en, waar nodig, bij te sturen. Een dergelijke gerichte interventie zal de lokale steun vergroten en de algehele effectiviteit van maatregelen voor de bescherming van de tijger verhogen.

Als India er niet in slaagt om de tijger te beschermen, zal dat niet alleen resulteren in een meer verarmd natuurlijk landschap, maar ook in een verarmd menselijk landschap. Er is echter voldoende bewijs voor optimisme dat tijgers en mensen binnen eenzelfde context naast elkaar kunnen bestaan. De mogelijkheid van mens en tijger om naast elkaar te bestaan, die ik in mijn studie aantoon, is van nature aanwezig en wordt beheerst door traditionele instituties en normen. Verder is er bewijs dat de waargenomen lokale praktijken een duurzaam karakter hebben. Als hedendaagse natuurbeschermers enkele van de beproefde manieren van de plattelandsbevolking, die altijd samen met de tijger heeft geleefd, kunnen integreren in hun aanpak voor de bescherming van de tijger, kan het moderne India, ondanks zijn enorme bevolking en uitdagingen, slagen in het behoud van de tijger.

Curriculum Vitae

Shekhar Kolipaka was born in the town of Vizianagaram in Andhra Pradesh state of India in the year 1973. He studied mathematics, physics and chemistry at the intermediate level and commerce for his bachelors degree at the Andhra University in Visakhapatnam, India. He has a broad education with master's degrees in business management from the Symbiosis Institute of Management Studies, India. Natural resource management from the Indian Institute of Management Studies, India and environmental sciences from the KwaZulu-Natal University, South Africa. Shekhar combines his interdisciplinary education to find solutions for wildlife conservation outside protected areas of India. During 2007-08 when wild tigers became locally extinct in his study area of Panna in Madhya Pradesh, he involved himself in tiger recovery efforts and undertook a series of action research projects to support the tiger reintroduction program in Panna. During his work with tigers, he was always bothered by the realistic prospects of tiger survival in human-dominated landscapes. He approached Prof. Dr. Hans de Iongh and Prof. Dr. Gerard Persoon at the Leiden University with the same question and requested their support to study human-tiger relations leading to coexistence academically. His study became a collaboration between the Institute of Cultural Anthropology and Development Sociology (CA-OS (FSW)) and the Institute of Environmental Sciences (CML) of Leiden University. In the biosocial investigation he carried out, he examined local people and tigers and studied their ability to adapt and coexist in the same area. The research that he conducted resulted in the present PhD thesis.

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During my work at Panna, I met and befriended several generous local people who have welcomed my staff and me to stay and use their homes. I am highly indebted to their generosity. My research work would not be possible without the support of Mr. Shyamendra Singh and Mrs. Bhavana Kumari of Ken River Lodge in Panna. I also owe much to their lodge staff and naturalists who have provided me useful local information. I thank Pugdundee Safaris and Mr. Manav Khanduja for his support for my work.

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Notes to the reader

- Chapters 2 to 5 are published articles, and the appendix sections, supplementary data, hard data used in the analysis and supporting information on these articles are all available on the online repositories of the journals.

- Chapter 3 is in preparation for submission to a journal at the time of printing of this thesis. The final published article may be restructured to accommodate the journal's style and therefore may look slightly different than the version presented in the thesis, but will not impact the findings. After publishing, appendix sections, data used in the analysis and supporting information will be available for download from the journal. The status of the publication and links to the data repository will be made available on www.wildlifetracking.in (Project Updates).

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