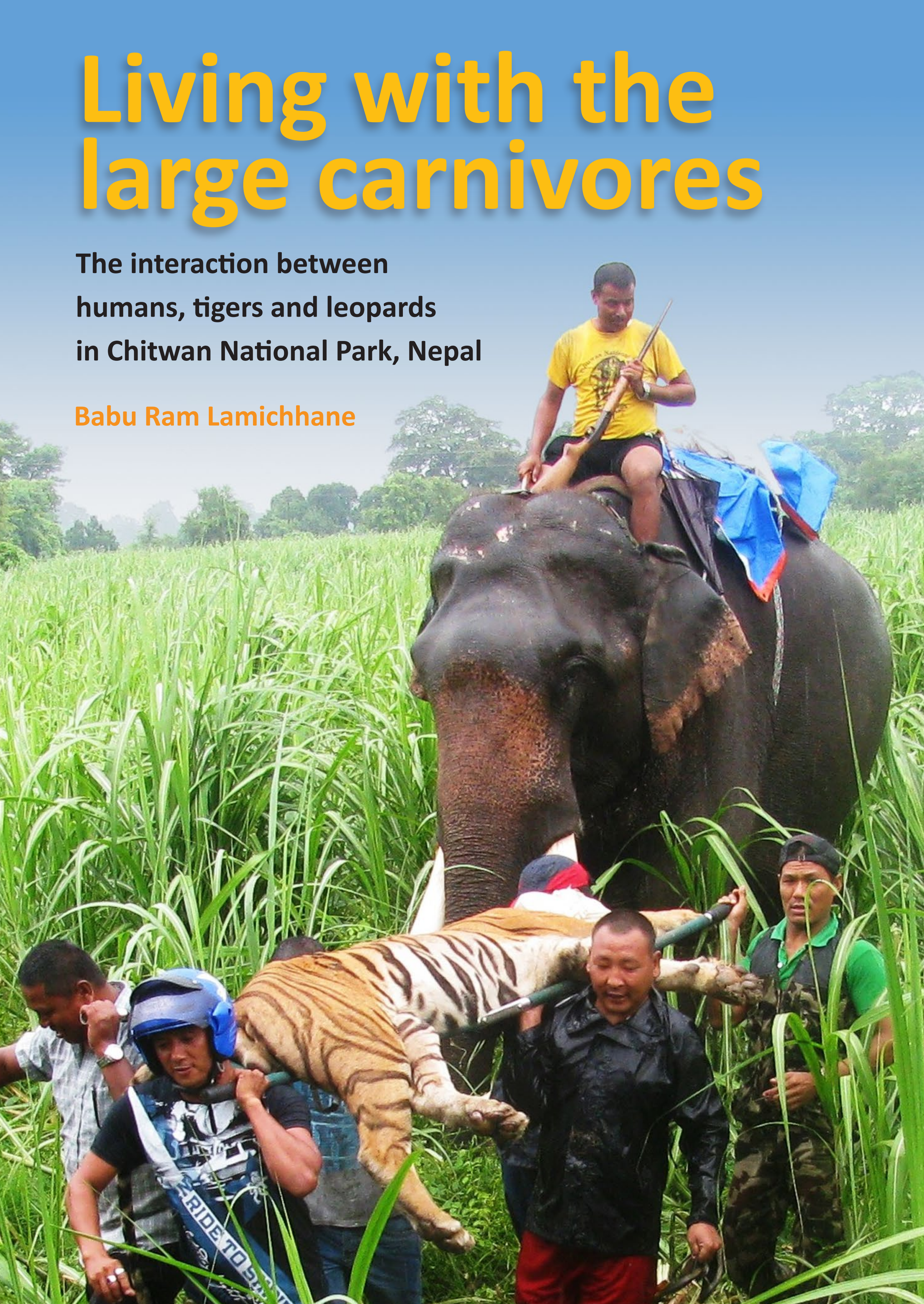
Living with the large carnivores

The interaction between humans, tigers and leopards in Chitwan National Park, Nepal

Babu Ram Lamichhane



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Front cover photo: A human-killing tiger rescued from sugarcane field close to a human settlement in buffer zone area of Chitwan National Park, Nepal.
Photo by Harka Man Lama / NTNC-BCC.

Back cover photos: Camera trap pictures of tiger and leopard from Chitwan National Park, Nepal
Photo by NTNC-BCC.

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Photo by Dr. Ashish Gurung.

Terms Used

Buffer Zone
In this study, the term buffer zone refers to the designated areas surrounding the national parks and wildlife reserves where people are living in close proximity and frequent interaction with wildlife. In Nepal, the parks/reserves share 30-50% of its annual revenue in the buffer zone to minimize the negative impacts of parks/reserves and wildlife.

Habitat mosaic
Habitats are natural areas where wildlife shelter. Habitat mosaic refers to multiple habitats such as grasslands, waterbodies and different types of forests occurring within the same landscape.

Human-wildlife conflict
The effects caused by humans and wildlife to each-other while living in the close proximity within the same landscape. Wildlife usually raid crops, kill livestock or cause safety threat to people. Sometimes people retaliate wildlife that affect their life and livelihood.

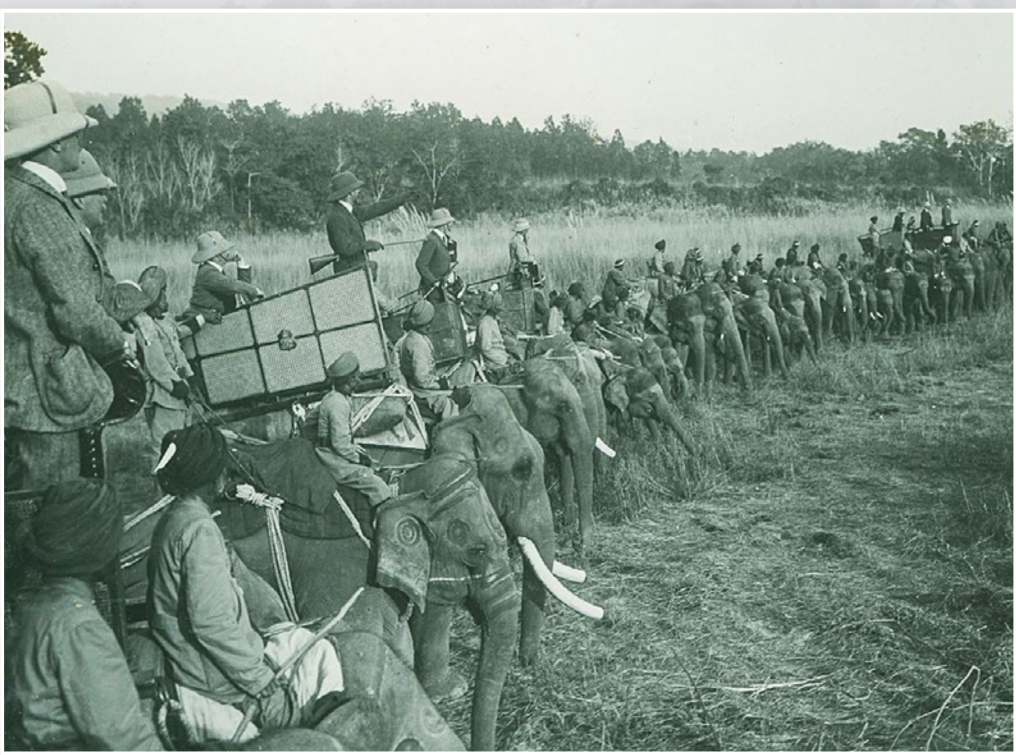
Human-wildlife coexistence
A situation of humans and wildlife sharing a landscape where wildlife is protected and their population persistence is ensured, their impacts on humans is socially acceptable and institutions are in place to maintain this balance effectively

Large carnivores
The term 'large carnivores' refers generally to the exclusive meat-eating animals of greater than 15 kg adult body mass. In this study, large carnivores primarily refer to tigers and leopards.

Livestock
Domestic animals such as cow, buffalo, goat, sheep and pig kept by peasants as a source of food or income for the household.

National Park
Area set aside for protection of wildlife and their habitats where human activities are limited. It falls in IUCN category II protected area (defined as areas exclusively secured for wildlife where human activities are limited and strictly regulated).

Wildlife
Wildlife, in general, refers to free-roaming living creatures without human control. This study focused on wildlife of medium to large body size (greater than 20 kg) which possibly affects human life and livelihood.



Glimpse of a royal hunt during the visit of British King George V in Chitwan (1911). Source: TheExplora (https://www.theexplora.com/wp-content/uploads/2013/11/33.jpg)

1 General Introduction

1.1. Background

Millions of species of living organisms appeared in the world in the process of evolution (Darwin, 1859). Among them, organisms belonging to a species *Homo sapiens*, we humans, evolved differently. With large brains and cognitive capacity, we learned to create favourable surroundings even in the harsh environments making us probably the most successful species in the entire history of life. The invention of fire, farming and fossil fuel contributed to rapid population expansion in different eras of human evolution. The industrial revolution of the 18th century triggered exponential growth and enabled us to occupy almost every part of the habitable places on the planet. As human population and needs are expanding, natural areas are continued to be exploited, altering the global landscape (Lambin & Meyfroidt, 2011). Widespread and massive exploitation has caused the destruction of wildlife habitats, changes in the global climate and the loss of many species, also known as the sixth mass extinction (Barnosky *et al.*, 2011). Some of the remaining natural areas have been set aside for protection as parks and reserves (Bruner *et al.*, 2001; IUCN, 2008; Leopold, 1963).

With ongoing fragmentation and degradation of the remaining natural areas (Lambin & Meyfroidt, 2011) and prevalence of humans in every part of the planet, wildlife species are forced to live in close proximity to humans (Inskip & Zimmermann, 2009). This leads to frequent human-wildlife interactions often resulting in negative impacts on each other. Such impacts are more intense in the areas where large mammals like Asian elephants (*Elephas maximus)*, greater one-horned rhinoceros (*Rhinoceros unicornis*) (hereafter termed 'rhino'), Bengal tigers (*Panthera tigris tigris)* and common leopards (*Panthera pardus fusca)* occur in high densities (Karki *et al.*, 2015; Subedi *et al.*, 2013) in relatively small protected areas within human-dominated landscapes (Wikramanayake *et al.*, 2004). Most protected areas are not sufficient to support such large mammals within protected areas. Agricultural crops and livestock raised by humans in the proximity of natural areas are alluring for wild herbivores and carnivores respectively. As a result, attacks on humans or economic damage by wildlife and subsequent persecution of wildlife in retaliation, generally referred to as 'human-wildlife conflict' (Peterson *et al.*, 2010; Redpath, Bhatia, & Young, 2015), is a frequent phenomenon, especially in the fringe of protected areas and forests (Lamichhane *et al.*, 2018a). Prevention or mitigation of such negative interactions is challenging when multiple endangered species of conservation importance are involved (Acharya *et al.*, 2016).

Terai Arc Landscape (TAL) in Nepal and India is one of such landscapes where diverse flora and fauna, including various endangered large mammals, occur in high densities (Wikramanayake *et al.*, 2004). Human density in Terai is also one of the highest in the world (Harihar, Pandav, & Goyal, 2011). The TAL straddles the Nepal-Indian border parallel to the Himalayas (Chanchani *et al.*, 2014) covering an area of 51,000 km^2 area in the Gangetic floodplain and Siwalik hills (foothills of Himalaya). It is a priority landscape for large mammal conservation focusing on tigers.

Chitwan National Park (CNP) in Nepal is one of the important parks in TAL and typifies the parks in tropical areas which have been experiencing frequent and intensive human-wildlife conflicts. Such conflicts have been recorded since its establishment in 1973 (Mishra, 1982a; Sharma, 1990). CNP is also a UNESCO World Heritage Site and a flagship park in Nepal whose success or failure largely determines the overall direction of wildlife conservation in the country. The park has been successful in recovering major wildlife populations including tigers, rhinos and elephants. As a consequence, wildlife attacks on humans and livestock as well as crop raiding by wild herbivores frequently result in economic losses (Lamichhane, *et al.* 2018a). In many cases, such losses and threats to human safety from large mammals result in the aggression from local people and less support for wildlife conservation (Acharya *et al.*, 2016). Managers have also raised the concerns about increased population growth among wildlife and have even suggested a cap on populations, albeit without empirical studies to back up their claims (Khadka, 2014). Therefore, a holistic understanding of how people and wildlife are interacting with each other is necessary (Carter, 2013).

1.2. Scope of the study

Wildlife conservation requires a multidisciplinary approach but most studies are limited to a single discipline, such as ecology or sociology (Carter, 2013). Various studies focusing on the ecology of large mammals has been conducted in Chitwan in the past (Karki *et al.*, 2015; Subedi *et al.*, 2013; Subedi *et al.*, 2017; Sunquist, 1981; Thapa, 2011). However, only a few studies focusing on human-wildlife interactions (Carter, 2013; Mishra, 1982a). Consequently, inter-species and wildlife-human interaction, especially in relation to large carnivores, is poorly understood. Hence, I examined the interaction between local communities and wildlife, specifically two large carnivores' tiger *Panthera tigris tigris* and common leopard *P. pardus fusca* (henceforth leopard), as well as inter-species competition (Fig 1.1).

I focused my study on tigers and leopards because tigers are the largest of the cats and the top predator in Asian forests (Goodrich *et al*., 2015). They are also one the most charismatic animals globally, but also highly threatened due to habitat loss and poaching. The leopard is a co-predator in most of the tiger ranges and beyond; they are regarded as the most adaptable and widely distributed felid. In spite of their adaptability, they are also threatened due to range collapse and widespread poaching for their pelt (Jacobson *et al*., 2016).

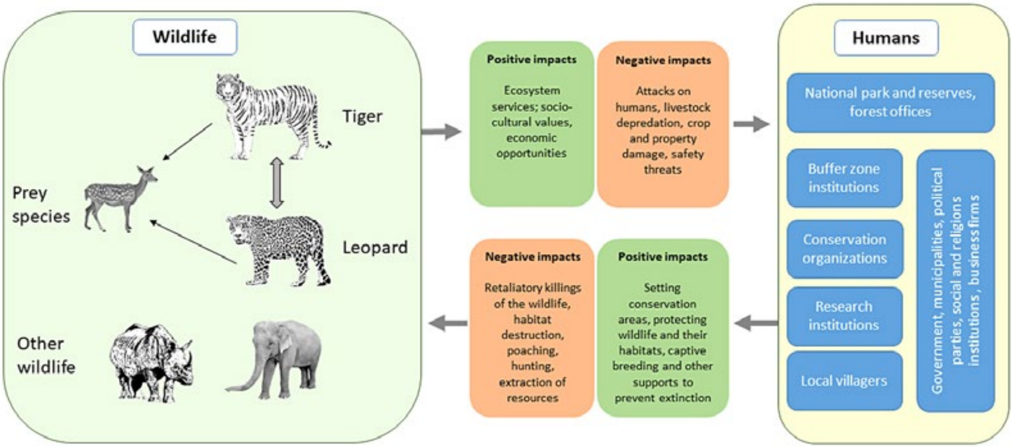


Figure 1.1. Schematic picture of human-wildlife interactions in a rural setting in close proximity of the protected areas.

In this study, I investigated the spatial and temporal patterns of wildlife attacks on humans and economic losses using empirical data. In order to enhace our understanding of human-carnivore interactions, I obtained ecological insight into large carnivores using camera trap surveys and diet analysis. I also examined the characteristics of conflict-causing tigers, and conflict mitigation measures through socio-economic surveys. The findings of the study are useful for devising a strategy for human-wildlife coexistence and sustainable conservation of the large carnivores in human-dominated landscapes in Nepal and beyond.

1.3. Large carnivore conservation

Large carnivores like tigers and leopards are some of the world's most admired animals, serving as flagship species for biodiversity conservation (Weber & Rabinowitz, 1996). They occur naturally in low densities due to energetic constraints but have significant influence on community structure through resource facilitation and trophic cascades (Ripple *et al.*, 2014; Schmitz, Hambäck, & Beckerman, 2000). They also provide a wide range of economic opportunities through tourism and various ecosystem services (Verma *et al.*, 2017). Protecting wildlife and their habitats is not only a moral responsibility, it is necessary for human well-being (Ehrlich & Wilson, 1991; Estes *et al.*, 2011). In spite of their ecological, social and economic importance, large carnivores are the most threatened group of taxa globally due to habitat fragmentation and loss, poaching and illegal trade for trophies, declining prey and conflict with humans (Inskip & Zimmermann, 2009; Karanth & Chellam, 2009).

Tigers are listed as 'Endangered' on the IUCN Red List due to a high threat of extinction in the wild globally (Goodrich *et al.*, 2015). They are confined to 6% of their historic range

(Joshi *et al.*, 2016). The global wild tiger population has declined more than 96% between 1900 and 2005 (Goodrich *et al.*, 2015). The remaining habitat is also not occupied in optimum density due to their poaching, hunting of the prey species and conflict with human communities (Walston *et al.*, 2010). To reverse the situation, heads of the tiger range countries made an political agreement by signing the St. Petersburg Declaration for Tiger Conservation in 2010 and formulated an ambitious plan to double the tiger population by 2022 (GTI, 2010). Yet, tiger populations continue to decline in many countries (Goodrich *et al.*, 2015). Nepal signed the St. Petersburg Declaration in 2010 and committed to doubling its tiger population from 121 to 250 adult tigers by formulating the National Tiger Recovery Priorities (NTRP) (GTI, 2010). Government and conservation organizations are putting efforts to increase the tiger population to achieve the target. Tigers are confined to five national parks and adjoining forests in TAL–Nepal. A recent estimate shows 235 tigers in Nepal. Chitwan National Park has a high density of tigers with about 40% of the total population of Nepal (DNPWC, 2018).

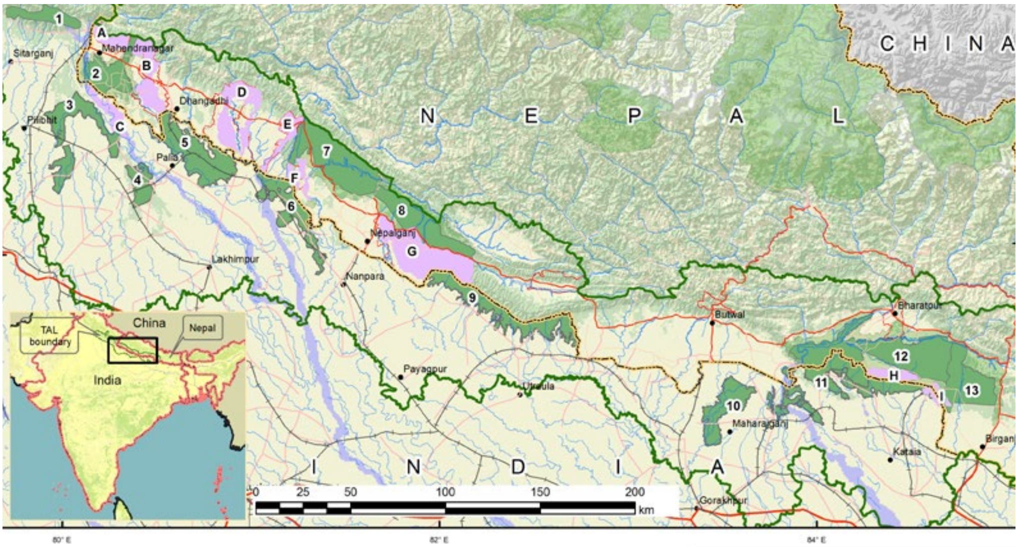
Leopards are a highly adaptive and widespread felid across Asia and Africa (Nowell & Jackson, 1996). Previously, it was believed that leopards are abundant across their range (Nowell & Jackson, 1996; Sunquist & Sunquist, 2002). However, recent studies have documented a collapse of up to 75% of their historic range (Jacobson *et al.*, 2016). Consequently, leopards are listed as ‘Vulnerable’ on the global IUCN Redlist (Stein *et al.*, 2018). Only a small portion (17%) of the leopard’s extant range falls within protected areas (Jacobson *et al.*, 2016). Leopards are perceived as highly adaptive and tolerant to anthropogenic pressure and are very discrete in their behaviuor. Thus, despite their threatened status, leopards have received less attention from conservationists (Jacobson *et al.*, 2016; Thapa *et al.*, 2014). CNP is also home to one of the Nepal’s largest populations of leopards (Thapa, 2011).

Tigers and leopards are large carnivores, both solitary hunters, and sympatric in most of the Asian forests. Paleontological and molecular studies suggest leopards evolved in Africa and dispersed to Asia ca. two million years ago, whereas tigers are an entirely Asian species that appeared approximately 1.5 million years ago (Lovari *et al.*, 2015; Turner & Anton, 1997). The body mass of the tiger (female – 140 kg, male – 220 kg) is four times that of a leopard (Seidensticker, 1976). Interference and competition often result in the displacement of leopards towards fringe areas, a phenomenon that is frequently observed with increase in tiger density (Harihar *et al.*, 2011; Odden, Wegge, & Fredriksen, 2010). However, such interference is not uniform. Some studies have also reported a large spatiotemporal overlap between tigers and leopards (Azlan & Sharma, 2006; Seidensticker, 1976; Simcharoen *et al.*, 2018; Wang & Macdonald, 2009). Similarly, a diet overlap between tigers and leopards, especially of medium-sized prey, has been reported in a number of studies (Karanth & Sunquist, 1995; Lovari *et al.*, 2015). Thus, prey abundance also plays a key role in determining the types of tiger-leopard interactions (Carter *et al.*, 2015; Karanth & Sunquist, 2000; Seidensticker, 1976). Such interactions also lead to an increase in livestock depredation by tigers or leopards where wild prey density is low (Wegge, Yadav, & Lamichhane, 2018). Both tigers and leopards co-occur in relatively high densities in the Terai of Nepal (Karki *et al.*, 2015; Lamichhane, *et al.*, 2018b; Thapa *et al.*, 2014; Thapa, 2011) including CNP. How these two sympatric carnivores with large diet overlaps find their niche within the same landscape requires a further investigation (Lovari *et al.*, 2015; ‘Chapter 4’).

1.4. Terai of Nepal: Historical perspective

Survival of threatened wildlife species, especially carnivores, in increasingly human-dominated landscapes is conservation dependent (Karanth & Chellam, 2009). To ensure their survival in future, scientists recommend the protection of core breeding areas (or source sites) that have the potential to repopulate neighbouring areas embedded in larger landscapes (Joshi *et al.*, 2016). CNP is one of such source sites within the larger Terai Arc Landscape (TAL) (Wikramanayake *et al.*, 2004). The TAL, part of a global biodiversity hotspot (Myers *et al.*, 2000), straddles the Nepal-Indian border parallel to the Himalayas (Wikramanayake *et al.*, 2004) covering a 51,000 km^2 area in the Gangetic floodplain and Siwalik hills (foothills of Himalaya). It is a priority landscape for large mammal conservation focusing on tigers. Until recently, Terai forests and grasslands supported one of the highest densities of large mammals in the world (Seidensticker *et al.*, 2010).

Before the 1950s, the Terai was almost entirely forested (Fig 1.3) (Wikramanayake *et al.*, 2010). Only small settlements of indigenous ethnic groups, such as Tharu, Darai,



Symbol	PA name	Symbol	PA name
1	Nandhaur WLS	8	Banke NP
2	Shuklaphanta NP	9	Suhelwa WLS
3	Pilibhit TR (Formerly FD	10	Sohagibarwa WLS
4	Kishanpur WLS	11	Valmiki TR
5	Dudhwa NP	12	Chitwan NP
6	Katerniaghat WLS	13	Parsa NP
7	Bardia NP		

Symbol	Corridor	Symbol	Corridor
A	Boom-Bhrahmadev	F	Khata
B	Laljhadi	G	Kamdi
C	Laggabagga-Tatargunj	H	Someshwor
D	Basanta	I	Parsa Valmiki
E	Karnali		

Legend

- TAL Protected Areas
- Corridors
- Rivers
- TAL boundary
- International boundary
- Major city/town
- Railway
- Highway
- Metalled roads
- Other roads

Figure 1.2 The Trans-boundary Terai Arc Landscape in Nepal and India (Source: Dhakal *et al.* 2014).

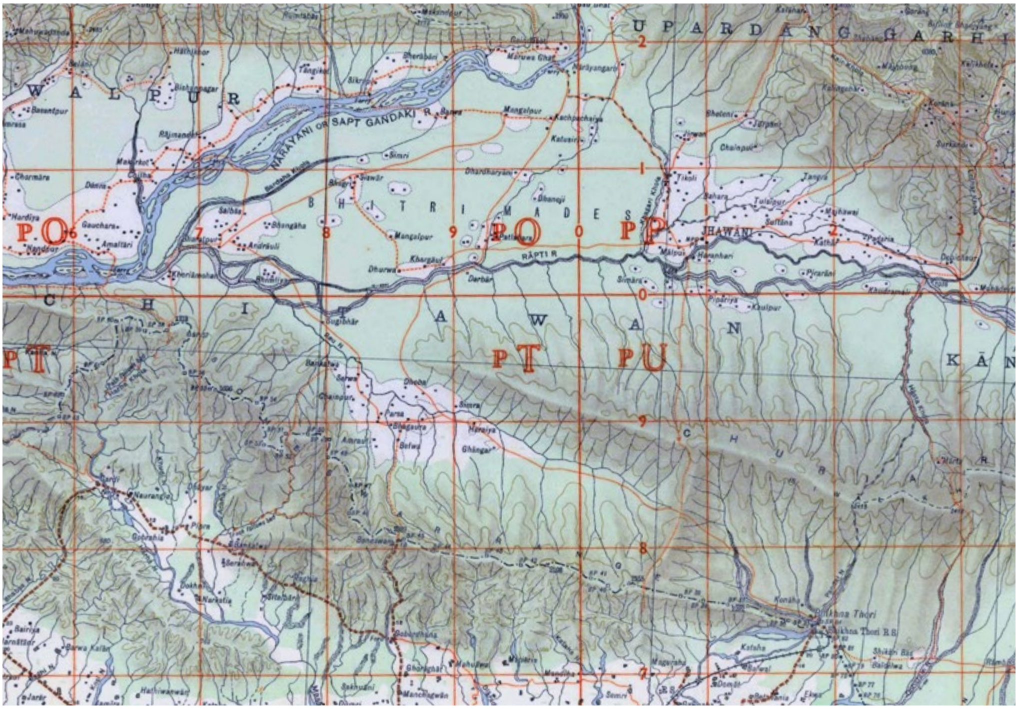


Figure 1.3 Historical Map of Chitwan Valley published by British Army in 1948. The green colour represents the forests, blue lines are river/streams and the yellowish-brown lines representing roads. Most of the valley was forested untill the 1950s with small and scattered settlements of indigenous communities. (Source: University of Texas Library, Webpage: http://legacy.lib.utexas.edu/maps/topo/india_253k/txu-pclmaps-oclc-181831961-birganj-72-a-1948.jpg).

Majhi and Mushahar were scattered near rivers; people farmed, hunted and fished for subsistence (Fig. 1.3) (Smythies, 1942). The widespread prevalence of a virulent strain of malaria prevented people from the adjacent hills to settling in the remote jungle (Guneratne, 2016; Wikramanayake *et al.*, 2010). Despite the long presence of the British in India, Nepal was never colonized. Initially, relations between British India and Nepal were hostile but became friendlier following the rule of Nepal's autocratic prime minister Junga Bahadur Rana (1846 - 1878) (Ghori, 1964). Junga Bahadur also declared the rhino as the 'royal animal', which restricted its hunting by local people (Mishra & Ottaway Jr., 2014). It provided some level of protection of Terai forests albit aimed primarily at facilitating big game hunting of aristocrats (UNESCO, 2003). Thus, vast tracts of forests remained relatively intact with abundant wildlife till the 1950s. The infrequent visitors were Nepal's royalties and their distinguished guests from Europe (mostly British) on hunting expeditions (Fig 1.4) (Smythies, 1942). Among the diplomatic efforts to ensure the continuance of their autocratic rule in Nepal, the Rana Prime Ministers (descendants of the Junga Bahadur) wooed British royals and aristocrats from the East India Company by inviting them big game hunting in Nepal's Terai, primarily in Chitwan. Hunting chronicles record a staggering 120 tigers, 38 rhinos, 27 leopards and 15 bears killed in

Figure 1.4 A glimpse of a royal hunt during the visit of King George V of England in Chitwan. During a 10-day hunt, between 18 - 28 December (1911) 39 tigers, 18 rhinos and 4 sloth bears were killed.
(Source: *TheExplora* https://www.theexplora.com/wp-content/uploads/2013/11/15.jpg).

a single expedition, indicating the abundance of wildlife at this time (CNP, 2013b). It is believed that irregular big game hunting such as this had little impact on the total wildlife population in the highly productive, intact and interconnected forests with insignificant human pressure (Wikramanayake *et al.*, 2010).

The situation changed rapidly in Nepal's Terai in the second half of the twentieth century. A malaria eradication programme was implemented during the mid-1950s. Subsequently, an influx of subsistence farmers started to migrate down from the hills. They were allowed to clear forest for agriculture and settlement. In Chitwan Valley alone, more than 60,000 ha (49%) of the forest was converted into farmlands in less than 30 years (1948–1977), the majority of which occurred between 1960 and 1970 as a part of the Rapti Valley Development Programme (UNESCO, 2003). The flat and fertile areas of the Terai was a boon for the subsistence farming communities from degraded hilly areas. The human population increased by five times between 1950 and 1971 (CNP, 2013b). During this forest conversion, many wildlife lost their habitat and became exposed to humans. These animals were regarded as pests (raiding crops or livestock depredation) and subsequently killed. As a result of the combination of habitat loss and rampant killings, the wildlife population suffered a catastrophic decline. The rhino population in the Chitwan Valley dropped from ca. 800 in 1950 to less than 100 individuals in 1965 (Subedi *et al.*, 2013).

By the time, rhinos had already disappeared from other parts of Terai. Wild water buffalo and swamp deer were extirpated in Chitwan during the 1960s (CNP, 2013b). This unprecedented decline of endangered wildlife in Terai became an international concern. In 1959, the King Mahendra established the Mahendra Mriga Kunja (deer park), comprising 175 km^2 from the north of Rapti River to the foothills of the Mahabharat (the present-day Barandabhar corridor forest) in Chitwan Valley. South of the Rapti River (the current park) was declared a rhino sanctuary in 1963 and intensive rhino patrolling was carried out by a dedicated team (*Gaida gasti* in Nepali) (CNP, 2013b). Villages with a total of 22,000 inhabitants had to be relocated in oder to establish the rhino sanctuary south of the Rapti River (Mishra, 1982b). However, small-scale hunting by the royal family continued till the early 1970s before legislation for the protection of wildlife was enacted (Sharma, 2015).

The rapid decline of wildlife, especially large mammals, was a global concern in the twentieth century (Fisher, Simon, & Vincent, 1969). There was an increasing trend for countries to initiate the legal protection of endangered wildlife, as was the case for Nepal's neighbor, India, which ratified a wildlife protection act in 1972. In this context, Nepal also began institutionalized and systematic conservation efforts by ratifying the National Parks and Wildlife Conservation Act in 1973. A century after the world's first national park (Yellowstone established in 1872), Chitwan NP was established in 1973 as the first National Park of Nepal. In the following decades, about a dozen other parks and reserves were established in the country (Bhattarai *et al.*, 2017).

As elsewhere in the world, conservation began with strict protection, focusing particularly on the large and charismatic mammals, and with limited scope for people's rights (Nepal & Weber, 1995). A unique system for deploying the National Army for wildlife protection was started in CNP in 1975 and rolled out successively in the other parks/reserves. As a consequence, conflicts between park officials and local communities (also called 'park-people conflict') became more pronounced in these initial years (Mishra, 1982a; Sharma, 1991). It did not take long for all concerned to recognize the need for support from local communities living in the vicinity of the park in order to sustain conservation (Heinen & Mehta, 2000).

Along with efforts to establish protected areas, the rights of indigenous people and community participation in natural resources management were gaining attention globally. By the early 1980s, community participation or co-management of natural resources became popular, not only in Nepal but in many parts of the world, as a result of the limited success of the strict conservation policies (Borrini-Feyerabend *et al.*, 2004; Persoon & Van Est, 2003).

Initial experiments in the forestry sector included 'community forests' in the Midhill region of Nepal (Gilmour & Fisher, 1991). Community forestry was successful in restoring forests while meeting community needs for forest products (Arnold & Campbell, 1986). After a decade of community forestry practice, community participation in wildlife conservation was initiated in the late 1980s by piloting 'Integrated Conservation and Development Programs (ICDP)' in Annapurna Conservation Area Project in Central Himalayas (Bajracharya & Dahal, 2008). Participatory conservation initiatives also spread into the

Terai regions in the early 1990s envisioning buffer zones around the parks/reserves (Bhattarai *et al.*, 2017). During the same period, at the level of national politics, a people's movement rejected Nepal's single-party autocratic rule and re-established multi-party democracy.

In 1996, the newly elected democratic parliament amended the National Parks and Wildlife Protection Act of 1973 to give local communities living around the park a role in conservation and ensured benefits for them from parks/reserves through buffer zone policy. The policy made provision for 30-50% of the park's revenue to be diverted to the respective buffer zone (MOFE, 1998) and endorsed guidelines for fund utilization. The buffer zone programme initiated the conservation and community development measures in the buffer zone area in 1998. One of them was a compensation scheme for people affected by damage caused by wildlife. Gradually, a sense of ownership developed among local communities towards the park and wildlife conservation. Following these participatory conservation initiatives, habitat restoration in the buffer zone, especially in community forests, created opportunities for both wildlife and people. Strict protection by the army in the core area continued. However, during the peak insurgency of the Maoist communist guerilla movement in Nepal (2000 - 2005), wildlife conservation was compromised as national priorities shifted towards settling the political turmoil. Army guard posts were retracted to the larger bases or headquarters, which directly affected the number and coverage of anti-poaching patrols. The poachers took advantage of vacant areas in the park and large numbers of wildlife were poached during this period (Subedi *et al.*, 2017). Incidents of human–wildlife conflict also peaked during this period (2002 - 2004) (Lamichhane *et al.*, 2018a). After a peace agreement was reached between the Maoist rebels and the government in 2005, the conservation programmes were gradually restored (CNP, 2013; Subedi *et al.*, 2013). As a result of these conservation efforts, Nepal has observed a gradual increase in large mammal populations in the past decade (Karki *et al.*, 2015; Subedi *et al.*, 2013).

1.5. Context of the study

1.5.1. Socio-economic context of Nepal

Nepal is a diverse country ecologically as well as culturally. Its disproportionately high biodiversity is attributed to the altitudinal variation (70 – 8,848 m) and its situation on the boundary of the Palearctic and Indomalayan Ecozones (MOFSC, 2002; Myers *et al.*, 2000). Nepal also has a varied human population comprised of different castes and ethnicities of both Aryan (southern to central part) and Mongol (central and northern part) origin. The geographic division of mountains (Himal) in the north, Midhills (Pahad) in the middle and Plains (Terai) in the south also fragments the population. The population of Nepal is 26.5 million (2011) with an annual growth rate of 1.35% (Central Bureau of Statistics 2012[1]).

[1] Data from the National Population and Household Survey of 2011 is the primary source for all the quantitative socio-economic statistics. This is the latest nationwide census in Nepal.

Terai has a high population density (392 per km^2) compared with other regions (Hills - 185.7 and Mountain - 34.4 per km^2). The majority of the population is young (55% below 25 years) entering into reproductive age. Hence, the population is expected to grow in the coming 20 - 30 years, although it should be noted that the growth rate has slowed in recent years with increased education and changes in livelihoods towards off-farm employment.

There are more than 100 castes and ethnic groups in Nepal with more than 90 spoken languages (CBS, 2012). In terms of religion, the community is predominantly Hindu (more than 80% of the population) followed by Buddhists (11%), Islam (4%), Christian (1%) and others (4%). Hence, the social structure is highly influenced by the Hindu caste system. People with different origins, especially from different ethnic communities, do not belong to the social framework of the Hindu castes (Bista, 1971). However, given the greater influence of Hindus, ethnic groups like *Gurungs, Magars, Rais, Limbus* and *Tharus* are ranked third in the system, after *Brahmin* and *Chhetries*.

Although ethnic diversity in Nepal is highly complex with many overlapping categories (Hangen, 2007), it can broadly classified into four categories: 1) high-caste Hindus (*Brahmin and Chhetries*); 2) indigenous communities of the Midhills (*janajati*), such as Tamang, Gurung, Magar and Chepang; 3) *Madhesi* (People from Terai); and 4) low-caste Hindus (*Dalit*). In traditional society, the high-caste Hindus had a higher social status whereas the low-caste Hindus remained underprivileged. Indigenous groups and Hindus

Figure 1.5 View of Paddy field in the buffer zone of Chitwan National Park.

of the middle caste (*Vaishya*) were placed in between the high and the low caste Hindus. None of the groups has an absolute majority (Hangen, 2007). Within each category, there are multiple groups also cutting across the categories and each with their own social hierarchy. In the past, these groups were geographically separated and homogenous within particular localities. However, high migration trends after the 1950s, especially Midhills to Terai and rural to urban areas, has resulted in a community comprised of all ethnic groups and castes, i.e. 'traditional' identity is gradually fading.

Nepal is one of the world's least-developed countries with an annual average income per capita of 730 US dollars (2016) and a national Gross Domestic Product (GDP) of 21 billion US dollars (World Bank, 2016). In the past five decades, Nepal has received substantial foreign aid for poverty alleviation, development projects and for the conservation/ management of natural resources (average 6% of GDP). Such aid has contributed partially to a reduction in absolute poverty and an uplift in the country's economic status (Bhattarai, 2005; MOF, 2017). Nepal is a predominately agricultural country with 65% of the population involved in largely subsistence farming (CBS, 2012). Agricultural land is highly fragmented with three quarters of the holdings smaller than one hectare and an average holding of 0.8 ha. Most of the agriculture is rain-fed. Rice, maize, wheat and millet are the four major crops (Fig 1.5). Livestock is an integral part of subsistence agriculture, but the stock size is small. Households own a small number of a single species, usually buffalo, cattle, goat, sheep, pigs and birds (chicken and duck), or a combination of multiple species. They depend on forests for the ecological goods and services required to support their livestock and farms (Adhikari, Di Falco, & Lovett, 2004). The close link and close physical proximity between society and the natural environment are major causes of human-wildlife conflicts (Acharya *et al.*, 2016).

However, this trend has been gradually changing as the younger generation are less interested in farming. Remittance has become a major component of the Nepalese economy (31% of GDP) with a large volume (more than four million) of Nepalese youths working in the Gulf countries and South East Asia (particularly Malaysia) (Department of Foreign Employment, 2017). With increasing income from off-farm labour and people's attraction to urban areas, the livelihood dependency on forests is decreasing.

Hinduism and Buddhism have a strong influence on the social values and beliefs of traditional Nepalese society. Both Hinduism and Buddhism believe in countless supernatural beings in the form of different creatures responsible for the creation, protection and destruction of human life (Berreman, 1997). Multiple creatures in the form of supernatural humans or animals such as snakes, birds, cows, tigers, elephants and many plants, including *Ficus* trees, are regarded as deities and still worshipped (Ingles, 1995). The cow has a special place in Nepalese society. It is a holy animal culturally and has legal status as national animal (the slaughter of cows in Nepal is not allowed). Along with religion, traditional Nepalese society is also influenced greatly by '*Dharma*' which means a basic value system of a correct lifestyle in harmony with nature. *Dharma* is often translated as a religion in English but it is more than just religion, it is a cosmic law. The people of Nepal believe in receiving *Dharma* by performing and participating in religious rituals as well as undertaking activities benefiting society and other living creatures (Berreman, 1997; Ingles, 1995). Social and cultural beliefs that respect nature and living creatures favour the conservation of wildlife. However, in recent decades, such beliefs are fading in the face of the increasing influence of modern lifestyles (Ingles, 1995), shrinking natural areas and ever more people living in urban areas who are increasingly detached from interaction with nature.

1.5.2. Wildlife Conservation in Nepal: Opportunities and Challenges

Wildlife conservation in Nepal is an example of the broader partnership between government, local communities and non-governmental organizations (Bhattarai *et al.*, 2017). Nepal is a signatory to the Convention on Biological Diversity, CITES, Ramsar and other international biodiversity and wildlife conservation conventions. The Nepal Biodiversity Strategy 2002 and subsequent action plans are the guiding documents for biodiversity conservation in the country. The National Parks and Wildlife Conservation Act 1973 (Sixth amendment 2018) provides the legal framework for protected areas and wildlife conservation. The Department of National Parks and Wildlife Conservation (DNPWC) under the Ministry of Forests and Environment is the focal government institution dedicated to wildlife conservation and management of protected areas. (Bhattarai *et al.*, 2017).

Currently, there are five different types (categories) of protected areas in Nepal (Table 1.1) covering more than 23% of the country (Fig 1.6). Although coverage of the protected areas is reltively high (about one forth), they are disproportionately located with larger areas at higher altitude (Paudel & Heinen, 2015). While these protected areas are home to the majority of Nepal's fauna species (85% of mammals, 96% of birds and 71% herpetofauna), about 60% of the country's plants occur outside these areas (Shrestha *et al.*, 2010). Although threatened animal species are well protected, some ecosystems and forest types, especially in the Midhills, are not accommodated by the protected areas of Nepal (Paudel & Heinen, 2015). National parks, wildlife reserves and hunting reserves are managed by the government (DNPWC). Conservation areas are managed by the government, communities or conservation organizations. Of six conservation areas, two (Api Nampa and Blackbuck) are managed by the government, one by the community (Kanchanjungha) and three (Annapurna, Manaslu and Gaurishankar) are managed by the National Trust for National Conservation (NTNC). NTNC is a quasi-governmental organization formed by legislation to support nature conservation initiatives in Nepal (NTNC, 2018). NTNC is also actively involved in wildlife research and monitoring, habitat management, rescue of problem/orphan wildlife, management of captive animals (zoo and rehabilitation facilities), capacity building and community participation in conservation.

In Nepal, buffer zones are part of a protected area system (IUCN Category - VI protected area, IUCN 2008) with legally defined boundaries. Buffer zones are managed by communities in close coordination with the respective park authorities. The role of local communities is well recognized in the buffer zones where the buffer zone user groups,

Table 1.1. Protected Area (PA) types and functions in Nepal.

	Type of PA	IUCN PA category	Number of PA	Functions /type of conservation
1	National Park	II	12	Protected by the army, conservation focusés on the entire ecosystem and habitats, resources extraction is limited, ecotourism & research activities allowed
2	Wildlife Reserve	II	1	Protected by the army, conservation focuses on target species, resources extraction is limited, ecotourism & research activities allowed only when the target species is not affected.
3	Hunting Reserve	IV	1	Hunting of surplus animals of certain species (in Dhorpatan blue sheep and wild boar) based on population surveys. Highest bidder gets the opportunity to hunt in the supervision of the reserve. Rest of the species are protected as in NP or WR
4	Conservation area	VI	6	People live inside conservation areas and can meet their livelihood in harmony with nature. Managed by the government (2), community (1) or conservation organizations (3)
5	Buffer zone	VI	13	People live inside the buffer zone and can meet their livelihood in harmony with nature. Managed by the community in close coordination with the respective park/reserve
	Total		20 (+13)	

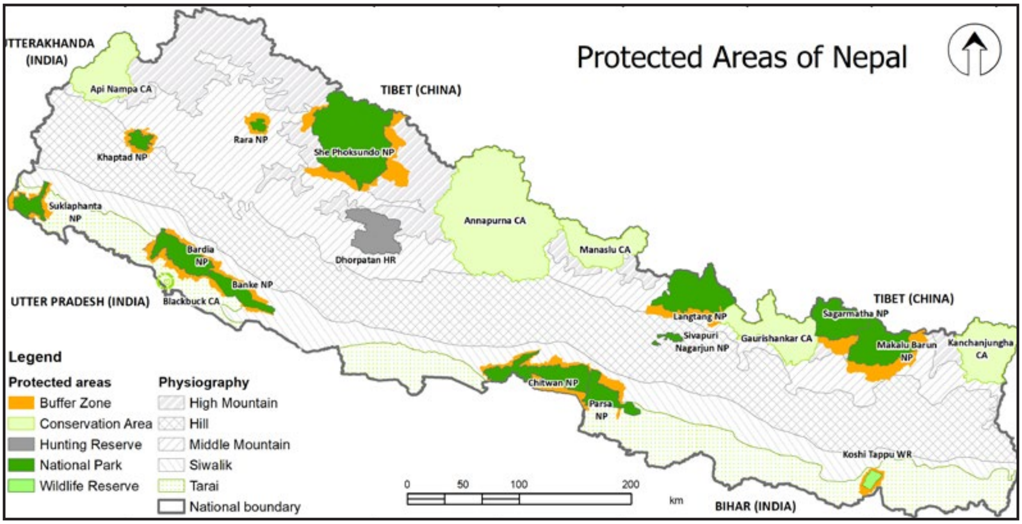


Figure 1.6. Protected areas of Nepal.

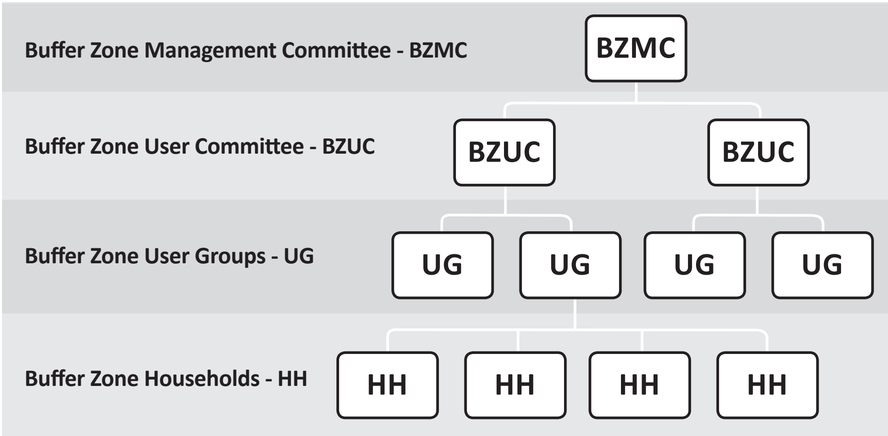


Figure 1.7 The organizational structure of the Buffer Zone in Nepal.

buffer zone user committees and buffer zone management committees are democratically elected (CNP, 2013b). Each user (resident household in the designated buffer zone area) is a member of the user groups who elect the representatives of the group at the hamlet level. The elected user group members also select the Buffer Zone User Committee (BZUC) members covering a larger area and many user groups. The chairpersons of BZUC become members of buffer zone management committee, the apex body for the buffer zone management (Fig. 1.7).

Creating a balance between nature conservation and the needs of local communities has been the core theme of the participatory conservation or co-management in the buffer zone (Persoon & Van Est, 2003). Different strategies originated from traditional practices or were introduced by conservation organizations and have been adopted in the buffer zone to facilitate community participation in conservation, reduce forest dependency and improve livelihoods. Such strategies include homestays, cultural programmes for visitors, biogas installations, improved livestock breeding and high value and alternative crops (mushroom farming, commercial banana farming, fish farming, etc.). One particularly noteworthy approach is the unique and successful 'Vulture restaurant' in Kawasoti, Nawalparasi (Western part of Chitwan's buffer zone), which has demonstrated how conservation can be intertwined with local culture and benefit both wildlife and people (Persoon & Lamichhane, 2017). As previously mentioned, cows are regarded as holy and protected by law in Nepal. When they age and become unproductive, they become a burden for the villagers. These old cows are purchased from local farmers and kept in a holding facility at the vulture restaurant where they live their retired life. When a cow dies at the restaurant, it is left in the open space in the forest. The vultures come and feed on these carcasses leaving just the skin and bones. The skin and bones are then sold, which provides an income to sustain the vulture restaurant (Persoon & Lamichhane, 2017).

Similarly, thousands of local youths voluntarily participate in wildlife conservation through community-based anti-poaching units. These units are a sub-committee of the BZUCs and are mandated to report any illegal activity in their respective area. These youth groups are also involved in the protection or rescue of wildlife in human areas, awareness programmes in the community and vigilance around the park for suspected activities related to poaching. Local youths are also involved in tourism-related services, e.g. being nature guides, working in hotels/restaurants and souvenir shops, which provide them with an alternative livelihood.

In addition to such community-based programs, forest conservation and management is another priority activity of the buffer zone programmes. Most of the forests in the buffer zone are managed by the user groups as a buffer zone community forest. The community forests are handed over to the user group for management based on a five-year operational plan approved by the park authority. The bottom line for the management of these forests in the buffer zone is that they should not harm the wildlife (both residents and those migrating from the park) and their habitat. These community forests also provide fodder, fuelwood, timber and other non-timber forest products to their users. It offsets the anthropogenic pressure in core areas of the park. In addition to the services to local livelihoods, the community forests close to tourist attractions also generate substantial revenue from eco-tourism activities such as elephant safaris, canoeing, jungle safaris and safari walks. Although in recent decades the restoration of forests in the buffer zone has created opportunities for both people and wildlife, it has also increased interaction with wildlife leading to people's lives and livelihood being threatened (Gurung, Smith, McDougal, Karki, & Barlow, 2008; Lamichhane *et al.*, 2018a).

In addition to the protected areas, there are 10 forest corridors or areas of biodiversity significance that have been declared protected forests and are managed by the Department of Forests and Soil Conservation. Community-managed and government-managed production forests also provide additional habitats for wildlife but with little attention for their conservation.

National and international non-governmental organizations like World Wildlife Fund (WWF) and Zoological Society of London (ZSL) also actively participate in nature conservation in Nepal through fundraising, supporting government initiatives as well as developing innovative conservation ideas and models. WWF started working in Nepal in 1967, initially for a rhino conservation programme. In 1993, the WWF Nepal Program office was established in Kathmandu under the WWF US. Terai Arc Landscape has been the major focus of WWF Nepal since establishment, although they are also active in mountains (Sacred Himalayan Landscape). Similarly, the ZSL started supporting rhino conservation and veterinary support programmes in the 1990s in Terai of Nepal. The ZSL Nepal office was established recently (2014) in Kathmandu and their programmes focus on the conservation of endangered wildlife in Terai. Local NGOs focusing on particular groups of flora and fauna are also active, including Bird Conservation Nepal, Small Mammals Conservation and Research Foundation, Friends of Nature, Himalayan Nature, Amphibian and Reptile Conservation Society Nepal.

Nepal has achieved remarkable success in controlling poaching of charismatic animals like tigers and rhinos in recent years (Aryal *et al.*, 2017). However, a huge investment is required from government, local communities and conservation partners to sustain this success. Poaching remains a major threat, especially for large mammals, as the demand for wildlife products is rising massively. Habitat degradation and fragmentation are the next major challenges as Nepal is expected to progress rapidly towards economic growth after a long period of political instability. Recently, Nepal has entered a new phase politically following the abolition of the monarchy, promulgation of a progressive constitution and the adoption of a democratic federal government system. Large-scale infrastructure projects such as roads, railways, irrigation canals and hydropower are necessary for the economic development of the country. However, such projects will also destroy or fragment intact habitats and result in the deterioration of the ecosystem's functionality. With a growing population, the increasing demand for land for agriculture and housing puts pressure on the remaining natural areas. Such fragmentation and degradation of natural areas often block the migration routes of wildlife or push wildlife to the periphery, leading to higher levels of human–wildlife interaction. Moreover, reduced poaching and conservation efforts have resulted in an increase in wildlife populations (Karki *et al.*, 2015; Subedi *et al.*, 2017) but their habitats have actually been shrinking. Thus, the success of conservation efforts also present novel challenges. Resource depletion with increasing competition in core habitats and increased conflicts with the communities at the edges can be expected.

Nepal is sandwiched between India and China, with no physical barriers at the border. Wildlife knows no political boundaries. Thus, large mammals and birds frequently move across the border. In 2013, a joint survey of tigers between India and Nepal documented evidence of 10 tigers moving in the forests across the border in the TAL (Chanchani *et al.*, 2014). Similarly, in 2013, a satellite radio-collared snow leopard roamed in three countries: Nepal, India and China (DNPWC, 2015a). CNP (~50) and buffer zone (~50) shares a border of ~ 100 km with India's Valmiki Tiger Reserve. Large mammals like tigers, rhinos and elephant frequently move between the CNP and the Valmiki Tiger Reserve (Chanchani *et al.*, 2014; Pant *et al.*, 2016).

The Himalayas is an area greatly affected by global climate change. It is having a huge impact on wildlife and their habitats both directly and indirectly (Xu *et al.*, 2009). Drought, flash flood, fire and other undesirable climatic incidents are already evident and pose significant threats to wildlife conservation. The changing climate and high mobility of human populations are also facilitating the spread of invasive species in critical wildlife habitats threatening native biodiversity (Lamichhane & Awasthi, 2009; Murphy *et al.*, 2013). Moreover, infectious wildlife diseases are also emerging as a threat to biodiversity as well as to human health (Daszak, Cunningham, & Hyatt, 2000).

2.1. Research Objectives and Questions

2.1.1. Study objectives

This study aims to contribute to the sustainable conservation of large carnivores by increasing understanding of the interactions between large carnivores and human communities and facilitating their coexistence in and around Chitwan National Park.
The specific research objectives are:

- To assess the spatial and temporal patterns and characteristics of human-wildlife conflicts in Chitwan National Park (Nepal) with a focus on large carnivores;
- To identify the characteristics of conflict-causing large carnivores;
- To better understand the predator-predator and prey-predator relationship;
- To understand the contribution of buffer-zone programmes to reduce human-wildlife impact.

2.1.2. Research questions

A. How are wildlife, especially the large carnivores, affecting communities in terms of attacks on humans and economic losses?

> **A.1.** What are the types and the extent of the conflicts caused by large carnivores in relation to herbivores in Chitwan?
> **A.2.** What are the spatial and temporal patterns of human-wildlife conflicts? Does increasing wildlife population caused a respective increase in human-wildlife conflicts?
> **A.3.** Does moon phase have an effect on the human-wildlife conflict incidents?
> **A.4.** Who is more vulnerable to the human-wildlife conflict in the community?

B. Is an entire population of the tiger or a specific group of individuals (sub-set of the population) causing the conflicts?

> **B.1.** Which were the identified conflict-causing tigers? Where and when were they active? How they were managed?
> **B.2.** What was the origin of the conflict-casing tigers? Were they involved temporarily in the conflict or for a long time?
> **B.3.** Are these conflict-causing tigers different? How to distinguish the specific group of individuals involved in conflicts?

C. Which factors are facilitating the co-occurrence of tigers and leopards in Chitwan and how tiger-leopard interaction is affecting the conflict with communities?

> **C.1.** What is the density and the abundance of tigers and leopards in CNP and in the buffer zone?
> **C.2.** Is there spatial or temporal partitioning between tigers and leopards? Are leopards pushed out of the park due to competition with tigers?

C.3. When are tigers and leopards active?
C.4. What is the diet composition of tigers and leopards in CNP?

D. How are communities responding to wildlife impacts?

D.1. What are the implemented conflict mitigation programs in the buffer zone?
D.2. How effective are these mitigation measures in reducing the conflict?
D.3. To what extent does the park revenue sharing with buffer zone community help in conflict mitigation?
D.4. What is the perception of people on wildlife conservation?
D.5. Does compensation schemes help communities to replenish the losses from wildlife?

2.2. Study Area

This study was carried out in the Chitwan National Park (CNP) and adjoining forests in Nepal. CNP is located in South-central Nepal between 27°16.56' - 27°42.14'N latitudes and 83°50.23' - 84°46.25'E Longitudes. It lies in the eastern part of the trans-boundary Teri Arc Landscape (TAL), a priority tiger conservation landscape (Chanchani *et al.*, 2014). CNP and the adjoining forests of the Valmiki Tiger Reserve in India and Parsa National Park in Nepal form a large (~3000 km^2) intact forest area that has been identified as a level 1 tiger conservation unit (Wikramanayake *et al.*, 1998). Tigers are thriving in this unit with an interconnected population of ~ 150 tigers (Chanchani *et al.*, 2014; Lamichhane *et al.*, 2018b) majority of which (~ 100 tigers) are from CNP.

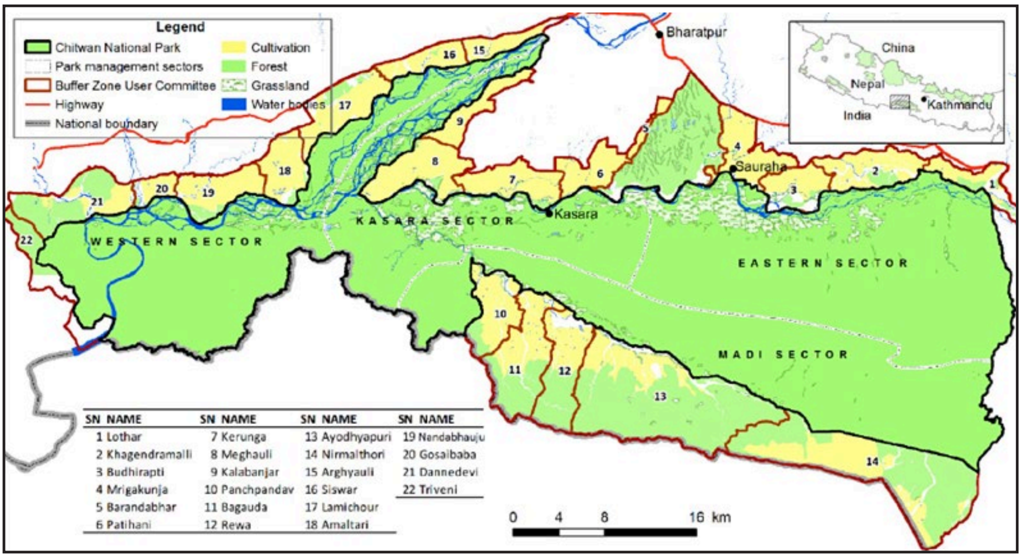


Figure 1.8. Chitwan National Park and buffer zone area.

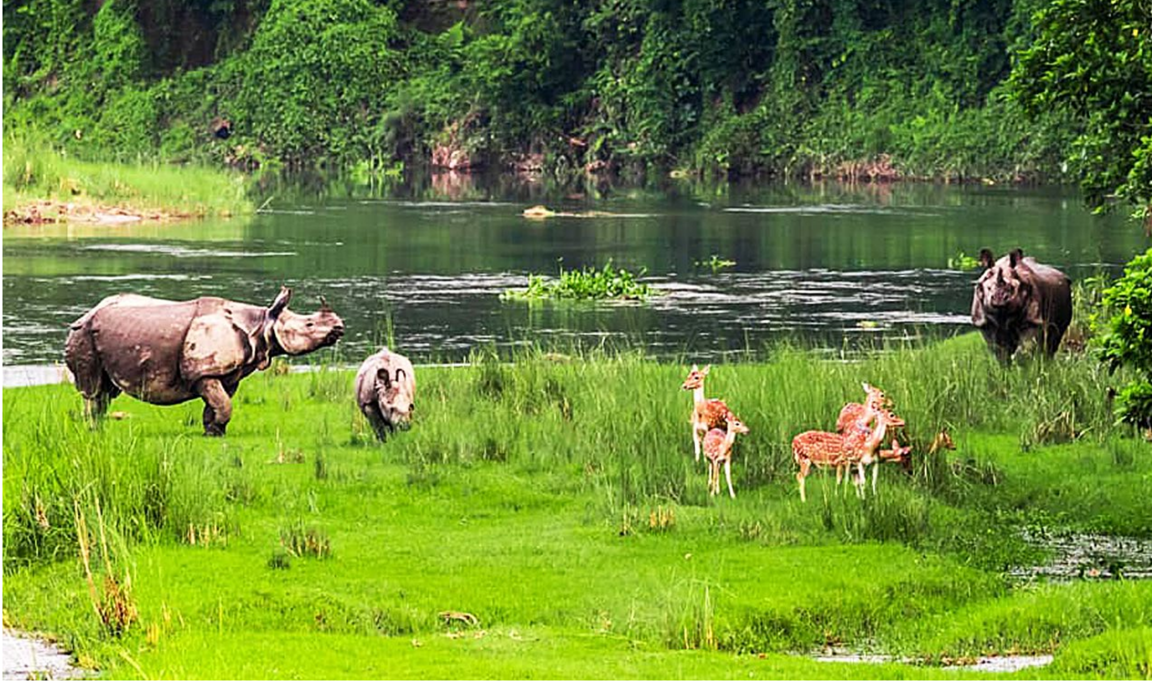


Figure 1.9 Rhinos and spotted deer grazing on the grassland at the bank of the river (Photo by Sagar Giri).

Figure 1.10 Grasslands and forests of Chitwan.

CNP lies in the outer boundary of the Himalayas. About 60% of the park is covered by Churia, the foothills of the Himalayas, which run in the middle of the park roughly parallel to the Indian border and in places the range divides, forming interior *Dun* valleys (also known as '*inner Terai*'). The park is drained by three rivers (Narayani, Rapti and Reu) and their tributaries. Alluvial floodplains of these rivers (about 40% of the park) harbour highly productive riverine forests and grasslands supporting a high density of wildlife. The Narayani River marks the western boundary, the Rapti River marks the northern boundary, the Reu River and the international border with India along the Valmiki Tiger Reserve marks the southern boundary for CNP (Fig. 1). Parsa National Park (PNP) is contiguous with the boundary of CNP. A corridor forest, the Barandabhar, connects the park with the northern hill forest.

CNP was established in 1973 with an area of 544 km^2. The park was extended to 932 km^2 in 1977. It was recognized as a UNESCO World Heritage Site (Natural) in 1984 (Site no. 284) for its exceptionally high diversity of megafauna and dynamic floodplain and churia (Himalayan foothills) ecosystem. During 1999 – 2002, a village of 1,700 households in the buffer zone south of the Rapti River (northern part of the park) was relocated about 15 km north. This additional habitat of approx. 21 km^2 was incorporated into the CNP in 2016 making the total area of the park 953 km^2.

An additional 750 km^2 buffer zone surrounding CNP was created in 1996 (21 Km^2 of BZ was later incorporated into the CNP in 2016). More than half of the buffer zone (55%) is usable wildlife habitat including forests, grasslands, shrubland, river and water bodies; the rest is used for agricultural land and settlements (Karki *et al.*, 2015). Historically, only a few settlements of the indigenous Tharu, Bote and Darai communities surrounded the present-day park (Fig. 2). However, many people from the hilly area migrated into the Chitwan after the 1950s. Now the community is a mix of indigenous people and immigrants from the hills (e.g. Brahmin, Chhetries, Tamang, Gurung, and Magar). Human density is relatively high (261.5 persons per km^2 in 2011) and increasing at the rate of 2.06% annually (CBS, 2012). The buffer zone includes more than 45,000 households in 12 municipalities from five districts (Chitwan, Makawanpur, Nawalpur, Parasi and Parsa).

The majority of people rely on subsistence farming. Agricultural land is highly fragmented and the majority does not have year-round irrigation facilities. Livestock is an integral part of subsistence agriculture. Farmers traditionally used livestock-drwan ploughs (bulls of buffalo or oxen) but today tractors are more common. Buffalo, cattle and goats are the main livestock but their stock per household is small (average 1 cow and/or 1 buffalo and/or 3 goats) (Lamichhane *et al.*, 2018a). Grazing was common in the buffer zone until the last decade but it is gradually shifting towards stall feeding as a result of grazing restrictions, adoption of improved livestock and commercial farming, and a shortage of labour (Gurung, Nelson, & Smith, 2009). The land is highly productive with three main crops harvests annually; rice and maize in the spring and summer whereas wheat or mustard in winter are the major crops. Some farmers are also attracted to the commercial farming of fruits (banana, papaya) and vegetables. Dependence on agriculture is decreasing as the younger generation prefers off-farm activities like tourism (nature guides and work in hotels), service and foreign employment (Lamichhane *et al.*, 2018a).

Figure 1.11 A typical house of local Tharu community, with walls made from grass reeds stitched together by mud. Livestock is integral part of the rural households.

Adjoining forests outside of the buffer zone (national forest and community forests) are administered by the District Forest Offices (DFRS, 2015). The focus of forest management in these areas is the production of timber and fulfill the community need for non-timber forest products. But the forest in the northern part of the Barandabhar corridor has been declared as a protected forest. Although the protected forests are oriented towards the conservation of wildlife species and their habitats, there is a high human pressure especially in terms of forest resources collection and livestock grazing.

2.3. Study outline

This study includes both social and ecological components. The ecological part of the study was focuses on two large carnivores, i.e. tigers and leopards. I used camera-trap surveys to study their distribution, density and activity patterns. Camera-trap pictures were also used to identify conflict-causing tigers in Chitwan and distinguish their characteristics. Moreover, the fecal samples of tigers and leopards were collected and analysed in order to understand their diets. I also compiled the compensation claim records of human-wildlife conflict victim families in the buffer zone of Chitwan to analyse the spatial and temporal patterns of the human-wildlife conflict. Fund utilization records of the buffer zone programmes was obtained from audit reports. I mapped the fences and other the conflict mitigation measures through field surveys. I also conducted social surveys (Questionnaire survey, focused group discussions and semi-structured interview) to assess the people's attitude toward wildlife conservation and human-wildlife conflict management.

The dissertation is presented in six chapters including four chapters published or accepted for publication in scientific journals in the form of research articles. These articles were written in cooperation with several co-authors including both Ph.D. supervisors and external individuals. I am the lead author in all articles and contributions of different co-authors are listed at the end of each chapter. The references cited in all chapters are grouped and presented at the end.

Chapter 1 - Introduction
The introductory chapter provides the general background of the study with scientific theories, gaps in knowledge globally and locally, the context of nature conservation in Nepal and CNP in particular, the objectives and key research questions, an overview of the research approach and a brief introduction to the chapters.

Chapter 2 - Spatio-temporal patterns of human–wildlife conflicts
This chapter provides an overview of human–wildlife conflict in the buffer zone of Chitwan NP. It presents the temporal and spatial patterns of the conflicts and associated ecological and socio-economic factors. A database of HWC incidents in Chitwan from the past 18 years has been used for analysis. The findings are useful for managers and conservationists in terms of devising conflict mitigation measures. The chapter was published as a research article in 'PLOS One' journal in April 2018.

Chapter 3 - Characteristics of conflict-causing tigers of Chitwan
This chapter examines whether specific groups or individual tigers within the source population are involved in human–wildlife conflicts. I compared images of tigers attacking humans and livestock or entering into settlements with tiger photographs obtained from the camera-trap studies. This enabled me to trace the origin of these tigers, their movement range and physical characteristics over a number of years. Morphological and demographic characteristics, as well as management actions, were documented for conflict-causing tigers. This chapter was published as a research article "Are conflict-causing tigers different? Another perspective for understanding Human-tiger conflict in Chitwan National Park, Nepal" in *Global Ecology and Conservation* journal in July 2017.

Chapter 4 - Consequences of tiger–leopard interaction on human–carnivore impacts
This chapter presents analysis of the factors associated with the co-occurrence of large carnivores, tigers and leopards within a human-dominated landscape. The study was

carried out using camera traps. Along with density and abundance estimates of tigers and leopards, various factors such as topography, habitat types, human disturbance and prey facilitating their co-occurrence was analysed. Overlap in temporal activity and diet between tigers and leopards was also examined. I found that spatial and temporal partitioning between tigers and leopards allowed them to share the same landscape albeit occupying a different niche (article accepted for publication in *Biodiversity and Conservation* journal).

Chapter 5 - Contribution of buffer zone programmes to conflict mitigation
This chapter explores the different conflict mitigation programmes practiced by Chitwan National Park, buffer zone user committees (BZUC) and local residents and their contribution to reducing conflict incidents. This chapter also looks at how much priority has been given in terms of financial expenditure by BZUCs for conflict management programmes. Focused group discussions, questionnaire survey data and official records of Chitwan NP and BZUC related to conflict mitigation measures as well as local people's attitudes were collected and analysed. The chapter was published as a research article in '*Human Ecology*' journal in February 2019.

Chapter 6 - Synthesis
This chapter provides a synthesized view of the previous chapters (chapter 2–5), with a general discussion on the findings and management implications.

Capturing a tiger that killed a person and multiple livestock in southern part of Chitwan National Park's buffer zone.

2 Spatio-temporal patterns of attacks on human and economic losses from wildlife in Chitwan National Park, Nepal

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Abstract

Wildlife attacks on humans and economic losses often result in reduced support of local communities for wildlife conservation. Information on spatial and temporal patterns of such losses in the highly affected areas contribute in designing and implementing effective mitigation measures. We analyzed the loss of humans, livestock and property caused by wildlife during 1998 to 2016, using victim family's reports to Chitwan National Park authorities and Buffer Zone User Committees. A total of 4,014 incidents were recorded including attacks on humans, livestock depredation, property damage and crop raiding caused by 12 wildlife species. In total >400,000 US dollar was paid to the victim families as a relief over the study period. Most of the attacks on humans were caused by rhino, sloth bear, tiger, elephant, wild boar and leopard. A significantly higher number of conflict incidents caused by rhino and elephant were observed during full moon periods. An increase in the wildlife population did not coincide with the respective rise in conflict incidents reported. Underprivileged ethnic communities were attacked by wildlife more frequently than expected. A number of attacks on humans by carnivores and herbivores did not differ significantly. An insignificant decreasing trend of wildlife attacks on humans and livestock was observed with significant variation over the years. Tiger and leopard caused >90% of livestock depredation. Tigers killed both large (cattle and buffalo) and medium-sized (goat, sheep, pig) livestock but leopard mostly killed medium-sized livestock. Most (87%) of the livestock killing during 2012-2016 occurred within the stall but close (<500m) to the forest edge. Both the percentage of households with livestock and average holding has decreased over the years in the buffer zone. Decreased forest dependency, as well as conflict mitigation measures (electric and mesh wire fences), have contributed to keep the conflict incidents in control. Strengthening mitigation measures like construction of electric or mesh wire fences and predator-proof livestock corrals along with educating local communities about wildlife behavior and timely management of problem animals (man-eater tiger, rage elephant etc.) will contribute to reduce the conflict.

Keywords: Wildlife attacks on humans; livestock depredation; moon-phase and conflict; Chitwan National Park, Nepal

2.1. Introduction

With ongoing fragmentation and degradation of the remaining natural areas (Joshi *et al.*, 2016), wildlife species are forced to live in close proximity to humans leading to frequent human-wildlife interactions (Inskip & Zimmermann, 2009). Such interaction is more intense in the areas where large mammals like Asian elephants (*Elephas maximus)*, greater one-horned rhinoceros (*Rhinoceros unicornis*), Bengal tigers (*Panthera tigtris tigrris)* and common leopards (*Panthera pardus ficusa)* are in high densities (Karki *et al.*, 2015; Subedi *et al.*, 2013) in relatively small protected areas within human-dominated landscapes (Wikramanayake *et al.*, 2004). Attacks on humans and property damage by wildlife and subsequent persecution of wildlife in retaliation are generally referred to as 'human-wildlife conflict' (Peterson *et al.*, 2010; Redpath *et al.*, 2015). This is a frequent phenomenon especially in the fringe of protected areas and forests (Pant *et al.*, 2016; Silwal *et al.*, 2017). Prevention or mitigation of such negative interaction is challenging when multiple endangered species of conservation significance are involved (Acharya *et al.*, 2016).

We selected Chitwan National Park (CNP) in Nepal for this study because it has been experiencing frequent and intensive human-wildlife conflicts since its establishment in 1973 (Sharma, 1990). CNP is also a flagship park in Nepal whose success or failure largely determines the overall direction of wildlife conservation in the country (Carter *et al.*, 2012). Conservation was started in core areas of the park in the 1970s through strict protection by the national army with limited rights of people. As a consequence, park-people (human-human) conflict was more pronounced in the initial years of park establishment (Bhattarai *et al.*, 2017; Nepal & Weber, 1995; Nepal & Weber, 1995; Sharma, 1990). Soon, the need for support of local communities living in the vicinity of the park was recognized to sustain the conservation (Mishra, 1982a). Participatory conservation programs were initiated in the early 1990s in Nepal (Heinen & Mehta, 2000). The government endorsed a Buffer Zone Policy in 1996 with a provision of 30-50% of the park revenue diverted to the respective buffer zone (MOFE, 1998). Following these participatory conservation initiatives, habitat restoration in the buffer zone, especially in community forests, created opportunities for both wildlife and people. Strict protection by the army in the core area also continued. During the past four decades, as a result of these conservation efforts, CNP has observed a gradual increase in the large mammal populations (Karki *et al.*, 2015; Subedi *et al.*, 2013). The park has a high density of mega-herbivores such as elephants and rhinos and large carnivores like tigers and leopards (Karki *et al.*, 2015; Subedi *et al.*, 2013; Thapa, 2011). In the surrounding areas of the Park, human density is also relatively high (261.5 persons per km^2 in 2011) and the human population is increasing at 2.1% annually (CBS, 2012). Probably as a consequence, a rise in the number of conflict incidents from wildlife has been reported by previous studies, especially in the buffer zone areas (Gurung *et al.*, 2008; Pant *et al.*, 2016; Silwal *et al.*, 2017). In contrast, another study from Chitwan also showed that human and wildlife (tiger as an example) can coexist with temporal displacement in well-protected areas at fine spatial scale (Carter *et al.*, 2012).

Studies in Africa show the effect of moon phase on the activity of carnivores, especially lions (Cozzi *et al.*, 2012; Packer *et al.*, 2011; Tumenta, 2012), herbivores (Gunn *et al.*, 2014; Traill, Martin, & Owen-Smith, 2016) and their interaction with humans. Packer *et al.* (2011) from their study in Tanzania found more attacks by lions on humans during the dark nights following the full moon, when the moon rises more than an hour after dusk. Cozzi *et al.* (2012) reported no difference in the activity of lion and hyena over the lunar cycle but found an influence of moonlight availability on the hunting behavior of wild dog and cheetah. Crop-raiding by African elephants was less during the full moon phase (Gunn *et al.*, 2014). We are not aware of published studies on the impact of moon-phase on human-wildlife conflict in Asia.

Previous studies about human-wildlife interaction in CNP and BZ focused on either a single species (Dhungana *et al.*, 2018; Gurung *et al.*, 2008; Pant *et al.*, 2016) or only on human casualty (Acharya *et al.*, 2016; Silwal *et al.*, 2017) but comprehensive analysis of human-wildlife conflicts over a longer time-span remain unreported. Thus, in our study, we present a comprehensive analysis of human-wildlife conflicts around CNP during a time span of 18 years (1998 to 2016) using the largest available dataset for a park in Nepal. We analyzed the types of loss from wildlife in time and space, and the factors associated. We tested two hypotheses in our study: 1) human-wildlife conflict incidents increase with the increase in the wildlife population and 2) Lower number of conflict-incidents occur during full-moon phases.

2.2. Materials and methods

2.2.1. Study area

Chitwan National Park (CNP) (27°16.56’ - 27°42.14’N and 83°50.23’ - 84°46.25’E; area 953 km^2), a World Heritage Site, is Nepal’s first National Park established in 1973. It is a part of the Terai Arc Landscape, a priority tiger conservation landscape (Wikramanayake *et al.*, 2004). The park has a monsoon-dominated sub-tropical climate with an average monthly maximum temperature between 24°C - 38°C, monthly minimum temperature between 11°C - 26°C, annual rainfall ~2250 mm and relative humidity 89-98% (2000 - 2010). The park is well known for its biodiversity with a species diversity of approximately 70 mammals, over 600 birds, 56 reptiles and amphibians, 156 butterflies, 120 fish (CNP, 2018). It is also one of the core breeding sites of tigers (Karki *et al.*, 2015). CNP holds the world’s second largest population of greater one-horned rhinoceros (Subedi *et al.*, 2017).

The park is dominated by forest (80%) including the majority of sal (*Shorea robusta*) forest followed by riverine forest and mixed hardwood forest. In addition, there are grasslands (12%), exposed surface (5%) and water bodies (3%) (Thapa, 2011). The park is drained by three major river systems, i.e., Narayani, Rapti and Reu rivers. The Narayani River marks the western boundary, the Rapti River marks the northern boundary, Reu River and the international border with India along the Valmiki Tiger Reserve marks the southern boundary (Figure 2.1). The Parsa National Park is contiguous in the eastern boundary. A corridor forest called Barandabhar connects the park with the northern hill forest.

An additional 750 km^2 of the buffer zone (BZ) surrounding CNP (~5 km) was created in 1996 (21 Km^2 of BZ was included into core area in 2016). More than half (55%) of the BZ consists of wildlife habitats such as forests, grasslands, shrubland, river and water bodies; the rest the area is used for agriculture and settlements (Karki *et al.*, 2015). There are >80 community forests in the buffer zone which are managed by the communities. The BZ includes > 45,000 households in 12 municipalities from four districts (Chitwan, Makawanpur, Nawalparasi and Parsa) (CBS, 2012). There are ~1,700 user groups under 22 Buffer Zone User Committees (BZUC) which are administered by a Buffer Zone Management Committee at park level (CNP, 2015). Historically there were only a few settlements of the indigenous *Tharu, Bote* and *Darai* communities surrounding the Park. Many people from the hilly area migrated into the Chitwan Valley after the eradication of malaria in the mid-1950s (Subedi *et al.*, 2013). Now the community is a mixture of indigenous people and 'Hills migrants' (*Brahmin, Chhetries*), 'Ethnic migrants' (*Tamang, Gurung, Magar* etc.), 'Dalit' or so-called untouchables (*Kami, Damai, Sarki* etc.) and other minorities (*Madhesi, Muslim* etc.) (CBS, 2012). Primarily people depend on subsistence agriculture although many new economic activities such as tourism and commercial farming are increasing. Livestock keeping is an integral part of subsistence agriculture, and grazing was common in the buffer zone till the early 2000s but it shifted swiftly towards stall feeding.

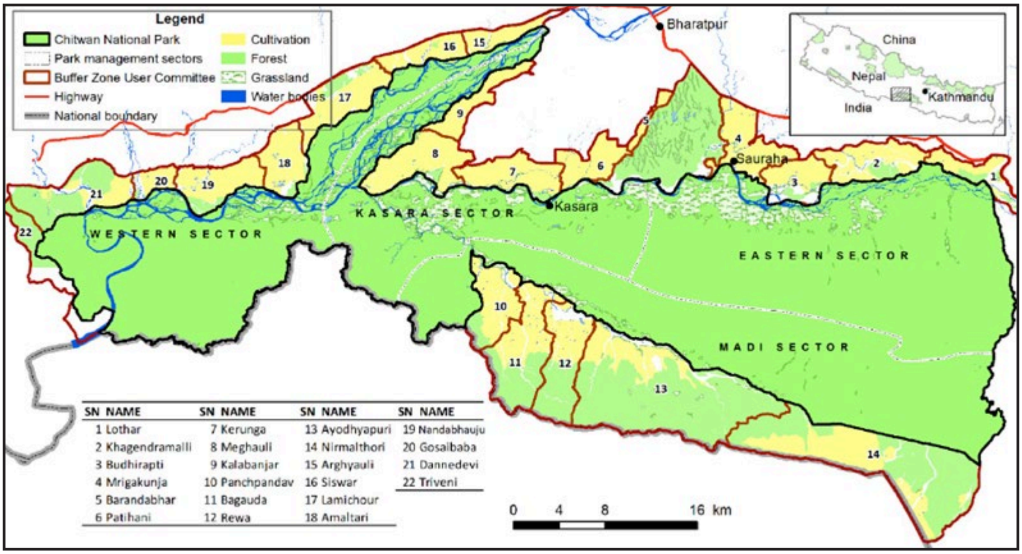

Figure 2.1 Chitwan National Park and Buffer Zone area, showing the land cover and management sectors. The labels (1 - 22) represents the Buffer Zone User Committees (BZUC) and the table (bottom left) gives the names of respective BZUC.

2.2.2. Loss from wildlife reported to Park and buffer zone authorities

We collected data on wildlife attacks on humans and economic loss reported to the CNP authorities and the BZUC from 1998 to 2016. People started to report the loss from wildlife (primarily attacks to human and livestock depredation) to the BZUCs after the relief scheme for wildlife victims started in 1999 along with the implementation of the Buffer Zone Program (MOFE, 1998). A guideline for relief distribution was endorsed by a meeting of the Buffer Zone Management Committee in 1999 (CNP, 2015). The wildlife victims in the BZ self-reported the incidents through applications to the local authorities (CNP or BZUC) primarily to claim compensation (only partial cost is covered so it is termed 'relief' hereafter). The conflict incidents were verified by the BZUC and subsequently, relief was released as per the guidelines. These data of relief application and distribution were kept in registers by BZUCs between 1998 and 2009. Government endorsed the relief guideline of wildlife losses in 2009 and designated respective protected areas or district forest offices for relief distribution (Acharya *et al.*, 2016; MOFE, 2017). Thus, CNP started to process and verify the relief applications as from 2009 onwards. Since then, the government revised the guideline two times (in 2013 & 2015) increasing the relief amounts (CNP, 2015). We compiled all the relief applications of wildlife victims reported to both BZUCs and CNP during 18 years (1998 to 2016). The data were managed according to Nepalese fiscal year which runs from mid-July to mid-July based on the Nepalese Calendar (Bikram Sambat). For the consistency of the data for time series analysis, we used these fiscal years. Data of initial years (1998/99 to 2006/07) included the victim's name and address, respective BZUC, fiscal year, type of loss, wildlife causing the loss, amount claimed and received. Data after 2006/07 also include the date of the incident (CNP, 2015).

2.2.3. Detailed data collection of livestock depredation

We visited 254 households who lost livestock in the last five years (2012-2016) to verify the compensation claim records and get additional information about the incidents. The field survey was conducted during March – May 2016 and February – March 2017. Name and address of the applicants were obtained from the database of CNP & BZUCs. The household heads or family members (above the age of 16) were interviewed using a pre-structured questionnaire (Supplementary Information S1 File). The research (and the questionnaire) was approved by the ethics committee of the Institute of Cultural Anthropology and Development Sociology (Leiden University, Netherlands). Similarly, the study was also approved by the 'Technical Committee' of Department of National Parks and Wildlife Conservation which issues the research permits to studies in protected areas in Nepal. We obtained written consent of the interviewee before starting the interview. We have anonymized the identity of the interviewee before proceeding to analysis. All the necessary approvals have been obtained from the Government authorities and buffer zone user committees. GPS location of the house and livestock depredation place were recorded. Socio-economic status of the family, livestock herding practices, preventive measures and relief for the loss were collected in a standard format. We digitized the forest edge (border of the forest and cultivated areas) using high-resolution satellite images in Google Earth.

2.2.4. Data analysis and statistics

We categorized the data into four types of losses a) attacks on humans (death & injury), b) house and property loss, c) livestock depredation (buffalo, cattle, goat, sheep, pig, duck/chicken) and d) crop raiding. Based on surname of the victim we derived the ethnicity of the victim into five categories of having different livelihood strategies – 1) *Hill migrant* (Brahmin, Chhetri and Thakuri migrated from hills), 2) *Ethnic migrant* (Ethnic communities of hills like Gurung, Magar, Tamang, Newar etc. migrated to Chitwan), 3) *Indigenous Terai* (Tharu, Bote, Darai, Mushahar), 4) *Dalit* (under-privileged casts of Kami, Damai, Sarki etc.) and 5) Others (Madhesi, Muslim etc.). The surname of a person is a reliable indicator of ethnicity in Nepal (Gurung, 2003).

We also assigned the lunar day (1 – new moon, 15 – full moon) for the date of the incident using the Gregorian-Lunar Calendar Conversion Table of Hong Kong Observatory (http://www.hko.gov.hk/gts/time/conversion.htm). We defined six moon phases of five-day period blocks. For instance, a 'new moon' phase was defined as the period from two days prior to the new moon to two days after the new moon (Traill *et al.*, 2016). A similar five-day block was used for the full moon and other four moon phases in between.

The conflict incidents were associated with the spatial layer of BZUC in Q-GIS (QGIS Development Team, 2016) based on the address of the victim for spatial analysis. Descriptive summaries of yearly, monthly and seasonal wildlife attacks on humans and livestock depredation were calculated using Pivot table function of Microsoft Excel 2013 (Microsoft Redmond, USA) and Statistical analysis was done in R (R Core Team, 2017). Chi-square tests of independence were applied to compare the frequency of attacks (death and injury) and livestock depredation by wildlife species over the years, seasons, months and moon phases. An independent t-test was applied to compare the incidents caused by herbivores and carnivores, human death and injuries, and livestock depredation by tiger and leopard. Shapiro-Wilk test was performed to check the normality of the data. We also performed a Pearson's correlation test between livestock depredation frequency and the number of people on foreign employment from Chitwan district over the years as a measure of livelihood change (CBS, 2012; CTEVT, 2014). Foreign employment is one of the major factors in Nepal to reduce forest dependency with a shortage of labor for grazing and other agricultural work as well as adopt alternative livelihood with increased capital (Fox, 2018). The distance between the livestock depredation location and nearest forest edge and park boundary was calculated in QGIS using NNJoin plugin (QGIS Development Team, 2016).

We used a linear regression to test the hypothesis that the frequency of conflict incidents increases respective to an increasing wildlife population. The frequency of human attacks by tiger and rhino over the years during the study period was modeled as a function of the tiger and rhino population. Data on the tiger and rhino population in CNP & BZ over the years (2000 – 2015) were collected from published reports of the surveys in different years (DNPWC, 2006, 2015b; Karki *et al.*, 2015; Karki *et al.*, 2009;

Subedi *et al.*, 2013). The surveys were done within 3-5 years interval. The population for the years in between the surveys was reconstructed using a linear regression.

2.3. Results

2.3.1. Types of incidents and relief payment

A total of 4,014 incidents of human and economic loss from 12 wildlife species (Table 2.1) were reported to BZUCs or CNP authority during 18 years (1998 July to 2016 July) including 732 attacks on humans (168 fatalities and 564 injury), 2,213 incidents of livestock depredation, 418 incidents of damage to house and property and 651 crop-raiding incidents.

Table 2.1. Types of loss caused by wildlife in the buffer zone of Chitwan National Park. The numbers in the parenthesis indicates the frequency of reported cases of the incident caused by the particular wildlife species.

Species	Attacks on Human	House & property loss	Livestock depredation	Crop raiding*
Blue bull* (*Boselaphus tragocamelus*)	death (1), injury (1)	-	-	-
Spotted deer* (*Axis axis*)	injury (1)			paddy (2)
Elephant (*Elephas maximus*)	death (26), injury (33)	house damage (301), grain storage (83) compound wall, toilet, water tank etc. (11), vehicle (3)	-	paddy (328), maize (17), wheat (2), banana (1), others (20)
Gaur (*Bos gaurus*)	injury (3)	-	-	-
Leopard (*Panthera pardus*)	injury (36)	-	buffalo calf (9), cattle calf (18), goat (550), sheep (8), pig (46), duck/chicken (2)	
Mugger crocodile (*Crocodylus palustris*)	death (1)**, injury (2)	-	cattle (1), goat (4)	-
Burmese python (*Python bivittatus*)	-	-	duck/chicken (4)	-
Rhino (*Rhinoceros unicornis*)	death (55), injury (180)	crop storage (4)	-	paddy (123), wheat (110), banana (2), sugarcane (5), others (25)
Sambar deer* (*Rusa unicolor*)	injury (1)	-	-	-
Sloth bear (*Melursus ursinus*)	death (5), injury (142)	-	goat (67), pig (4)	-
Tiger (*P. tigris*)	death (64), injury (55)	-	buffalo (189), cattle (362), goat (718), pig (42), sheep (14)	-
Wild boar* (*Sus scrofa*)	death (2), injury (41)	-	-	paddy (3), others (1)

** Compensation scheme covers the crop raiding by elephant, rhino and wild water buffalo. Although crop raiding by deer and wild boar is widespread, it is not reported by the locals.*
***There is a case of a human killed by mugger crocodile inside the park in 2016.*

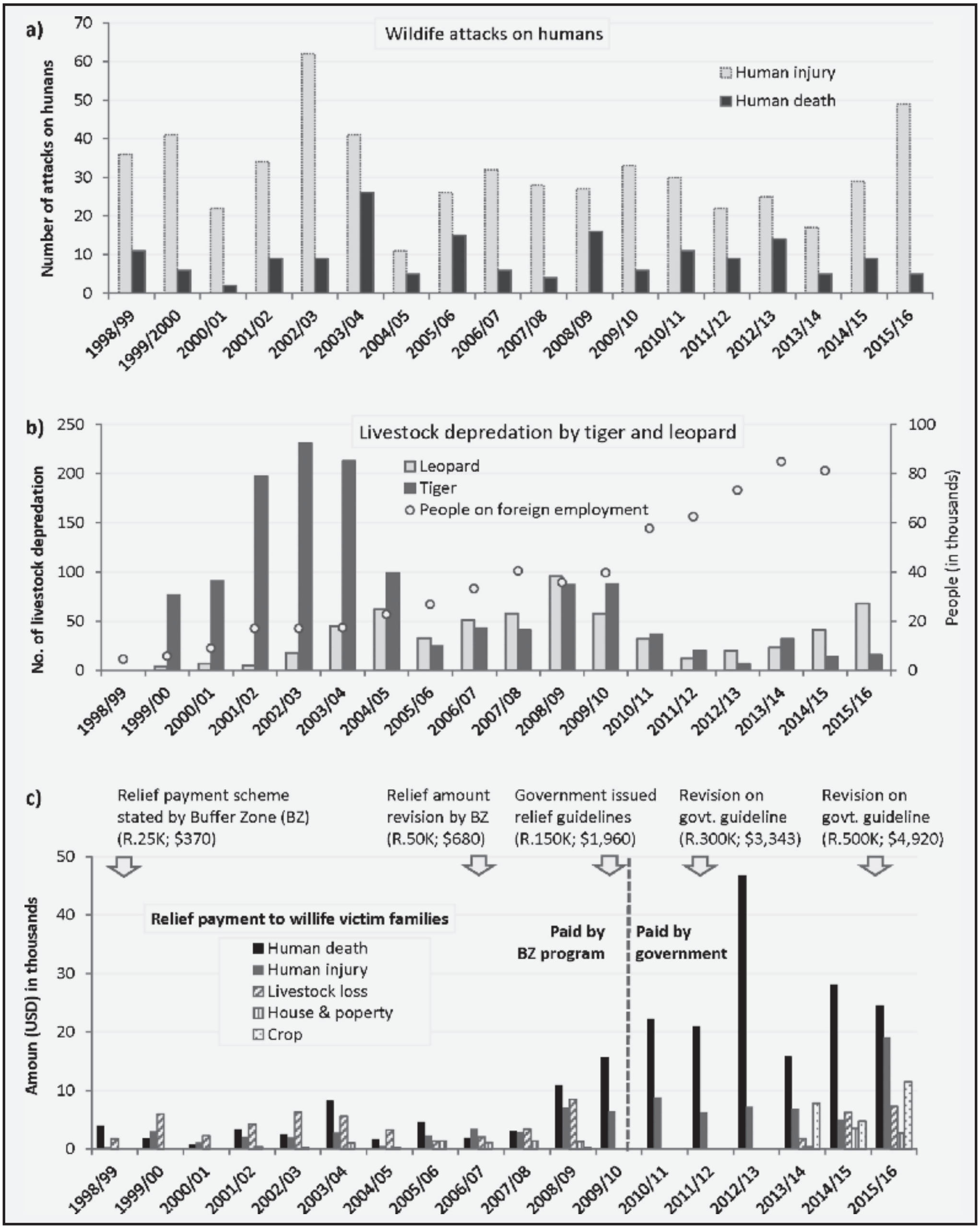

Figure 2.2 Wildlife attacks on humans, livestock depredation and relief payments over the years in Buffer Zone of Chitwan National Park, Nepal, a) Human death and injury b) livestock depredation caused by tiger and leopard, and its relationship with people on foreign employment c) Amount of relief distribution to the victim families with timeline of relief distribution scheme. The numbers in parenthesis are the relief amount per victim of human death provisioned in relief guidelines of Buffer Zone or government, R=Nepalese Rupees, K=thousand.

A total of USD 403,648.51 (Nepalese Rupees 33,911,971) was paid as a relief to the victims' families for wildlife attacks or economic loss from wildlife during 1998 – 2016 (Annex Table 2.1). A majority (54%) of the payments was provided to families as a relief for a relative who died in a wildlife attack, followed by treatment of injured ones (21.5%), relief for livestock depredation (13.8%), crop raiding (7.1%) and property loss (3.5%) (Figure 2.2).

2.3.2. Effect of moon phase

A significant difference on the frequency of conflict incidents caused by elephant (χ^2=27.32, df=5, P<0.001) and rhino (χ^2=21.54, df=5, P<0.001) was observed between the moon phases with more incidents occurring during full moon periods (Figure 2.3). In contrast to the herbivores, the carnivores had a minimum number of incidents during the full moon period but the relationship was not significant for both tiger (χ^2=7.51, df=5, P>0.05) and leopard (χ^2=3.72, df=5, P>0.05).

2.3.3. Human death and injury

A total of 732 wildlife attacks with an annual average of 9.3 human deaths (SD = 5.7) and 31.3 human injuries (SD 11.8) were recorded between 1998 and 2016. The linear regression shows a marginal decrease of both human death (-0.06/year) and human injury (-0.45/year). The annual sum of wildlife attacks on humans varied significantly over the years (χ^2=81.17, df=17, P<0.001). Compared to human injuries, a significantly lower (t=7.1, df=24.53, p<0.001) number of the wildlife attacks resulted in human fatalities. The number

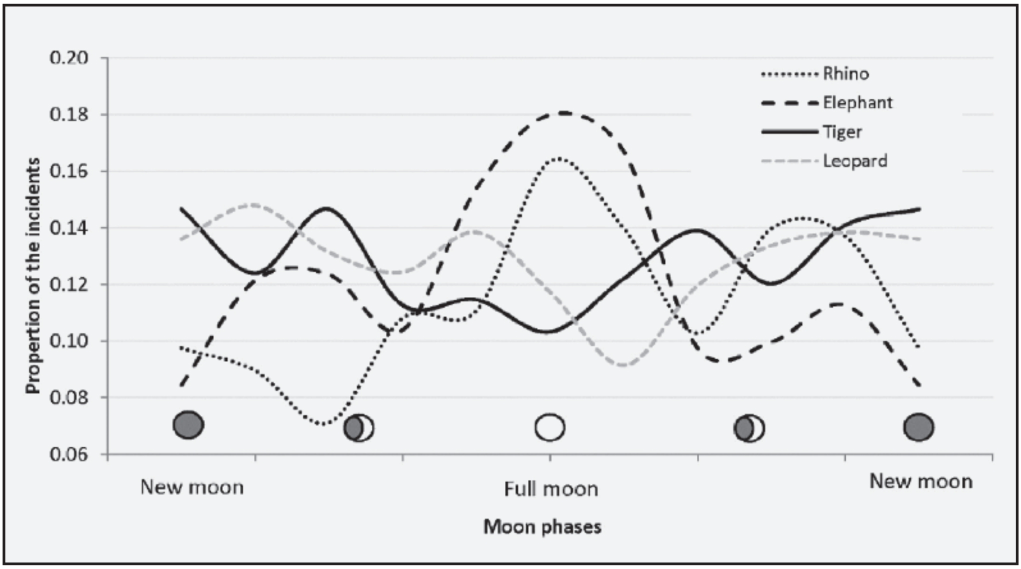

Figure 2.3 Proportion of the reported human-wildlife interactions with elephant, rhino, tiger and leopard in Chitwan NP between 2001 and 2015 plotted over the lunar phases.

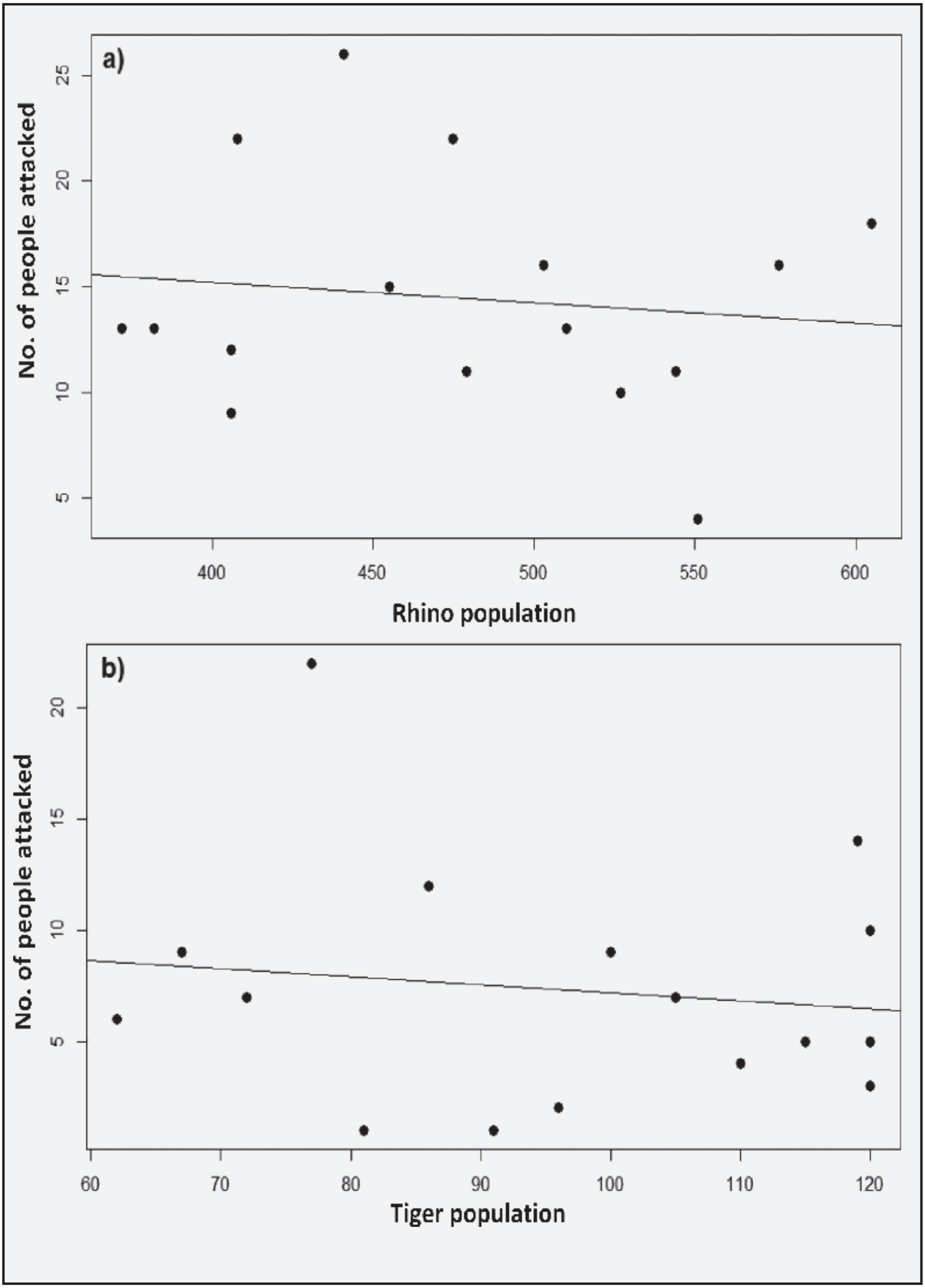

Figure 2.4 Number of attacks on humans (y-axis) plotted over the population of a) rhino (*Rhinoceros unicornis*) and b) tiger (*Panthera tigris*) in the x-axis.

Table 2.2. The expected and observed proportion of wildlife attacks on humans of different ethnicity.

Ethnicity of people attacked	Expected proportion (%)	Observed proportion (%)	Deviation from expected (%)
Hill migrant	41.7	39.1	-6.8
Ethnic migrant	27.8	16.5	-68.3
Indigenous	17.3	30.1	42.6
Dalit	8.2	11.1	25.5
Others	5.0	3.3	-51.2

of attacks by herbivores (rhino, elephant, wild boar, deer) was not significantly different ($t=0.76$, $df=30.1$, $p>0.05$) from the number of attacks by carnivores (tiger, leopard and sloth bear). More than two third of the human killings were caused by tiger (38.3%) and rhino (32.1%), but more human injury was caused by rhino (32%, n=567) and sloth bear (26.1%) compared to tiger (9.9%) and elephants (5.8%) (Table 2.1). The linear regression analysis did not show a significant influence ($P>0.05$) of tiger and rhino population trends on the frequency of attacks on humans (Figure 2.4) leading us to reject our hypothesis.

There was a significant variation in the frequency of wildlife attacks between the different communities ($\chi^2=305.1$, df=4, $P=<0.001$). Indigenous and Dalit communities were attacked more frequently whereas ethnic and hill migrant communities were attacked less frequently than expected (Table 2.2).

Among the BZUCs, a significant difference in the number of attacks on humans ($\chi^2=257.5$, df=21, $P=<0.001$) and livestock depredation ($\chi^2=992.1$, df=21, $P=<0.001$) was observed (Figure 2.5). Five of 22 BZUCs of Chitwan recorded > 50% of human deaths and 13 BZUCs reported five or more human deaths in their area. The highest number of human killing (24) was recorded from Ayodhyapuri BZUC in Madi valley (south of the park) followed by Kalabanjar BZUC (18).

2.3.4. Livestock depredation

An annual average of 122.94 (SD=80.97) incidents of livestock depredation was recorded around CNP during the study period. Tiger and leopard caused most (>90%) of the reported livestock depredation (n=2,213). The annual frequency of livestock depredation by tigers was significantly higher ($t=2.2$, df=20, $p<0.05$) compared to leopards but in recent two years (after 2014) leopards caused more livestock depredation than tigers (Figure 2.2). The overall trend of livestock depredation between 1998 and 2016 shows an insignificant decline with a significant variation over the years ($\chi^2=901.54$, df=17, $p<0.001$).
A maximum number of livestock were killed from 2002 to 2004 and numbers decreased sharply afterward. Although some fluctuations were observed, we could not find a significant difference between the average number of livestock depredation over the months ($\chi^2=3.87$, df=11, $P=0.97$) and seasons ($\chi^2=0.27$, df=3, $P=0.97$) (Figure 2.6a). We found a significant ($p<0.05$) negative correlation (Pearson's correlation coefficient - 0.60) between livestock depredation and the number of people on foreign employment over the years in Chitwan district.

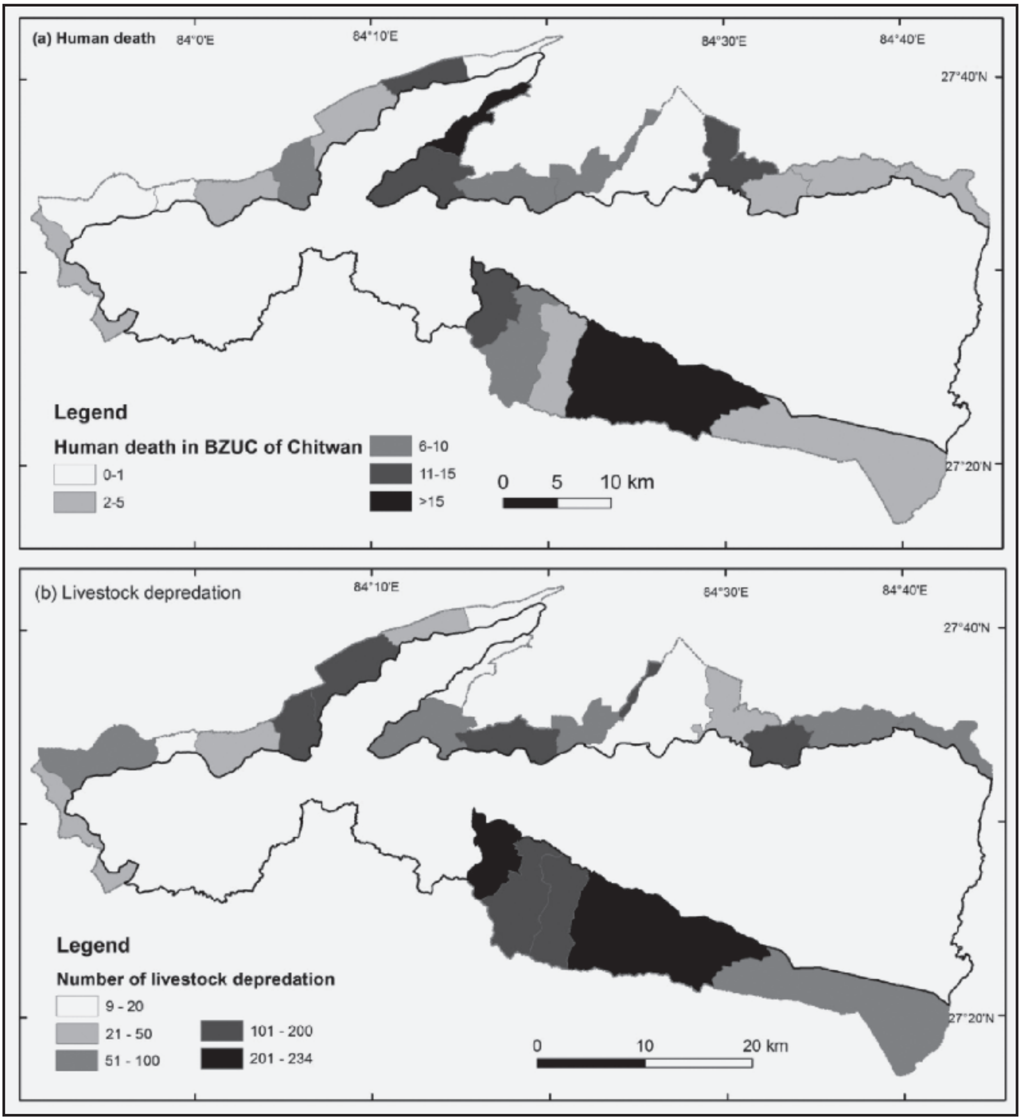

Figure 2.5 Spatial distribution of a) human killing and b) livestock depredation in the buffer zone of Chitwan National Park, Nepal.

There was a significant difference between tiger and leopard's livestock preference (χ^2=279.58, df=4, P<0.001). Tigers killed both medium-sized (goat/sheep and pig, 58%) and large-sized livestock (buffalo and ow/oxen, 41%) but leopards mostly (>96%) killed smaller sized goat/sheep or pig (Figure 2.3b).

A questionnaire survey with the victim's households who lost livestock in the last five years shows that most of the livestock depredation by carnivores (87.7%, n=253) was caused inside the stall. The livestock killing occurred mostly (86.8%) in close proximity i.e. <500m distance of the forest village edge (Figure 2.6b). Both the percentage of households having livestock and the average size of holding (except for the goats) have decreased over the years (Table 2.3). Livestock contributes an income for 74% of the households and 7% reported it as a primary source (Figure 2.7).

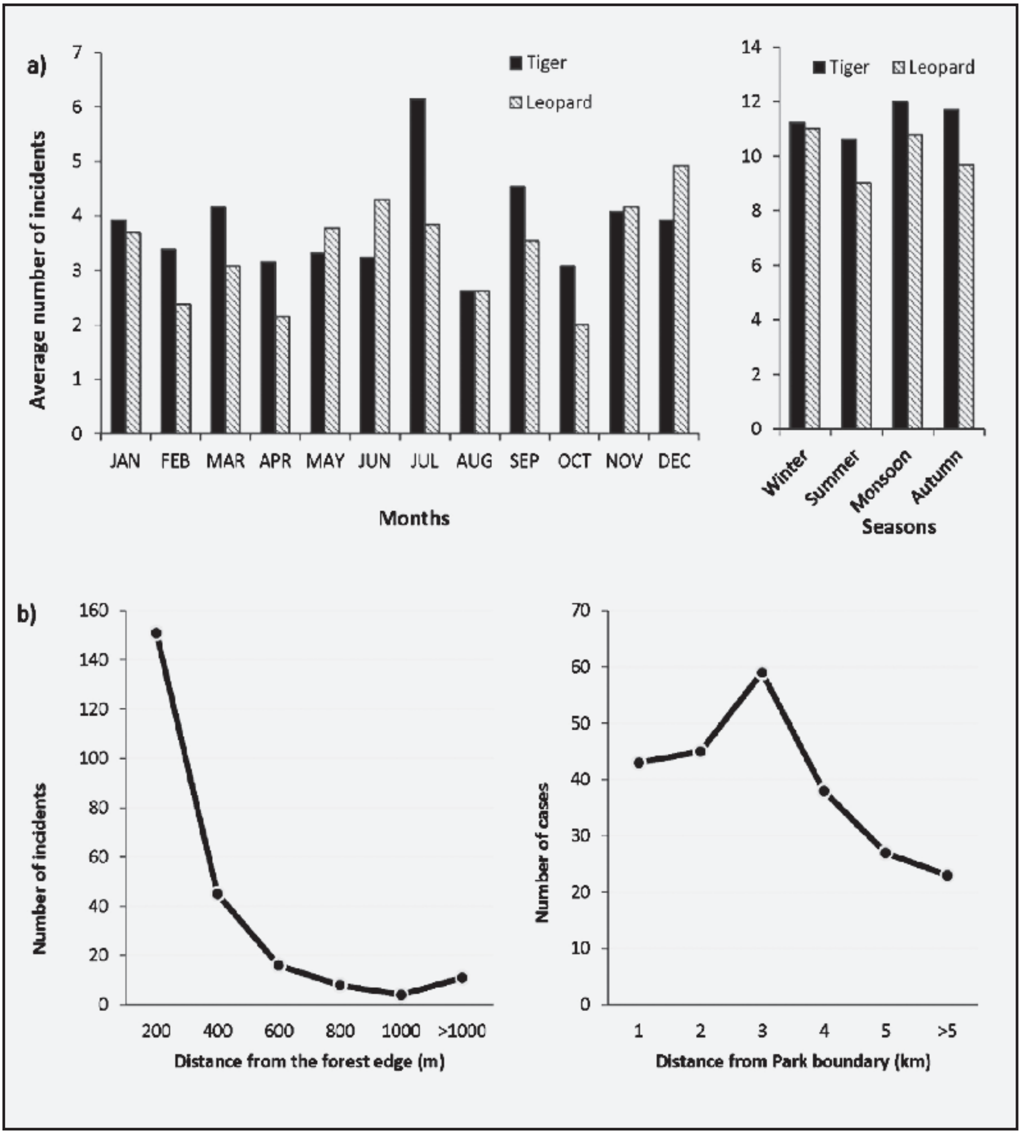

Figure 2.6 a) Average number of livestock depredation incident per month and season in the buffer zone of Chitwan National Park during 1998 – 2016, b) Number of livestock killed by tigers (*Panthera tigris*) and leopards (*P. pardus*) in the distance from forest edge and park boundary.

Table 2.3. Percentage of households with livestock, average livestock ownership per household and percentage of households grazing their livestock. Data for 1997 and 2006 obtained from Gurung et al. (2010).

Type of livestock	% Households with livestock			Average per household			% of Households grazing the livestock (2017)
	1997* (n=354)	2006* (n=400)	2017 (n=254)	1997* (n=354)	2006* n=400)	2017 (n=254)	
Goat	74	71	**70**	2.80	2.80	**3.27**	11.46
Cattle	57	47	**36**	1.80	1.20	**0.91**	7.51
Buffalo	81	67	**47**	2.50	1.60	**1.02**	11.86
All livestock	94	91	**88**	7.10	5.60	**5.40**	18.04

**The average value comes from Madi valley (Southern buffer zone) of Chitwan National Park.*

Most of the carcasses of killed livestock (94.8%, n=248) were found by the victim families. Three fourth (75.7%, n=235) of them were buried and 8.9% were consumed within families (6.8%) or neighbors (2.1%). Less than 15% of the carcasses were left and probably consumed by tiger/leopard or scavenger. A majority (60.8%) of the respondents reported the subsequent livestock killing in their locality (village) by the tiger or leopard.

2.4. Discussion

We present the most comprehensive analysis of wildlife attacks on humans and economic loss in the buffer zone of Chitwan National Park, Nepal published to date. Livestock depredation was the most frequent among the reported types of losses followed by attacks on humans, crop raiding and property damage. Losses were caused by 12 wildlife species with the maximum number of incidents caused by tiger followed by elephant,

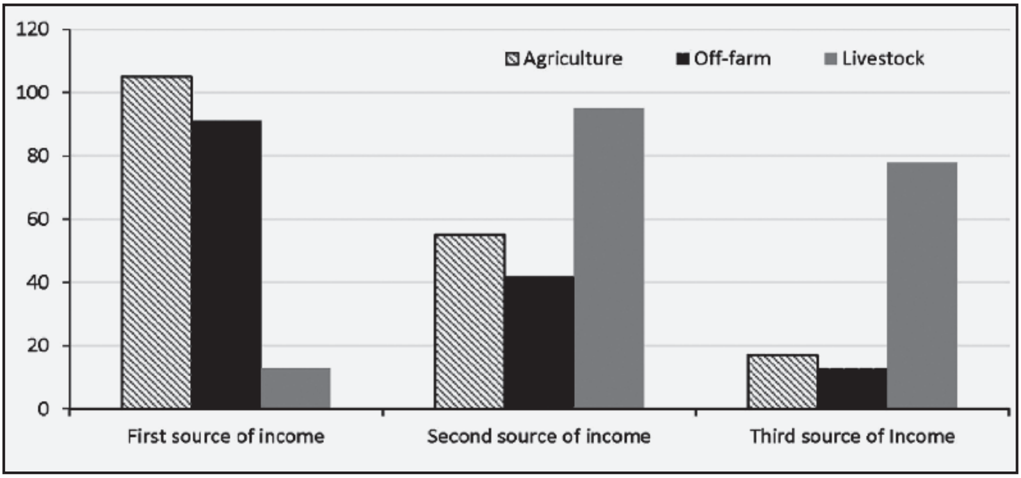

Figure 2.7 Dependency of livestock depredation victim households on agriculture, livestock and other off-farm activities.

leopard and rhino. Although crop raiding by deer and wild boar is widespread, the government guidelines do not provide relief and thus, these remain un-reported (NTNC, unpublished data). Our study shows that the relief claim data can provide a valuable source of information about the human-wildlife conflict.

2.4.1. Effect of moon phase

Our results partly support the hypothesis that the moon phase has an influence on wildlife activity and conflict with humans. We detected significantly higher conflict incidents caused by greater one-horned rhinos and Asian elephants during full moon phase. It is not surprising to find higher conflict incidents of Greater one-horned rhinos during moonlight nights as they are active both day and night with a peak during early morning and late afternoon (Subedi, 2012). Our finding of higher incidents of Asian elephants during moonlight nights is contrary to Gunn *et al.* (2014) who reported lower incidents of crop raiding by African elephants (*Loxodonta africana)* during full moon nights. Such difference could be due to 1) the behavioral difference between the elephant species, 2) differences in landscape patterns with thick vegetation in Chitwan compared to wide open African savannas and 3) difference in crop guarding practices.

The number of conflict reports of both tiger and leopard was lowest during the full moon, the difference was not significant to other phases of the lunar cycle. Packer *et al.* (2011) documented the higher number of lion attack on humans during dark period in the nights in Tanzania. But higher livestock depredation during the full moon period was reported by Tumenta (2012) in Waza National Park, Cameroon. Both tigers and leopards are nocturnal predators (Carter *et al.*, 2012; Thapa, 2011) causing the majority of the attacks on human and livestock during the night. There is a lack of details on whether they attack during moonlight or dark nights but studies of lions, another nocturnal predator in Africa, shows less success in obtaining wildlife prey during moonlit nights. Our finding was based on conflict records reported by people and our data include date but not the time of the incident. This limited our conclusions on the actual effect of moon rise and night luminescence. A detailed study with incident time is required to fully understand the effect of moon phase.

2.4.2. Human loss and injury

Our report of an average annual of 40.6 wildlife attacks on humans with 9.3 fatalities, is higher than previously reported by Silwal *et al.* (2017). The total number of wildlife attacks per year could be higher since our data only cover the buffer zone and do not include the incidents when people were illegally entering the core area of the park. Dhungana *et al.* (2018) reported about one-fourth of attacks on humans occurred in core area who do not get the relief. Comparing to other protected areas in Nepal, CNP observed the highest rate of human casualties (DNPWC, 2014, 2015a, 2016). A high density of multiple large mammal species (rhino, tiger, gaur, sloth bear etc.) occurs in CNP (DNPWC, 2015b; Karki *et al.*, 2015) in close proximity of the human habitation. The

Park is narrow and elongated maximizing the interaction zone between humans and wildlife. However, there are other protected areas in South Asia where conflict is more intense. In the Sundarbans in Bangladesh (having 106 tigers, ~6,000 km^2 area) where annually 22 human fatalities on tiger attack has been recorded (Miller, Jhala, & Jena, 2016).

In spite of an increasing wildlife population in the park and human population in the buffer zone, we did not find the respective increase on the fatalities or injuries from wildlife. This could be attributed to 1) less human-wildlife interaction with reduced dependency of communities on forests, 2) separation of forest and farmlands/ settlements by installing electric and mesh wire fences along the forest border in the buffer zone with the support of government and NGOs, 3) increased awareness and 4) other preventive measures (such as predator-proof corrals, alternative crops) practiced by communities. The trend of wildlife attacks on humans in Chitwan is more or less stable over the study period but still substantial. Further strengthening of mitigation measures and awareness among communities will contribute in reducing human loss.

There was a difference in the expected and observed rate of attacks by wildlife to members of different ethnic communities. Due to higher dependency on forests for their traditional livelihood practice, frequent interaction of *Terai indigenous* and *Dalit* communities with wildlife resulted in more wildlife attacks on them. Both of these groups are underprivileged in society who live in close proximity of the forests (Dangol & Gurung, 1991) and generally have lower economic opportunities for alternative livelihoods. Previous studies from Chitwan show that >80% of the wildlife attacks on humans happen within the 2 km of the park boundary (Pant *et al.*, 2016; Silwal *et al.*, 2017).

2.4.3. Livestock depredation

The annual average of 123 livestock killing in CNP is comparable to Bardia National Park (118/year, NTNC unpublished data) in western Nepal but higher than other protected areas. Much higher livestock killing has been reported in some of the Indian Parks (462/ year, Kanha National Park) (Miller *et al.*, 2016). Grazing restrictions in the core areas of the parks and community-managed buffer zone forests have contributed to keep the livestock depredation cases lower compared to Indian parks where free grazing is common (Gurung *et al.*, 2009; Miller *et al.*, 2016).

Tiger and leopard caused most of the livestock depredation with the highest number of incidents by tigers. However, in recent years (after 2014) leopards caused more losses. Increasing tiger population of Chitwan may have pushed leopards into the fringes of the park or in the buffer zone where they kill livestock frequently. A similar observation was reported in Bardia, the other park in Nepal's Terai (Odden *et al.*, 2010). We found a gradual shift of the buffer zone communities towards off-farm based income sources with reduced dependency over agriculture and livestock. Households with livestock as well as average holding have reduced gradually over the years. Most of the households (>80%) practice stall feeding. Out of the grazing households (n=45) nearly half (46.7%) graze their cattle in community forest, others graze on private land or road-side and other fallow land. Grazing was common until the early 2000s (Gurung *et al.*, 2009) in the BZ area but in recent years, stall feeding is facilitated by grazing restrictions, adoption of the improved variety of livestock, the use of commercial livestock feeds and a shortage of labor for grazing. For instance, we found a significant negative correlation between the number of people on foreign employment and the number of livestock killed. We suggest that the increase in foreign employment has reduced dependency on forests as a consequence.

Most of the livestock killing occurred at the stall which suggests the need for better husbandry practices with predator-proof livestock corrals. The carcasses were mostly found and buried or consumed by the victim families. This practice is likely to have caused more livestock loss as the tiger or leopard could not continue feeding on the carcass for a longer time and they go for another livestock kill. More than 60% of the respondents reported additional livestock killing by the tiger or leopard within a couple of weeks time in their locality. In the past, before starting a relief scheme, the park authorities promoted burying of the carcass to avoid poisoning in retaliation. Leaving the carcass in safe places in the forest instead of burying it and providing quick relief to the owner will contribute to reduced livestock killing.

Figure 2.8 A predator-proof corral for goats constructed by a household in the buffer zone. Partial subsidy for construction of the corral was provided by a conservation organization.

2.4.4. Temporal trend of conflicts

We found an insignificant but decreasing trend of the wildlife attacks on humans and livestock with a significant variation over the years. The reported conflict incidents peaked during 2002-2004. Gurung *et al.* (2008) reported the restoration of community forests in the buffer zone providing refuge habitat for wildlife as a contributing factor for increased conflict. In addition to this, the socio-political situation also contributed in some way to the increased conflict. During 2000 - 2005, Maoist insurgency peaked in Nepal. During this period, ~75% of the guard posts in the park were abandoned and army personnel retracted to larger bases or headquarter leaving the way open for local villagers and poachers to enter more freely (Martin & Martin, 2006). Such disturbance in the park resulted in an increased interaction between people and wildlife leading to more loss of human and livestock. The high disturbance in the core areas of the park might have pushed animals into the fringes for safe refuge.

However, our data did not support the hypothesis that an increase in wildlife populations results in the respective increase of conflicts. With reduced poaching (Aryal *et al.*, 2017), wildlife population like rhino and tiger has peaked in recent years in Chitwan whereas higher conflict incidents were recorded during 2002-2004. The highest number of human killing in 2004 can be linked to 3 man-eaters killing >15 people including five persons killed in a single incident (Chitwan National Park, 2004; Gurung *et al.*, 2008). Similarly, elephant attacks on human peaked in 2012 when a rage elephant was active around Chitwan (Silwal *et al.*, 2017) which attacked >10 people, six of them died. In case of large mammals, not all individuals in wildlife population are equally responsible for human or economic loss but few rage animals make a larger share of the conflict incidents (Lamichhane *et al.*, 2017). In addition, the measures of conflict reduction practiced by buffer zone communities and reduced interaction of human-wildlife as mentioned earlier might have kept the conflict incidents in control. Our study has not examined the property damage and crop raiding in detail. We recommend future studies on these aspects to understand and mitigate human-wildlife conflict.

2.5. Conclusion

Our results show that increasing wildlife population is not directly related to the more conflicts. Reduced forest dependency with changing livelihood strategy (reduced grazing, increased off-farm household income), conflict mitigation measures (electric and mesh wire fences) and public awareness have largely contributed to reduce the loss from wildlife. Strengthening of the mitigation measures, reducing forest dependency and awareness programs to the vulnerable communities will minimize the conflict. Timely identification and management of problem animals like man-eater tiger and rage elephant will reduce the human killing and injury. Change in livestock husbandry by making more secured or predator-proof corrals especially in forest fringes will reduce the livestock loss.

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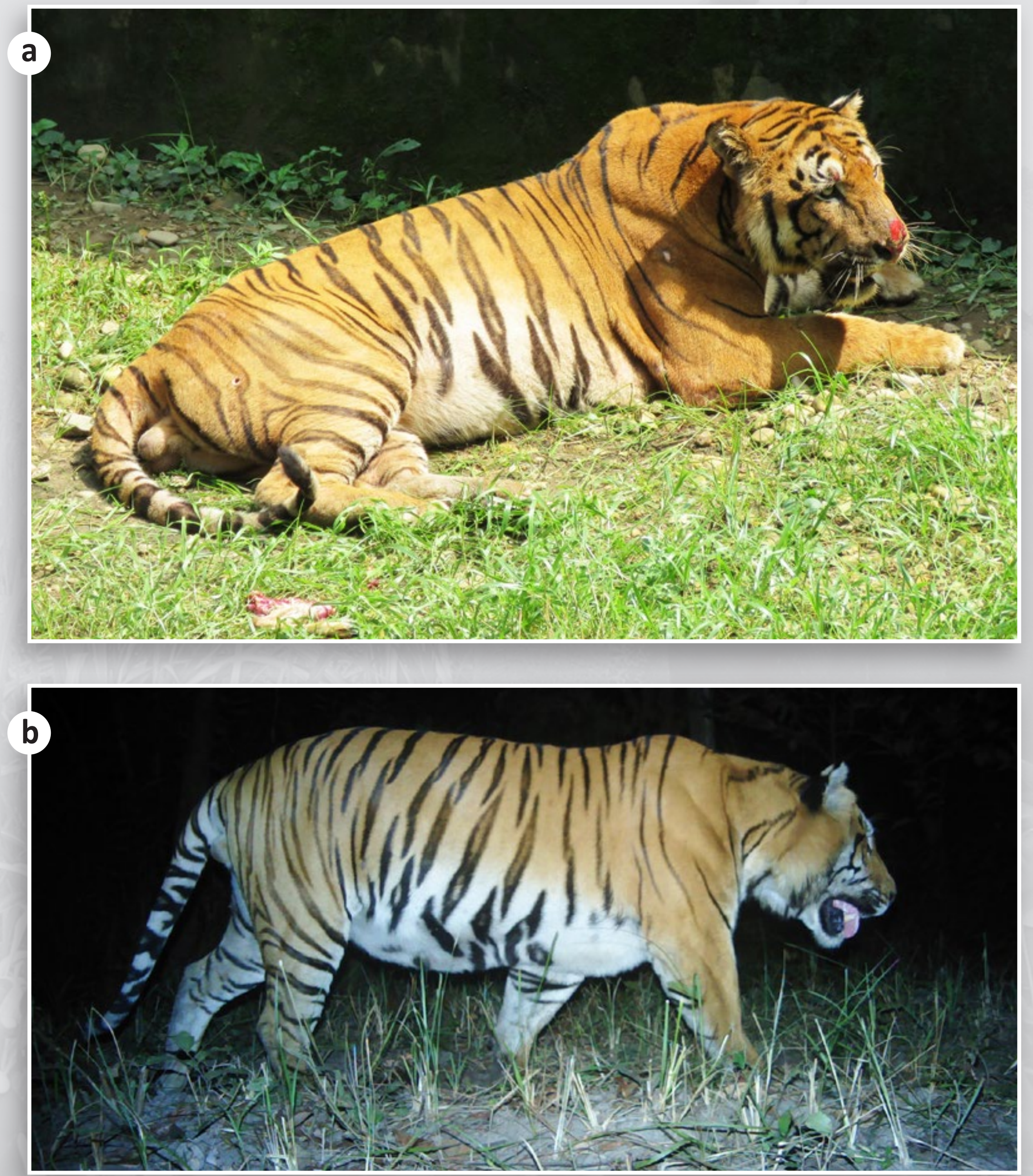

One of the human-killing tigers rescued from buffer zone of Chitwan National Park and kept in enclosure (a). The tiger holds multiple wounds on its body. This tiger was photographed in a camera trap previously from the park (b) (Source of image: DNPWC/NTNC)

3 Are conflict-causing tigers different? Another perspective for understanding human-tiger conflict in Chitwan National Park, Nepal.

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Abstract

We analyzed characteristics of the problem-causing tigers in Chitwan National Park (Nepal) to determine if specific groups or individuals in the source population have a higher probability to get involved in conflicts with humans. From 2007 to 2016 we identified a total of 22 such tigers including 13 that killed humans, six serial livestock killers and three tigers that threatened human safety (with no reported human and livestock casualty). Thirteen of these tigers were controlled or killed and four were relocated. We compared a subset of 15 ‘problem tigers’ involved in the conflict between 2009 and 2013 with the Chitwan’s tiger population obtained from three different sessions of camera trapping (2008/09, 2010 and 2013). We found that < 5 % of this source population (tigers recorded in camera trap) were involved in the conflict. We conclude that transient tigers without a territory or physically impaired animals are more likely to be involved in the conflict and recommend an early warning system be adopted to anticipate conflicts before they occur. This system should include regular monitoring and timely identification of problem tigers followed by decisive management action to either remove the tiger or encourage local people to modify their behavior to reduce the risk of conflict.

Keywords: Chitwan National Park; Nepal; Human-tiger conflict; *Panthera tigris tigris,* Problem animal; Tiger conservation

3.1. Introduction

Along with legal and institutional protection of endangered species like tigers (*Panthera tigris*), support is needed from local communities living in fringes of protected areas (Inskip *et al.*, 2014). Such support is especially important in locations where tigers occur in small isolated protected areas in a human-dominated landscape (Wikramanayake *et al.*, 2004). Local tolerance can quickly be compromised if tigers repeatedly threaten humans and their livestock (Goodrich, 2010). To gain local support, managers need to respond quickly and decisively (Barlow *et al.*, 2010). The Terai Arc Landscape (TAL) in Nepal and India is a typical example of the challenges. In recent years, increasing tiger population with reduced poaching and forest regeneration in community managed forests in buffer zones has increased the possibility for human-tiger conflict (Chanchani *et al.*, 2014; Gurung *et al.*, 2008; Wegge *et al.*, 2018). One of the core tiger areas in TAL, the Chitwan National Park (CNP), currently supports >100 tigers (Karki *et al.*, 2015; Walston *et al.*, 2010). The high-quality tiger habitat in CNP serves as a source for tigers dispersing into more marginal habitat adjacent to human settlements (Smith, 1993).

Human-tiger conflict (HTC) is generally expressed in three forms - i) tiger attacks on humans, ii) tiger attacks on livestock and iii) threats to human safety from tigers living in close proximity to human habitation (Goodrich, 2010). Human deaths by tigers in and around CNP have increased six folds from average annual deaths of 1.2 (1979 – 1998) to 7.2 (1998 – 2006) (Gurung *et al.*, 2008). Between 2007 and 2014, an average of 4 persons was killed and 2.7 injured per annum. In the same period, an average of 44 livestock was killed by tiger annually (Dhungana *et al.*, 2018). These deaths and conflicts reduce support for tiger conservation (Goodrich, 2010) and in retaliation people kill tigers by poisoning or physical attacks with guns or spears (CNP, 2013a). The government has initiated a program to identify and promptly respond to problem individuals; this effort may reduce retaliatory killings of tigers.

Studies on human-tiger conflicts have analyzed factors that contributed to human tiger-conflict and also assessed their socio-economic impacts (Bhattarai & Fischer, 2014; Dhungana *et al.*, 2018; Gurung *et al.*, 2008; Silwal *et al.*, 2017). Many factors like season, distance to park boundary, a number of livestock and community attitude have been identified as related to the level of conflict (Van Bommel *et al.*, 2007). However, only a few studies have focused on individual characteristics (e.g. age, sex, physical condition, territorial behavior) of problem-causing animals and their management (Barlow *et al.*, 2013). Most previous studies regarded the entire tiger population as conflict causing with the general assumption that when a population increases, conflict also intensifies.

Protected areas in Nepal and India are typically surrounded by buffer zones with marginal habitats and high human density (Gurung *et al.*, 2008; Spiteri & Nepal, 2008). Younger tigers are often pushed out of the core areas of reserves into buffer zones by mature, resident tigers (Kolipaka *et al.*, 2017; Smith, 1993). Older and weaker male tigers are also driven from their territories by dominant males. Both these younger and the older post-reproductive tigers living in marginal habitat are the most likely to come in conflict with humans. However, despite frequent reports of conflict caused by tigers (Gurung *et* *al.*, 2008; Silwal *et al.*, 2017) from Chitwan NP, Sunquist (2010) described explicitly that by nature tigers are very adaptive and can live very close to people but stay un-noticed in areas with sufficient prey, space and cover. Carter *et al.* (2012) suggested that, in Chitwan, temporal separation (humans using in daytime and tigers active in the night) allows humans and tigers to use the same area at a fine spatial scale. These apparently contradictory findings of tiger behavior and their interactions with people have evoked a debate among conservationists about the balance between conflict and coexistence (Harihar *et al.*, 2013; Karanth *et al.*, 2013). In a study that focused on livestock killing, Linnell *et al.* (1999) suggested that a specific subset of animals were responsible for most of the human-carnivore conflict and they proposed intensive monitoring of movement and predatory behavior to identify these animals.

Our study examined human-tiger conflict in greater depth and tested the hypothesis that conflict causing tigers differ in individual characteristics (age, sex, territorial behavior and physical condition) from the other tigers in the population. We anticipate that not all individuals in a tiger population are equally involved in the conflict. Instead, we suggest most conflict results from the behavior of a specific group of animals which are pushed out of the core areas and adopt the human or livestock killing activities (Linnell *et al.*, 1999). We used camera trap data to compare problem tigers to the general tiger population of Chitwan.

3.2. Methods

3.2.1. Study Area

Chitwan National Park (27°16.56'– 27°42.14'N and 83°50.23' – 84°46.25'E; area 953 km^2), designated in 1973 as the first national park of Nepal, has a monsoon-dominated sub-tropical climate with an average monthly maximum temperature between 24°C - 38°C, monthly minimum temperature between 11°C – 26°C, annual rainfall ~ 2,250 mm and relative humidity 89-98% (2000 – 2010). It is a World Heritage Site (UNESCO, 2016) with a unique assemblage of rare and threatened fauna which includes approximately 70 mammal species, over 600 bird species, 49 species of reptiles and amphibians, 156 species of butterflies and 120 species of fish (CNP, 2018). Chitwan is a priority tiger conservation area with a population of >100 tigers (Dhakal *et al.*, 2014). CNP also supports the world's second largest population of the greater one-horned rhinoceros (DNPWC, 2015b; Subedi *et al.*, 2013).

Situated in the south-central lowlands in the inner Terai (Fig 3.1), the park is dominated by forest (80%) including sal forest, riverine forest and mixed hardwood forest. In addition, there are grasslands (12%), exposed surface (5%) and water bodies (3%) (Thapa, 2011). The park is drained by three major rivers systems, i.e., Narayani, Rapti and Reu rivers. The Narayani River marks the western boundary, the Rapti River marks the northern boundary, Reu River and the international border with India along the Valmiki Tiger Reserve marks the southern boundary for CNP. Parsa National Park (PNP) is contagious with the boundary of CNP. A corridor forest, Barandabhar, connects the park with the northern hill forest.

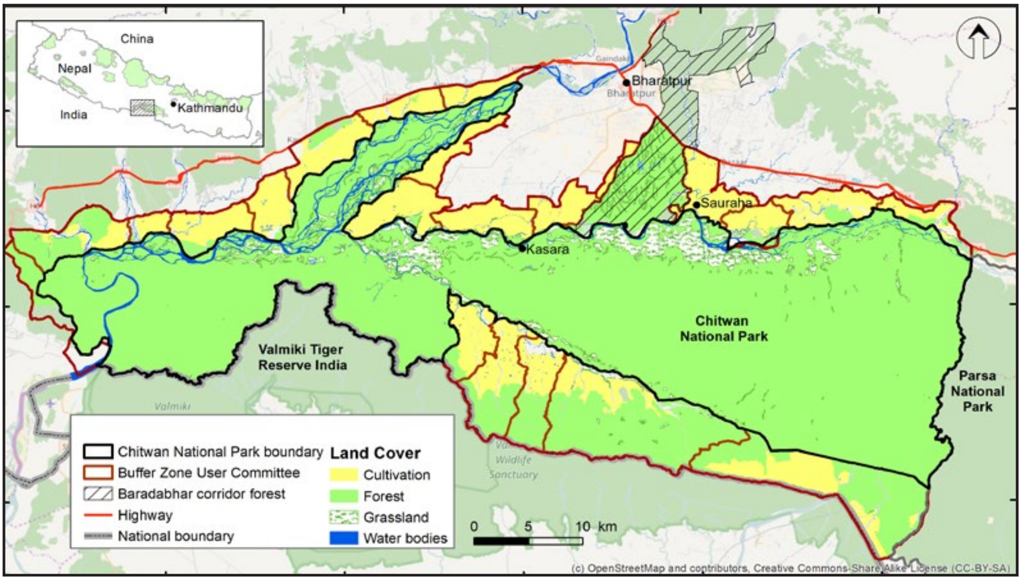

Figure 3.1 Study area: Chitwan National Park, buffer zone area and adjoining forest areas.

An additional 750 km^2 buffer zone (BZ) surrounding CNP was created in 1996 (21 Km^2 of BZ was later included into the core area in 2016). More than half (55%) of the BZ is useable wildlife habitat including forests, grasslands, shrubland, river and water bodies; the rest is agriculture and settlements (Karki *et al.*, 2015). The BZ includes > 45,000 households in 12 municipalities from four districts (Chitwan, Makawanpur, Nawalparasi and Parsa) (CBS, 2012). Historically, only a few settlements of the indigenous Tharu, Bote and Darai communities surrounded the Park. However, many people from the hilly area migrated into the Chitwan Valley after malaria eradication in the mid-1950s. Now the community is a mix of indigenous people and immigrants from hills (e.g. Brahmin, Chhetries, Tamang, Gurung, and Magar) (CBS, 2012). A majority of people rely on subsistence agriculture but dependence on agriculture is decreasing as the younger generation prefers off-farm activities like tourism (nature-guides and work in hotels), service and foreign employment. Livestock keeping is an integral part of subsistence agriculture, and grazing was common in the buffer zone until the last decade. In recent years there has been a gradual shift towards stall feeding with grazing restrictions, adoption of improved livestock and a shortage of labor (Gurung *et al.*, 2009). Adjoining forests outside of the buffer zone (National forest and community forests) is administered by the District Forest Offices.

3.2.2. Conflict-causing tigers in Chitwan

Records of problem tigers (e.g. rescued, euthanized, poisoned, shot) in the period between 2007 and 2016 were compiled from the headquarter and veterinary section of the CNP office, the National Trust for Nature Conservation (NTNC) and the personal records of the first author who has been involved in fieldwork in CNP since 2009. Based on the type of problems caused, these tigers were classified into four categories i) accidental human-killer - killed but did not eat one human, ii) Repeated human-eater - killed and ate one to several humans (Gurung *et al.*, 2008), iii) serial livestock killer - involved in >3 livestock killing incidents within a month from the same locality in the buffer zone and iv) safety threat (no attack or livestock kill but threatened people by entering into a village). In our dataset, we have not included the opportunistic livestock killers (involved in <3 livestock killing incidents within a month) as we lack the identity of such tigers. We set a cut-off of 3 livestock kills per month based on the dietary requirement of the tiger. If a tiger primarily depends on livestock for its diet, it would kill at least three livestock in a month (Karanth *et al.*, 2004).

Each case of a problem tiger was verified with wildlife technicians of NTNC and veterinary officers of CNP who participated during rescue or control activities. Detailed records including date, GPS location, age, sex, physical condition and photographs of the captured/killed tigers were maintained. Age and sex of the tigers which were not controlled were identified through unique track characteristics or measurement and camera trap pictures. Controlled problem tigers were classified as adults (>3 years), sub-adults (2-3 years) and cubs (<2 years) based on their size, weight or dentition at the time of capture.

3.2.3 Spatial and temporal distribution of problem tigers

The unique stripe pattern of tigers (Karanth & Nicholas, 1998) enabled us to trace the history of problem tigers by comparing their photos with previous camera trap images. The first comprehensive camera trapping in the lowland of Chitwan was done in 2008/09 (Jhamak Bahadur Karki *et al.*, 2009). The entire national park (lowland as well as Churia hills) was covered in successive camera trapping efforts in 2010 (Karki *et al.*, 2015) and 2013 (Dhakal *et al.*, 2014). Photographs of problem tigers obtained during their capture between 2009 and 2013 were thus compared with the photo library of Chitwan's tiger population. Additionally, we also compared problem tiger photos with tigers of Parsa National Park (PNP) and Valmiki Tiger Reserve, India (Chanchani *et al.*, 2014; Maurya & Borah, 2013). Camera trap location and date were recorded for each problem tiger. Camera trapped and conflict locations of the tigers are presented as points and polygons in a map (Fig 3.3).

3.2.4. Data analysis - comparison of problem animals and source population

Tiger individuals identified from camera trap surveys during three different sessions 2009, 2010 and 2013 in CNP were used to represent the Chitwan tiger population (generally known as the minimum tiger population or 'Mt+1'). Wegge *et al.* (2004) showed that >80% of the tigers present in the area are captured during a 15-day survey consisting of a systematic camera trap grid of 2x2 sq km. All the three camera trapping sessions followed this as recommended by the Tiger Monitoring Protocol of Nepal (DNPWC, 2009). We assumed that the problem tigers recorded between 2009 and 2013 in Chitwan Valley (including the core area, buffer zone and surrounding forest areas) originated from the

Table 3.1 Number of tiger individuals captured in camera trap (Mt+1) during the 2009, 2010 and 2013 surveys in Chitwan National Park, Nepal.

Year	Adult	Sub-adult	Cub	Unknown	Total
2009	36	8	5		49
2010	53	3	6		62
2011	27	4	1		32*
2012	30	3		1	34*
2013	55	5	7	1	68
Total	**201**	**23**	**19**	**2**	**245**

** Derived based on common individuals captured in 2010 and 2013*

CNP population. We identified individuals analyzing unique stripe pattern, estimated their age and sex in most cases based on camera trap photos. A multi-annual dataset of the tiger population was compiled for 2009 -2013 and (Table 3.1). A tiger captured in camera traps in a year was regarded as one observation. This dataset was used as a measure for the Chitwan tiger population. We coded '0' – non-problematic' and '1' - problematic for the tiger in a particular year based on conflict records.

We used a binomial logistic regression by constructing a Generalized Linear Mixed Model (GLMM) (Zuur, Ieno, Walker, Saveliev, & Smith, 2009) to test the hypothesis that conflict causing tigers have different characteristics than those in the source population. In the GLMM, conflict-causing tiger between 2009 and 2013 was used as the dependent variable. Four independent variables i.e. age, sex, physical condition, territorial behavior and their interaction (age*territory and physical condition*territory) were used to examine their contribution to tiger becoming a problem causing individual. Year was treated as a random variable as some tigers were active in multiple years. The analysis was done in R (R Core Team, 2017).

Age (cub, sub-adult, adult or unknown) and sex (male, female or unknown) of the tigers in the population were identified from camera trap photos. Males have visible testes which allowed us to identify the sex. We categorized the age of animals based on their size and body configuration and also comparing changes from photos obtained in previous years. Tigers of uncertain age were categorized as 'unknown'. Physical condition was categorized as impaired (1) or healthy (0) based on veterinary examination of captured/ rescued problem tigers or from examining camera trap photos for signs of injury, limping or other abnormalities. The impaired category is defined as the severe injury or illness which threatens a tiger's survival and was visible in the camera trap photo. Tigers were categorized into three territorial behavior categories: 1) Resident: Tigers captured in multiple years from nearby (periphery of 20 km of previous CT capture) location, or female tigers with cubs, or tigers frequently re-captured (at least three times) in adjacent locations (20km) in a single camera trap session; 2) Transient: Tigers captured from different locations (>20km from the periphery of previous CT capture) during different camera trap sessions or sub-adult tigers captured in different locations from the natal territory or sub-adult tigers with linear movement over time; 3) Unknown: Tigers captured only in a single year with fewer than three recaptures for which we are not sure about their territorial behavior.

3.3. Results

3.3.1. Problem tigers and their management

Between 2007 and 2016 a total of 22 problem tigers were recorded in Chitwan NP and surrounding areas, including 13 that killed humans (including six human-eaters), six serial livestock killers and three tigers that threatened the human safety (no actual attack or loss) (Table 3.2). Thirteen out of 22 identified as conflict-causing tigers were removed from their habitat (killed or put in captivity) and four were relocated (released at a different location). Annually, an average of 2.8 (SD = 1.9, range 1 – 7) tigers were involved in the conflict and 1.4 (SD = 0.7, range 1 – 3) tigers were removed from Chitwan NP or surrounding forests (Fig 3.2). Some problem tigers were poisoned (n=3) or killed in defense using a spear (n=1) by villagers. Only one of the conflict-causing tigers (human-eater) was killed by the army (park authority) in 2007. Since 2007, such tigers were captured and either released in the wild (4), or moved to a park enclosure or sent to a zoo (n=8). No action was taken for five of the identified problem tigers because these tigers either accidentally attacked people in the buffer zone or attacked people only in the core areas of the park (Table 3.2). Most tigers that repeatedly killed livestock or attacked people in the buffer zone are captured by the park authority as they pose a threat to human safety.

Four of the conflict-causing tigers (serial livestock-killers and safety threats) were released in core areas of CNP or Bardia National Park. Two tigers successfully rehabilitated in CNP (2012 – 2014) and were photographed in a healthy condition in successive camera trap surveys. Two others were translocated to Bardia, and fitted with satellite collars. One of them was poisoned by poachers in the buffer zone after three months (April 2011) and the other tiger's satellite signal was lost after two weeks (January 2014).

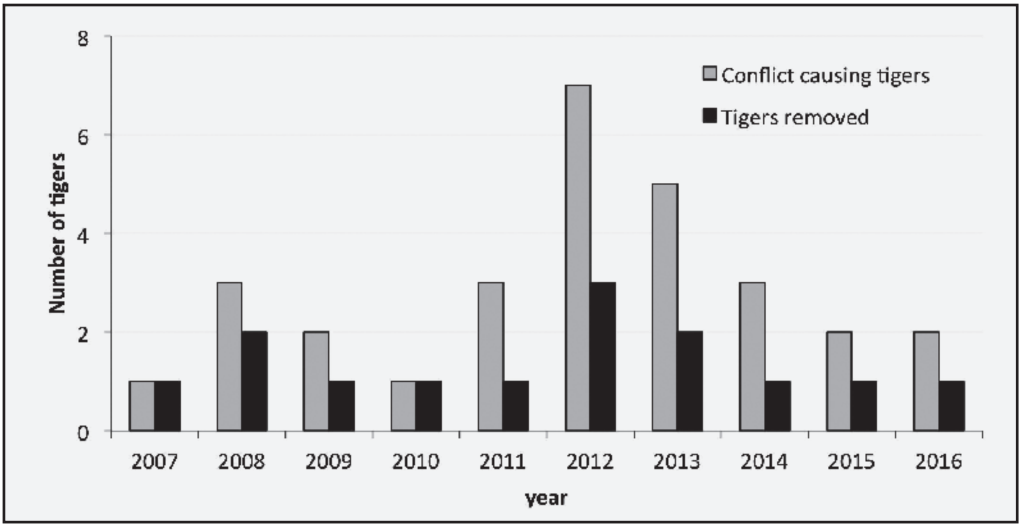

Figure 3.2 Number of problem tigers recorded and controlled in Chitwan National Park and surrounding forest areas.

Table 3.2 Type of conflict caused by the tigers and management action taken in Chitwan National Park, Nepal and surrounding areas during 2007 to 2016.

Action taken	Type of problem tiger				Total
	Attacks to human (accidental)	human-eater	Safety threat	Serial livestock killer	
Killed by authority		1			1
Killed by villagers		1		3	4
Put in enclosure or zoo	2	4	1	1	8
Released in wild			2	2	4
No Action*	4	1			5
Total	**6**	**7**	**3**	**6**	**22**

** These tigers might have captured or killed in different locations or in different years as we lack their detail identity.*

We sexed 20 problem tigers recorded between 2007 and 2016, 6 were female. An equal number of adults and sub-adults (9) were involved in the conflict with humans (Table 3.3).

3.3.2. Spatial and temporal distribution of problem tigers

A majority of the problem tigers (17) were found in the buffer zone area but most of them originated from the park. Nine of the 22 problem tigers were found in settlements and cultivated areas outside of the forest (Table 3.4). Two of the problem tigers had trans-boundary movement, i.e. using both CNP and Valmiki Tiger Reserve of India in the southern side (Fig 3.3). Out of 22 problem tigers, we only obtained photos of 15 individuals, 13 of them matched to the camera trap photos (including two tigers photographed after release into wild). A few (n=4) were captured in camera traps as a cub with their mother and were involved in conflict after leaving their natal territory

Table 3.3 Age and sex composition of problem-causing tigers recorded from Chitwan National Park and surrounding forests during 2007 to 2016.

Sex	Adult	Sub-adult	Unknown	Total
Female	4	1	1	6
Male	5	8	1	14
Unidentified	-	-	2	2
Total	**9**	**9**	**4**	**22**

Table 3.4 The land use type where problem tigers occurred in Chitwan National Park, buffer zone and national forest between 2007 and 2016. The buffer zone is a designated zone surrounding the national park (~ 5 km); all forest lands outside the buffer zone are labeled here as national forests.

Location	Habitat		Total
	Forest or grassland	Agriculture or settlements	
National Park	2	-	2
Buffer Zone	8	9	17
National Forest	3	-	3
Total	**13**	**9**	**22**

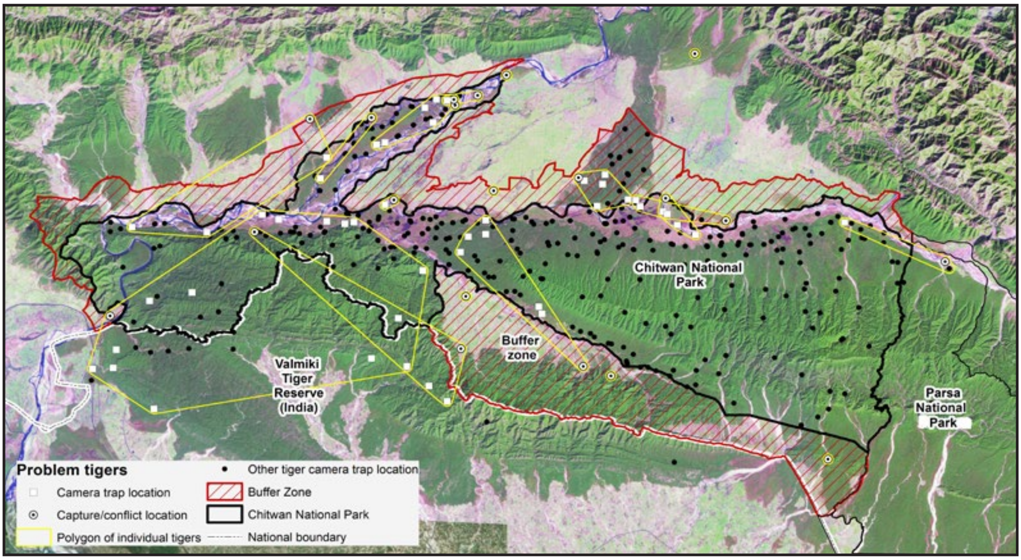

Figure 3.3 Problem tigers camera trapped, rescued or killed location in Chitwan National Park and the surrounding areas during 2008 - 2016. The white square with a black point inside represents locations where problem tigers caused conflict or captured, colored dots represent the camera trapped location of problem tiger in different years and black dots represent the camera trap locations of other tigers (source population) in 2013. The polygons represent the locations of problem tigers based on camera trap captured & tiger rescued locations.

(Fig 3.3). Two thirds (67.6%, n=71) of the camera trapped locations of problem tigers were in the park. With the exception of one (called Nangra pothi, human-eater, that was active for eight years in the Western part of the park) all the problem tigers were involved in conflicts with humans temporarily (for a few months to a year only) (Table 3.5).

3.3.3. Source population and problem animals

An average of 4.3% of the tigers captured in camera traps was found to be involved in the conflict in 2009, 2010 & 2013 (Fig 3.4). A total of 131 unique tiger individuals were recorded in camera traps in CNP in 2009, 2010 & 2013 including 15 tigers which were identified as conflict causing individuals between 2009 and 2013. About two thirds (64.4%) of the tigers were captured in a single year only. Including the multiple year observation of some tigers, we recorded 245 observations of tigers in five years.

The logistic regression analysis showed that physical condition and territorial behavior are the important factors related to problem tigers, but age and sex had no significant effect (Table 3.6). The transient and physically impaired tigers are more likely to be involved in conflict compared to territorial and healthy ones (Table 3.7). In our study, 2% of the resident tigers and 30% of the transient tigers were involved in the conflict. The majority (62.2%, n =37) of these transient tigers includes dispersing sub-adults searching to

Table 3.5 Tigers of Chitwan National Park and surrounding forests, involved in the conflict with humans during 2007-2016. The symbols in the table represents, '1' = involved in conflict, '0' = tiger present but not involved in conflict, 'C' = tiger in captivity, '-' = Status unknown, and 'x' = dead.

SN	Tiger ID	Years (2007 – 2016)											Remarks
		Conflict type	07	08	09	10	11	12	13	14	15	16	
1	Jagatpur SA (F)	Attacked human	-	-	-	-	-	-	-	-	0	1	Died in enclosure at CNP (2016)
2	Kumroj (M)	Killed human	-	-	-	-	-	-	0	0	1	x	Died in enclosure at CNP (2016)
3	Triveni (M)	Killed human	-	-	-	0	0	0	0	1	x	x	Died in enclosure
4	UK Bhale2 (M)	Killed human	-	-	-	-	-	-	-	1	-	-	
5	Madi -Sitalpur (M)	Killed livestock	-	-	-	-	-	0	1	0	0	0	Came from Valmiki Tiger Reserve (VTR) India, released in CNP camera trapped later in VTR
6	Madi – Ganeshkunja SA (M)	Killed livestock	-	-	-	-	-	0	1	-	-	-	Released in Chitwan, recaptured and released in Bardia
7	Devnagar pothi (F)	Killed human	-	-	0	0	0	0	1	x	x	x	Old female - died in enclosure
8	UK7 (U)	Killed human	-	-	-	-	-	-	1	-	-	-	
9	Kawasoti SA pothi (F)	Safety threat	-	-	-	-	-	1	0	0	0	0	Released in Chitwan, subsequently camera trapped
10	Pratappur pothi (F)	Killed human	-	-	0	0	0	1	x	x	x	x	Old female - Killed by villagers on self-defense
11	Meghauli SA (M)	Killed human	-	-	-	0	0	1	C	C	C	C	Transferred to Kathmandu zoo
12	UK6 (U)	Killed human	-	-	-	-	-	1	-	-	-	-	
13	Barandabhar pothi (F)	Killed human	-	-	-	-	-	1	-	-	-	-	Outside of Buffer zone
14	Nirmalbasti bhale (M)	Killed livestock	-	-	-	-	-	1	x	x	x	x	Poisoned
15	Madi – Gardi SA pothi (F)	Safety threat	-	-	-	-	1	C	x	x	x	x	Died in enclosure
16	Kawasoti SA (M)	Killed livestock	-	-	-	0	1	C	x	x	x	x	Died in enclosure
17	Sauraha SA (M)	Safety threat	-	-	-	1	x	x	x	x	x	x	Released in Bardia (poisoned by poacher)
18	Majhuwa SA Male (M)	Killed human	-	0	1	x	x	x	x	x	x	x	Died in enclosure
19	Nangra pothi (F)	Killed human	-	1	1	0	1	1	1	1	1	1	Killed 19 persons
20	Buddhanagar SA (M)	Killed livestock	0	1	x	x	x	x	x	x	x	x	Poisoned
21	Lamichaur (M)	Killed livestock	0	1	x	x	x	x	x	x	x	x	Poisoned
22	Temple tiger SA (M)	Killed human	1	x	x	x	x	x	x	x	x	x	Shot by army

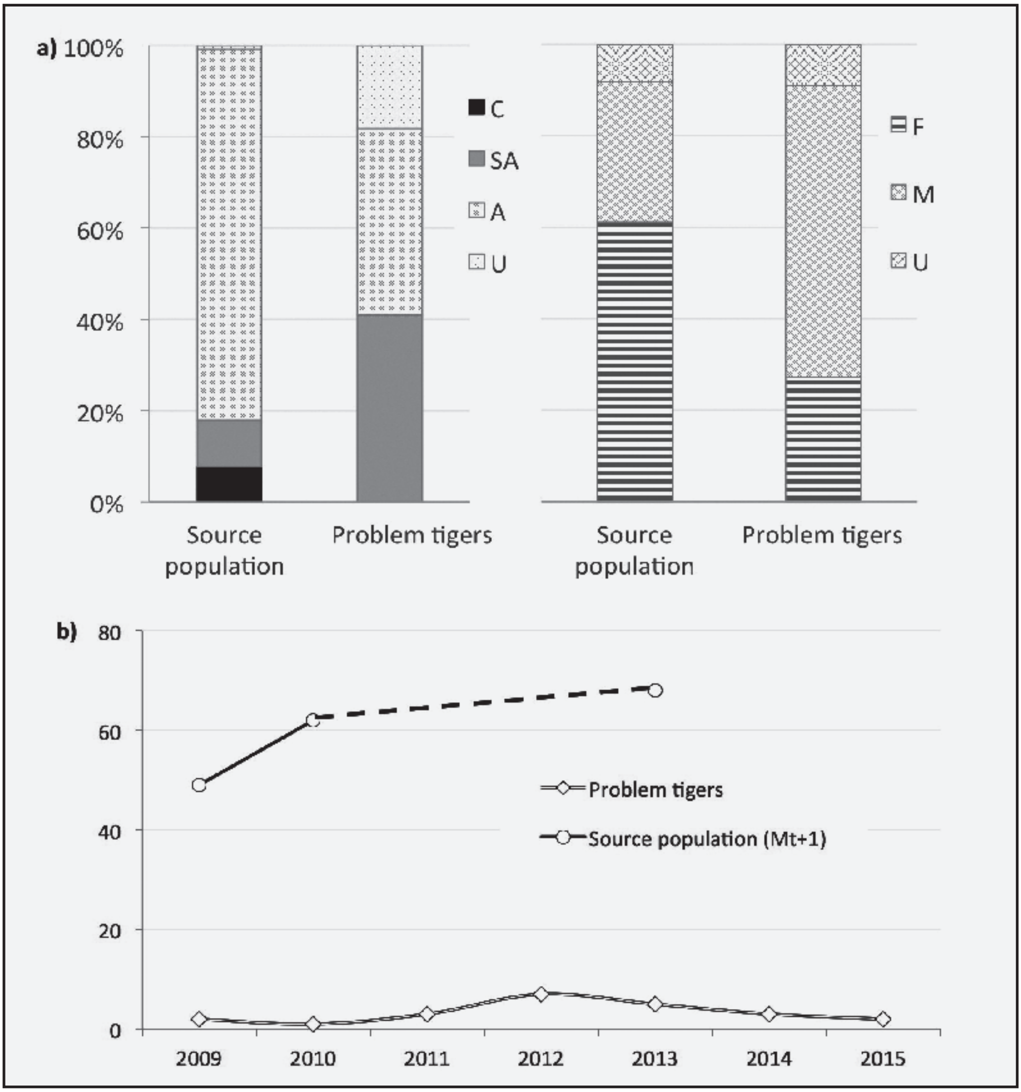

Figure 3.4 a) Age & sex structure of the source population and problem tigers in Chitwan National Park in between 2009 - 2015. (C – Cub, SA – Sub-adult, A – Adults, U – Unknown age, U – Unknown sex, M – Male and F – Female). b) Number of problem individuals and tigers in the source population. The number of tigers photographed in camera traps (Mt+1) was used as a source population, the estimated tiger population is higher than this. The dotted line of the source population represents the expected number of tigers based on 2010 and 2013 data as the survey was not done in between (2011 and 2012).

establish territory. Similarly, only 5% of the healthy tigers and nearly two-thirds (63 %) of the physically impaired tigers were involved in the conflict. The full model that considers all four factors predicts that the probability of a resident tiger to be involved in the conflict is 0.003, while this probability of transient tigers is 0.08, the healthy tiger is 0.0002 and physically impaired tiger is 0.68.

Table 3.6 Likelihood Ratio Test (LRT) of logistic regression models fitted to 'problem tigers' of Chitwan Naional Park. Model: glmer (formula: ProbTig ~ Territory + PhyCondition + Sex + Age + (1|Year), family = binomial (link=logit))

Model	Df	AIC	LRT	Pr(>Chi)	Model structure
FULL		97.98			Territory + PhyCondition + Age + Sex
Territory	2	106.36	12.38	0.002**	Full model - territorial behavior
Physical Condition	1	103.36	7.38	0.006*	Full model - PhyCondition
Sex	2	96.73	2.74	0.25	Full model - sex
Age	2	94.55	0. 56	0.75	Full model - age

Table 3.7 Parameter values of individual variables of GLMM fitted to tigers (problem individuals and source population) of Chitwan National Park.

Parameters	Estimate	Std. Error	z-value	Pr(>|z|)
(Intercept)	-3.29E+00	4.81E-01	-6.849	7.42E-12***
TeritoryTransient	2.50E+00	7.90E-01	3.164	0.00155**
TeritoryUnknown	-3.63E+01	1.07E+07	0	1.0
PhyConditionImpired	2.54E+00	9.66E-01	2.632	0.00848**
PhyConditionUnknown	1.10E+02	4.91E+07	0	1.0
SexM	-6.48E-01	7.03E-01	-0.923	0.356
SexU	-3.22E+01	7.43E+06	0	1.0
AgeC	-3.51E+01	1.58E+07	0	1.0
AgeSA	-1.31E-01	8.38E-01	-0.156	0.87629

3.4. Discussion

Our study compared the characteristics of problem tigers in relation to the population as a whole. We observed that only a small portion of the tigers (< 5%) in the population, or an average of two individuals per year, are involved in the conflict with people. Prompt action by park authority in removing or killing 13 of 22 problem tigers may have reduced human-tiger conflict. We found that transient tigers, including dispersing sub-adults and pushed out old individuals that have lost their territories have a higher probability of becoming problem tiger compared to territorial residents. Earlier studies in Chitwan reported similar observations about dispersing sub-adults (Smith, 1993). Also in India young and inexperienced tigers were more likely to be involved in livestock killing and later shifted to natural prey gradually with experience (Kolipaka *et al.*, 2017). In our study, attacks on humans most often were by physically impaired tigers or animals that were driven from their territories by another tiger. For example, we have observed one male and two females captured in camera traps for multiple years without reports of conflict (Table 3.5). They became human-killers only after they were driven out from their territories into marginal habitat.

Only a few studies have focused on a subset of problem-causing individuals in carnivore population (Barlow, Ahmad, & Smith, 2013; Linnell *et al.*, 1999). Our result of 4.3% of the tigers in the total population involved in the conflict is comparable to data reported by Barlow *et al.* (2013) in Bangladesh Sundarbans. Barlow and colleagues profiled

2013
Tiger photographed in camera trap. It was healthy and detected in core area of the park with no reports of conflict.

2015
Recorded in bad shape in fringe areas of the park and buffer zone

2015
Killed two humans (a woman in Barandabhar corridor forest and a man in Kumroj community forest) in Eastern sector of buffer zone. The tiger was captured and put in enclosure to prevent additional loss.

Figure 3.5 One of the conflict-causing tigers of Chitwan (Kumroj M, Table 3.5). This male tiger was healthy when it was photographed in camera traps in 2013. No conflict case has been reported possibly caused by this tiger before 2015. In September 2015 it killed two persons in the buffer zone and was later controlled. The tiger died in the enclosure after few weeks. (Source: DNPWC/NTNC, Om Prakash Chaudhary)

110 human-killing tigers based on location and year of the people killed in 23 years (1984 – 2006) and estimated 8 human-killing tigers were responsible for human mortalities. In comparison with the recent population estimate of 106 tigers (Dey *et al.*, 2015) in the Sundarbans, only 7.5 % of the tigers were involved in human-killing. In contrast to Barlow *et al.* (2013), we have also included livestock killers and tigers causing safety threats in the group of 'problem tigers' and compared with the minimum count of the source population (camera trapped individuals i.e. Mt+1) only. If we compare the subset of problem tigers with the estimated tiger population of Chitwan given by capture-recapture models (i.e. 120, Dhakal *et al.*, 2014), only 2.4% of the tiger population is involved in conflicts in CNP which is much lower than the estimate from Bangladesh.

Our observations show that residential territorial males or females are less likely to be involved in conflicts with people when they occur in prey-rich areas like Chitwan as described by Sunquist (2010). In the recovering buffer zone forests (Barandabhar corridor) of Chitwan, Carter *et al.* (2012) found that resident tigers coexist with humans and avoided conflict by temporal separation. Multiple year camera trapping surveys in Barandabhar by NTNC shows that the tiger population has increased since 2013 (four to eight residential tigers) (NTNC-BCC, 2016). In contrast, more attacks on humans by tigers were recorded in 2012 (two persons killed) & 2013 (two killed, one injured) when a human-killing tigress was active (Table 3.5, Devnagar pothi F). Although more residential tigers are using Barandabhar, the number of human casualties in this area has dropped (only a human death during 2015 – 2016, caused by a transient tiger - Fig 3.5). Most resident tigers live compatibly with humans in undisturbed habitat with abundant prey but there are occasional individuals which are involved in conflicts that should be identified and removed in a timely way. Thus, tiger range countries including Nepal should consider criteria for responding rapidly to problem tigers. Along with removal or other mitigation measures for intense conflict scenarios, providing safe passage through corridors to other protected areas or forests with a low density of tigers (Wegge *et al.*, 2018) could reduce the possibility of conflict. Enhancing the quality of grasslands and wetlands through intensive management and increasing prey density inside core areas and dispersal corridors is equally important to reduce conflict and facilitate dispersal. A similar observation was made in Parsa WR where tiger population has escalated from seven in 2013 to 20 in 2016 where dispersing tigers from Chitwan contributed a lot to the increase (Lamichhane *et al.*, 2018b).

Our study provides a new perspective and detailed insight into the understanding of the human-tiger conflict. It demonstrates that most problem-causing tiger fall into two categories, 1) old and injured animals and 2) young dispersing animals forced to reside in the periphery until they establish breeding territories. Regular monitoring of the tigers in fringe areas using camera traps or satellite telemetry, paired with the involvement of local communities, can provide crucial information about such potential problem individuals (Gurung *et al.*, 2008). Rapid response teams (RRT) formed under the buffer zone user committees (BZUC) can be trained and mobilized as para-ecologists (Schmiedel *et al.*, 2016) in tiger monitoring and communicating respective communities (early warning) if such tiger is detected. This can save human lives and reduce livestock depredation through preparedness of communities. Vulnerable human settlements located close to the forest also need to adapt their activities by avoiding the forests or entering in groups with proper alertness when such potential problem individuals are detected in their locality. Technical support, data management and analysis should also be conducted by appropriate authorities and experts.

Previous studies on problem animal management proposed different actions such as translocation, lethal control or captivity (Goodrich & Miquelle, 2005; Treves & Karanth, 2003). In contrast, Barlow *et al.* (2010) and Gurung *et al.* (2008) highlighted identification and regular monitoring of problem individuals by radio and satellite collaring as the top priority action for mitigation of the human-tiger conflicts. Translocation of problem individuals shows mixed results (Fontúrbel & Simonetti, 2011; Linnell *et al.*, 1997) but it can be a viable option for healthy and non-human-killing tigers with a proper post-release monitoring. There is an increased public concern regarding lethal measures but it is a viable option to control individuals with sustained involvement in conflicts (especially human-killing) or physically impaired individuals with less potential for recovery. A limited number of such animals can also be housed in captivity in rescue centers or zoos for educational purposes.

3.5. Conclusions

Based on our study, we conclude that most tigers can live in close proximity to humans but a small portion (<5% in our study) of the population is involved in the conflict and these individuals can be labeled as ‘problem animals’. Such individuals need to be properly identified and removed quickly. Their removal may reduce the conflict, decrease anger of villagers. Tigers, especially dispersing sub-adults, need to be monitored (i.e. using camera traps; satellite telemetry) in habitat edges where high interaction between people and tigers occur. Information about such tigers should be communicated through a participatory early warning system. Awareness programs focusing on the most vulnerable communities will be helpful to reduce human and livestock mortality from tigers. As the Chitwan tiger population increases, more sub-adults and transient tigers are likely to disperse out of core areas and come into conflict with local people. Facilitating dispersal of such tigers through corridors can also reduce risks of conflict.

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Writing – original draft: BRL, HHD
Writing – review & editing: BRL, GAP, HL, SP, NS, CPP, MD, HHD

Tiger and leopard footprint at the same location in front of a camera-trap. Both the tiger and leopard walked on this location within few hours interval. In the picture, larger is tiger footprint and smaller is leopard footprint.

4 Factors associated with co-occurrence of large carnivores in a human-dominated landscape

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Abstract

We investigated the factors facilitating co-occurrence of two large carnivores, tigers (*Panthera tigris*) and common leopards (*Panthera pardus*), within a human-dominated landscape. We estimated their density and population size using camera-trap photographs and examined spatial seperation of habitats, temporal activity pattern, and diets in Chitwan National Park, Nepal. A Bayesian spatially-explicit capture-recapture model estimated densities of 3.2–4.6 (3.94 ± 0.37) tigers and 2.6–4.1 (3.31 ± 0.4) leopards per 100 km^2 with a population size of 70–102 tigers and 66–105 leopards. Tigers occupied the prime habitats (grasslands and riverine forests) in alluvial floodplains of the Park whereas leopards appeared in Sal forests and marginal areas where livestock are present. Both tigers and leopards showed crepuscular activity patterns with a high overlap but tigers were less active during the day compared to leopards. Leopards' activity in the day increased in the presence of tigers. Tiger and leopard diet overlapped considerably (90%). Compared to leopards, tigers consumed a higher proportion of the large prey and a smaller proportion of livestock. Our study demonstrates that sympatric large carnivores can coexist in high densities in prey-rich areas that contain a mosaic of habitats. To increase the resilience and size of the Chitwan carnivore population, strategies are needed to increase prey biomass and prevent livestock depredation in adjacent forests. Long-term monitoring is also required to obtain a detailed understanding of the interaction between the large carnivores and their effects on local communities living in forest fringes within the landscape.

Keywords: Tiger (*Panthera tigris*); Common leopard (*Panthera pardus*); abundance and density; diet; activity pattern; Chitwan National Park (Nepal)

4.1. Introduction

Large carnivores have a relatively greater influence on the community structure through resource facilitation and trophic cascades, although they remain in low densities naturally due to energetic constraints (Ripple *et al.* 2014, Schmitz *et al.* 2000). They are threatened globally by habitat fragmentation and loss, poaching and illegal trade for their body parts, declining prey and conflict with humans (Karanth & Chellam, 2009). Because survival of large carnivores is conservation dependent in increasingly human-dominated landscapes (Linnell, Swenson, & Andersen, 2001; Weber & Rabinowitz, 1996; Wikramanayake *et al.*, 2004), conservation strategies should focus on the protection of core breeding areas (or source sites) which have the potential to repopulate neighboring areas when embedded in larger landscapes (Kenney *et al.*, 2014). The Terai Arc Landscape (TAL) in Nepal and India is one of such landscapes for conservation of large mammals including top-predators tigers and common leopards (hereafter called 'leopards') (Chanchani *et al.*, 2014).

Tigers and leopards have been the two largest sympatric felids in Asian forests for a long time (Goodrich *et al.*, 2015; Jacobson *et al.*, 2016; Simcharoen *et al.*, 2014; Stein *et al.*, 2018). Paleontological and molecular studies suggest leopards evolved in Africa and dispersed to Asia ca. two million years ago whereas tigers are endemic to Asia; they appear in the fossil record ca. 1.5 million years ago (Lovari *et al.*, 2015; Turner & Anton, 1997). Both are obligate meat-eaters and solitary hunters. However, they differ in body size; an adult tiger (65–306 kg) is approximately four times the body weight of adult leopard (28–90) (Seidensticker, 1976).

Interference and inter-guild competition of large carnivores resulting in the displacement of the subordinate by dominant is common (Holt & Polis, 1997; J. D.C. Linnell & Strand, 2000). Such competition by tigers (dominant) towards leopards (subordinate) has been widely observed (Harihar *et al.*, 2011; Odden *et al.*, 2010). However, Karanth and Sunquist (2000) found high dietary overlap and Seidensticker (1976) reported spatial overlap with no evidence of displacement. High dietary and spatial overlap suggests that both interference and resource competition may occur (Lovari *et al.*, 2015; Seidensticker, 1976). Ultimately, prey composition and density, as well as habitat types, play a key role in determining the nature of tiger–leopard interactions (Carter *et al.*, 2015; Lovari *et al.*, 2015; Simcharoen *et al.*, 2018).

Lovari *et al.* (2015) reported a large overlap in tiger and leopard diet in the western part of TAL indicating no prey partitioning. They suggested additional research was needed to examine if spatial and/or temporal partitioning occurs between these large cats. We selected Chitwan National Park (CNP) situated in the eastern part of TAL for this study to examine the factors facilitating the co-occurrence of these large carnivores. CNP holds one of the largest populations of tigers and leopards in TAL (Karki *et al.*, 2015; Thapa, 2011). Tigers and leopard co-occur in CNP with a large overlap in their home ranges (Seidensticker, 1976). Co-occurrence could be facilitated by high prey biomass, diversity of prey sizes and dense vegetation that may reduce tiger leopard encounter rate (Bhattarai & Kindlmann, 2012a; Simcharoen *et al.*, 2018). However, McDougal (1998) recorded intra-guild predation of at least five leopards by tigers in less than two years in the western part of CNP when the tiger population was recovering there. Since the tiger density has increased in CNP, the impact on the spatial dynamics of leopards remains unknown. Given the relatively small size of CNP and the adjoining forests in the human-dominated landscape, an understanding of these competitive dynamics is critical to ensure conservation of both tigers and leopards. Although tigers are relatively well studied in CNP (Smith, 1993; Smith & McDougal, 1991; Sunquist, 1981), few studies have been conducted on leopards (Thapa 2011). Establishing baseline ecological, behavioral and demographic data is also important for future management strategies.

This study examined how two sympatric large carnivores, tigers and leopards, co-occur in CNP, a global biodiversity hotspot (Carter *et al.*, 2015). Our research questions are 1) what is the density and population size of tigers and leopards, 2) what factors influence the spatial distribution of tigers and leopards 3) do their diurnal activity patterns differ, and 4) what is their dietary composition and overlap. We tested the broad hypothesis that co-occurrence of tigers and leopards in Chitwan is facilitated by the temporal and spatial separation of habitats with varying degree of prey and human disturbances. Our results will have implications for the conservation of these large carnivores in human-dominated landscapes.

4.2. Materials and methods

4.2.1. Study area

Our study was conducted in Chitwan NP (27°16.56’ – 27°42.14’N and 83°50.23’ – 84°46.25’E; area 953 km^2), and adjoining forests (495 km^2). CNP, a World Heritage Site, is the flagship park in Nepal, well known for its biodiversity with species diversity of ~70 mammals, >600 birds, 49 reptiles and amphibians, 156 butterflies, and 120 fish species (CNP, 2013b). The Park is contiguous to Parsa National Park on the east and Valmiki Tiger Reserve (India) on the south (UNESCO, 2003). These three adjacent forests combined make it one of the largest intact forest patches (~3,500 km^2) in the TAL (Lamichhane *et al.*, 2018b). CNP is connected to the Hill forests of Mahabharat (outer Himalayas) on the north through a forest corridor called Barandabhar (Fig. 1). The Park is characterized by a monsoon-dominated sub-tropical climate with an average monthly maximum temperature of 24°C – 38°C, monthly minimum temperature 11°C-26°C, annual rainfall ~2250 mm and relative humidity 89 98% during 2000 – 2010 (Subedi *et al.* 2017). Sal (*Shorea robusta*) dominated forest is the climax vegetation covering nearly 70% of the Park where wildlife density is relatively low. Floodplain grasslands (9.6%) and riverine forests in different stages of succession (10%) support a high density of wildlife. Different water bodies (rivers, streams, oxbow lakes) cover 3% of the Park (Thapa, 2011).

CNP is recognized as one of the core breeding sites of the tigers globally (Walston *et al.*, 2010) and contains a major population of leopards (Thapa, 2011). Other carnivores such as Asiatic wild dog (*Cuon alpinus*), striped hyena (*Hyaena hyaena*), clouded leopard (*Neofelis*

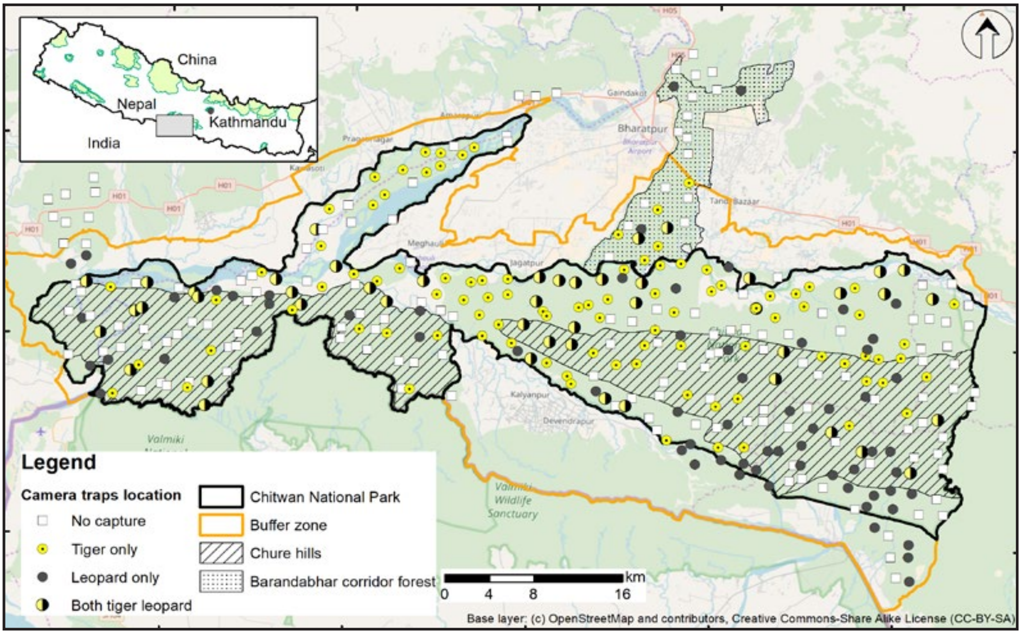

Figure 4.1 Study area (Chitwan National Park and surrounding forests) showing locations of camera-traps and captures of tiger and leopard in 2013.

nebulosa) and three smaller cats (fishing cat *Prionailurus viverrinus*, Jungle cat *Felis chaus* and leopard cat *Prionailurus bengalensis*) (Lamichhane, Dhakal, Subedi, & Pokheral, 2014) also occur in the Park. A wide range of ungulates including chital (*Axis axis*), sambar (*Rusa unicolor*), hog deer (*Axis porcinus*), barking deer (*Muntiacus vaginalis*), wild boar (*Sus scrofa*), gaur (*Bos gaurus*), Nilgai (*Boselaphus tragocamelus*) and two primates (rhesus macaque *Macaca mulatta* and langur *Semnopithecus hector*) serve as prey species for the carnivores.

The Park is surrounded by a buffer zone (729 km^2) ~5km from the boundary. About half of the buffer zone is covered by forests/grasslands, the remaining half includes human settlements and agricultural areas (Karki *et al.*, 2015). These buffer zone forests have significantly higher human pressure but increasingly are managed for national and foreign ecotourism safaris (Carter *et al.*, 2015; Wegge *et al.*, 2018). In addition, the communities exploit these forests for fodder, fuelwood, grazing and non-timber forest products following a regulated system of forest use. There are >45,000 households living in the buffer zone spread over 12 municipalities belonging to three states and four districts (Chitwan, Makawanpur, Nawalpur and Parsa). The majority of people rely on subsistence agriculture but dependence on agriculture is decreasing as the younger generation prefers off-farm activities such as tourism (e.g. nature-guides, jobs in hotels), national and foreign employment. Livestock has been an integral part of subsistence agriculture and until the last decade, open grazing was common in the buffer zone. With the establishment of community managed forests and grazing restrictions in these forests, a gradual shift has occurred towards stall feeding (Gurung *et al.*, 2009). These changes are driven in part by the adoption of improved livestock, commercialization of the farms and a shortage of labor (Lamichhane *et al.*, 2018a). Adjoining forests outside of the buffer zone (including state-managed forests and community forests) administered by the Department of Forests experience more human pressure from subsistence communities as timber exploitation is the focus of the management instead of wildlife conservation or tourism.

4.2.2. Camera-trap survey

We set 362 camera-trap grid cells with a spacing of 2 km in Chitwan National Park and adjoining forests (~1,400 km^2) (Karanth & Nicholas, 1998). A pair of motion sensor digital camera-traps (Reconyx 500 & 550, Bushnell Trophy Cam HD) were deployed in each cell during the dry season in 2013 (18 Feb – 04 May). Cameras were set to take three pictures per trigger with no delay to ensure complete capture of animals within 15 m distance of the camera trap. Camera-traps were active in each site for a minimum of 15 days and checked twice a week. Due to limited availability of camera-traps and logistical challenges, the survey area was divided into four blocks that ranged from 272–423 km^2; these were surveyed successively. Prior to camera deployment, intensive sign surveys helped us identify potential survey sites to increase the probability of photographing tigers/leopards and maximize camera safety. Camera-traps were mounted on trees or on wooden poles 45 cm above the ground, perpendicular to, and 5-7 m apart on either side of game trails, forest roads, and riverbeds without using a lure. Tiger and leopard photographs obtained in camera-traps were systematically sorted in separate folders. Paired camera-traps at each sampling point obtained photos of both flanks of tigers and leopards in most of the events (~80%) which enabled us to identify individuals accurately based on their coat marking patterns (Karanth & Nicholas, 1998; Thapa *et al.*, 2014). Because paired cameras operated independently, ~20% of capture events were composed of photos of a single flank.

Individual identification was conducted by three independent observers and cross-verified collectively where 4–7 observers participated. We also used Extract-Compare Software to verify manually identified tiger and leopard individuals (Hiby *et al.*, 2009).

4.2.3. Estimating density and abundance

We estimated density and abundance of tigers and leopards through Baysean Spatially-Explicit Capture-Recapture Bayesian (B-SECR) models implemented in the package 'SPACECAP' (Gopalaswamy *et al.*, 2012) in R 3.4.0 (R Core Team, 2017). SPACECAP requires three input files i.e. 1) tiger capture history with the location, animal ID and sampling occasion; 2) camera activity records (1 – active and 0 – not-active) for each camera-trap location and sampling occasion; and 3) home range centers. Around a 15 km buffer of the camera locations, equally spaced points (580 m apart, a grid size of 0.336 km^2) were generated to represent hypothetical home range centers (n=13,288). This resulted in an area of 3,854 km^2 of tiger and leopard habitat after removing the 2,739 km^2 area of settlements. We ran the analysis with four different combinations 1) trap response present 2) trap response absent 3) half-normal and 4) negative-exponential detection functions and reported the density and population size obtained from the best-performing model

(Gopalaswamy *et al.*, 2012). We ran a Markov Chain Monte Carlo (MCMC) over 100,000 iterations with a burn-in of 10,000 and a thinning rate of 5. An augmentation value of 400 and 350 (more than five times the number of animals captured or Mt+1) was set for tigers and leopards respectively. We produced a pixelated map of tiger and leopard density at the size of home range center (0.336km^2) and calculated average density within each survey grid (2 x 2 km^2) using QGIS (QGIS Development Team, 2016).

We estimated the tiger and leopard abundance by multiplying the estimated density from B-SECR models with the respective effective sampled areas (Srivathsa *et al.* 2015). Effective sampling area was calculated following Srivathsa *et al.* (2015). Estimated sigma (σ) value was derived from converged B-SCR models for tigers and leopards and a buffer of sigma (σ) × sqrt (5.99) was added to the camera trap array (Thapa and Kelly 2016). Effective sampling area was obtained by removing the non-habitat (settlement and agriculture) from the buffer area.For abundance and density estimates, we reported the calculated 95% confidence intervals around the point estimate.

4.2.4. Factors affecting tiger and leopard occurrence

We used a binomial logistic regression by constructing a Generalized Linear Model (GLM) to analyze the variables associated with tiger and leopard occurrence in a location measured as detection in camera-traps (Zuur *et al.*, 2009). In the GLM, the occurrence of tigers or leopards within each camera trapping grid was used as the response variable. Fourteen explanatory variables representing environmental parameters, prey distribution and anthropogenic pressure were defined (Appendix 4.1). The environmental variables included coverage area of four habitat types (grassland, Sal forest, riverine forests and waterbodies) within the grid, physiography (flat or churia hills) and average ruggedness of the terrain. The ruggedness index was calculated in QGIS from the 30 m resolution digital elevation model of ASTER satellite images (QGIS Development Team, 2016). Land cover data obtained from the classification of 30 m resolution landsat satellite images, land cover was grouped into four habitat types and area of the habitat in each cell was calculated in QGIS (Thapa, 2011).

Similarly, we used the independent detection frequency of three major prey species (chital, sambar and muntjac) in camera trap photos as explanatory variables. Photographs of a prey species or people captured within an hour was recorded as one independent detection. Anthropogenic pressure was represented by the number of independent detections of local people and livestock in the camera trap photos. Distance to forest edge (assuming closer the edges, higher the anthropogenic activities) and management type (assuming low human pressure in Park core areas and high pressure in forests outside) were also used as a measure for anthropogenic pressure. In addition, the average density of another large cat within grid cell obtained from the pixelated density output of SPACECAP was also used as an explanatory variable. Using multi-model inference in ‘MuMIn’ package in R (Grueber, Nakagawa, Laws, & Jamieson, 2011), we ranked the best models based on AIC value (lower AIC value indicates higher model ranking). Final models for the tiger and leopard were obtained by averaging the top candidate models supporting the data equally well ($\Delta AICc \leq 2$, Burnham & Anderson 2003). The analysis was done in

R (R Core Team, 2017). All the analyses can be reproduced using the R-script and the associated data provided in the supplementary files (S1–S7).

4.2.5. Temporal activity pattern

Temporal activity pattern and extent of overlap between tiger and leopard were calculated using 1) a non-parametric kernel density function of activity detected by camera-traps (Ridout & Linkie, 2009), 2) coefficient of overlaps, $\hat{\Delta}$, ranging from 0 (no overlap) to 1 (complete overlap) and 3) a non-parametric Kolmogorov-Smirnov test to compare activity distributions. The time stamp of each independent detection (photograph taken at least 30 minutes apart at the same camera-trap station) was used to fit the density function of the activity pattern. We used 10,000 bootstrap samples to measure 95% confidence intervals (CI) (Ridout & Linkie, 2009). We compared the activity pattern and calculated the overlap coefficient between tigers and leopards for locations a) where both tigers and leopards occurred and b) where either tiger or leopards occurred. The analysis was conducted using the 'overlap' package in R (R Core Team, 2017).

4.2.6. Diet of tiger and leopard

Scat samples of tigers and leopards (all that were found intact) were collected along the roads, trails and streambeds in Chitwan National Park and Barandabhar corridor forest between January and March 2017. Although there was four years gap between the camera-trap survey and the diet study, we assume no substantial change in prey availability. Experienced observers can make the distinction between tiger and leopard scats fairly accurately based on size and morphology as well as the presence of secondary signs such as scrape marks and pugmarks (Bhattarai and Kindlmann 2012b; Upadhyaya *et al.* 2018). Tiger tracks (>8cm pad width) and scrapes (>35 cm long and >19 cm wide) are larger than leopard tracks (<6.5 cm pad width) and scrape (<25 cm long and <15 cm wide). In a similar study in Bardia NP, using molecular identification of the carnivore, Upadhyaya *et al.* (2018) reported 96% accuracy of field identification (n=101). Prey remains in the scat such as hairs, feathers, bones, hooves and teeth were separated. Prey species in the scat were primarily identified through microscopic analysis of medullary and cuticular hair structures as described by Mukherjee *et al.* (1994). Microscopic analysis of hair was carried out at the laboratory of NTNC's Biodiversity Conservation Center, Chitwan. Prey species present in the scat were identified by comparisons of hair structure with reference samples maintained at NTNC and the Wildlife Institute of India (Bahuguna, 2010). We used the non-linear (asymptotic) model developed by Chakrabarti *et al.* (2016) for calculation of the per scat biomass consumed by tigers and leopards (Simcharoen *et al.* 2018). The model is as follows.

$$Y = 0.033 - 0.025 \exp^{-4.28X}$$

Where 'Y' is the biomass consumed and 'X' scaled prey weight (Chakrabarti *et al.*, 2016).

We also evaluated tiger-leopard diet overlap by using Pianka's index (O) which ranges between 0 (total separation) and 1 (total overlap) (Gotelli, 2001).

4.3. Results

4.3.1. Density and abundance of tigers and leopards

A total sampling effort of 6,085 trap-nights yielded 2,950 tiger and 1,453 leopard photographs in 329 and 209 independent detections respectively. Of the 362 sampling locations, tigers were detected from 143 locations; leopards from 110, including 47 locations where both species were photographed. Out of 78 tiger and 71 leopard individuals identified, we included in our analysis 71 tigers and 65 leopards identified from photos showing either both flanks or right flank for capture-recapture analysis and excluded seven tigers and five leopards showing only the left flank in photos to avoid possible duplication (Table 4.1).

All model parameters in Bayesian spatial capture-recapture (in program SPACECAP) for both tigers and leopards converged based on Geweke diagnostic statistics (z scores less

Table 4.1 Details of tiger and leopard capture in camera-traps in Chitwan National Park, Nepal during the survey between February and May 2013 (M: Males, F: Females, U: Sex Undetermined).

Parameters	Tiger	Leopard
Number of camera stations with capture	143	110
Number of independent detections	329	207
Capture rate (number of detections per 100 trap days)	5.4	3.4
Number of individuals captured	78 (50 F, 18 M, 10U)	71 (32 F, 27 M, 11 U)
Both flanks	61	58
Right flank only	10	7*
Left flank only	7	5*

** These individuals were excluded from capture-recapture analysis to avoid any duplication.*

Table 4.2. Estimates of tiger and leopards density (animals 100 km-2) and abundance (N) for Chitwan National Park, Nepal obtained from Bayesian spatially explicit capture–recapture (B-SCR) implemented in SPACECAP (Gopalaswamy et al. 2012) along with the posterior summaries of model parameters (sigma, lamda, beta, psi, p1 & p2).

Parameters	Tiger			Leopard		
	Estimate ± SD	95% CI	Gweke diagnostics |z score|	Estimate ± SD	95% CI	Gweke diagnostics |z score|
Sigma (σ)	5089.2 ± 191.0	4746 - 5475	1.2956	7002.52 ± 604.67	5841 - 8176	-0.0716
Lamda (λ0)	0.029 ± 0.004	0.021 - 0.038	-1.2801	0.003 ± 0.001	0.003 - 0.004	-0.1049
Beta (β)	1.33 ± 0.19	0.97 - 1.71	0.5596	3.28 ± 0.23	2.84 - 3.74	-0.1471
Psi (ψ)	0.32 ± 0.04	0.25 - 0.39	-0.4057	0.31 ± 0.04	0.23 - 0.39	0.989
N-Super	152 ± 14	123 - 179	-0.2921	128 ± 15	99 - 157	0.807
Density (D)	3.94 ± 0.37	3.19 - 4.64		3.31 ± 0.4	2.57 - 4.07	
p1	0.028 ± 0.004	0.02 - 0.037		0.003 ± 0.001	0.003 - 0.004	
p2	0.103 ± 0.014	0.076 - 0.131		0.072 ± 0.011	0.051 - 0.095	
Effective Sampling Area (km2)	2142.2			2571		
Ñ	86 ± 8	70 – 102		85 ± 10	66 - 105	

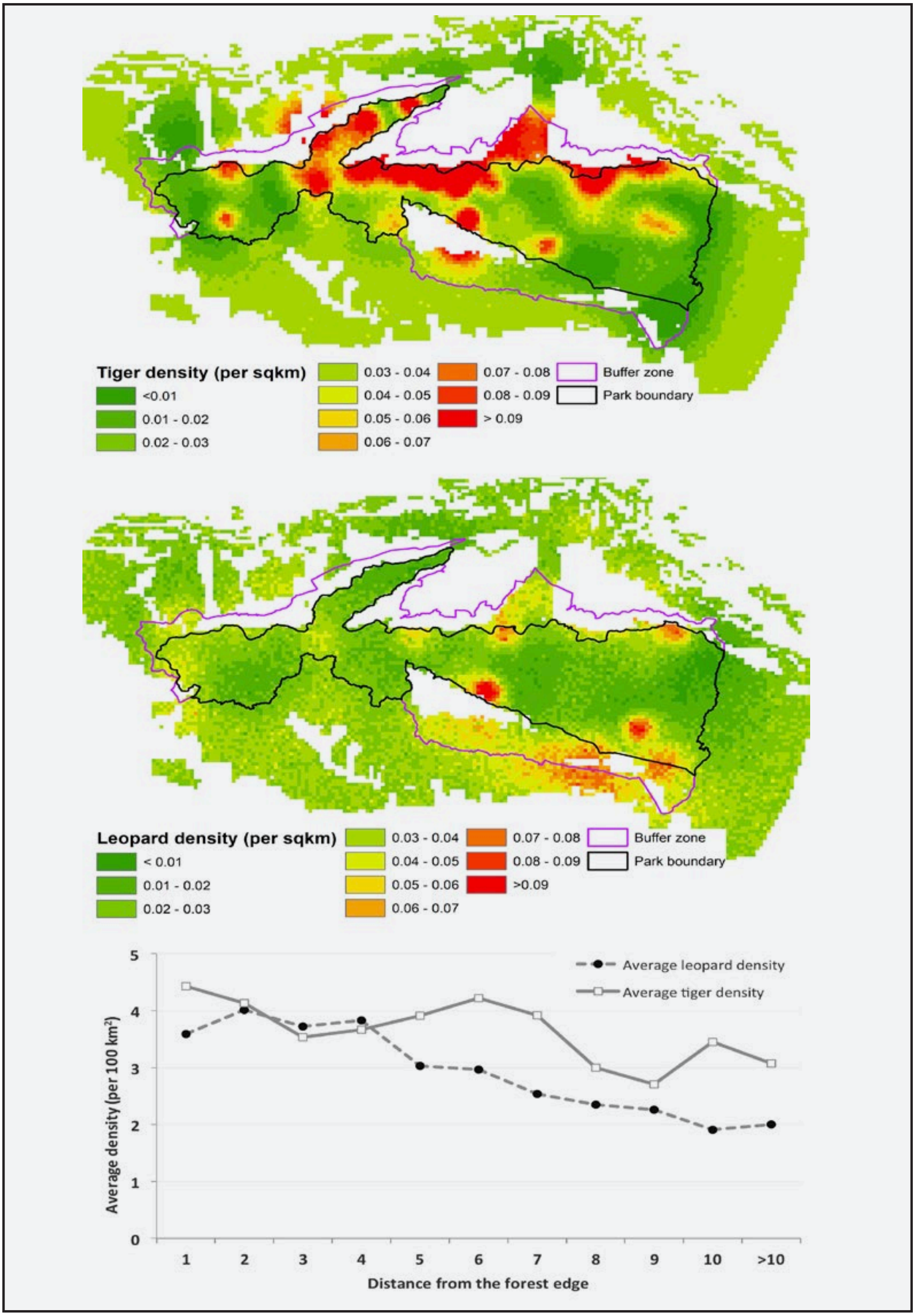

Figure 4.2 Density heat map obtained from SECR-B from SPACECAP for a) tiger; b) leopard in Chitwan NP and surrounding forests; and c) Average density in relation to the distance to the forest edge.

Table 4.3 Model-averaged parameter values of individual variables obtained from the GLM fitted to Tiger (A) and Leopard (B) detection during a camera-trap survey in Chitwan National Park, 2013.

Parameters	Estimate	Unconditional SE	Z value	Relative importance	Pr(>|z|)
(A) Tiger					
(Intercept)	-2.087	0.592	3.516	-	<0.001 ***
Chital	0.064	0.027	2.326	1.00	0.020 *
Grassland	0.006	0.003	1.992	1.00	0.046 *
Livestock	-0.130	0.066	1.981	0.97	0.048 *
Management_CNP	0.843	0.405	2.074	0.93	0.038 *
Muntjac	0.082	0.047	1.732	0.92	0.083 .
Riverine_forest	0.942	0.353	2.658	0.75	0.008 **
Sal_forest	0.180	0.111	1.611	0.70	0.107
Sambar	0.057	0.032	1.769	0.64	0.077 .
Physio_Lowland	0.452	0.299	1.508	0.44	0.132
Ruggedness	-0.003	0.003	1.010	0.24	0.313
Waterbodies	0.609	0.664	0.914	0.19	0.361
Local_people	-0.043	0.037	1.150	0.16	0.250
Leopard_density	-0.167	0.154	1.080	0.10	0.280
(B) Leopard					
(Intercept)	-1.613	0.378	4.258	-	<0.001 ***
Chital	0.051	0.025	2.031	1.00	0.042 *
Livestock	0.118	0.044	2.701	1.00	0.007 **
Sal_forest	0.203	0.104	1.938	1.00	0.053 *
Sambar	0.035	0.027	1.294	0.31	0.196
Waterbodies	0.773	0.639	1.206	0.29	0.228
Ruggedness	0.003	0.002	1.062	0.23	0.288
Tiger_density	-0.052	0.049	1.062	0.21	0.288
Grassland	0.002	0.002	0.934	0.10	0.350
Distance_forest_edge	-0.027	0.046	0.59	0.05	0.555
MgmtCNP	0.179	0.310	0.574	0.05	0.566
Physio_Lowland	-0.136	0.254	0.535	0.05	0.593

than 1.6) on the best performing model (trap-response present with negative exponential detection function for tiger and trap response present with half normal detection function for leopard). The tiger density was estimated 3.2 - 4.6 (mean = 3.94, SE = 0.37) individuals per 100 km^2. Tiger density was highly concentrated in the floodplain areas close to the rivers in the northern part of the Park (Fig. 2a, c). Similarly, leopard density was estimated 2.6 - 4.1 (mean = 3.31, SE = 0.39) animals per 100 km^2 in CNP and adjoining forests. We estimated population size of tiger between 70 and 102 (86 ± 8) and leopard between 66 and 105 (85 ± 10) based on density and effective sampled area (2142.2 km^2 for tiger and 2571.1 km^2 for leopard) (Table 2). We also generated surface density maps (Gopalaswamy *et al.* 2012b) to visually depict posterior estimates of pixel-level densities of tigers and leopards in the landscape at the scale of 0.3364 km^2 (Fig. 2a, b). Density of leopards was higher close to the forest edges and decreased with increasing distance (Fig. 2b, c).

4.3.2. Factors related to tiger and leopard occurrence

Based on the averaged value of the top candidate models, tiger detection in the camera trap survey grid cell was positively related to the area of grassland and riverine forest,

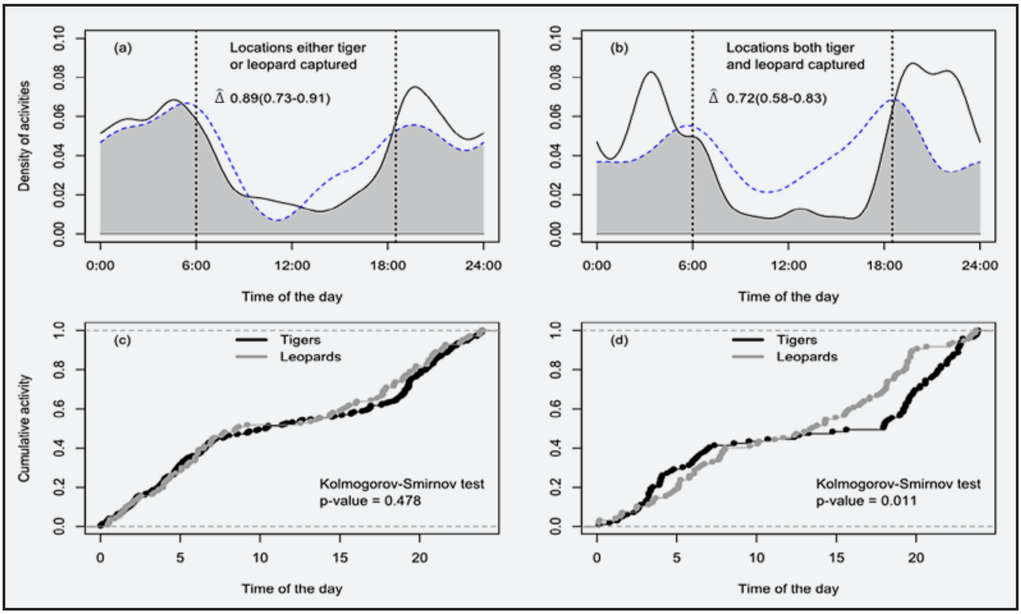

Figure 4.3 Temporal activity pattern of Tigers and Leopards in locations where only tiger or leopard occurred (a and c) and locations where both tiger and leopard occurred (b & d). On the figures of the first row (a and b), the shaded area represents the overlap, the continuous and dashed lines represent the activity of tigers and leopards respectively as detected in camera-traps. The vertical dotted line represents sunrise (6:00) and sunset (18:30) during the survey period. The figures on lower row (c and d) show the cumulative activity over the hour of the day.

detection of chital and core areas of the Park but negatively related to livestock presence (Table 4.3). In contrast to tigers, the leopards were more likely to be detected in the grids containing larger areas of sal forest as well as presence of chital and livestock (Table 4.3).

4.3.3. Activity pattern

Both tigers and leopards showed a crepuscular activity pattern, although this was more pronounced in tigers (Fig 3). There was a high overlap = 0.83 (0.78 – 0.91) in the temporal activity of both species across all habitats. Activity overlap was = 0.72 (0.61 – 0.82) in the locations where tiger and leopard co-occurred and it was = 0.87 (0.84 – 0.95) where tigers and leopards were captured separately (Fig. 4.3). Activity density of tigers peaked just before sunrise and after sunset whereas, leopard activity peaked exactly at the sunrise and sunset. Comparatively, leopards were more active during the day in the areas where they co-occurred with tigers. A Kolmogorov-Smirnov test showed the activity distribution of tigers and leopards differ significantly (p=0.011) at locations where both species were photographed. However, their activity distribution did not differ (p=0.478) at locations where just one species was detected in a camera trap.

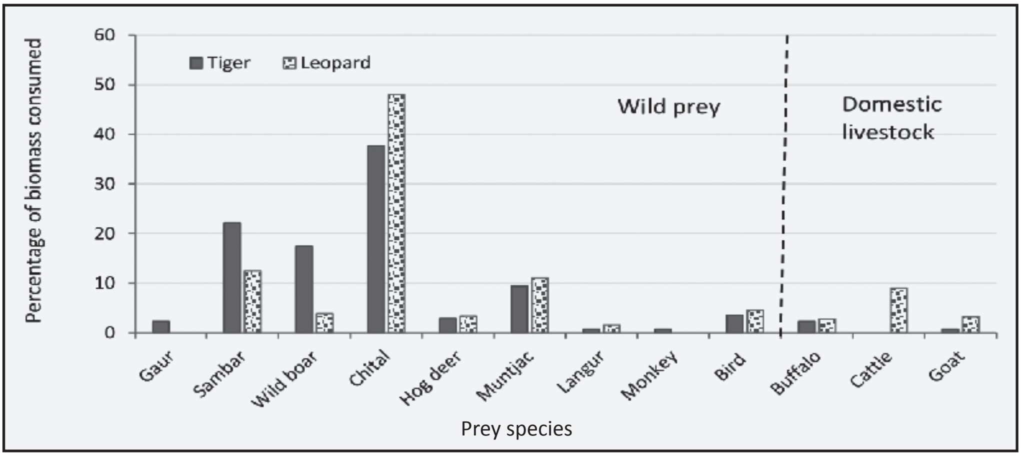

Figure 4.4 Proportion of prey biomass consumed by tigers and leopards in Chitwan National Park and surrounding forests.

4.3.4. Diet of tiger and leopard

Among the prey species, chital contributed the highest biomass in the diet of tigers (38 %) and leopards (48%). Tigers, however, consumed a greater biomass of the large prey such as sambar (22%) and gaur (2.3%) compared with leopards (12% & 0% respectively). Estimated consumed biomass of livestock was higher in leopard diet (15%) compared with tiger (3%) (Fig 4.4). Analysis using Pianka's prey overlap index demonstrated a 90.0% overlap in tiger and leopard diet.

Figure 4.5 Major prey-species of tigers and leopards in Chitwan.

4.4. Discussion

We documented a high density of two sympatric carnivores in a national park and adjoining forests interspersed in a human-dominated landscape. We also observed spatial and temporal seperation between tigers and leopards, thus supporting our hypothesis. Tiger distribution was positively related to the habitats in the river floodplain (alluvial grasslands and riverine forests) and prey but was negatively related to the disturbance (livestock presence and forests outside of CNP). In contrast, leopard distribution was positively related to less productive habitat i.e. sal forests, locations with livestock presence (disturbance) and prey species (chital). Leopards also adjusted their activity (increased in the daytime when tigers are less active) in locations where they co-occur with tigers. Both tiger and leopard occurrence showed a significant positive relationship with detection of chital in camera traps which was expected as chital constitutes a major portion of tiger and leopard diet. However, habitat type was different for tigers and leopards. The mosaic of habitats and different levels of anthropogenic pressures in these habitats have facilitated co-occurrence of tigers and leopards as they are able to occupy different niches in time and space.

4.4.1. Tiger-leopard density

Our density estimates of tigers and leopards are comparable with those reported in previous studies (Thapa 2011; Karki *et al.* 2015). Karki *et al.* (2015) estimated 4.5 tigers per 100 km^2 in CNP. In India, tiger densities (SECR based) range between 1.15 to 8.9 animals per 100 km^2 (Kalle *et al.* 2011). Much lower tiger densities (individuals 100 km^2) are reported from other tiger range countries like Lao PDR (0.2 – 0.7; Johnson *et al.* 2006), Bhutan (0.52; Wang & Macdonald 2009), Malaysia (1.1 – 1.8; Kawanishi & Sunquist 2004) and Thailand (2.0; Duangchantrasiri *et al.* 2016). Tiger density in Chitwan NP is also high when compared to that recorded in other parks in Nepal (Bardia NP – 3.3, Shuklaphanta NP – 3.4, Parsa NP– 1.4, Banke NP – 0.16; Dhakal *et al.* 2014; Lamichhane *et al.* 2018a).

Leopard density in our study is also close to the estimates reported by Thapa (2011) for CNP (3.4 leopards per 100 km^2) and Thapa *et al.* (2014) for Parsa NP (3.5 per 100 km^2). The density estimate of 3.9 individuals per 100 km^2 in a protected forest in Cambodia (Gray and Prum 2012) is comparable to our estimates. But the mountainous terrain in Bhutan has a much lower leopard density (1.04 individuals 100 km^2). In India, the leopard density varied in parks between 2.07 and 13.1 individuals per 100 km^2 (Harihar *et al.* 2011; Kalle *et al.* 2011; Thapa *et al.* 2014).

A decrease in leopard density (9.76 to 2.07 individuals per 100 km^2) with an increase of tiger density (2.67 to 5.8 individuals per 100 km^2) has been reported from India (Harihar *et al.* 2011). In contrast we found both tiger and leopard densities increased over the last decade in CNP and remained relatively stable in few years before the survey (2010 – 2013) (Thapa 2011; Karki *et al.* 2015). Similar observations of leopards (in high density) that were unaffected by interference from lions, another apex predator, was reported from Sabi Sand Game Reserve in South Africa (Balme *et al.* 2017). For a multiple decades, tigers and leopards have co-occurred with a large overlap of home range and diet (Seidensticker 1976). Factors facilitating the high density of these two large cats in Chitwan may be a combination of high density of ungulates (73 prey per km^2, Dhakal *et al.* 2014), mosaics of the habitats (Bhattarai and Kindlmann 2012a), control of hunting with enhanced protection, habitat restoration in the buffer zone (Gurung *et al.* 2008) and support from local communities (Nepal and Spiteri 2011).

4.4.2. Spatial distribution of tiger and leopard density

Carnivore density is not evenly distributed in CNP but concentrated in certain patches. Contrary to the general expectation, both tiger and leopard densities were estimated to be relatively higher near the Park boundary. The Park is bordered by three major rivers which create highly productive floodplains with alluvial grasslands and riverine forests that harbor a high density of ungulates and lie in proximity to these rivers (Lehmkuhl, 1994; M. K. Shrestha, 2004). Thus, a high tiger density close to the Park edges is a function of ecological factors (highly productive alluvial grasslands and riverine forests) (Smith, 1993; M. E. Sunquist, 1981). Similarly, leopard density was also higher close to the Park boundary or forest edge and decreased with increasing distance. Such a pattern of leopards using fringe areas has also been documented in Bardia and Shuklaphanta National Parks of TAL Nepal (Odden *et al.*, 2010; Pokheral & Wegge, 2018) and Rajaji of TAL India (Abishek Harihar *et al.*, 2011). High densities of large carnivores (both tigers and leopards) and their prey in close proximity to the Park boundaries may help to explain the high incidence of human-wildlife conflict in CNP (Average annual 9.3 ± SD 5.7 human death, 31.3 ± SD 11.8 human injury and 122.94 ± SD 80.97 livestock depredation) compared with other parks in Nepal (Bhattarai & Fischer, 2014; Lamichhane *et al.*, 2018a).

The physiography of the Park may also have facilitated the uneven density distribution of tigers and leopards. The Churia Hills, covering >60% of the Park (Thapa & Kelly, 2017), stretch east to west in the middle of the Park. Lower prey density in these Hills resulted in lower use of higher elevations by tigers (Smith, McDougal, & Sunquist, 1989). Recent studies have documented both tigers and leopards occupying this habitat (Karki *et al.*, 2015) but in lower densities i.e. 1.5 tigers and 2.1 leopards per 100 km^2 (Thapa & Kelly, 2017).

Tigers were concentrated in the prime habitats having a high density of prey species and leopards in comparatively marginal habitats. A higher proportion of livestock in the diet of leopards compared to that in tiger diet also supports the leopard use of the boundary of CNP and buffer zone area where local communities graze their cattle occasionally. We suspect that interference competition by tigers led to habitat partitioning by these two species (Carter *et al.*, 2015; Seidensticker, 1976). The density heatmap shows that high-density areas of tigers and leopards are mostly separated from each other except for small overlapping areas in the northern portion of the study area (Barandabhar Corridor Forest). A large number of livestock attacked by leopards has been reported by communities in recent years near the corridor forest where such a concentration of carnivores was observed (Lamichhane *et al.*, 2018a). With the increasing number of tigers dispersing from parks to the corridor forests, leopards may have been pushed into the edges where they kill the livestock (Lamichhane *et al.*, 2018a; Odden *et al.*, 2010).

4.4.3. Daily activity pattern and diet

Both tiger and leopard showed nocturnal behavior with pronounced activities during dawn and dusk. Tiger activity intensity was less during daytime (6:00 - 18:30) (< 30% of total activity) compared to that of leopards (~ 40 % of the activities during the day). Both tiger and leopard activity coincides closely with higher overlap (0.87) in locations where only a single species was photographed. The activity overlap decreased (0.72) and activity distribution of the two species differed significantly in areas where both species occurred. The decrease in the overlap is primarily due to leopards being more diurnal in the presence of tigers. More than 50% of the leopard activities were diurnal in locations overlapped with tigers and it declined to < 40% diurnal in areas where tigers were absent. Thus, leopards exhibited temporal avoidance of tigers. Kawanishi & Sunquist (2004) also observed a shift in leopard behavior to more nocturnal activity in the absence of tigers.

Scat analysis demonstrated that chital was the most important (estimate as biomass) species in the diet for both tigers and leopards as observed in other studies (Lovari *et al.*, 2015; Wegge *et al.*, 2018). Although there was a large overlap in prey of tigers and leopards, niche separation in the diet was observed with tigers preferring larger-sized prey (Bhattarai & Kindlmann, 2012b). Rosenzweig (1966) showed coexistence between predator species is the result of size difference leading one species to hunt a different set of prey species. Wild prey contributed to most of the diets of tigers and leopards indicating that prey is not a limiting factor in the park and buffer zone. Prey occurs in relatively high densities in CNP and the buffer zone (73 prey animals/ km^2; Dhakal *et al.* 2014) but density is very low in the forests outside these areas due to high anthropogenic pressure and possibly hunting (Shrestha 2004; NTNC unpublished data). Increasing wild prey density in these forests is important to sustain the high density of tigers/leopards and reduce livestock depredation especially from dispersing (or pushed out) large cats (Kolipaka, 2018; Lamichhane *et al.*, 2017).

Livestock contributed to only a small portion of the big cats' diets in Chitwan NP; lower than the previously reported by Bhattarai and Kindlmann (2012b). Reduced availability of livestock in forests due to grazing restrictions in the Park and community managed buffer zone forests may have led to the lower encounter of livestock by tigers and leopards(Gurung *et al.*, 2009) which is also reflected in their diets. The annual average of 50.6 incidents of livestock depredation in the buffer zone of CNP during 2011 – 2016 (Lamichhane *et al.*, 2018a) is low when compared to data from parks in India (462/year, Kanha NP; Miller *et al.* 2016) where free grazing is common. Lamichhane *et al.* (2018a) reported a higher frequency of livestock depredations caused by leopards versus tigers during 2014 – 2016. Comparatively more leopard scats were detected in the buffer zone or corridor forest (82%, n=57) while more tiger scats were detected in the park (53%, n=148) suggesting leopards are being pushed out of the CNP (Bhattarai & Kindlmann, 2012b).

4.5. Conclusions

Our study documents a unique scenario of large carnivores co-occurring in high density with spatial and temporal separation of resources within a human-dominated landscape. The high density of large cats in alluvial floodplains close to the park boundaries should be considered when designing strategies to reduce livestock depredation and attacks on humans by these large cats. Additionally, managing the mosaic of habitats will help to maintain the diversity and density of prey to support tigers and leopards. High and stable densities of tigers in the core areas of CNP in recent years may have increased recruitment of tigers and resulted in higher rates of dispersal. A result may be that more tigers are attempting to occupy buffer zone forests, ultimately exerting pressure on leopards to move into marginal habitats. With improved management in buffer zone forests (e.g. restoration of degraded forests, grasslands and wetland management), managers should expect higher densities of both tigers and leopards in these forests. Strategies to increase prey density and reduce livestock depredation should be adopted in buffer zones or outside forests to reduce potential conflict with humans. Regular monitoring of wildlife, especially in the fringe areas, will help improve understanding of the interactions between carnivores and humans. Monitoring will also help to reduce conflict by establishing an early warning of the vulnerable communities when tigers and leopards are in close proximity.

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Validation: SM, MD, LPP, NS, CPP, HHD
Writing – original draft: BRL, HHD
Writing – review & editing: BRL, HL, GAP, NS, MD, BNO, VS, CPP, LPP, HHD

a

b

a) Crop guarding tower (machan) constructed by the farmers to guard their crops from wildlife and (b) mesh-wire fence constructed along the border of agriculture areas and forest (river) by a Buffer Zone User Committee (Photos by Pabitra Gotame/NTNC-BCC)

5 Contribution of Buffer Zone Programs to Reduce Human-Wildlife Impacts: the Case of the Chitwan National Park, Nepal

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Abstract

Buffer zones around parks/reserves are designed to maintain ecological integrity and to ensure community participation in biodiversity conservation. We studied the fund utilization pattern of buffer zone programs, mitigation measures practiced, and attitudes of residents in buffer zone programs of Chitwan National Park, Nepal. The buffer zone committees spent only a small portion (13.7%) of their budget in direct interventions to reduce wildlife impacts. Human-wildlife conflicts were inversely related to investment in direct interventions for conflict prevention and mitigation. Peoples' attitudes towards wildlife conservation were largely positive. Most of the people were aware of buffer zone programs but were not satisfied with current practices. We recommend that buffer zone funds be concentrated into direct interventions (prevention and mitigation) to reduce wildlife conflicts. Our findings will be helpful in prioritizing distribution of funds in buffer zones of parks and reserves.

Keywords: Human-wildlife conflict; Buffer Zone; compensation; fences, Chitwan National Park;

5.1. Introduction

Throughout the world, the expansion of human land use in the expense of natural ecosystems caused wildlife habitats to become increasingly insular, fragmented and degraded (Lambin & Meyfroidt, 2011). Some remaining habitats are set aside for protection as parks/reserves where many wildlife populations are recovering (Bruner *et al.*, 2001; IUCN, 2008; Naughton-treves, Holland, & Brandon, 2005). Often in close proximity to these areas, communities farm crops or raise livestock presenting an attractive food source for wild animals, which consequently frequently raid crops, kill livestock or attack humans. In retaliation they may be killed. Such reciprocal impacts by humans and wildlife are among the major threats to wildlife conservation (Dickman, 2010; Madden, 2004). Management of such impacts is even more challenging where endangered wildlife causes serious damage to human lives or livelihoods (Woodroffe, Thirgood, & Rabinowitz, 2005).

Historically, communities managed wildlife impacts locally by clearing habitat or retaliating wild animals perceived as threats (Treves, Wallace, & White, 2009). Such a responses are either illegal or socially unacceptable where they do not comply with national and international regulations for biodiversity conservation (Madden, 2004). Wildlife managers strive to increase or maintain wildlife populations through protection and habitat management, while local communities are interested in access to the natural resources as well as their own safety and property (Andrade & Rhodes, 2012). While human-wildlife impacts are the result of simple competition over shared resources, they may also reflect political conflict between local residents and institutions having contrasting viewpoints about wildlife (Treves *et al.*, 2006). If such conflicts are not managed, affected communities can become antagonistic towards wildlife and conservation authorities, adversely affecting overall conservation goals (Madden, 2004; Woodroffe *et al.*, 2005). Managing conflict thus needs both a biophysical and a sociopolitical approach (Treves *et al.*, 2006) to promote non-lethal management and strategies to increase community tolerance for wildlife (Treves *et al.*, 2009).

When wildlife and humans are sharing the same landscape in close proximity, it is almost impossible to entirely avoid wildlife damage. However, community tolerance of actual and perceived threats can be built through co-management of conflict (Treves *et al.*, 2006), including timely compensation for losses, participation in planning and execution of conservation programs, as well as equitable sharing of conservation benefits (Nyhus, Osofsky, Ferraro, Fischer, & Madden, 2005; Wegge *et al.*, 2018). Buffer zones are often created surrounding the core protected areas to facilitate such processes with the dual purpose of maintaining ecological integrity and ensuring participatory conservation or co-management (Budhathoki, 2004; Heinen & Mehta, 2000; Persoon & Van Est, 2003; Sayer, 1991; Spiteri & Nepal, 2008). Often in the buffer zone areas, communities are subsidized as compensation for wildlife impacts, while wildlife is protected with refuge habitats and migration corridors (Kolipaka, 2018; Sayer, 1991; Wegge *et al.*, 2018). Reducing negative impacts of wildlife on communities and protecting wildlife and their habitat should be the priority actions in the buffer zones (Budhathoki, 2004; Heinen & Mehta, 2000; Silwal *et al.*, 2013).

Reducing human-wildlife impacts requires a combination of strategies based on the location and species involved that can be broadly categorized into 1) preventive measures (or direct interventions), 2) mitigative measures and 3) indirect interventions (Goodrich, 2010; Treves *et al.*, 2009). The direct interventions aim to reduce the severity of the impacts by lowering the frequency and extent of damage from wildlife, whereas mitigative measures and indirect interventions aim to raise residents' tolerance to impacts (Treves *et al.*, 2009). Spatial separation of human and wildlife through physical barriers (fences), guards, repellents are common preventive measures (Goodrich, 2010; Karanth & Madhusudan, 2002; Treves *et al.*, 2009). In addition, altering human behavior through awareness about wildlife, establishing early warning systems, predator-proof corrals, changing to crops less palatable to wildlife, improving livestock husbandry, and manipulating problem wildlife (both lethal and non-lethal) also mitigate human-wildlife impacts.

We selected Chitwan National Park (CNP) in Nepal for this study because it typifies a national park in the tropics where wildlife density inside the park is increasing and communities around the park are experiencing frequent economic loss and safety threats from wildlife (Lamichhane *et al.*, 2018a). Participatory conservation and habitat restoration in the periphery of the park were initiated in the 1990s and a buffer zone was legally declared in 1998 (Budhathoki, 2004). Despite their existence of over 20 years, there are only a few studies focusing on buffer zone programs in Nepal, and whether they have helped to reduce human-wildlife conflict is not well understood. In this study, we examined whether buffer zone interventions are adequate in reducing the negative impacts of wildlife by analyzing buffer zone fund utilization over a decade around CNP. We assessed the fences and mitigation measures practiced by the communities, and examined attitudes of local communities towards wildlife conservation and the management of conflicts to gain more insight in the complex processes of human-wildlife interactions. Our research questions are 1) Are buffer zone funds adequate to reduce the damage caused by wildlife in human life and livelihood? 2) What preventive and mitigative measures are practiced and proposed? And, 3) What are people's attitudes towards wildlife conservation, conflict prevention and mitigation?

5.2. Methodology

5.2.1. Study area

The study was conducted in the buffer zone of Chitwan National Park (CNP), Nepal. CNP (953 km^2) is situated in South Central, Nepal between 27°16.56' - 27°42.14'N latitudes and 83°50.23' - 84°46.25'E Longitudes (Fig. 1). CNP is the first national park of Nepal, established in 1973 and a UNESCO world heritage sites. It is well known for high biodiversity, with nearly 70 species of mammals, >600 birds, 54 herpetofauna and 126 fish species (CNP, 2013b). CNP is one of the 42 tiger source sites globally and holds the second largest population of the greater one-horned rhinoceros (*Rhinoceros unicornis*) (Subedi *et al.*, 2017; Walston *et al.*, 2010). A variety of ungulates including four deer (sambar *Rusa* *unicolor*, chital *Axis axis*, hog deer *A. Procinus*, muntjac *Muntiacus vaginalis*), gaur (*Bos gaurus)*, wild boar (*Sus scrofa)*, nilgai (*Boselaphus tragocamelus)* are the major herbivores of the park. In addition to tigers and leopards, there is a range of carnivores such as sloth bear (*Melursus ursinus*) wild dog (*Cuon alpinus)*, stripped hyena (*Hyaena hyaena)*, clouded leopard (*Neofelis nebulosa)*, jackal (*Canis aurenus)*, fishing cat (*Prionailurus viverrinus), jungle cat (Felis chaus),* and leopard cat (*Prionailurus bengalensis)*.

Contiguous habitat exists toward the South-West (Valmiki Tiger Reserve, India) and the East (Parsa National Park) of CNP. The park is bordered by the Narayani River in the West, the Rapti River in the North and the Reu River and the international border with India in the South. On the other side of these rivers, highly populated human settlements and agricultural areas exist. A corridor forest called Barandabhar connects the park with the northern hill forest (Fig 5.1). The park is dominated by forest (>80%) including a majority of Sal (*Shorea robusta*) forest followed by riverine forest and mixed hardwood forest. Highly productive alluvial floodplain grasslands close to the bordering rivers cover 9.6% of the park, 5% exposed surface and 3% water bodies (CNP, 2016; Thapa, 2011).

An additional 750 km^2 of the buffer zone surrounding CNP was created in 1996 (21 Km^2 of BZ was later included in the park in 2016). More than half (55%) of the buffer zone is effective wildlife habitat including forests, grasslands and water bodies; the rest is used for agricultural land and settlements (Karki *et al.*, 2015). There are more than 70 buffer zone community forests covering approximately 11,000 ha (CNP, 2017). Buffer zone regulations and guidelines provide the legal framework of buffer zone programs in Nepal. Accordingly, the buffer zones are managed in three tiers: 1) user groups are formed at the hamlet level, 2) user committees are formed from the representatives of the user groups, and 3) chairpersons of the user committees form a buffer zone management committee for each protected area. In Chitwan there are 1,770 User Groups and 22 Buffer Zone User Committees (BZUC). BZUCs are responsible for designing and implementing

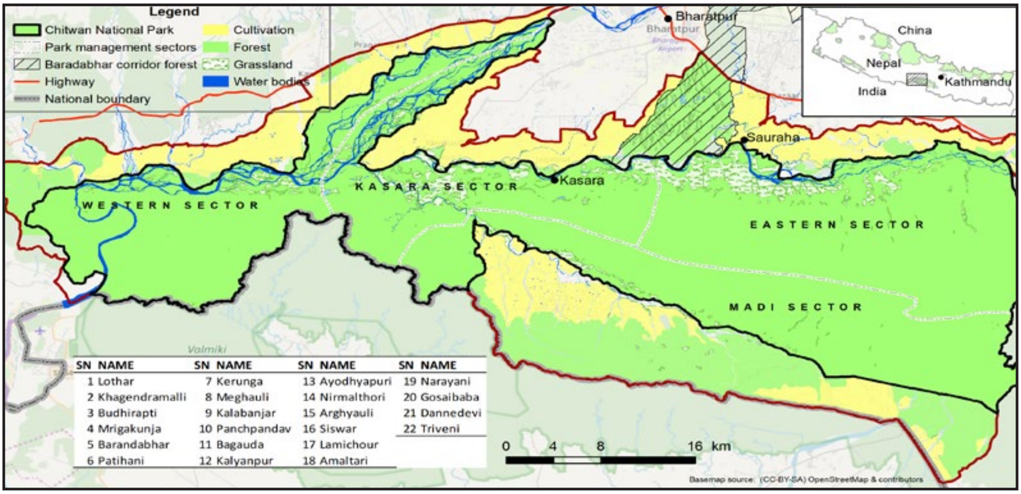

Figure 5.1 Chitwan National Park and buffer zone area.

buffer zone programs. They also deal with the wildlife victims for the recommendation of compensation payments to the national park and liaison between the community and the park authority. The park management and buffer zone are divided into four sectors i.e. Eastern (Sauraha), Northern (Kasara), Southern (Madi), and Western (Amaltari) sector for effective administration (Fig. 5.1).

Historically, only a few settlements of the indigenous Tharu, Bote and Darai communities (of Tibeto-Burmese origin) surrounded the present-day park. However, many people from the hilly area migrated into the Chitwan after the 1950s (Mishra, 1982a). Now the community is a mix of indigenous people and immigrants from the hills including high caste Hindus (*Brahmin, Chhetries*), Tibeto-Burmese hill ethnic groups (*Tamang, Gurung, Magar*) and underprivileged lower caste Hindus (*Kami, Damai, Sarki* etc.). Human density is relatively high (261.5 persons per km^2 in 2011) and increasing rapidly by 2.06% annually in Chitwan (CBS, 2012). The buffer zone includes more than 45,000 households in 12 municipalities in five districts (Chitwan, Makawanpur, Nawalpur, Parasi and Parsa). A majority of people rely on subsistence agriculture but dependence on agriculture is decreasing as the younger generation prefers off-farm activities like tourism (nature-guides and work in hotels), service and foreign employment (Lamichhane *et al.*, 2018a). Livestock keeping is an integral part of subsistence agriculture, and grazing was common in the buffer zone until the last decade. In recent years there has been a gradual shift towards stall feeding combined with restricted grazing, adoption of improved livestock and a shortage of labor (Gurung *et al.* 2009). The demand and preference of youths for off-farm labor has greatly increased during the last decade which resulted in the shortage of labor for farming (Lamichhane *et al.*, 2018a).

5.2.2. Data collection

Fund utilization records

Our study focused on direct financial investments made through the BZUCs in the buffer zone of CNP. We focused on direct investment because it is often difficult to measure the impacts of indirect interventions such as awareness raising, alternative livelihoods, and community development to reduce conflict (Treves *et al.*, 2009). BZUCs are part of the legal bodies for buffer zone management and are mandated to operate their own accounts (Budhathoki, 2004). We collected the income and expenditure records of the BZUCs from their audit reports between 2005/06 to 2014/15 (10 years). As per the buffer zone regulations, it is mandatory for each buffer zone user committee to conduct the annual financial audit. The reports are managed according to the Nepalese fiscal year which runs from mid-July to mid-July based on the Nepalese Calendar (Bikram Sambat) (Lamichhane *et al.*, 2018a). For consistency of data for time series analysis, we used these fiscal years. The audit reports include the sources and amount of the income received by each BZUC in each fiscal year. The indirect benefits in the communities such as income generation in the buffer zone area from tourism do not fall within the scope of our research. Our study does not include the income and expenditure of the more than 70 community forest user groups in the buffer zone which also spend a large amount of their budget in prevention and mitigation of human-wildlife impacts.

Assessment of fences and conflict mitigation measures

We mapped the fences constructed along the boundary separating forest and human settlements/agricultural lands. Members of the survey team walked along the fences in all BZUCS with a GPS device (Garmin etrex 10) using the track log. Waypoints were recorded every 200 m and the type of fence, condition and functionality of the fence, and year established were recorded in a standardized data form. The GPS tracks were downloaded by DNRGPS software and the fence line feature was extracted from the GPS track. Characteristics of the fences recorded in the data form were associated to a line feature. Spatial analysis such as type and length of fence in different user committees and management sectors of the parks was done in QGIS 2.7 (QGIS Development Team, 2016).

The status of the fences and role of the fences in conflict mitigation were assessed through a focused group discussion in each of the four sectors of CNP with 12–20 participants. One day long focused group discussion was conducted in each sector (Fig 5.1) during August – September 2016. Two authors (BRL and SP) facilitated the group discussions. The chairman, the secretary and an office assistant of the BZUCs who are key persons responsible for designing/implementing buffer zone programs and conflict management were invited to participate in the discussion. The sub-group of three persons from each BZUC spent 2–4 hours to assess the status of the human-wildlife conflict, current practices, and future priorities of conflict mitigation within the respective BZUC area. For each of the mitigation measures, the group was asked to rank high, medium or low for construction costs, maintenance costs and effectiveness in reducing conflict along with the risks/challenges. Each of the group presented their findings written in a chart paper for all the participants. The participants provided feedback on the presentations and the chart papers were finalized for each committee. All BZUC representatives participated in the workshops actively. The information on the final chart paper was entered into the excel spreadsheet to represent the summary for each buffer zone user committee. This information is summarized from all BZUCs and presented in a table (Table 5.3).

Questionnaire survey

We conducted a questionnaire survey in the buffer zone of CNP during April–June 2016 to assess people's attitude towards buffer zone management practices and human-wildlife conflict management. To ensure the spatial coverage, we stratified our survey in four management sectors of the Chitwan National Park and three buffer zone user committees (BZUC) were randomly selected within a sector. Within the map of the 12 selected BZUCs (three in four sectors each), we generated 35 random GPS points using QGIS. The nearest household to the GPS point was navigated using a map and GPS device. If there was no household within 500 m of the random point, it was excluded from the survey. We requested the household head to participate in the survey whenever possible. If the household head was not available or ready to participate, we interviewed another member of the household aged 16 or above. We moved to the next household for the survey if there were no members of the first household available or they were not ready to participate in the survey. Consent to participate in the survey was read out to the respondent as some of them were unable to read themselves. All the households approached agreed to participate in the survey. Four trained field assistants with long experience in the buffer zone conducted face to face interview using a structured questionnaire that took one hour on average to fill out. The questionnaire was originally prepared in English and translated in a local Nepali language and a pilot survey (n=12) was conducted to test the questionnaire and train the field assistants before conducting the actual survey. The questionnaire was reviewed and approved by the ethics committee of Institute of Cultural Anthropology and Development Sociology, Leiden University (Appendix 5.1). Similarly, the Department of National Parks and Wildlife Conservation in Nepal issued research permit to this study after approval from a 'technical committee' at the department which reviews the research applications in Nepal's protected areas.

The questionnaire was divided into four sections: 1) personal and household information such as age, gender, ethnicity, occupation, migration, household income sources, land and livestock owned, forest resources need; 2) past experience with wildlife and their impacts on the households, 3) conflict management and compensation practices; and 4) attitude towards the wildlife and buffer zone program. The attitude of the respondents towards different statements related to wildlife conservation, national park, buffer zone and conflict management was measured on a five-point Likert scale where 1 denoted 'Strongly agree' and 5 denoted 'Strongly disagree' (Likert, 1932; Stapp *et al.*, 2016). The statements were read to the respondents and they were asked to score the statements on the scale.

5.2.3. Data analysis and statistics

We categorized income sources of the BZUCs derived from audit reports into four categories: 1) committee internal sources, such as fees or royalties for resource extraction (mostly sand gravel, sometimes wood) within committee's area, memberships, fines and income from investments; 2) park revenue shared according to existing buffer zone guidelines (30 – 50 % of the total park income); 3) grants and subsidies from other government line agencies (municipalities, district coordination committees); and 4) support provided by conservation NGOs, projects and environmental non-governmental agencies for conservation actions within the BZUC. Redundant budget headings such as programs advance and bank balance from previous years which could be repeated with the previous year's budget were excluded from the analysis.

The buffer zone management guidelines provides five broad categories (and proportion of budget) for expenditure namely a) community development (30%), b) wildlife conservation (30%), c) income generation (20%), d) conservation education (10%), and e) administrative costs (10%). BZUCs prepare a five-year action plan and implement priority actions based on the available budget. Sometimes, the conservation NGOs and government line agencies also approach to the BZUCs to implement activities of their interest within the framework of BZUC action plan. Thus, there was a wide range of activities conducted by the BZUCs, some are cross-cutting the broad five categories. Although all these activities are supposed to reduce the wildlife impacts on humans and increase community tolerance, there is no specific category for targeted activities on wildlife conflict prevention and mitigation. As our research interest lies in the direct investment on reducing human-wildlife impacts, we re-categorized expenditure based on the activities mentioned in the audit reports into eight categories and two additional items i.e. others and unspecified for those not covered within eight categories and unspecified in the audit reports (Table 5.1). The amount of the funds received and expenditure in each category was summarized as percentages and presented in bar graphs in the final analysis.

We used linear regression and Pearson's correlation to assess the relationship between the investment made to reduce human-wildlife impacts in the buffer zone and the frequency of wildlife attacks on humans and livestock. The data on the frequency of wildlife attacks over the years was obtained from Lamichhane *et al.* (2018). The analysis was done in R (R Core Team, 2017).

Table 5.1 Expenditure categories of the buffer zone user committee fund utilization.

SN	Expenditure category	Description of the category
1	Prevention and mitigation of wildlife impacts	• Construction and maintenance of the fences (electric, mesh wire, barbed, concrete wall etc.) • Construction of guarding machan (tower) • Subsidy for predator-proof corrals or alternative crops (fish ponds, mentha etc.) • Relief support for the wildlife victims
2	Wildlife conservation and habitat management	• Plantation, grassland and wetland management, anti-poaching patrolling, forest management, wildlife monitoring
3	Community development	• Construction of buildings • Road, culvert, bridges, canal etc. • Community infrastructures (cremation site, resting places) • Drinking water and irrigation facilities
4	Community engagement and IGA	• User groups mobilization, saving and credit groups, cooperatives, trainings on income generation activities such as vegetable farming, mushroom farming, livestock husbandry
5	Conservation education	• Awareness materials development and broadcast such as radio programs, hoarding boards, posters, pamphlets • Conduct awareness camps targeted to specific groups • School education support • Exposure visits
6	Alternative energy	• Biogas subsidy, solar energy, improved cooking stoves
7	Climate change adaptation and disaster risk reduction	• Preparation and implementation of community adaptation plans • Disaster relief funds • Support to the disaster victim families
8	Administrative costs	• Salary of the office secretary • Salary of the forest guards and other support staff • Allowances for the committee members • Training for the committee members and office staff • Office maintenance costs (electricity, fuel, telephone, water, sanitation etc).
9	Others	• Other than the above mentioned eight categories such as investment in the share market, household surveys, food & snacks etc.
10	Unspecified	• Unspecified in the audit reports

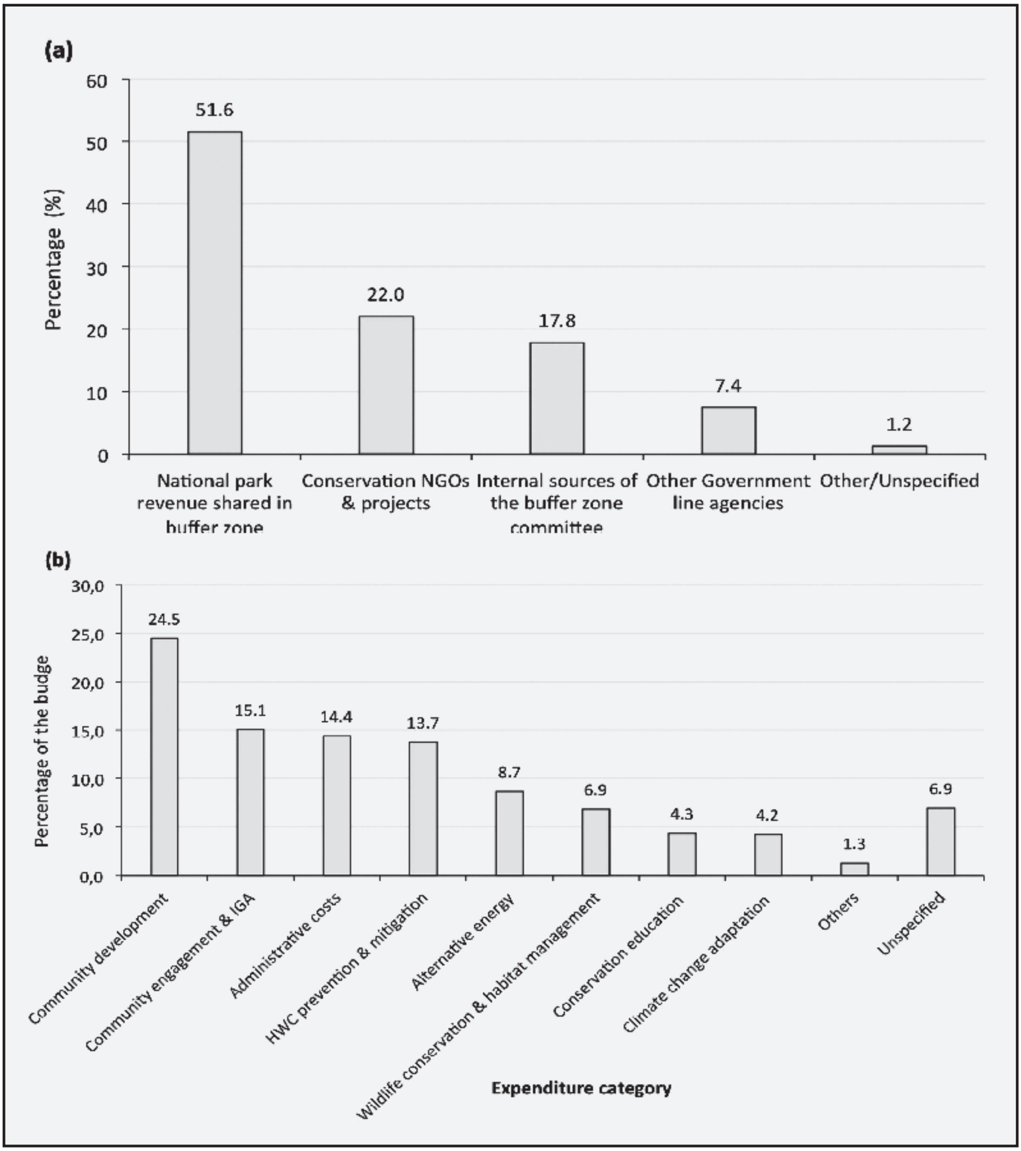

Figure 5.2 (a) Income sources and (b) expenditure in different category by the buffer zone user committees of Chitwan National Park, Nepal during 2005–2015 based on records on annual audit reports.

The Likert scale attitude data were converted into the attitude index by summing response values for each questions dividing by the number of respondents (De Vaus, 2013; Spiteri & Nepal, 2008). We also assessed the socio-economic variables explaining the positive attitude using a binary logistic regression in SPSS 20 (IBM, 2012). The attitude index towards buffer zone management was converted into a dichotomous value to use as the response variable in logistic regression. The values below the mean value on the 1-to-5 was scored as ‘1’ representing the positive attitude and vice versa. Eight independent variables included in the regression analysis which could affect the attitude of people (Carter *et al.*, 2014) were 1) distance to the park, 2) distance to the forest edge, 3) ethnicity, 4) management sector, 5) sex, 6) education, 7) land ownership and 8) occupation.

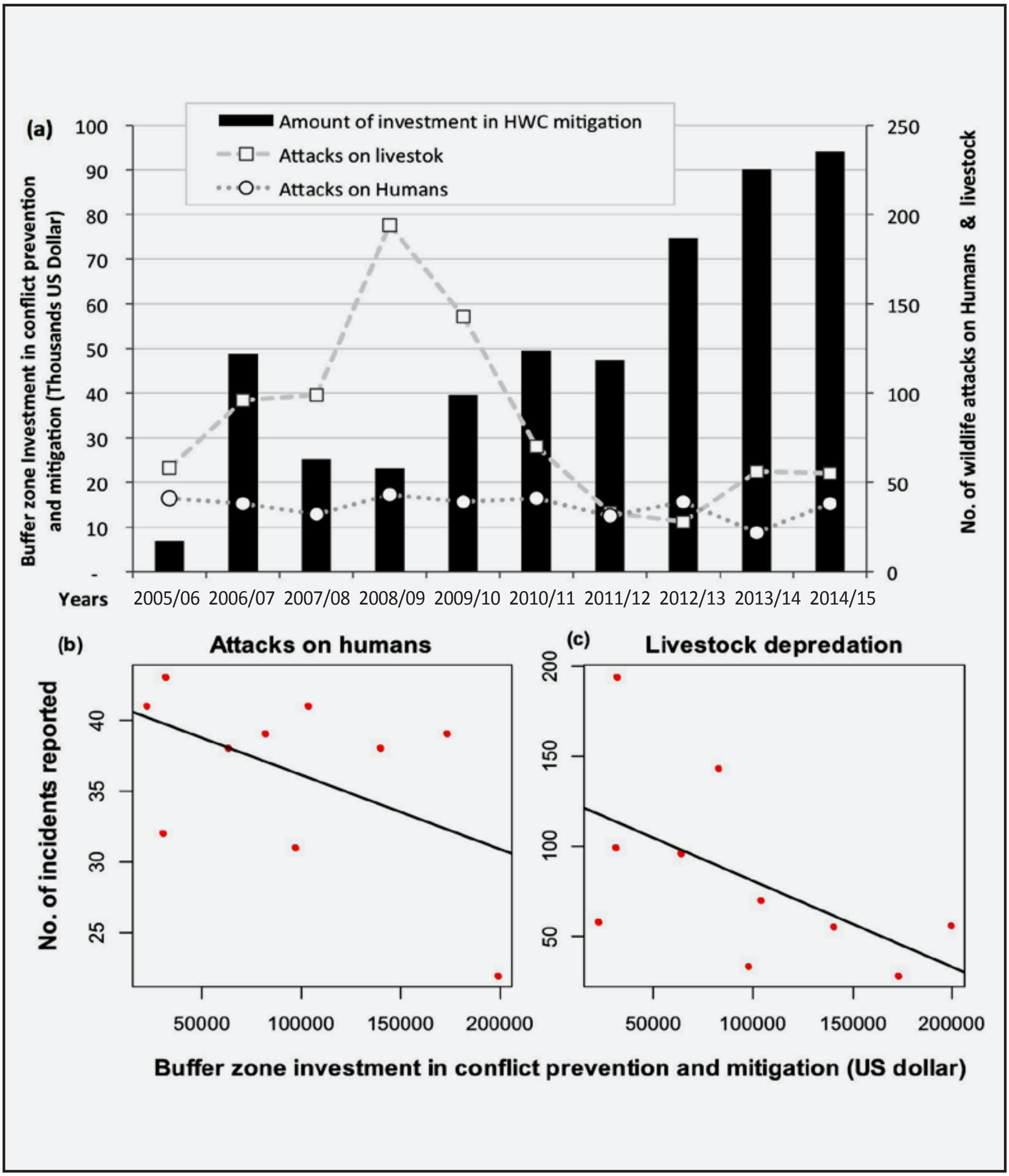

Figure 5.3 Buffer zone investments to minimize human-wildlife impacts and number of incidents (wildlife attacks on humans and livestock) over the years based on audit reports (a) and linear regression of investment versus wildlife attacks on humans (b) and livestock depredation (c).

5.3. Results

5.3.4. Buffer Zone investments and fund utilization

Through the BZUCs, more than US$5.6 million of direct investment was made during 2005/06–2014/15 in the buffer zone of CNP, an average of US$558,000 (range 130,000–1,173 ,000) per annum. Revenue shared by the national park contributed more than half of the BZUC budget (Fig. 5.2).

Contrary to our expectation, the BZUCs spent only a small portion (13.7%) of their fund directly on prevention and mitigation of the human-wildlife conflict through activities such as construction/maintenance of the fences and providing relief for the victims (Fig. 5.2b). However, the amount of budget spent on wildlife conflict prevention and mitigation has been increasing gradually as the total park revenue has been increasing (Fig. 5.3a). The investment for conflict mitigation interventions was negatively correlated to wildlife attacks on humans (-0.49) and livestock depredation (-0.56) but the relationship was not significant (p=0.14 and 0.09 respectively) (Fig. 5.3b).

5.3.5. Assessment of the mitigation measures

Out of the total budget spent on conflict prevention and mitigation, BZUCs invested most of the funds in the construction and maintenance of the physical barriers (85%). The buffer zone communities have constructed approximately 275 km of fence along the forest – settlement boder (Fig. 5.4), about half including electric fences (140 km). The other half includes fences (single or combination with an electric fence) made from barbed wire, mesh wire, PCC with mesh wire, or a dyke (along the rivers) (Table 5.2). Community leaders evaluated multiple mitigation measures practiced within the BZUCs during the focused group discussions (Table 5.3). Most of the BZUCs (13 of 22) proposed mesh wire fences (5 – 7 feet) with PCC on the bottom (2 – 3 feet) as the priority action for conflict mitigation in future (Table 5.3).

Table 5.2. Types and lengths of the fences in different management sectors of the buffer zone of Chitwan National Park based on a field survey in October–December 2017.

Management sector	Types and lengths of fences (km)						Total
	Electric	Barbed	Mesh wire	Mesh wire with PCC	Concrete wall	Others	
East	25.5	21.9	8.9	5.8	4.1	1.8	68.02
Kasara	26.4	13.6	24.0	15.0	1.9	–	80.95
South	47.4	4.8	–	–	–	1.5	53.78
West	40.9	10.5	21.0	–	–	–	72.36
Total	**140.2**	**50.9**	**53.9**	**20.8**	**6.0**	**3.4**	**275.10**

Table 5.3. Major types of fence and other preventive measures currently practiced for reducing HWC in the buffer zone of Chitwna National Park.

Physical barriers

Type of intervention	Years of implemen-tation	No. of BZUCs practicing	Total length of the fences (km)	Future Priority action for no. of BZUCs	Target species	Construction costs #	Maintenance costs	Effectiveness in reducing conflict	Additional evaluation/remarks
Barbed fence	1989-2017	16	50.9	-	All	Medium	Medium	Low	Effective for deer, not effective for wild boar, rhino and elephants
Electric fence 2017	2001-	19	140.2	9	Rhino, elephant	Medium	High	Medium	Effective when maintained properly, regular maintenance is a challenge
Mesh wire fences	2008-2012	12	53.9	-	All	Medium	Medium	Low	Stops deer but not effective for wild boars, rhinos
Mesh wire fences with PCC	2013-2017	7	20.8	13	All	High	Low	High	Effective for most of the species except elephants, cost of construction is high
Concrete wall	2015-2017	3	5.9	1	All	Very High	Low	High	High construction costs, stops natural water flow in flood prone areas

Other

Type of intervention	Years of implemen-tation	No. of BZUCs practicing	Total length of the fences (km)	Future Priority action for no. of BZUCs	Target species	Construction costs #	Maintenance costs	Effectiveness in reducing conflict	Additional evaluation/remarks
Predator-proof corrals	2015-ongoing	7	NA	6	Tiger, leopard	Low	Medium	High	Chances of predation when animals are out of the corrals
Community Guarding machan	All time	4	NA	-	All species	Low	Medium	Medium	Labor intensive, needs active guarding
Awareness programs	1995-ongoing	All	NA	15	All species	Low	Medium	Low	Effective in reducing wildlife attacks on humans, more awareness programs needed
Other*	Different periods	7	3.4	8	Selected species	NA	NA	NA	

** Other includes flashlights, Dyke, fish Pond etc. # costs (USD) per km of fence construction (Very high – more than 10,000 USD per km; High - 5,000 to 10,000; Medium – 1000 to 5000 USD; Low – less than 1,000 per km)*

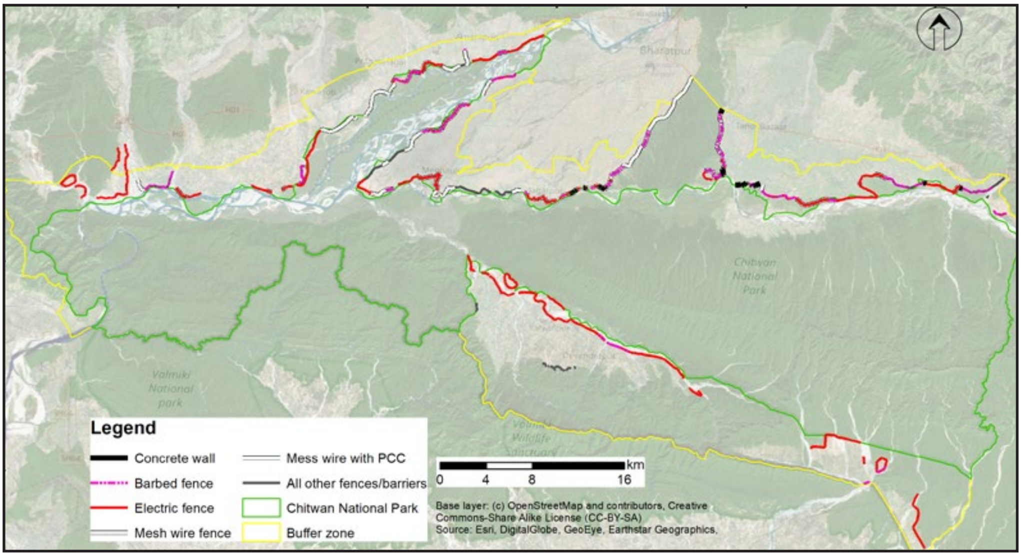

Figure 5.4 Fence installed along the forest - settlement borders in Buffer zone of Chitwan National Park, Nepal.

5.3.6. Attitude towards the buffer zone programs and conflict mitigation

A total of 399 respondents were interviewed, a majority male (58%) and involved in farming (85%). Ages ranged between 16 and 78 years with an average of 45 years. About three quarters (73%) of the respondents had primary education while less than 10% had secondary or higher education and 17% were illiterate. Ethnicity was divided into four categories 1) High cast Hindu (44%), 2) Hill Tibeto-Burmese (24%), 3) Terai Tibeto-Burmese (21%) and 4) Lower caste Hindu (11%). Average land holding per household was 0.5 ha. Most of them (87.5%) had livestock or poultry.

The overall attitude of respondents towards wildlife conservation was positive (2.37 ± SE 0.25) on a 1-to-5 scale (Table 5.4). People's attitude towards the participation of households in wildlife conservation, particularly the willingness to manage human-wildlife conflicts, was more positive (1.91) compared with the attitude towards current practices of conflict mitigation (2.51), the role of the national park (2.42) and the role of the buffer zone program (2.84). Regression analysis shows that a positive attitude is associated with the management sectors (East and Kasara) and ethnicity (Table 5.5).

5.3.7. Conflict management and compensation payments in the buffer zone

About half of the respondents (44.6%) reported the increase in damage from wildlife during the previous five years primarily due to widespread crop raiding by herbivores while another half thinks damage either decreased (43.9%) or has not changed (11.5%). The highest number of the respondents (67%) reported wild boar as the main problem causing species around Chitwan NP followed by rhinos and chital. Conflicts with carnivores

Table 5.4. Attitude of people towards the carnivore conservation, participation and conflict mitigation in Chitwan National Park, Nepal based on questionnaire survey in April - June 2016 ($\bar{x}$ and S.E. - mean and standard error of the attitude scores for each question; G $\bar{x}$ -mean attitude score for each group of questions).

Questions 1-to-5 scale (1 = Strongly Agree, 5 0.0 Strongly disagee)	Average Score		
	$\bar{x}$	S.E.	G $\bar{x}$
General attitude towards wildlife			2.04
1. Wild animals have a right to live in the forest	1.45	0.06	
2. Wildlife attracts tourists and brings revenue to the Park, which benefits us	1.90	0.05	
3. If tiger and leopard disappear from Chitwan, it is a not a good news for me.	1.55	0.04	
4. Tiger and leopard population should be increased in coming years	2.29	0.08	
5. Wildlife conservation benefits me directly.	3.01	0.07	
Conflict management			2.51
6. Wildlife should be conserved only if conflict with humans can be reduced.	1.43	0.05	
7. Existing conflict-mitigation measures for wildlife conflict is not adequate	1.89	0.05	
8. In case of severe conflict, problem animals should be terminated	4.20	0.05	
Role of the national park			2.42
9. National Park authorities are responsible for HWC, they should manage it	1.89	0.06	
10. National Park authorities are playing a positive role for human-wildlife conflict mitigation	2.75	0.05	
11. Government relief for loss done by wildlife is helping to victim families.	2.63	0.05	
Role of the buffer zone			2.84
12. Buffer zone institutions playing a positive role for human-wildlife conflict mitigation	2.57	0.05	
13. Buffer zone institutions have given adequate priority to HWC mitigation	3.34	0.05	
14. Community forests are playing a positive role in HWC management	2.62	0.05	
Household responsibility & participation for conflict mitigation			1.91
15. I live close to the forest with risk of wild animals and it's also my responsibility to avoid it	2.30	0.05	
16. I would like to participate in community wildlife conflict mitigation programs.	1.84	0.04	
17. I would like to learn more about wild animals, their behavior and ecology.	1.66	0.04	
18. I should participate to maintain electric fences and physical barriers constructed to avoid conflict	1.85	0.04	

were reported to be less severe. Five carnivores – tiger, jackal, sloth bear, leopard, and jungle cat – were reported to be affecting local residents by threatening their safety or lifting livestock/poultry. Additionally, smaller animals such as monkeys, birds, snakes and porcupines were also reported having negative impacts on the life and livelihoods of people on smaller scales (Fig. 5.5).

The majority of the respondents (60%) were not satisfied with the buffer zone programs and suggested to focus more on direct interventions to reduce wildlife impacts (Fig. 5.6a). Similarly, more than two third of the respondents (71.7%) were aware of government compensation for wildlife damage. However, most of them (more than 90%) were not satisfied with the existing payment mechanism. It took an average of 6.6 months to

Table 5.5. Binary logistic regression examining the relation between sociodemographic variables and positive attitudes towards buffer zone management in Chitwan National Park.

Variables	B	S.E.	Wald	p	
Distance to park	0.00	0.00	0.85	0.36	
Distance to forest edge	0.00	0.00	1.56	0.21	
Ethnicity					
High caste Hindu	–	–	5.51	0.14	
Hill Tibeto-Burmese	1.39	0.61	5.25	0.02	*
Terai Tibeto-Burmese	1.18	0.65	3.29	0.07	
Lower caste Hindu	1.39	0.63	4.85	0.03	*
Management sector					
East	–	–	9.75	0.02	*
Kasara	-0.97	0.45	4.59	0.03	*
South	0.04	0.39	0.01	0.91	
West	0.48	0.42	1.34	0.25	
Gender					
Male	–	–	–	–	
Female	0.21	0.29	0.53	0.47	
Have livestock					
Yes	–	–	–	–	
No	-0.27	0.50	0.30	0.58	
Education					
Illiterate	–	–	5.30	0.15	
Primary education	-0.83	0.75	1.23	0.27	
Secondary education	0.13	0.60	–4	0.83	
Higher education	0.72	0.79	0.82	0.37	
Land ownership					
less than 0.1 ha	–	–	2.91	0.41	
0.1 - 0.5 ha	-0.09	0.57	0.02	0.88	
0.5 - 1 ha	0.50	0.46	1.22	0.27	
greater than 1 ha	0.48	0.48	1.01	0.32	
Occupation					
Agriculture	–	–	2.67	0.45	
Off-farm business	-0.47	0.69	0.46	0.50	
Student	0.14	0.90	0.02	0.88	
Other	0.43	0.91	0.22	0.64	

receive the payments and most of the respondents viewed it as a lengthy and highly bureaucratic procedure. The highest number of people (36.1%, n=399) prefer the compensation payments to be made by BZUCs or community forest user groups while others think municipalities, other conservation organizations or the national park authority itself should make the payments (Fig 5.6b).

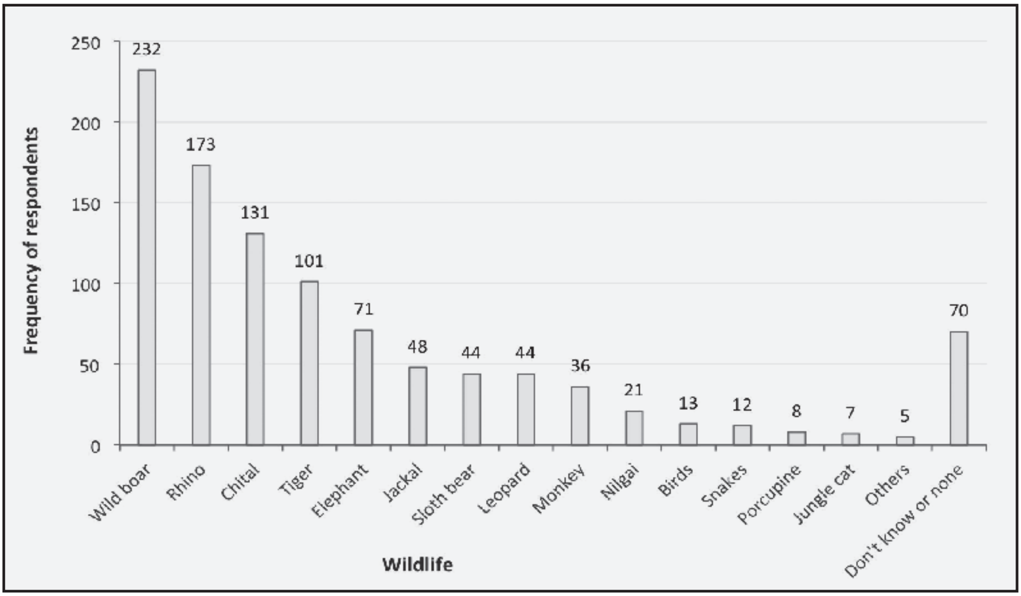

Figure 5.5 Frequency of respondents reporting the problem caused by different wildlife species during a questionnaire survey conducted in April – June 2016 in buffer zone of Chitwan National Park, Nepal.

5.4. Discussion

We found that the buffer zone program around CNP has been firmly institutionalized. They receive a regular support from the government (30 – 50% of the park revenue shared with the buffer zone) as well as grants and subsidies provided by conservation organizations and government line agencies. We documented that a relatively low proportion of the budget was spent on direct interventions to reduce wildlife impacts on communities (13.7%). However, the amount of investment in buffer zone programs, as well as the fund spent in reducing human-wildlife impacts are gradually increasing over the years with increasing revenue of the park. We suggest that various preventive and mitigative measures practiced by the BZUCs have contributed to reduce the wildlife attacks on humans and livestock, although crop raiding was found widespread. Most of the people were positive towards wildlife conservation but they were not satisfied with current practices of the buffer zone program as well as conflict prevention and mitigation measures.

5.4.1. Buffer zone fund utilization

The annual budget of all BZUCs sums more than US$1.2 million in recent years, which is a large amount in a poor country such as Nepal. The annual budget of the park and buffer zone substantially increased after the government raised the daily entry fee in 2013 from Nepalese Rupees 500 (~ US$5) per day to Rupees 1,500 (~US$15) per day. The number of visitors is also increasing gradually (~ 150,000 in 2016/17; CNP, 2017). In addition to the park revenue, more than 70 community forests in the buffer zone also earn annually approximately 0.5 million US dollar from ecotourism activities (CNP, 2017) spending some of it to manage human-wildlife impacts. Not all parks/reserves in Nepal have such a large revenue (DNPWC, 2017). Despite such large and sustained investments over two decades in Chitwan's buffer zone, wildlife damage on life and livelihood of the local community is still substantial (Dhungana *et al.*, 2018; Lamichhane *et al.*, 2018a; Pant *et al.*, 2016; Silwal *et al.*, 2017). Studies show a marginal decrease of wildlife attacks on humans and livestock by carnivores in recent years (Dhungana *et al.*, 2018; Lamichhane *et al.*, 2018a) while people reported a rise in crop raiding by wild herbivores.

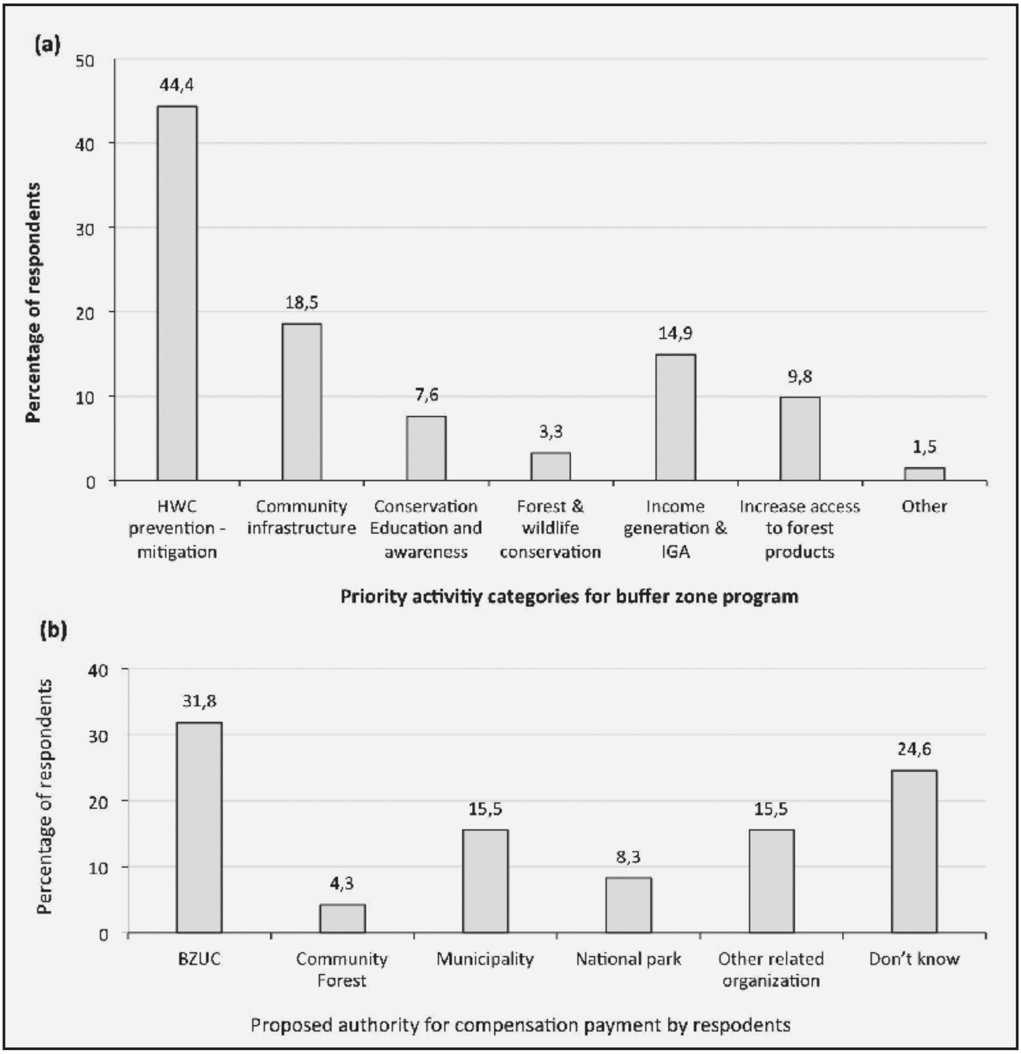

Figure 5.6 (a) Priority actions of the buffer zone program and (b) authority for compensation payments as per the respondents in Chitwan National Park, Nepal.

The buffer zones are designated primarily to create human-wildlife coexistence by providing an ecological buffer to wildlife and a socioeconomic buffer to the communities (Budhathoki, 2004; Heinen & Mehta, 2000; Nepal & Weber, 1994). Although, Nepal endorses these aims, the buffer zone program in Chitwan has given higher priority to community development (24.5%) compared to prevention and mitigation of human-wildlife impacts (13.7%). Similar finding with a much higher proportion of the budget spent on infrastructure development (42%) has been reported by Silwal *et al.* (2013). Additionally, community engagement and IGA programs (15.1%) and alternative energy such as biogas subsidy, solar energy and improved stoves (8.7%) were also implemented to develop alternative livelihoods and reduce forest dependency. In contrast, only 7% was spent on wildlife and habitat management. Such preference towards community development programs is influenced by the political interest of the buffer zone leaders. Although the buffer committees are elected through a democratic process, local political parties have a great influence. The elected members are also interested in gaining popularity in the community through such development activities which supports their political career. The infrastructure development and construction work also generate local economic opportunities for a broader range of community members such as employment for laborers, market for different products and services. However, investments in community development raise aspiration of people from the buffer zone program which is unable to fulfill the extensive development needs with a limited budget. Such concerns have beeb raised since the establishment of the buffer zone in Nepal (Heinen & Mehta, 2000). Hence, prioritization of the activities is required to obtain the intended benefits of the buffer zone programs.

The inverse correlation between budget spent in direct interventions for conflict prevention/mitigation and wildlife attacks on human and livestock depredation respectively indicates the importance of such interventions. Populations of large carnivores and herbivores are increasing over the years (Karki *et al.*, 2015; Subedi *et al.*, 2017) whereas conflict incidents have not increased proportionally (Lamichhane *et al.*, 2018a). Fences have been installed along the forest-settlement borders by the BZUCs and community forest user groups using their internal funds as well as the support of the park authority, conservation NGOs and other government agencies (Banikoi *et al.*, 2017). In addition, interaction between wildlife and humans have also decreased through the facilitation of buffer zone programs and livelihood diversification from off-farm income (less depended on forests, and hence, less frequent visits to wildlife inhibited forests) (Khatiwada *et al.*, 2017). Buffer zone programs also initiated a compensation payment mechanism in 1999 to wildlife damage to humans, livestock, and property damage which is continued in a different form after the government endorsed the relief guidelines for wildlife damage in 2009 nationally (Lamichhane *et al.*, 2018a). Most of the buffer zone committees have also established a basket fund for the immediate relief of victims. Such measures probably have also contributed to reduce the resentment of people towards wildlife.

Although our findings indicate the need of prioritization of buffer zone programs towards direct interventions on conflict prevention and mitigation, the existing buffer zone policy of Nepal favors community development provisioning 30% of the annual budget

(Budhathoki, 2004). However, the policy suggests, such activities should be small-scale, production oriented and have a clear linkage to reduce pressure on forests and enhancing human-wildlife coexistence (MOFE, 1998). In contrast, the community development activities in Chitwan's buffer zone includes community buildings and infrastructures (30%), river embankments (26.1%), road construction (24.1%), drinking water and irrigation facilities (13.7%). A study focusing on conservation incentive distribution in Chitwan's buffer zone shows residents experiencing the greatest costs in terms of crop damage or livestock are benefited least (Spiteri & Nepal, 2008). Thus, despite of large investments in the buffer zone, the affected communities still remain deprived.

5.4.2. Direct interventions to reduce human-wildlife impacts

We documented a range of preventive and mitigative measures practiced over time in the buffer zone of CNP for reduction of detrimental wildlife impacts on local communities. During the initial years of the buffer zone programs (early 1990s), barbed fences (sometimes accompanied by trenches) were installed encompassing forest patches with the dual purpose of preventing domestic livestock grazing and checking wildlife to enter into the settlements (Sharma, 1990). These fences effectively stopped some wild herbivores such as chital and muntjac while rhinos and wild boars usually break through such fences (Sharma, 1990).

In early 2000, electric fences have been adopted (constructed using local materials) in the buffer zone to stop large animals like elephants and rhinos (Sapkota *et al.*, 2014). Generally, the electric fences are 5 – 6 feet tall with 2 – 3 parallel galvanized wire attached to wooden poles using plastic insulators and connected to the energizer which gives intermittent electric pulses. Electric fences became very popular; 19 of the 22 BZUCs installed them in their areas during 2006 –2012 with a total length of 140 km. In some communities, the electric fences reduced up to 60% livestock depredation and 70% of crop loss especially from the rhinos (Sapkota *et al.*, 2014). Regular maintenance of the electric fences is necessary to function well, which was the major challenge in Chitwan NP's buffer zone. Banikoi *et al.* (2017) reported only 26% of the electric fences are operational around Chitwan NP, the rest are non-functional due to lack of maintenance. Although BZUC receives funds from the park authority annually, they do not have a practice of allocating funds for maintenance of the fences. During our survey, we also observed that local people sometimes break the fences to enter forests for forest resources.

With the recent failure of the electric fences, the BZUCs are replacing or complementing the fences with the construction of mesh wire fences or concrete walls. During the focused group discussions with community leaders, a majority expressed a preference for construction of fences that are effective for wide range of species, reasonable cost, durable and requiring a low level of maintenance. Among the different types of the fences, most of the community leaders preferred the 5 – 7 feet tall mesh wire fence with 2 – 3 feet concrete base along the forest-settlement borders (Fig 5.7). In areas with frequent elephant visits, they suggested two electric fence wires attached towards the forest side of the mesh wire fence. Along the rivers, dikes with electric fences on the top were proposed.

Figure 5.7 An example of the mesh wire fence communities prefer to construct along the forest-settlement border. The fence has a concrete base of about 2 feet and 5 feet tall mesh wire anchored to the iron poles set in a concrete base.

The fence construction should be synchronized among the BZUCs to avoid the increase of wildlife impact in other areas without fences. In addition to monetary investments of the buffer zone programs, some regulations such as grazing restriction (Gurung *et al.*, 2009) and limits on forest resources collection have also contributed to a reduction of damage caused by wildlife, especially to the livestock depredation around Chitwan NP (Lamichhane *et al.*, 2018a). Because most of the livestock depredation happened within the stalls, some committees (six of 22 BZUCs) recommended a subsidy for predator-proof corrals, especially for goats.

5.4.3. Attitudes of local people towards conservation and buffer zone program

People's attitude towards wildlife conservation was largely positive similar to those reports of previous studies (Carter *et al.*, 2014; Stapp *et al.*, 2016). We found that people's willingness to participate in conflict prevention and mitigation is relatively high compared with the attitude towards current practices of buffer zone and management of human-wildlife impacts. Although attitude index is still towards the positive side (below 3 on 1-to-5 scale), the role of buffer zone programs received least positive response among the categories.

Only ethnicity and the management sector had a significant effect on attitudes of people towards buffer zone programs. Eastern sector of Chitwan is associated with generally positive attitude, while Kasara sector with negative attitude. The eastern sector received more attention since the establishment of the park and buffer zone activities were initiated here in the 1990s, thus a positive attitude is expected here. In contrast, the Kasara sector has experienced a high number of human (western & central part) and livestock loss (eastern part) caused by wildlife. Although the southern or Madi sector are most affected by the wildlife impacts, their attitude was not significantly different. Hill Tibeto Burmese ethnic groups are involved in more off-farm activities and foreign employment which could have resulted in positive impacts as they have less day to day interaction with wildlife. The positive attitude of lower caste Hindu was not expected but the recent focus of buffer zone programs on underprivileged groups might have been a contributing factor.

The majority of people think wildlife damage is decreasing or not changed over the previous five years as documented in an earlier study based on reported cases of wildlife attacks on humans and livestock (Lamichhane *et al.*, 2018a). Compared to the initial decades of park establishment (Mishra, 1982a; Nepal & Weber, 1995; Sharma, 1991) the wildlife damage has been reduced in recent decade (Dhungana *et al.*, 2018; Lamichhane *et al.*, 2018a; Sapkota *et al.*, 2014). However, about half (44.6%) of the respondents still think there is an increase in wildlife impacts. The reason could be the widespread crop raiding by herbivores. For instance, locals reported herbivores like wild boar, rhino and spotted deer are causing more damage in their life and livelihood compared to carnivores (Lamichhane *et al.*, 2018a). Although different preventive measures are practiced, they seem to be less effective in deterring crop-raiding herbivores, especially wild boar, from entering agricultural areas. The majority of the respondents (55%) were aware of buffer zone activities in their locality but only 40% of them were satisfied with the current interventions. Although a wide range of activities covered by the buffer zone programs over the years, local people suggested to focus on direct interventions to reduce wildlife impacts.

Although ~75% of respondents were aware of compensation for wildlife damages, a large majority (more than 90%) were not satisfied with current practice. They think the process is highly bureaucratic and payment is not sufficient. The Nepalese government has endorsed compensation guidelines to the damages caused by major 14 wildlife species throughout the country (MOFE, 2017). To receive the payment, victims should make an application to the respective park together with 6 – 9 supporting documents based on type of the damage (attack on human, livestock, property damage or crop raiding) including the photographic proof of damage, financial loos assessed by authorized persons, and recommendation from the respective municipality as well as the buffer zone user committee. The parks used to forward the application to regional forest directorates which review the application and releases the funds through the same channel. Recently, the government amended the guidelines and gave authority of fund disbursement to respective park authority. On average, locals received the payments more than half a year after the incident. The compensation payments cannot deliver the intended outcome of increasing the tolerance of wildlife damage when the victims are dissatisfied with the payment in terms of time, amount, and procedure (Nyhus *et al.*, 2005). Respondents have thus suggested to simplify the payment process and authorize local institutions such as BZUCs, respective parks or local government (municipalities) to make the compensation payments. Moreover, the existing compensation scheme only covers a group of species (tiger, common leopard, snow leopard, clouded leopard, rhino, elephant, gaur, wild water buffalo, bears, wild boar, wild dog, grey wolf, mugger crocodile, Burmese python). Crop raiding by wild boar and chital is reported frequently and was not covered by the compensation guideline during our survey. Loss caused by chitals and wild boars were widespread in the buffer zone, and thus considered too costly for the government to cover, and quantification of the loss is difficult. However, recent amendment of the compensation guidelines in 2018 included the crop loss from wild boar.

5.4.4. Implications for buffer zone policy in Nepal

Our study documented the importance of the buffer zone programs in reducing human-wildlife impacts and encouraging community participation in conservation. It has been more than two decades since the buffer zone program was formally recognized in Nepal (Budhathoki, 2004; Heinen & Mehta, 2000). At present, Nepal is in political transition after promulgation of a new constitution in 2015 establishing a federal democratic republic. Subsequently, a range of policies and institutional reforms has been ongoing within the framework of the new constitution. The position of national parks and wildlife reserves are well defined under the responsibility of the federal government, whereas the status of buffer zone management is not clear. As the buffer zone is part of an integrated system of the protected area, its close association with the respective park is important. However, the buffer zone may fall under the jurisdiction of the state government and the local government (municipalities) based on the constitutional provisions. This could impact implementation of the buffer zone programs.

Along with institutional arrangement, buffer zone management guidelines also need a prioritization of activities. Our study shows the need for increasing investment in direct intervention to reduce human-wildlife impacts. Local residents of the buffer zone in our study suggested prioritizing the buffer zone activities to minimize wildlife impacts on people and increase access to forest products rather than emphasizing community development. There are various government line agencies to carry out the development works. Thus, we recommend amendment of the buffer zone management guidelines with the provision of 25 – 50% of the buffer zone budget in direct interventions of conflict prevention and mitigation. Recently, Shivapuri-Nagarjun National Park next to Kathmandu (capital city of Nepal) has developed separate guidelines for its buffer zone management allocating 25% for the prevention and mitigation measures of human-wildlife impacts. This could be adopted by other buffer zones of the national parks and reserves in Nepal.

5.5. Conclusion

Our study has several implications for conservation policy particularly on designating buffer zones and prioritizing actions. First, prioritizing the buffer zones programs in direct interventions to reduce wildlife impacts by provisioning a certain portion (25 – 50%) of buffer zone funds will benefit the local community as well as reduce the conflict. The communities preferred to construct the 5 – 7 feet tall mesh wire fences with 2 – 3 feet concrete base along forest-settlement border through buffer zone funds. Second, improving the benefit-sharing mechanism by targeting the most affected communities will result in the intended benefits of the buffer zone programs (Spiteri & Nepal, 2008). Similarly, compensation payment should be revised to cover all conflict-causing wildlife and payment procedures should be simplified by giving more responsibility to buffer zone user committees, local government bodies like municipalities or the respective protected areas. We also recommend a systematic review of the current implementation of buffer zone programs to understand existing problems and design improved strategies for local engagement in wildlife management and conservation in the changing national and global context.

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Writing – original draft: BRL, GAP, HHD
Writing – review & editing: BRL, HL, GAP, HHD, HHD

A human dummy constructed on the pole of electric fence to scare animals away
(Photo by Pabitra Gotame/NTNC-BCC).

6 Synthesis

6.1. Introduction

Large carnivores play an important role in ecosystem functioning (Ripple *et al*., 2014). On the other hand, these carnivores including tigers (*Panthera tigris*) and leopards (*P. pardus*) are locally and regionally threatened with extinction (IUCN, 2018). Expansion of human land use at the expense of natural areas caused their habitats to become increasingly insular, fragmented and degraded. Survival of these wider ranging species is dependent on conservation in increasingly human-dominated landscapes (Karanth & Chellam, 2009; Lambin & Meyfroidt, 2011). Some of the remaining habitats have been set aside for protection as parks and reserves where their populations are recovering (Bruner *et al*., 2001; IUCN, 2008; Leopold, 1963). However, most protected areas are not sufficient to support viable populations of large carnivores on their own for long-term conservation (Wikramanayake *et al*., 1998). Alternative strategies are required in which wildlife and humans co-adapt and coexist in a shared landscape (Carter & Linnell, 2016). The strategy includes protection of core breeding areas (or source sites) of wildlife connected through the forest corridors and embedded in larger landscapes (Joshi *et al*., 2016). The Terai Arc Landscape (TAL) in Nepal and India supports a wide range of species, including large mammals (both herbivores and carnivores) (Chanchani *et al*., 2014). My study focused on two large carnivores - tigers (*Panthera tigris*) and leopards (*Panthera pardus*) in a protected area (Chitwan National Park) and its buffer zone, within the TAL.

In spite of their ecological and cultural roles, tigers and leopards sometimes affect local communities by killing livestock or attacking humans (causing injury or death). Local people affected by these carnivores may subsequently persecute them or engage in retaliation (Madden, 2004). Management of such negative impacts is challenging when serious damage to human lives or livelihoods is caused by globally threatened large carnivores (Dickman, 2010; Woodroffe *et al.*, 2005). In many cases, such impacts reduce support for wildlife conservation (Acharya *et al.*, 2016). Thus, a holistic understanding of how people and wildlife are interacting with each other is necessary to facilitate the coexistence (Carter, 2013). I focused this study on large carnivores (particularly tigers and leopards) in Chitwan National Park (CNP) and adjoining forests. I used both a socio-economic and an ecological approach by collecting data related to inter-species interaction between tigers and leopards, their impacts on humans and responses (or efforts) of the communities to minimize the impacts. The combined information was analysed to answer the following research questions of my study:

i) How does wildlife affect communities in terms of attacks on humans and economic losses?
ii) Is an entire population of large carnivores or a specific group of individuals (sub-set of the population) causing the conflicts?
iii) Which factors facilitate the co-occurrence of tigers and leopards in Chitwan and how does it affect the conflict with communities?
iv) How are communities responding to wildlife impacts?

The four chapters (Chapter 2 - 5, presented as research papers) answer these research questions. Chapter 2 provides an overview of the wildlife attacks on humans and economic losses (livestock depredation, crop raiding and property damage). This chapter also makes a comparison between the wildlife damage caused by herbivores and carnivores. Chapter 3 examined whether all individuals within a large carnivore population have equal chances to cause conflict with communities or whether, in fact, some individuals or group of individuals are disproportionately involved in the conflict. The tiger was studied as a representative member of large carnivores. In Chapter 4, I studied the interaction between two large carnivores, i.e. tigers and leopards, in terms of distribution, density, activity pattern and diet as well as the influence of such interaction in human-large carnivore conflicts. Another chapter (Chapter 5) focused on responses of the communities in terms of reducing wildlife impacts. This chapter (Chapter 6) integrates the findings of Chapters 2 - 5.

6.2. Large carnivore impacts on humans and the social aspects of coexistence

6.2.1. Wildlife attacks on humans and livestock

In Chapter 2, I presented the spatial and temporal patterns of wildlife attacks on humans and wildlife in the buffer zone of CNP. I found 12 wildlife species attacked on humans during 1998 – 2016, with an average of 40.6 attacks (9.3 fatalities and 31.3 injuries) annually. Attacks on humans by herbivores (rhinos, elephants, wild boars etc.) were more numerous compared to attacks caused by large carnivores (tigers, leopards and sloth bears). This indicates that the majority of wildlife attacks on humans may be accidental due to sudden encounters rather than by deliberate attacks to kill for food. The communities whose livelihood is more dependent on forests like the Terai indigenous communities and the *Dalits* (underprivileged group) were attacked more frequently than expected whereas the immigrant communities were attacked less frequently. The reason for this may be that indigenous and *Dalit* communities enter the forests more often to extract natural resources which are necessary for their livelihood. The immigrant community generally tries to find safe and accessible areas to settle. They are also involved in diverse economic opportunities and less dependent on forests, thereby reducing the encounters with wildlife. Alternative livelihoods and awareness programs targeting the vulnerable communities (indigenous and *Dalit*) will help to reduce the conflict.

Similarly, every year an average of 123 heads of livestock was killed by carnivores. Most of the livestock depredation was caused by tigers and leopards. Leopards mostly killed medium-sized livestock (goats and pigs) whereas tigers killed both medium and large-sized livestock (cattle, buffalo). Tigers caused more livestock depredation than leopards during the entire study period; however, leopards have killed comparatively more livestock in recent years (2014 - 2016). The increasing tiger population and density might have exerted pressure on the leopards, pushing them towards marginal habitats close to human settlements where they killed livestock.

The frequency of conflict incidents caused by large carnivores (tigers and leopards) was comparatively lower during a full moon period, but the difference was not statistically significant. In contrast, there was a significantly higher number of conflict incidents caused by herbivores (rhinos and elephants) close to full moon periods. Attacks on humans and livestock by tigers and leopards occur more frequently at night as both tigers and leopards are nocturnal predators (Carter *et al*., 2012; Thapa, 2011) which prefer hunting in the dark. During full moon periods, the higher luminescence at night may prevent tigers and leopards from coming out of the forest, thereby reducing the possibility of attacks on humans and livestock. Such ecological instinct can be utilized for conflict prevention by increasing the light in the periphery of the house (including livestock corrals and in the streets) especially during dark nights (new moon periods). Similarly, using the flashlights when walking at night should be encouraged to prevent wildlife attacks.

6.2.2. Changing social context and conflicts

I found that there was an insignificant but decreasing trend of the wildlife attacks on humans and livestock over time with a significant variation over the years (Chapter 2). An increase in wildlife populations did not result in a respective increase in the number of conflicts. Wildlife populations like greater one-horned rhinos (*Rhinoceros unicornis*) and tigers have peaked in recent years in CNP whereas, the highest conflict incidents were recorded during 2002 – 2004 (Lamichhane *et al*., 2018a). Gurung *et al*. (2008) also documented the higher number of tiger attacks on humans between 1998 and 2004. After 2004, conflict incidents decreased, probably due to introduction of a number of conflict mitigation measures practiced in the buffer zone, including segregation of human use and wildlife areas through grazing restrictions, construction of fences and other measures. The livelihoods of local communities are also gradually changing.

The construction of fences, predator-proof corrals, awareness programs and other mitigation measures practiced by buffer zone communities have reduced human-wildlife interaction ultimately resulting in a lower incidence of conflicts. In addition, the changing social context and diversified livelihood options of local communities in the periphery of Chitwan has also helped to reduce the impacts of wildlife. For example, I found a significant inverse relationship between the number of people who took foreign employment and the number of livestocks killed. When a member of a family takes a job abroad, the household income increases and they have the freedom to choose other economic opportunities that reduce dependency on livestock and forest resources. This ultimately reduces the possibility of wildlife attacks on family members or their livestock. Thus, the attraction of the younger generation towards non-farming jobs (in service and business sector) or foreign employment may reduce the conflict and facilitates the coexistence between local communities and wildlife. Increasing income from tourism enterprises in the area has also contributed to reduce the number of conflicts by providing an alternative livelihood to locals as tourist guides, jobs in hotels and other tourist facilities.

Similarly, there was a gradual decrease in the percentage of households owning livestock as well as the average size of stock per household in the buffer zone of CNP. Most of the households (more than 80%) practice stall feeding, which is facilitated by grazing restrictions, adoption of improved livestock varieties, the use of commercial livestock feeds and a shortage of labour for grazing. However, in the previous five years (2012 – 2016), most of the livestock killing occurred at stalls or corrals, which suggests a need for better husbandry practices with predator-proof livestock corrals, especially in the forest fringe areas.

Our findings show an inverse relationship between people's migration for remittance and the number of conflict incidents and demonstrate the influence of the household livelihood strategy on human-wildlife conflicts. A study by Bhandari (2013) and one by Han (2014) on rural livelihood changes documented labour shortage as the main reason for local villagers to shift from agriculture to off-farm income options (also called 'farm exit') in Chitwan. As young and working, generally male, community members leave to take up employment abroad, it facilitates the family adopting off-farm activities and reduces the chances of an encounter with wildlife. Thus, the changing social context of Chitwan is also favourable in terms of reducing the human-wildlife conflict and it enhances human-carnivore coexistence.

6.3. Large carnivores and humans: biological aspects of coexistence

6.3.1. Ability of tigers to coexist with humans

From the study of the Chitwan tiger population (Chapter 3), I found that not all individuals within a population have an equal chance to cause the conflict and the majority of tigers coexist with humans without causing conflict. My finding is consistent with the findings of Sunquist (2010) in Nepal and Kolipaka (2018) in India. Sunquist has described the amazing ability of healthy tigers to coexist with humans based on his study that tracked radio-collared tigers in Chitwan during the 1970s. In spite of this, there have been frequent cases of tiger attacks on humans and livestock in Chitwan (Gurung *et al.*, 2008). For this reason, I looked in detail at the conflict incidents in CNP caused by tigers during 2007 – 2016. I documented that a majority of the tigers in the population avoided encounters with humans. Most of the resident tigers with a territory in prey-rich areas were not recorded coming out of the park or the forest area. Only a small group of individuals (less than 5%) within the tiger population had emerged from the forests and attacked humans or killed livestock. I concluded that healthy and resident tigers (rather than transient) are less likely to cause such conflicts with humans. Carter *et al*. (2012) reported similar findings from Chitwan regarding resident tigers coexisting with humans and avoiding conflict by temporal separation.

I have also documented the empirical evidence that an increase in tiger population alone does not result in an increase in attacks on humans or livestock in CNP and in the Barandabhar corridor forest. Based on multiple year camera trapping surveys in the Barandabhar, the resident tiger population increased from four to eight between 2013 and 2016 (NTNC-BCC, 2016). In contrast, more attacks on humans by tigers were recorded in 2012 (two persons killed) and 2013 (two killed, one injured) compared to 2016 (no casualties). A human-killing tigress was active during 2012–2013. The tigress started killing humans after she became too old and was pushed out from her territory in the park by other tigers. Although more residential tigers are using Barandabhar, the number of human casualties in this area has dropped afterward (only a woman was killed in 2015). The woman was killed by a transient human-killing tiger (not the residential tigers of Barandabhar) which was later captured by park authorities. The tiger died in captivity (CNP, 2015).

6.3.2. Conflict-causing individuals are different

Based on the findings of my study (Chapter 3), I concluded that there are few individuals within the large carnivore population that disproportionately contribute to human-wildlife conflicts. Similar findings were reported by Swan *et al*. (2017) and Linnell *et al*. (1999). Most of the attacks on humans or livestock depredation were caused by transient tigers without territory. More than half of them were injured or in poor health. I found that most conflict-causing tigers fall into two categories: either they are old and injured animals or they are young dispersing animals forced to reside in the periphery until they establish breeding territories. Only 2% of the resident tigers but 30% of the transient tigers were involved in conflicts. The majority of conflict-causing transient tigers included dispersing sub-adults seeking to establish a territory. An earlier study in Chitwan by Smith (1993) has also reported similar observations about dispersing sub-adults. Kolipaka (2018) also found during his study in India (Panna Tiger Reserve) that young tigers are more likely to visit areas close to the settlements and as they mature, they tend to avoid the human areas and establish territories within the forests.

In my study, I identified 22 tigers that were responsible for most of the conflict incidents during 2007 – 2016 including 13 tigers (including six man-eaters) that killed humans, six serial livestock killers and three stray tigers that threatened the human safety (but did not cause an attack or loss). Thirteen out of these 22 tigers were removed from their habitat (killed or put in captivity) and four were relocated (released at a different location). Some conflict-causing tigers were poisoned (n=3) or killed by villagers in self-defense using a spear (n=1). No action was taken for five of the identified conflict-causing tigers because these tigers either accidentally attacked people in the buffer zone or only attacked people in the core areas of the park, following illegal intrusions. Most tigers that repeatedly killed livestock or attacked people in the buffer zone, posing a threat to human safety, were captured by the park authority. Such removals have lowered the risks of human-carnivore conflict in CNP and adjoining forests in recent years. I conclude that conflict-causing individuals are atypical and show differences with the main population, i.e. young tigers without an established territory, older tigers pushed out of the territory or injured or unhealthy tigers.

6.3.3. Tigers and leopards co-occurring in a human-dominated landscape

I found a high density of two sympatric large carnivores – tigers as dominant and leopards as subordinate – in CNP and adjoining forests (Chapter 4). In contrast to my findings, other studies report the displacement of the subordinate due to intra-guild competition between the predators (Harihar *et al*., 2011; Holt & Polis, 1997; Linnell & Strand, 2000; Odden *et al*., 2010). In my study, the density of both tigers and leopards has increased in the past decade and the populations remained stable between 2010 and 2013. They had a large dietary overlap but their coexistence was facilitated by spatial and temporal segregation of habitats. Tiger distribution was positively related to prime habitats in the river floodplain (alluvial grasslands and riverine forests) having high prey density in core areas whereas it was negatively related to disturbance (livestock presence). In contrast, leopard distribution was positively related to less productive habitat (i.e. sal forests) and locations with livestock presence (disturbance).

Both tiger and leopard occurrence showed a significant positive relation with the detection of their major prey animal, chital *(Axis axis*) in camera. Although chital was the primary prey for both the carnivores, the spatial location was different, i.e. tigers in grasslands and riverine forests, whereas, leopards in sal forests. Leopards also adjusted their activity in locations where tigers were present by increasing their activity in the daytime when tigers are less active. The mosaic of habitats and different levels of anthropogenic pressures in these habitats facilitated tigers and leopards to co-occur by occupying different niches in time and space. The different findings of my research to other studies is probably due to the large prey biomass in the CNP consisting of various sizes of prey including primates (<20 kg) to gaur (*Bos gaurus*, >500kg). A further factor is the habitat mosaics of the park, which consist of grasslands, wetlands and woodlands supporting high densities of multiple carnivore species (Holt & Polis, 1997; Linnell & Strand, 2000; Odden *et al*., 2010).

6.3.4. Leopards on the edge: effects of large carnivores' interactions on humans

My study reveals habitat partitioning by tigers and leopards (Chapter 4) which could be the result of interference competition between the species. It has also influenced their impact on humans. High and stable densities of tigers in the core areas of CNP in recent years have increased recruitment and dispersal of young tigers. These tigers attempt to occupy forest with a low tiger density inside park, the buffer zone or forests outside of buffer zone(Smith, 1993). This ultimately exerts pressure on leopards and pushes them into marginal habitats and forest edges. For instance, more leopards than tiger scats were detected in the buffer zone and in the corridor forest. Livestock grazing and other human activities (collection of vegetables, non-timber forest products, firewood and fodder collection) are comparatively more frequent in those areas. This increases the chances of a leopard encounter with humans and livestock. Wild prey is relatively low in such marginal habitats, hence leopards kill the livestock for their diets (Lamichhane *et al*., 2018a; Odden *et al*., 2010). A higher proportion of livestock in the diet of leopards compared with tigers also supports their use of the boundary of CNP and the buffer zone area where cattle grazing is more common compared to the park (Gurung *et al*., 2009). Such effects have already been observed in the buffer zone of CCNP where communities have reported more livestock being attacked by leopards than tigers in recent years (2014 – 2016). This indicates that leopards are probably more involved more in conflicts with humans, compared to tigers around CNP.

CNP is relatively small (~1,000 km^2) and surrounded by the human settlements and agricultural areas with high human densities (~300 per km^2) in the north, south and west. The park is bordered by three rivers, namely the Narayani, the Rapti and the Reu. High densities of large carnivores are concentrated on one side of these rivers (the park side) whereas communities live or conduct intensive agricultural activities on the other side of the rivers. Although these rivers seem to be geographical barriers, the presence of these rivers does not restrict the movement of people or wildlife. Thus, frequent and intense human-wildlife impacts have been documented close to these rivers (Lamichhane *et al*., 2018a). A long interaction zone (~ 150 km) between humans and wildlife along these rivers with a high density of wildlife in the park at close proximity of humans could be the reason for the comparatively higher number of wildlife attacks on humans and livestock in Chitwan compared to other protected areas of Nepal (DNPWC, 2014, 2015a, 2016). This should be considered when preparing strategies to manage human-wildlife conflicts in and around CNP.

6.4. Conflicts to coexistence: the role of buffer zone

The buffer zone around CNP is designated primarily to create human-wildlife coexistence by compensating for negative impacts of wildlife on local communities and by providing an ecological buffer (Budhathoki, 2004; Heinen & Mehta, 2000; Nepal & Weber, 1994). I found that a range of preventive and mitigation measures was practiced over time in the CNP buffer zone in order to reduce the impact of wildlife on local communities (Fig 6.1). These measures have positively contributed to reducing wildlife attacks on humans and livestock, although crop raiding remains widespread (Chapter – 5). I found an inverse correlation between the budget spent on direct interventions for conflict prevention/ mitigation and the number of wildlife attacks on humans and livestock. In spite of the gradual increase in wildlife populations in CNP, the conflict incidents either remained stable or decreased due to fences and other conflict prevention initiatives (Lamichhane *et al*., 2018a). This decrease was also facilitated by the changing social context and preference of the local villagers towards for employment opportunities less dependent on agriculture and forests.

Figure 6.1 Buffer zone users erecting of a wire mesh fence along the forest settlement border to stop animals entering agriculture fields and settlements. Various kinds of fences installed along the forest edges have contributed to reducing the negative wildlife impacts on humans.

However, I documented that a relatively small proportion (13.7%) of the buffer zone fund was spent on direct interventions to reduce wildlife impacts on communities. A relatively higher proportion of the buffer zone fund (24.5%) was spent on development activities (construction of buildings and other community infrastructure) not directly related to human-wildlife conflict mitigation. Similar concern have been raised since the starting of the buffer zone program (Heinen & Mehta, 2000). Aware of the smaller proportion of funding spent on conflict mitigation, the local residents suggested the buffer zone institutions to prioritize their activities and focus more on conflict mitigation (Chapter 5).

Buffer zone committees also provided compensation for losses from wildlife before 2009. The government of Nepal endorsed guidelines for compensation nationally and started providing compensation according to these regulations. Although people were aware of compensation provisions for wildlife damages, the majority (more than 90%) were not satisfied with the current practice. They think the process is highly bureaucratic and the payments are inadequate, especially for livestock loss and crop damage. Locals reported it taking more than six months to receive compensation payment. Such payments cannot deliver the intended outcome, i.e. increasing tolerance of wildlife damage, when the victims are unhappy with the delays in payment, the amount received and the procedures (Nyhus *et al*., 2005). Respondents have therefore, suggested to simplifying the payment process and authorizing local institutions such as Buffer Zone User Committees, respective parks or local government (municipalities) to make the compensation payments. Moreover, the existing compensation scheme only covers a limited group of species (tiger, common leopard, snow leopard *Panthera uncia*, clouded leopard *Neofelis nebulosa*, rhino, elephant, gaur, wild water buffalo *Bubalus arnee*, bears, wild boar *Sus scrofa*, wild dog Canis alpinus, grey wolf Canis lupus, mugger crocodile *Crocodylus palustris*, Burmese python *Python bivittatus*). Crop raiding by wild boar and chital is reported frequently but was not covered by the compensation guidelines at the time of our survey (a 2017 amendment includes wild boar in the scheme).

6.5. Human-carnivore coexistence from theory to practice

My study on the social and biological aspects of human-carnivore interactions shows that human-carnivore coexistence in a human-dominated landscape is possible. However, as pointed out by Carter and Linnell (2016), there is no common understanding between social and biological scientists about the meaning of coexistence. Here, I define coexistence as a situation of humans and large carnivores sharing a landscape where carnivore population persistence is ensured, their impacts on humans is socially acceptable and institutions are in place to maintain this balance effectively (Chapron & López-Bao, 2016). Thus, coexistence is possible by managing not only human-carnivore interactions, but also the human-human interactions. The biological needs of carnivores should be considered and social tolerance of carnivores should be enhanced to create a coexistence situation in practice.

6.5.1. Considering the biological needs of the carnivores

My findings (Chapter 3), as well as previous studies, have revealed that large carnivores (especially tigers) naturally avoid human areas when their requirements are fulfilled in natural habitats. However, carnivores require large areas that can support sufficient prey for their survival (Sunquist, 1981; Thapa 2011). But the remaining natural habitats are becoming smaller as a result of habitat fragmentation and degradation. Thus, an alternative approach to large carnivore conservation has been proposed, where the biological needs of large carnivores can be addressed in a shared landscape with humans (Carter & Linnell, 2016). It starts with allocating core protected areas by legal provisions and connecting these areas through biological corridors (Chapron & López-Bao, 2016). Around the core-protected areas, an interaction zone (also known as buffer zone) could be defined where wildlife have refuge habitats and local communities are compensated for any negative wildlife impacts (Fig 6.2) (Budhathoki, 2004; Heinen & Mehta, 2000; Nepal & Weber, 1994).

When multiple carnivore species are share the same landscape, interference competition can result in habitat partitioning or displacement of the weaker species. My study documents the co-occurrence of two large carnivores (leopards being the subordinate species, and tigers being the dominant one) facilitated by spatial (habitat) and temporal partitioning. A mosaic of habitats in the protected areas with varying degrees of vegetation cover and prey species could facilitate co-occurrence. The density of carnivores also depends on the prey availability (Karanth *et al.*, 2004). Diversity and density of prey species is also high in heterogeneous (or mosaics of) habitats (Bhattarai & Kindlmann, 2012a). Thus, the management of habitat mosaics is important for increasing density of multiple carnivore species. This can be done with active floodplain management, by controlled burning, periodic cutting, removing invasive species and woody vegetation or with hydrological measures.

Most large carnivores are territorial. When they breed and new animals are added to the populations, the young (or sub-adults) look for areas to establish a territory. As available habitats are limited, they compete to establish the territory in the park or buffer zone, which often leads to violent fights. Sometimes, the younger animals displace adult or old animals; at other times the young animals may get badly injured. The loser of a fight has a high probability of coming into conflict with local communities. If dispersal corridors are available, younger animals could disperse to larger areas in order to explore and establish their territories (Smith, 1993). This would also reduce the chances of conflict. In cases where no such migration is possible, these animals could be translocated (also called assisted migration) to areas where carnivore density is low.

6.5.2. Proactive management of conflicts-causing animals

My study provides empirical evidence that problem-causing individuals exist in large carnivore populations. These individuals have different characteristics compared to the

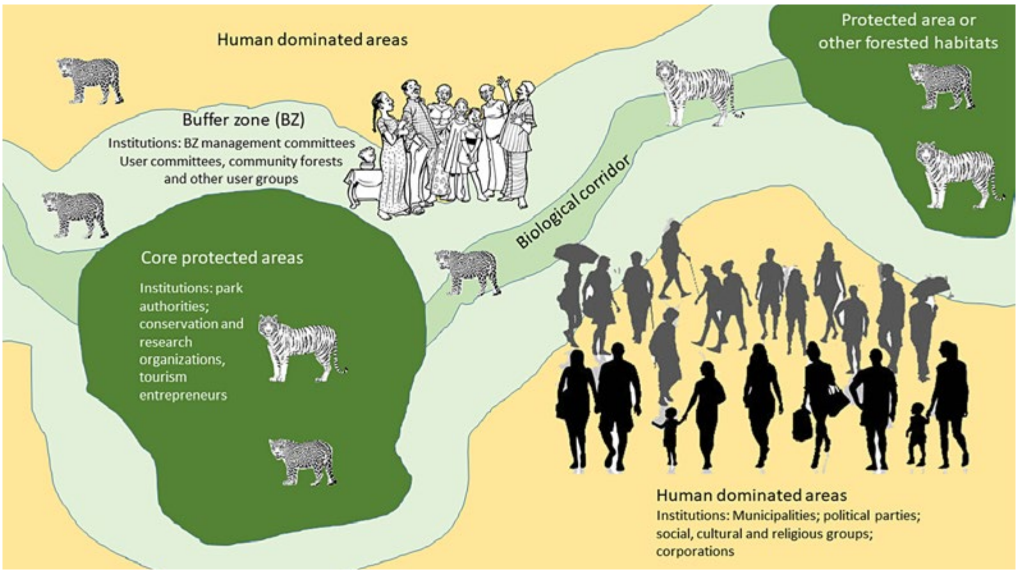

Figure 6.2 Schematic picture of human-large carnivore coexistence in a human-dominated landscape.

main population. Such animals should be identified and removed or managed in a timely fashion in order to reduce conflicts. Regular monitoring of large carnivores in fringe areas using technologies such as camera traps, satellite telemetry and non-invasive genetics paired with the involvement of local communities can deliver crucial information about potential problem individuals (Gurung *et al*., 2008). Community-based rapid response teams (RRT) of para-ecologists should be mobilized in the periphery of protected areas (Schmiedel *et al*., 2016). These teams monitor carnivores and communicate with respective communities (early warning) if such an animal is detected. The preparedness of communities can save human lives and reduce livestock depredation.

As tiger range countries, including Nepal, strive towards doubling the global wild tiger population, it is expected that tiger population grows and recruitment of new tigers increase. This will lead to increased competition for limited habitat available among tigers to establish their territories and pushing out the weaker ones that possibly cause conflit with local communities. Thus, tiger range countries should consider developing and implementing criteria for responding rapidly to such conflict-causing tigers. Along with removal or other mitigation measures for intense conflict scenarios, providing safe passage through corridors to other protected areas or forests with low density (Wegge *et al*., 2018) could reduce the possibility of conflicts. The enhancing of the quality of grasslands and wetlands through intensive management and increasing prey density inside park as well as buffer zones and forest corridors are equally important for reducing conflicts and facilitating dispersal.

6.5.3. Increasing social tolerance

Large carnivores, especially tigers, have a great significance in South-Asian culture (Kolipaka, 2018). The majority of the Nepalese are Hindus or Buddhists who traditionally believe that countless supernatural beings in the form of different creatures are responsible for the creation, protection and destruction of the human life (Berreman, 1997). They believe that every creature in nature has a supernatural role. For example, in traditional societies, if a person is killed by a tiger, instead of blaming the tiger, they consider it to be 'fate of that person' decided at birth and impossible to avoid. Without such a social belief system, it would not be possible to protect life-threatening carnivores freely roaming just a few hundred metres away from the human settlements (Chapter 4). Despite of frequent attacks by carnivores on humans and livestock, most people in the buffer zone support conservation efforts (Chapter 5). However, this traditional belief system is in decline, especially among the younger generation who are increasingly influenced by a modern lifestyle (Ingles, 1995). Thus, economic or socio-cultural incentives combined with legal provisions are necessary to increase the tolerance.

When wildlife and humans share the same landscape, their impacts on each other cannot be avoided entirely. However, the tolerance of communities towards wildlife can be increased by co-managing actual and perceived conflicts (Treves *et al*., 2006) and by ensuring individuals as well as communities benefit from conservation. Integrating the local community's livelihood into carnivore conservation facilitates the desired coexistence (Harihar, Veríssimo, & MacMillan, 2015). As I described in Chapter 5, buffer zone programs are part of such efforts and they play an important role in building social tolerance. For example, the buffer zone program in Nepal receives 30–50% of all park revenues. As wildlife populations grow in the park, this attracts more tourists and, in turn, increases park revenues. Part of this revenue is shared with the communities. Increased tourist numbers also benefit multiple stakeholders in the country, which also increases the social and economic value of wildlife. Community education and awareness programs are necessary for enhancing society's understanding of the value of wildlife. Quick compensation when losses are incurred due to wildlife will increase community tolerance (Nyhus *et al*., 2005; Wegge *et al*., 2018).

Human-wildlife conflict is not a simple competition over shared resources, it is also a political conflict between humans and institutions with contrasting viewpoints about wildlife (Treves *et al*., 2006). Coexistence is possible only when such conflicts between humans are managed and the various stakeholders have a common understanding (Carter & Linnell, 2016). Common understanding can be built among stakeholders by co-managing conflicts. Participation of different stakeholders facilitates such co-management.

6.6. Recommendations

I propose the following recommendations based on the results of my study and with respect to different aspects of human and large carnivore interactions. I have compiled specific recommendations for: wildlife managers, the buffer zone institutions, the conservation agencies and the research organizations.

6.6.1. For wildlife managers

Identification and management of the conflict-causing individuals

As our study has shown, only 5% of the CNP tigers population caused conflict with communities. Timely identification of such individuals and quick action to remove or manage them from conflict areas is an important method of reducing negative impacts. Training field staff (game scouts and rangers) in the tracking and monitoring of conflict-causing individuals will help to locate them quickly and avoid loss of human life and economic damage. In addition, monitoring of tigers and leopards in fringe areas using camera traps or radio-telemetry in collaboration with communities and conservation partners will benefit all stakeholders. In addition to tigers, there may be other problem-causing individuals from different large mammal species like elephants, rhinos, sloth bears and leopards. Similar management of such individuals will help to reduce conflict.

Management of habitat mosaics

The high density of tigers and leopards in CNP and adjoining forests is facilitated by high prey density, spatial partitioning occupying different habitat types and temporal partitioning. Management of habitat mosaics is therefore important for maintaining the density levels of both carnivores and herbivores. With reduced human pressure following the establishment of the national park, the open (short) grasslands are gradually

Figure 6.3 An awareness-raising event for local communities about tiger conservation and avoiding tiger attacks when in the forests.

converting into the tall grasslands, bushes and, ultimately, forests. Grasslands in this sub-tropical regions are only maintained by disturbance factors such as fire, flood, human extraction or livestock grazing. Grasslands provide crucial habitat, food and shelter for many herbivores. Carnivore density is highly dependent on herbivores. For this reason, interventions are required to manage the grasslands regularly in order to prevent their succession to climax forests (sal or riverine) and in order to maintain the habitat mosaics.

6.6.2. For buffer zone institutions

My study shows that the majority of buffer zone residents are aware of the buffer zone programs but they are not satisfied with the current practices. Based on my research findings, I propose the following recommendations to the buffer zone committees:

Prioritization of buffer zone programs

The buffer zone programs have made a significant contribution to reducing the wildlife impacts but I found that only a small proportion of the buffer zone budget is invested in direct interventions to reduce such impacts. Therefore, propitiation of buffer zone activities with more investment for direct interventions to prevent or to mitigate the wildlife impacts is recommended. Direct interventions may include the designing and constructing fences, alternative crops at the forest edges, installation of predator-proof corrals and relief for wildlife victims. I recommend allocating a certain portion (25 - 50%) of buffer zone funds for such direct investments, which will benefit the local community and reduce the conflict. In addition to these, indirect interventions such as habitat management inside community forests, tracking and identification of problem-causing individual tigers or other species, awareness programs and alternative livelihoods for vulnerable communities should be considered.

Reaching those most affected

Although buffer zone programs have invested in human settlements around the park for more than two decades, the majority of the locals expressed dissatisfaction with the programs. My research and previous studies have also documented that the most affected group of people in the buffer zone has benefitted at least from the policy. Thus, I recommend to categorize the users in the buffer zone and prioritize those individuals or families who are most affected or vulnerable to wildlife damage. The family members or the affected individuals should be compensated by providing them with both social and economic opportunities to replenish any losses caused by wildlife. To increase the tolerance and support for conservation, buffer zone institutions should also consider compensation for the crop losses, which is not currently covered by the government compensation scheme.

6.6.3. Conservation agencies

Conservation of large carnivores in the human-dominated landscape is challenging and needs the support of multiple stakeholders. Conservation organizations, especially the NGOs and INGOs, can play an important role in conflict prevention and mitigation.

Conservation education and awareness of the vulnerable communities

Human killings by the wildlife is the ultimate expression of man-animal conflict. Such incidents can be reduced to a minimum, if not avoided, by changing the attitudes and the behaviour of local communities living in the forest fringes. Education and awareness raising among the vulnerable communities about wildlife ecology and animal behaviour is necessary for such change to happen. Training these vulnerable communities to avoiding encounters with wildlife as well as to reduce the risks of attacks when animals are encountered will help to minimize the human casualties. The traditional skills of the indigenous groups could be adopted to avoid or minimize the risks of wildlife attacks.

Promoting alternative livelihoods

People's dependency on the forest for their livelihoods makes them vulnerable to wildlife attacks. I found that in spite of increasing wildlife populations, conflict incidents have decreased in recent years with the diversification of household incomes and the changing social context. Such processes can be facilitated by promoting alternative livelihood options that reduce dependency on forests. Some of the identified programs include training youths as tourist guides, homestays, alternative crops (mushroom farming, fish farming etc.) and cottage industry. Such efforts will diversify the household incomes, reduce the wildlife impacts on communities and increase support for conservation. Conservation organizations can help to identify the appropriate livelihood options for a particular location through a participatory process, build local capacity on development or commercialization of the products and linking these products to the market.

Figure 6.4 A female leopard being fitted with satellite-radio collar before releasing to Chitwan National Park in December 2018. The leopard was rescued from Gulmi, Nepal where it was trapped in a snare-trap set for porcupine by local villagers.

Local capacity building

Local communities living in forest fringes are generally deprived of good education and socio-economic opportunities. These are also the people most affected by the wildlife and benefitting the least from the buffer zone programs. Due to limited capacity, they are unable to obtain optimum benefits from participatory conservation programs. Conservation organizations can play an important role filling this gap. Different activities such as informal conservation education sessions, training, exposure visits, interaction programs targeting those deprived and underprivileged groups will help to bring them into the mainstream of participatory conservation. Such capacity building should focus on human-wildlife conflict management. Conservation organizations (I/NGOs) should also help in the adoption of innovative technologies for efficient and effective management of the wildlife and their impacts on communities.

6.6.4. Future research suggestions

I suggest the following research areas that will enhance our understanding of human-carnivore coexistence in human-dominated landscapes.

Understanding the behavior of dispersing tigers/leopards

Tiger and leopard densities are increasing in core protected areas and there is limited space available for sub-adult animals dispersing from their natal territories. These dispersing sub-adults are also often involved in conflicts with humans. Understanding how these dispersing tigers and leopards use the increasingly human-dominated landscape will provide crucial information for their conservation. Such information will also help to understand the causes and identify possible measures for conflict management. Capturing and installing GSM or satellite tags on such animals is a good way of obtaining movement and activity data. If such invasive methods are not possible, the non-invasive methods such as camera trapping and genetic analysis of their scat can also our understanding of the dispersal behaviour of sub-adult tigers and leopards.

Ecological study of leopards

Although tigers are well-studied in Chitwan, and in Nepal in general, there is only limited information about the leopards. Based on the camera trap data, I observed their co-occurrence with tigers. However, I have not explored the actual spatial overlap and adaptation mechanism of leopards to coexist with tigers. Thus, I suggest future research on leopards using radio or satellite tags in areas where tiger density is also high.

Continuous monitoring of tigers and leopards in the buffer zone

Most studies of tigers and leopards are cross-sectional and capture a brief window of time. To gain detailed understanding of human–carnivore interactions, a long-term study is needed. It is important to conduct such studies in the buffer zone where the interaction between humans and large carnivores is intense. Such studies will also support communities to establish an early warning system by detecting problem-causing individuals in fringe areas before they are involved in intense conflict.

Evaluation of buffer zone policy

Buffer zone programs were initiated in the early 1990s in Nepal and formally institutionalized in 1997. Despite long-term investments in the buffer zone, human-wildlife conflict remains a major challenge in Chitwan. With more than 20 years of implementation, it is also time to assess the effectiveness of the programs. Such a study will also help to identify any gaps and generate the necessary information to make adjustments to the buffer zone policy and ensure its effectiveness in a changing social and political context.

Cost-effectiveness of different mitigation measures

My study documented a range of conflict mitigation measures including different types of fences, predator-proof corrals, crop guarding towers, alternative crops, etc. However, we do not know the effectiveness of these measures in reducing losses caused by wildlife as well as the economic value of the construction or maintenance costs, etc. I therefore recommend a study focusing on the effectiveness of conflict-mitigation measures in Chitwan.

Habitat dynamics and its effects on prey and carnivore density

I documented the high density of carnivores facilitated by habitat mosaics. The Terai and Siwalik regions of the outer Himalayas have a dynamic system where both natural and anthropogenic forces are actively changing the landscape and vegetation. Chitwan represents one such system where anthropogenic pressure has been reduced in recent years. Recent assessments show that the vegetation is becoming thicker and grasslands (especially the open grasslands) are shrinking. Quantification of such habitat changes (both in core areas and buffer zone) and their effects on prey and carnivore densities need to be explored. Such studies will also provide guidance for interventions to maintain habitat mosaics.

Photo by: Sagar Giri

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Appendix

Appendix 2.1. (Chapter 2, Appendix 1)

Semi-structured questionnaire used to record the detail information on the livestock epredation cases.

Form No:

Date of Incident: Year ______ Month ______ Day ______ Time ______

1. G.P.S.

House:	E	N	Elev:
Place of incident:	E	N	Elev:

Livestock loss

Which livestock	***Killed or injured?***	***Killed by***	***How predator was identified?***	***Are you confident on identification?***
1-cattle, 2-buffalo, 3-goat, 4-sheep, 5-pig, 6-other -?	1-killed 2-injured	1-tiger, 2-leopard, 3-other, 4-don't know	1-sighting, 2-track/sign, 4-call/sound, 5-guess, 6-other?	1-very confident, 2-not sure, 3-guess only

1. Was the carcass found? ☐ Yes ☐ No If yes how far? (m)

2. Was tiger/leopard nearby carcass? ☐ Yes ☐ No

3. What was done to carcass?
   ☐ Left (did nothing) ☐ buried ☐ taken out and eaten ☐ Others (?)

4. Have the tiger/leopard again killed other livestock in the village?
   ☐ Yes ☐ No If yes, give details

5. What was the cost of killed livestock?
   a) At that time (NRs) b) What would be price now? (NRs)

6. Have you got relief of the loss? ☐ Yes ☐ No If yes how much? (NRs)
   How long it took to get the relief?

7. Additional information, if any

Chapter 2 - Appendix 2: Amount (in USD) of compensation released in each year for different types of losses by the Buffer Zone Program and Nepal Government over the years.

Fiscal year	Human death	Human injury	Livestock loss	House & property	Crop	Total
1998/99	4,059.04	310.42	1,797.86	-	-	6,167.32
1999/00	1,834.19	3,056.33	6,006.93	-	-	10,897.45
2000/01	710.23	1,158.65	2,317.47	-	-	4,186.35
2001/02	3,360.22	2,065.86	4,246.79	422.72	-	10,095.58
2002/03	2,564.10	2,013.14	6,305.21	269.23	-	11,151.68
2003/04	8,274.86	2,789.21	5,583.03	1,065.80	-	17,712.90
2004/05	1,680.33	582.36	3,292.12	295.74	-	5,850.56
2005/06	4,619.76	2,329.44	1,427.68	1,419.49	-	9,796.36
2006/07	1,901.92	3,484.31	2,056.98	1,147.75	-	8,590.95
2007/08	3,076.92	2,872.11	3,394.77	1,430.08	-	10,773.88
2008/09	10,934.54	7,121.97	8,460.83	1,296.94	232.54	28,046.81
2009/10	15,686.27	6,443.69	-	-	-	22,129.96
2010/11	22,222.22	8,775.77	-	-	-	30,997.99
2011/12	21,067.42	6,279.49	-	-	-	27,346.91
2012/13	46,796.66	7,306.87	-	-	-	54,103.53
2013/14	15,839.49	6,899.43	1,821.01	411.83	7,856.39	32,828.15
2014/15	28,130.86	5,081.89	6,286.21	3,478.95	4,777.56	47,755.47
2015/16	24,601.46	19,076.33	7,291.87	2,740.74	11,506.26	65,216.66
Total	**217,360.48**	**87,647.29**	**60,288.74**	**13,979.26**	**24,372.75**	**403,648.51**

Appendix 4.1 (Chapter 4 - Appendix 1)

Detailed descriptions of the Response and explanatory used in GLM variables.

SN	Variable	Variable description	Type of variable	Units
1	Grid	Camera trapping grid	Not Used	
4	Physio	Physiography – categories 1) lowland and 2) Churia	Explanatory variable in GLM1 & GLM2	-
5	Mgmt	Management type – Categories: 1) Chitwan NP and 2) Buffer zone or Division Forest office	Explanatory variable in GLM1 & GLM2	-
8	Tig_bino	Tiger Occurrence – Presence or absence of tigers in camera traps	Response variable GLM1	Presence/Absence
9	Leo_bino	Tiger Occurrence – Presence or absence of tigers in camera traps	Response variable GLM2	Leopards per 100 km^2 Presence/Absence
10	Leo_den	Average density of leopard within camera trap survey grid (calculated from the density surface obtained during B-SECR analysis in SPACECAP)	Explanatory variable in GLM1	
11	Tig_den	Average density of tiger within camera trap survey grid (calculated from the density surface obtained during B-SECR analysis in SPACECAP)	Explanatory variable in GLM1	Tigers per 100 km^2
12	Dist_fedge	Distance of the camera trap survey grid center from the forest-settlement edge	Explanatory variable in GLM1 & GLM2	km
13	Rug	Terrain Ruggedness Index	Explanatory variable in GLM1 & GLM2	Terrain Rug. Index
14	Sambar	Number of independent detections of Sambar (*Rusa unicolar*) in camera traps.	Explanatory variable in GLM1 & GLM2	Detections
15	Chital	Number of independent detections of Chital (*Axis axis*) in camera traps.	Explanatory variable in GLM1 & GLM2	Detections
16	Muntjac	Number of independent detections of Muntjac (*Muntiacus muntjak*) in camera traps.	Explanatory variable in GLM1 & GLM2	Detections
17	Livestock	Number of independent detections of domestic (cow, buffalo and goat etc.) in camera traps.	Explanatory variable in GLM1 & GLM2	Detections
18	Local	Number of independent detections of local people (livestock herding, grass & firewood collection, walking etc.) in camera traps.	Explanatory variable in GLM1 & GLM2	Detections
19	Grassland	Area of grasslands (tall and short) within the survey grid	Explanatory variable in GLM1 & GLM2	Hector
20	Salforest	Area of Sal dominated forests within the survey grid	Explanatory variable in GLM1 & GLM2	Hector
21	Rivforest	Area of riverine forests within the survey grid	Explanatory variable in GLM1 & GLM2	Hector
22	Waterbodies	Area of waterbodies (rivers, lakes, marshes) within the survey grid	Explanatory variable in GLM1 & GLM2	Hector

Appendix 5.1 (Chapter 5 - Appendix 1): Household survey Questionnaire on Human wildlife interactions in buffer zone of Chitwan NP

Form Reference No.

Interviewer: **Date:** **Start time:**

A. Personal and household information

a. Is the respondent house hold head? b. Respondent Name:
C. Address (VDC/ward/tole name): b .Sex: M/F c. Age: Occupation:
f. GPS Lat: long: Alt:
g. No of persons in household (m/f): h. religion/ethnicity
i.Education:
j. Have you migrated here? Yes / No if Yes how long ago?

Household information

1) Land owned (Kattha): irrigated non-irrigated
2) Livelihood source: Agri (%), Livestock (%), Off farm (%), Other (%)
3) Do you have livestock? Yes / No If No go to '2 l'
4) If Yes what kind and how many?

Livestock type	Goat/sheep	Cattle	Buffalo	Pig	Chicken/duck	Other
Number						

5) How do you keep your livestock? (1 - stall fed, 2. grazing in CF 3. grazing in park, 4. grazing in private land, 5-grazing in fellow land, 6. other)

Livestock type	Goat/sheep	Cattle	Buffalo	Pig	Chicken/duck	Other
Rearing practice						

6) What type of shed do you have for cattle and buffalo?
- ☐ i. No shed (keep in open)
- ☐ ii. Temporary without fence
- ☐ iii. Temporary with fence (tiger/leopard proof)
- ☐ iv. Permanent without fence
- ☐ v. Permanent with fence

7) What type of shed do you have for goat/sheep?
- ☐ i. No shed (keep in open)
- ☐ ii. Temporary without fence
- ☐ iii. Temporary with fence (tiger/leopard proof)
- ☐ iv. Permanent without fence
- ☐ v. Permanent with fence

8. Have you done or heard of livestock insurance?
☐ i. Yes, I have done ☐ ii. Heard of but not done ☐ iii. Never heard

9. If you have not done, Are you interested to do? ▢ Yes ▢ No. If No why?

10. Do you also feed industrial feed to your livestock? ▢ Yes ▢ No

11. Where do you get the fodder required for the livestock?
▢ i. Private land
▢ ii. CF
▢ iii. Park
▢ iv. Other

12. Do you or any of your family member also need to go forest? ▢ Yes ▢ No
If No go to '3a'. If Yes, where & how many times?

13. What time of the day you go in forest?

Where	How many times in a month		
	Winter	Summer	Monsoon
Park			
Community forest			

14. How long you spent in forest?

B. Experience with wildlife

a. Have you ever seen a wild tiger? ▢ Yes ▢ No. If yes how many times? and where?
▢ i) Park
▢ ii) BZ CF
▢ iii) BZ outside of forest
▢ iv) Outside of BZ

b. Which is the tiger you have seen (on photo)? ▢ i) tiger ▢ ii) leopard ▢ iii) both

c. Do you like if there are tigers & leopards in forest? Yes / No
▢ If No why?
▢ i) danger for people
▢ ii) danger for livestock
▢ iii) Other (describe)

d. Where do you think tiger/leopard should exist?
▢ i) Only in park ▢ ii) Park & buffer zone ▢ iii) All the forest area ▢ iv) Zoo only

e. Have tiger/leopard ever attacked on you or your family member? ▢ Yes ▢ No

f. Do you know anybody killed or attacked by tiger/leopard ? ▢ Yes ▢ No

g. Which are the five most problematic wildlife species in your area (please rank)

SN	Species	Major problem	Problem Intensity	Problem frequency

h. Any cases of loss caused by wildlife in your family in last 10 or 20 years? ☐ Yes ☐ No

i. What is the trend of loss from wildlife in last five years?
- ☐ i. Highly increasing
- ☐ ii. Increasing a bit
- ☐ iii. No change
- ☐ iv. Decreasing
- ☐ v. Highly decreasing

j. Why do leopards come out of the forest?
- ☐ i) Less prey in forest
- ☐ ii) They like livestock more
- ☐ iii) No sufficient place to live
- ☐ iv) Pushed out by tiger
- ☐ vi) Leopard unable to hunt wild prey
- ☐ vi) Don't know
- ☐ Vii) Other (Specify)

C. Conflict management & compensation

a. Are you happy with the conflict mitigation measures?

☐ Yes ☐ No If no what should be done?

b. How to manage a problem tiger/leopards?
- ☐ i) Kill
- ☐ ii) Capture & put in enclosure
- ☐ iii) Capture & release in other area
- ☐ iv) Other (Specify)

c. Do you know that you get compensation if your livestock is killed or your family member is attacked? ☐ Yes ☐ No

d. If yes is it enough? ☐ Yes ☐ No. If No, What was the % shortage?

e. How much compensation should be paid for human injury, killed and livestock?

	Human killed	Human injured	Livestock killed	House/ property destruction	Storage crop raid	Crop raid
Amount NRs or						
% of the loss						
Other						

f. How long it takes to get compensation? Months ()

g. Are you satisfied with present compensation process? Yes (), No ().
If no why?
☐ i) It is too lengthy
☐ ii) Information and service from park authority is not adequate
☐ iii) Information/service from BZUG/BZUC is not sufficient iv) Other (specify)

h. Which agency will be appropriate for relief distribution?
☐ i. Community forest
☐ ii. BZUC
☐ iii. BZMC
☐ iv. Respective National Park/ Wildlife Reserve/District Forest Office
☐ v. VDC/municipality
☐ vi. District Development Committee
☐ vii. Other?

i. What other things can be done to improve relief disbursing?
a. Do you know about the buffer zone program and national park?
☐ Yes ☐ No. If yes what are the major activities?
i)
ii)
iii)
b. What are the benefits and difficulties from buffer zone program or national park?

Benefits	Difficulties
1	1
2	2
3	3

c. Are you satisfied with the buffer zone programs or programs of national park ?
☐ Yes ☐ No. If No what should they do?

d. What should be the priority activities of the buffer zone program or national park ?
i)
ii)
iii)
iv)

e. Does buffer zone program has role in human wildlife conflict mitigation?

☐ Yes ☐ No.

If yes what could be it?

f. Do you think living in buffer zone is better option? ☐ Yes ☐ No ☐ No difference

g. If you got a chance do you want to live outside of the buffer zone?

☐ Yes ☐ No.

If Yes why?

If No why?

h. How buffer zone can benefit in your household or community?

i)

ii)

iii)

iv)

5. Community Perceptions towards Wildlife

5.1 Wild animals have a right to live in the forest.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.2 Wildlife attracts tourists and brings revenue to the Park, which benefits us

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.3 I know that if I live close to the forest, I am more at risk of conflict with wild animals, but it is my responsibility to avoid it

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.4 National Park authorities are responsible for HWC thus they should manage it.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.5 Buffer zone institutions playing a positive role for human wildlife conflict mitigation

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.6 I would like to participate in community wildlife conflict mitigation programs.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.7 In case of severe conflict, problem animals should be terminated.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.8 If tiger and leopard disappear from Chitwan, it is a good news for us.
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.9 Wildlife should be conserved only if conflict with humans can be reduced.
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.1 I would like to learn more about wild animals, their behavior and ecology.
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.11 Tiger and leopard population should be increased in coming years
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.12 Wildlife conservation does not benefit me directly.
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.13 National Park authorities are playing a positive role for human wildlife conflict mitigation
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.14 Buffer zone institutions have not considered HWC as a priority
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.15 Community forests are playing a positive role for HWC management
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.16 I should participate to maintain electric fences and physical barriers constructed to avoid conflict
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.17 Government relief for loss done by wildlife is helping to victim families.
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

5.18 Mitigation measures for wildlife conflict is adequate
☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

Thank you for your kind cooperation. Do you like to add anything more that we have not covered?

End time:

Summary

Living with the large carnivores

The interaction between humans, tigers and leopards in Chitwan National Park, Nepal

Large carnivores are some of the most admired animals throughout the world. As top predators in the food chain with high energy requirements, they have large home ranges and occur naturally in low densities. However, they have a relatively greater influence on the ecosystem through regulating herbivores and their effects extending down to plants in food web. Despite their natural and cultural values, they are one of the most threatened group throughout the world primarily due to habitat loss, poaching and illegal trade of body parts, declining prey species and conflict with communities. Expansion of human land use in expense of natural areas caused their habitats to become increasingly insular, fragmented and degraded. Some of the remaining habitats has been set aside for protection as parks/reserves but they are not sufficient to support viable populations of the large carnivores. Alternative strategies are required with protection of such source sites which have the potential to repopulate neighboring areas whence embedded in larger landscapes and connected through forest corridors. The Terai Arc Landscape (TAL) in Nepal and India is one of such landscapes supporting a wide range of rare and endangered animals including large mammals. In the eastern part of the TAL, Chitwan National Park (CNP) and the adjoining forests of Valmiki Tiger Reserve in India and the Parsa National Park in Nepal make one of the remaining large intact habitats for conservation of large carnivores.

The CNP is part of a global biodiversity hotspot and an UNESCO world heritage site. It is also a flagship park in Nepal. The park has high densities of large mammals such as the greater one-horned rhinoceros (*Rhinoceros unicornis*), the Bengal tigers (*Panthera tigtris tigrris)* and the common leopards (*Panthera pardus ficusa)*. The high density of subsistence farming communities lives in proximity of the park whose livelihood depends largely on forests. The communities grow crops or raise livestock which is attractive food source for wild animals. As a result, wild animals frequently raid crops, kill livestock or attack people. Sometimes people may persecute the wild animals and kill them. Such impacts caused to each-other by humans and wildlife is one of the major threats for wildlife conservation.

The wildlife managers strive to increase wildlife populations through protection and habitat management while local communities are interested in access to the natural resources as well as safety of their life and property. Historically, communities managed wildlife impacts locally by clearing habitat or retaliating wild animals for real or perceived threats. Such response is either illegal or socially unacceptable as it does not comply with national and international regulations for biodiversity conservation. Hence, human-wildlife conflicts is no more simple competition over shared resources, perhaps it is a political conflict between humans and institutions having contrasting viewpoints about wildlife. If such conflicts are not managed, affected communities can become antagonistic towards wildlife and conservation authorities, affecting overall conservation goals. Managing conflict thus needs deeper understanding of both biophysical and sociopolitical components. Thus, in this study, I examine the spatial and temporal patterns of the wildlife attacks on humans and livestock, interactions between large carnivores (tigers and leopards), identification and management of the problem-causing tigers, and community interventions for prevention and mitigation of such impacts. I present my study in six chapters i.e. an introduction, four chapters presented as research papers, and synthesis.

In Chapter 2, I analyze the loss of humans, livestock and property caused by wildlife during 1998 to 2016 using victim family's reports to Chitwan National Park authorities and Buffer Zone User Committees. The incidents included attacks on humans (death and injury), livestock depredation, house and property damage, and crop raiding caused by 12 wildlife species. Most of the attacks on humans were caused by rhino, sloth bear, tiger, elephant, wild boar and leopard. A significantly higher number of conflict incidents caused by rhino and elephant were observed during full moon periods. An increase in the wildlife population did not cause a respective rise in conflict incidents. Underprivileged ethnic communities were attacked by wildlife more frequently than expected. The numbers of attacks on humans by carnivores and herbivores did not differ significantly. An insignificant decreasing trend of wildlife attacks on humans and livestock was observed with significant variation over the years. Tiger and leopard caused >90% of livestock depredation. Tigers killed both large (cattle and buffalo) and medium sized (goat, sheep, pig) livestock but leopard mostly killed medium sized livestock. Most of the livestock killing during 2012 – 2016 occurred within the stall but close (<500m) to the forest edge. Both the percentage of households with livestock and average holding has decreased over the years in buffer zone. Decreased forest dependency as well as conflict mitigation measures (electric and mesh wire fences) have contributed to keep the number of conflict incidents low.

Chapter 3 focuses on the characteristics of the conflict-causing tigers in Chitwan National Park (Nepal) to determine whether specific groups or individuals in the source population have higher probability to get involved in conflicts with humans. From 2007 to 2016 a total of 22 such tigers were identified including 13 that killed humans, six serial livestock killers and three tigers that threatened human safety (with no reported human and livestock casualty). Thirteen of these tigers were controlled or killed and four were relocated. I compared a subset of 15 'conflict-causing tigers' between 2009 and 2013 with the Chitwan's tiger population obtained from three different sessions of camera trapping (2008/09, 2010 and 2013). I found that less than 5 % of this source population (tigers recorded in camera trap) were involved in conflicts. Transient tigers without a territory or physically impaired animals are more likely to be involved in conflict. Regular monitoring of the tigers in fringe areas with involvement of the community members will help to identify such animals. Quick management actions for such animals contribute in reducing the conflicts.

Co-occurrence of two large carnivores, tigers and leopards, and its consequences on conflicts with humans is studied in chapter 4. I estimate their abundance and density in CNP using camera-trap based capture-recapture. Tiger and leopard population size was estimated to be 83–125 and 84–139 respectively with densities of 3.0 – 4.2 (3.76 ± 0.31) tigers and 2.4 – 3.6 (3.01 ± 0.29) leopards per 100 km^2. Tigers occupied the prime habitats (grasslands and riverine forests) in alluvial floodplains whereas leopards appeared in Sal forests and marginal areas where livestock is present. Both tigers and leopards showed crepuscular activity patterns with a high overlap but tigers were less active during the day compared to leopards. Leopards' activity in the day increased in the presence of tigers. Tiger and leopard diet overlapped considerably (90%). Compared to leopards, tigers consumed a higher proportion of the large prey and a smaller proportion of livestock. The study showed that sympatric large carnivores can co-occur in high densities in prey rich areas with mosaics of habitats by occupying different habitats and shifting the activity patterns.

In Chapter 5, I study the role of the buffer zone programs to reduce the impact of human-wildlife conflicts. I analyzed the fund utilization pattern of buffer zone programs and various mitigation measures practiced in Chitwan National Park. I also assessed the attitude of people towards wildlife conservation and conflict mitigation. During a decade (2005/06 – 2014/15) >5.6 million US dollar was invested directly in the buffer zone of CNP. The buffer zone committees spent only a small portion (13.7%) in direct interventions to reduce wildlife impacts on humans but the actual amount spent is gradually increasing with a rise in overall budget over the years. Wildlife attacks on humans and livestock were inversely related to the investment in direct interventions of conflict prevention and mitigation. Approximately 275 km long fences including 140 km electric fences were constructed along the forest-settlement boarders in the buffer zone of Chitwan. People's attitude towards wildlife conservation was largely positive. Positive attitude was highly associated with the management sector (East) and ethnicity. Most of the people were aware of the buffer zone programs but majority of them were not satisfied with current practices and suggested to prioritize activities on prevention and mitigation of human-wildlife conflicts.

Large carnivores, (primarily tigers and leopards studied) occurred in high density in Chitwan National Park. Damage caused by wildlife is still substantial in buffer zone of the park. However, the impacts of human-wildlife conflicts especially in the form of attacks on humans and livestock has slightly decreased over the years despite increase in their populations. Strengthening mitigation measures like construction of electric or mesh wire fences and predator-proof livestock corrals along with educating local communities about wildlife behavior and timely management of problem animals (man-eater tiger, rage elephant etc.) contributing to reduce the conflict.

In conclusion, my study provided a clue for human-carnivore coexistence. Coexistence in this context means 'a situation of humans and large carnivores sharing a landscape where carnivore population persistence is ensured, their impacts on humans is socially acceptable and institutions are in place to maintain this balance effectively'. Human-large carnivore coexistence can be realized if biological needs of the carnivores are considered in their management and social tolerance of carnivores is enhanced. Along with legal provisions to conserve wildlife, strong cultural/social acceptance and respect to wild nature is necessary. The tolerance of local communities towards wildlife impacts should be increased by practicing targeted interventions to reduce the wildlife damages, promoting forest independent alternative livelihoods and quickly compensating the loss from wildlife. I also recommend to establish a tiger and leopard monitoring system in forest fringes involving the local communities as para-ecologists to better understand their interaction and factors facilitating their coexistence. Moreover, the problem causing individuals of tigers and leopards should be, identified properly, timely, and removed or managed before they cause a larger amount of loss.

Samenvatting

Leven met de grote carnivoren

De interactie tussen mensen, tijgers en luipaarden in Chitwan National Park, Nepal

Grote carnivoren zijn enkele van de meest bewonderde dieren over de hele wereld. Als toppredatoren in de voedselketen met hoge energiebehoeften, hebben ze grote territoria en komen ze slechts in lage dichtheden voor. Ze hebben echter een relatief grote invloed op het ecosysteem door hun invloed op het faciliteren van andere soorten en effecten in de voedselketen. Ondanks hun natuurlijke en culturele waarden zijn ze een van de meest bedreigde diergroepen wereldwijd voornamelijk door verlies aan habitat, stroperij, de illegale handel in dierlijke producten, achteruitgang van prooidieren en conflicten met lokale gemeenschappen. Uitbreiding van landgebruik voor mensen ten kosten van natuurlijke gebieden heeft ertoe geleid dat hun habitat in toenemende mate versnipperd, gefragmenteerd en gedegradeerd is geraakt. Enkele van de resterende habitats zijn tot nationale parken of reservaten verklaard maar deze gebieden zijn niet voldoende om levenskrachtige populaties van grote carnivoren in stand te houden. Alternatieve strategieën zijn nodig met bescherming van kerngebieden die het vermogen hebben om omliggende gebieden te herbevolken en die zijn ingebed in grotere landschappen en verbonden door middel van beboste corridors. Het Terai Arc Landscape (TAL) in Nepal en India is een van die landschappen die een heel scala aan zeldzame en bedreigde dieren, inclusief grote zoogdieren, ondersteunen. In het oostelijke deel van de TAL, vormen Chitwan National Park (CNP) en de naastgelegen bossen van het Valmiki Tiger Reserve in India en het Parsa National Park in Nepal één van de grote overgebleven habitats voor het beschermen van grote carnivoren.

Het CNP is een mondiale *hotspot* voor biodiversiteit en een UNESCO World Heritage Site. Het is een *flagship* park in Nepal. Het park heeft hoge dichtheden van grote zoogdieren zoals de grote eenhoornige neushoorn (*Rhinoceros unicornis*), de Bengaalse tijger (*Panthera tigtris tigrris),* en de gewone luipaard (*Panthera pardus ficusa*). Er is een hoge dichtheid van boerengemeenschappen die dicht bij het park wonen en die afhankelijk zijn van de bossen voor hun bronnen van bestaan. De gemeenschappen verbouwen gewassen en houden vee dat een aantrekkelijke bron van voedsel is voor de wilde dieren. Dit heeft tot gevolg dat de wilde dieren regelmatig gewassen eten, vee doden of mensen aanvallen. Soms achtervolgen en doden de mensen de wilde dieren. Dergelijke gevolgen voor zowel mensen als wilde dieren vormen één van de grootste bedreigingen voor deze wilde soorten.

De managers van de wilde dieren streven er naar de populaties te vergroten door bescherming en beheer van de habitat terwijl lokale gemeenschappen geïnteresseerd zijn in toegang tot de natuurlijke hulpbronnen en hun eigen veiligheid en die van hun bezittingen. Historisch gezien beperkten de gemeenschappen de schade toegebracht door de wilde dieren door het kappen van de habitat en het doden van wilde dieren vanwege echte of vermeende bedreigingen. Een dergelijke reactie is of illegaal of sociaal onacceptabel omdat het niet in overeenstemming is met nationale of internationale wetten met betrekking tot bescherming van biodiversiteit. Daarom gaat het bij *human-wildlife* conflicten niet eenvoudigweg om strijd om gedeelde hulpbronnen, maar is het misschien ook een politiek conflict tussen mensen en instituties die tegengestelde standpunten hebben over de natuur. Als dergelijke conflicten niet beheerst worden kunnen de betrokken gemeenschappen vijandig komen te staan tegenover de autoriteiten die belast zijn met het beheer van de natuur en de natuurbescherming, hetgeen gevolgen kan hebben voor de algemene natuurbeschermingsdoelen. Het beheersen van deze conflicten vereist een dieper begrip van zowel de biofysische als de socio-politieke componenten. Daarom heb ik in deze studie de ruimtelijke en temporele patronen onderzocht van de aanvallen van wilde dieren op mensen en vee, de interacties tussen grote carnivoren (tijgers en luipaarden), de identificatie en het beheer van probleem-veroorzakende tijgers, en de interventies van de gemeenschappen om dergelijke gevolgen te voorkomen of bij te sturen. Ik heb mijn studie in zes hoofdstukken gepresenteerd, namelijk een inleiding, vier hoofdstukken in de vorm van tijdschriftartikelen, en een synthese.

In Hoofdstuk 2 heb ik het verlies aan mensenlevens, vee en bezittingen geanalyseerd dat veroorzaakt werd door wilde dieren in de periode 1998 tot 2016 waarbij ik gebruik heb gemaakt van de rapporten over slachtoffers van de autoriteiten van Chitwan National Park en de comités van de gebruikers van de bufferzone. De voorvallen betroffen aanvallen op mensen (dood en gewond), predatie van vee, schade aan huizen en bezittingen, en schade aan gewassen veroorzaakt door 12 soorten wilde dieren. De meeste aanvallen op mensen werden veroorzaakt door de neushoorn, de lippenbeer, de tijger, de olifant, het wilde zwijn en de luipaard. Een significant groter aantal voorvallen van conflicten, veroorzaakt door neushoorns en olifanten, werd waargenomen gedurende periodes van volle maan. Een toename van de populatie wilde dieren veroorzaakte een overeenkomstige toename in het aantal conflicten. Zwakke etnische gemeenschappen werden vaker aangevallen door wilde dieren dan verwacht. De aantallen aanvallen op mensen door carnivoren en door herbivoren verschilden niet significant van elkaar. Een niet-significante afnemende tendens van aanvallen van wilde dieren op mensen en vee werd waargenomen met een significante variatie over de jaren. Tijgers en luipaarden veroorzaakten meer dan 90% van de predatie van het vee. Tijgers doodden zowel grote als middelgrote dieren (respectievelijk koeien en buffels, tegenover geiten, schapen en varkens) maar luipaarden doodden vooral de middelgrote dieren. In de periode 2012-2016 werd het grootste aantal dieren gedood in stallen die relatief (<500 meter) dicht bij de rand van het bos gelegen waren. Zowel het percentage huishoudens met vee en als bedrijven met een gemiddelde omvang in de buffelzone is in de afgelopen jaren gedaald. Zowel de afgenomen afhankelijkheid van het bos als de genomen maatregelen om conflicten te vermijden (elektrische hekken of een omheining met alleen gaas) hebben bijgedragen aan een reductie van het aantal conflicten.

Hoofdstuk 3 richt zich op de kenmerken van conflict-veroorzakende tijgers in Chitwan National Park teneinde vast te stellen of specifieke individuen in de bronpopulatie een grotere kans hebben betrokken te raken bij conflicten met mensen. Van 2007 tot 2016 is een totaal van 22 tijgers geïdentificeerd inclusief 13 dieren die mensen hebben gedood, zes tijgers hebben meerdere malen vee gedood en drie tijgers vormden een bedreiging voor de veiligheid van mensen (maar zonder menselijke slachtoffers te maken of vee te doden). Dertien van deze tijgers werden gevangen of gedood, en vier tijgers werden naar elders overgeplaatst. Ik heb een groep van 15 probleem-veroorzakende tijgers tussen 2009 en 2013 vergeleken met de beelden van de tijgerpopulatie van Chitwan zoals verkregen uit drie verschillende opnamenseries van camera-vallen (2008/9, 2010 en 2013). Ik heb gevonden dat minder dan 5% van deze bronpopulatie (tijgeropnames in de camera-val) betrokken was bij conflicten. Trekkende tijgers zonder een territorium of verwonde dieren bleken meer betrokken te zijn bij conflicten. Het regelmatig monitoren van de tijgers in de randgebieden met de hulp van leden van de gemeenschap zal helpen zulke dieren te identificeren. Snelle preventieve acties gericht op dergelijke dieren zullen bijdragen aan het reduceren van conflicten.

Het samen in hetzelfde gebied voorkomen van twee grote carnivoren, tijgers en luipaarden, en de gevolgen daarvan voor de conflicten met mensen is bestudeerd in Hoofdstuk 4. Ik schatte hun aantallen en dichtheden in Chitwan National Park met gebruik van camera-vallen gebaseerd op de methode van herhaalde opnames. De omvang van de populatie van tijgers en luipaarden werd geschat op respectievelijk 70 - 102 en 66 - 105 met dichtheden van 3,2 - 4,6 (3,94 ± 0,37) voor tijgers en 2,6 – 4,1 (3,31 ± 0,4) voor luipaarden per 100 km^2. Tijgers bezetten de beste habitats (graslanden en bossen langs de rivieren) in de alluviale vloedvlakten terwijl luipaarden vooral voorkomen in de zogenaamde *Sal*-bossen en marginale gebieden waar het vee rondloopt. Zowel tijgers als luipaarden vertonen gedurende de periodes van schemering activiteitenpatronen met een sterke mate van overlap maar tijgers waren minder actief gedurende de dag vergeleken met luipaarden. Activiteiten van luipaarden gedurende de dag namen toe in aanwezigheid van tijgers. Het dieet van tijgers en luipaarden overlapte behoorlijk (90%). Vergeleken met luipaarden consumeren tijgers een hoger percentage grote prooidieren en minder vee. De studie toont aan dat in hetzelfde gebied levende grote carnivoren in hoge dichtheden naast elkaar kunnen voorkomen in gebieden die veel prooidieren hebben in een mozaïeklandschap, door het bezetten van verschillende habitats en het verwisselen van activiteitenpatronen.

In Hoofdstuk 5 bestudeer ik de rol van de programma's in de bufferzone om de impact van de *human-wildlife* conflicten te beperken. Ik analyseer de manier waarop het geld van de bufferzoneprogramma's is gebruikt en de manier waarop de verschillende verzachtende maatregelen in Chitwan National Park zijn uitgevoerd. Ik heb ook de houding gemeten van de mensen tegen opzichte van de bescherming van de wilde dieren en de manier waarop conflicten werden afgehandeld. Gedurende een tiental jaren (2005/06 – 2014/15) is er meer dan US$ 5,6 miljoen direct geïnvesteerd in de bufferzone van Chitwan National Park. De comités van de bufferzones besteedden slechts een kleine gedeelte (13,7%) aan directe interventies om de impact van de wilde dieren op de mensen te beperken maar het feitelijke bedrag dat wordt besteed, stijgt met de toename van het hele budget over de jaren. Aanvallen van wilde dieren op mensen en vee namen af naar mate er meer geïnvesteerd werd in directe interventies voor preventie van conflicten en beschermende maatregelen. Een ongeveer 275 kilometer lange omheining, inclusief een 140 kilometer lang elektrisch hek, werd gebouwd langs de grens tussen de bossen en de nederzettingen in de bufferzone van Chitwan. De houding van de mensen ten opzichte van bescherming van wilde dieren was grotendeels positief. Deze positieve houding was vooral gekoppeld aan de (oostelijke) management sector van het park en de etnische achtergrond van de bewoners. De meeste mensen waren zich bewust van de bufferzoneprogramma's maar de meerderheid van hen was niet tevreden met de huidige praktijk en zij suggereerden om prioriteit te geven aan de preventie-activiteiten en het verminderen van *human-wildlife* conflicten.

Grote carnivoren (primair tijgers en luipaarden) komen in hoge dichtheden voor in Chitwan National Park. De schade die door de wilde dieren wordt veroorzaakt in de bufferzone van het park is nog steeds aanzienlijk. Echter de impact van *de human-wildlife* conflicten, vooral in de vorm van aanvallen op mensen en vee, is in de afgelopen jaren enigszins verminderd ondanks een toename van hun populaties. Het versterken van maatregelen, zoals het bouwen van elektrische omheiningen of hekken met gaas en predatorbestendige omheinde kralen, samen met voorlichting aan de lokale gemeenschappen over het gedrag van wilde dieren, en het tijdig optreden bij probleemdieren (mens-etende tijgers, of olifanten die verbouwde gewassen vernielen) dragen bij aan de vermindering van de conflicten.

Tot slot biedt mijn studie een sleutel voor het naast elkaar bestaan van mensen en carnivoren. De co-existentie in deze context betekent 'een situatie van mensen en grote carnivoren die een landschap delen waarin het voortbestaan van de populatie van carnivoren is verzekerd, hun impact op mensen sociaal acceptabel is en instituties zodanig functioneren dat deze balans effectief gehandhaafd wordt'. Het naast elkaar leven van mensen en grote carnivoren kan gerealiseerd worden als de biologische behoeften van de carnivoren worden gerespecteerd en de sociale tolerantie van carnivoren wordt vergroot. Naast wettelijke maatregelen om de wilde dieren te beschermen, zijn een sterke sociaal-culturele acceptatie en een waardering van de wilde natuur noodzakelijk. De tolerantie van lokale gemeenschappen ten opzichte van de impact van wilde dieren zou moeten worden vergroot door het in praktijk brengen van doelgerichte interventies om schade door wilde dieren te beperken, door alternatieve middelen van bestaan te bevorderen die minder van het bos afhankelijk zijn en door het snel compenseren van schade door wilde dieren. Ik beveel ook een monitorsysteem aan in de randgebieden van het bos om de lokale gemeenschappen te betrekken als zogenaamde 'burger- ecologen' om zodoende beter de interactie tussen dieren en mensen te kunnen begrijpen en de factoren te faciliteren voor hun vreedzame co-existentie. Bovendien zouden de individuele tijgers en luipaarden die problemen veroorzaken, tijdig en op een goede manier geïdentificeerd en verplaatst moeten worden voordat zij nog meer schade berokkenen.

Summary in Nepali language (सारांश)

ठूला मांशहारीसँग जीउँदा: चितवन राष्ट्रिय निकुञ्जमा मानव, बाघ र चितुवा बीचको अन्तरसम्बन्ध

ठूला मांशहारी प्रजातिहरु संसारभरि नै सबैभन्दा मनपराईने जनावरहरु हुन्। खाद्यश्रृंखलाको उच्च तहमा रहने यी मांशहारी जीवहरुको आवश्यकता परिपुर्ति गर्न ठूलो क्षेत्र आवश्यक पर्ने हुनाले प्राकृतिक रुपमै यिनीहरुको घनत्व कम रहेको हुन्छ। तथापि पारिस्थितिकीय प्राणालीको सन्तुलन कायम राख्न यिनीहरुको ठूलो भूमिका रहन्छ। यस्ता प्राकृतिक र सामाजिक महत्व हुँदाहँदै पनि ठूला मांशहारी जनावरहरु बासस्थान विनाश, चोरी शिकारी तथा अंग प्रत्याङ्गको अवैध व्यापार, आहार प्रजातिको घट्दो संख्या र स्थानीय बासिन्दाहरुसँगको द्वन्दका कारणले संसारभर नै खतरामा परेका छन्। मानवीय प्रयोगका लागि प्राकृतिक क्षेत्रहरु विनाश गरिँदै जाँदा यीनिहरुको बासस्थान झन् खुम्चिँदै, टुक्रिदै र क्षयीकरण हुँदै गईरहेका छन्। बाँकी रहेका मध्ये केही बासस्थानलाई संरक्षित क्षेत्रको रुपमा जोगाउने प्रयास भईरहेका छन् तर त्यस्ता क्षेत्रहरु यीनिहरुको संरक्षणको लागि पर्याप्त छैन। वैकल्पिक उपायको रुपमा यस्ता संरक्षित क्षेत्रहरुलाई जैविक मार्गहरुले जोडी भू-परिधिस्तरमा संरक्षण गर्ने प्रयास आवश्यक छ, जहाँ मानव र वन्यजन्तु सह-अस्तित्वमा बाँच्दछन्। नेपाल र भारतको तराई तथा चुरे क्षेत्रलाई समेट्ने तराई भू-परिधि यस्तै एउटा क्षेत्र हो जसले धेरै प्रकारका दुर्लभ तथा लोपोन्मुख जनावरहरुलाई बासस्थान प्रदान गर्दछ। यस तराई भू-परिधिको पूर्वी भागमा पर्ने चितवन राष्ट्रिय निकुञ्ज, पर्सा राष्ट्रिय निकुञ्ज र भारतको वाल्मिकी टाईगर रिजर्भ तथा आसपासका वन क्षेत्र समग्रमा तराई क्षेत्रमा बाँकी रहेको सबैभन्दा ठुलो नटुक्रिएको प्राकृतिक भु-भाग हो।

चितवन राष्ट्रिय निकुञ्ज विश्व सम्पदामा सूचीकृत जैविक विविधताले प्रचुर क्षेत्र हो। यो नेपालको एउटा प्रमुख निकुञ्ज हो। यहाँ बाघ, गैडा, चितुवा लगायतका कैयौ ठूला स्तनधारी वन्यजन्तुहरु तुलनात्मक रुपमा बढि घनत्वमा रहेका छन्। त्यस्तै, यस निकुञ्जको आसपासमा मुख्यत: कृषिमा आधारित समुदायको घनत्व रहेको छ जसको जिविकोपार्जन वनपैदावरको उपयोगमा निर्भर हुन्छ। समुदायले बालिनालि उत्पादन गर्दछन् तथा घरपालुवा पशु पाल्दछन् जुन वन्यजन्तुको लागि आकर्षक आहारा हुन सक्छ। परिणामस्वरुप वन्यजन्तुले कहिलेकाही बालिनाली खाईदिने, घरपालुवा पशु मार्ने तथा मान्छेलाई समेत आक्रमण गर्ने गरेको पाईन्छ। यसको प्रतिशोधको रुपमा समुदायले समेत कहिलेकाही मानवीय क्षति गर्ने यस्ता वन्यजन्तुहरु घाईते बनाउने तथा मार्ने समेत गर्दछन्। यसरी मानव र वन्यजन्तुले एकआपसमा गर्ने क्षति वन्यजन्तुको संरक्षणको लागि ठूलो खतराको रुपमा रहेको छ।

परापुर्वकालदेखि नै स्थानीय समुदायले वन्यजन्तुबाट हुने क्षति वा हुनसक्ने खतरालाई स्थानीय स्तरबाटै वन्यजन्तु लुक्न सक्ने क्षेत्रहरु फाँडेर वा त्यस्ता वन्यजन्तु मारेर व्यवस्थापन गर्दै आएका थिए। तर हाल यसरी वन्यजन्तुलाई वा तीनिहरुको बासस्थानको क्षति

गर्न राष्ट्रिय अन्तराष्ट्रिय कानुनहरुले बन्देज लगाएको छ। संरक्षणकर्मीहरु वन्यजन्तुको सुरक्षा तथा बासस्थान व्यवस्थापन गरी संख्या बढाउन लालायित रहन्छन् भने स्थानीय समुदाय प्राकृतिक श्रोत उपभोगमा पहुँच तथा आफ्नो जीउधनको सुरक्षा चाहन्छन्। त्यसैले मानव र वन्यजन्तुले एक आपसमा पार्ने असर खालि समुदाय र वन्यजन्तुबीचको मात्र द्वन्द होईन, यो त वन्यजन्तु र तीनिहरुको व्यवस्थापनको बारेमा फरक विचारधारा भएका संस्थाहरुबीचको सामाजिक द्वन्द पनि हो। यस्तो द्वन्द व्यवस्थापन गर्न नसकेमा, वन्यजन्तुको असर भोग्ने समुदाय (जो वन्यजन्तु बासस्थानको नजिकमा बस्छन्) वन्यजन्तु संरक्षणमा नकारात्मक हुनसक्छन् जसले संरक्षणका लक्ष्य प्राप्त गर्न कठिन हुन्छ। यस्तो द्वन्द व्यवस्थापनका लागि जैविक-भौतिक साथै आर्थिक-सामाजिक-राजनैतिक दुवै खाले विषयको गहिरो बुझाई जरुरी हुन्छ। त्यसैले मैले यस अध्ययनमा समयक्रम र स्थान विशेषमा वन्यजन्तुले मान्छे वा घरपालुवा पशुलाई गरेको आक्रमणको विवरण; बाघ र चितुवाबीचको अन्तरसम्बन्ध, समस्या दिने बाघहरुको पहिचान तथा व्यवस्थापन; समुदायले द्वन्द व्यवस्थापनको लागि गरिरहेको प्रयास बारेमा अनुसन्धान गरेर यो शोधपत्र तयार पारेको छु। यसलाई छ वटा अध्यायमा विभाजन गरिएको छ। पहिलो अध्याय परिचय रहेको छ भने त्यसपछिका चारवटा अध्याय अनुसन्धानात्मक लेखको रुपमा अन्तराष्ट्रिय जर्नलमा प्रकाशित भैसकेका वा हुने क्रममा रहेका छन् भने छैटौं तथा अन्तिम अध्याय चारवटा अनुसन्धानात्मक लेखको निचोडहरु समेटेर तयार पारिएको छ।

दोश्रो अध्यायमा चितवन राष्ट्रिय निकुञ्जको मध्यवर्ति क्षेत्रमा विगत १८ वर्ष (सन् १९९८ देखि २०१६) सम्म वन्यजन्तुबाट भएका मानवीय क्षति, पशुधन तथा सम्पत्ति क्षतिको पिडित परिवारले मध्यवर्ती उपभोक्ता समिति र चितवन राष्ट्रिय निकुञ्जलाई राहत पाउनको लागि दिएको निवेदनको आधारमा प्राप्त विवरणको विष्लेषण गरिएको छ। प्राय जसो मानवीय क्षति गैंडा, भालु, बाघ, बँदेल र चितुवाले गरेको पाइयो। गैडा र हात्तीबाट भएका घटनाहरु चन्द्रमास अनुसार पुर्णिमाको आसपास तुलनात्मक रुपमा बढि रहेको पाईयो। वन्यजन्तुको सँख्या बढेको अनुपातमा वन्यजन्तुबाट हुने क्षति नबढेको पाईयो। जनसंख्याको अनुपातको हिसाबले समाजमा पिछडिएका वर्गका मानिसहरु (दलित र आदिवासी) वन्यजन्तुको आक्रमणमा बढि पर्ने गरेको पाईयो। साकाहारी र मांशहारि जनावरले गर्ने क्षतिको संख्यामा विशेष अन्तर भेटिएन। वन्यजन्तुबाट हुने मानवीय तथा पशु क्षतिको वार्षिक सँख्या घटबढ भईरहेको र थोरै मात्रमा घटिरहेको पाईयो। पशुक्षतिको ९०% भन्दा बढि बाघ र चितुवाले गरेको पाईयो। बाघले ठुला तथा मझौला पशु (गाईगोरू, भैंसी, बाख्रा) आक्रमण गरेको तथा चितुवाले मझौला देखी साना पशु (बाच्छा-बाच्छी, बाख्रा) मारेको पाइयो। सन् २०१२ देखि २०१६ सम्म भएको पशुक्षतिको विस्तृत अध्ययन गर्दा, प्राय जसो (८५% भन्दा बढी) घटना बाँधेको बेला गोठमै र जँगल किनारा नजीक (५०० मि. भित्र) भएको पाईयो। पशुपालन गर्ने घरधूरी संख्या र पशुको संख्या दुवै घटेको पाईयो। जँगलसँगको घट्दो निर्भरता र मानव-वन्यजन्तु द्वन्द न्युनिकरणका उपायहरु (विद्युतीय तारबार वा मेसजाली)ले गर्दा द्वन्दका घटनाहरु कम गर्न सहयोग गरेको पाईयो।

तेश्रो अध्यायमा चितवन राष्ट्रिय निकुञ्ज र आसपासको क्षेत्रमा विगत १० वर्षमा मान्छे वा पशुलाई आक्रमण गर्ने बाघहरुको विशेषता अध्ययन गरियो। सन् २००७ देखि २०१६ सम्म यस्ता २२ वटा बाघहरु रहेको पाईयो जसमध्ये १३ वटा बाघले मान्छे मारेको ६ वटाले नियमित रुपमा पशुवस्तु मार्ने गरेको र तीनवटा बाघ गाँउमा पसेर आतंकित गरेको तर कुनै क्षति नगरेको पाईयो। यी २२ मध्ये १३ वटालाई नियन्त्रणमा लिईएको र थप चारवटा लाई अन्य क्षेत्रमा स्थानान्तरण गरिएको पाईयो। यीमध्ये २००९ र २०१३ को बीचमा सकृय रहेका १५ वटा बाघहरुलाई क्यामेरा ट्र्यापबाट प्राप्त फोटोहरु (सन् २००९, २०१० र २०१३) सँग तुलना गरी हर्दा चितवनमा रहेमा मध्ये ५% भन्दा कम बाघहरु मात्रै यस्तो द्वन्दमा सहभागी वा सकृय रहेको पाईयो। आफ्नो क्षेत्र बनाउन नसकेका तथा आफ्नो क्षेत्रबाट लखेटिएका र शारीरिक रुपले अशक्त वा घाईते बाघहरुले यसरी मानिस वा पशुको आक्रमण गर्ने संभावना बढि रहेको पाईयो। मानव बस्ती नजिकको जँगल क्षेत्रहरुमा बाघको नियमित अनुगमन गरी यस्ता खतरा हुन सक्ने बाघहरुको पहिचान गर्न सकिने देखिन्छ। यसरी पहिचान भएका बाघहरुको सिघ्र व्यवस्थापन गरेर क्षति कम गर्न र द्वन्द घटाउँन सकिन्छ।

दुई ठूला मांशहारीहरु बाघ र चितुवाको सहअस्तित्व तथा मानव-वन्यजन्तु द्वन्दमा यसको प्रभाव विषयमा चौथो अध्यायमा अध्ययन गरिएको छ। क्यामेरा ट्रायपिङ् विधिबाट बाघ र चितुवाको घनत्व क्रमश ३.२ - ४.६ (३.९४ ± ०.३७) र २.६ - ४.१ (३.३१ ± ०.४) प्रति १०० वर्ग कि.मी. रहेको पाईयो। त्यस्तै बाघ र चितुवाको संख्या क्रमश: ७० – १०२ र ६६ - १०५ रहेको थियो। बाघले निकुञ्जको प्रमुख बासस्थान नदितटीय घाँसे मैदान तथा वनक्षेत्र ओगटेको पाईयो भने साल वन र मानव तथा घरपालुवा पशुको चाप भएको क्षेत्रमा चितुवा भेटिने सम्भावन बढि पाईयो। बाघ र चितुवा दुवै एकाबिहानै सुर्योदयअघि र साँझ सुर्यास्तपछि बढि सकृय रहने गरेको तर तुलनात्मक रुपामा बाघभन्दा चितुवा दिउँसोमा बढि सकृय रहेको पाईयो। बाघको उपस्थिति भएको क्षेत्रमा चितुवा दिउँसोमा बढि सकृय रहेको (जतिबेला बाघ कम सकृय हुन्छ) पाईयो। बाघ र चितुवाको आहारा धैरै (९०%) मिल्दोजुल्दो रहेको तर बाघको आहारामा चितुवाको तुलनामा ठूला आहारा प्रजाति (गौरीगाई, जरायो, बँदेल)को अनुपात बढि र घरपालुवा पशुको अनुपान कम रहेको थियो। यो अध्ययनले, आहारा प्रजाति प्रचुर रहेको र फरक बासस्थानहरुको संमिश्रण रहेको क्षेत्रमा ठूला मांशहारीहरु फरक बासस्थानहरु ओगटेर तथा आफ्नो सकृय हुने समय बदलेर सहअस्तित्वमा रहन सक्छन् भन्ने देखायो।

अध्याय पाँचमा, मानव-वन्यजन्तुबीच एक-आपसमा पार्ने प्रभावहरुलाई न्युनिकरण लागि मध्यवर्ती क्षेत्र कार्यक्रमको योगदान र समुदायले अबलम्बन गरेका उपायहरुबारे अध्ययन गरियो। त्यस्तै वन्यजन्तु संरक्षण र द्वन्द व्यवस्थापन सम्बन्धि समुदायको सोचको समेत लेखाजोखा गरियो। पछिल्लो दशकमा (सन् २००५/०६ देखि २०१४/१५ सम्म) ५६ लाख अमेरिकी डलर भन्दा बढि प्रत्यक्ष रुपमा चितवनको मध्यवर्ती क्षेत्रमा खर्च भएको पाईयो। यसमध्ये मध्यवर्ती उपभोक्ता समितिहरुले प्रत्यक्ष रुपमा मानव-वन्यजन्तु द्वन्द न्यनिकरणको

कार्यक्रममा औसत १३.७% रकम खर्च गरेको पाईयो। मध्यवर्तीको बजेट बढ्दै जाँदा यस्ता कार्यक्रमको बजेट पनि पछिल्ला वर्षहरुमा बढ्दै गएको देखिएको छ। मध्यवर्ती क्षेत्रबाट द्वन्द नियन्त्रणमा भएको लगानी बढ्दा वन्यजन्तुबाट हुने मानवीय र पशुधन क्षति कम भएको पाईयो। चितवनको मध्यवर्ति क्षेत्रमा करीब २७५ कि.मी. छेकबार (विद्युतीय ताराबार १४० कि.मी. सहित) बस्ती र जँगल सिमानामा निर्माण भएको पाईयो। वन्यजन्तु संरक्षणप्रति स्थानीय बासिन्दाहरुको सोच समग्रमा सकारात्मक रहेको पाईयो। पुर्वि सेक्टरका बासिन्दा र जनजाति तथा दलित जातिको सोच अन्यको तुलनामा बढि सकारात्मक पाईयो। प्राय:जसो स्थानीय बासिन्दालाई मध्यवर्ति कार्यक्रमबारे जानाकारी रहेको तर तीनिहरुमध्ये धेरैजसो मध्यवर्तीको कार्यक्रमहरुबाट सन्तुष्ट नरहेको र भविष्यमा मध्यवर्ति कार्यक्रमले वन्यजन्तुबाट हुने क्षति नियन्त्रणका कार्यक्रमलाई पहिलो प्रथमिकतामा राख्नुपर्ने बताए।

चितवन राष्ट्रिय निकुञ्जमा ठुला मांशहारी (खासगरी बाघ र चितुवा) बढि घनत्वमा रहेको पाईयो। वन्यजन्तुबाट हुने धनजनको क्षति अझै ठूलो मात्रमा रहेको पाईयो। वन्यजन्तुको सँख्या निरन्तर बढिरहेको देखिए पनि मानवीय क्षति र पशुधनको क्षतिमा थोरै मात्रामा घटेको देखिएको छ। वन्यजन्तु रोकथामका उपायहरु (जस्तै विद्युतीय तारबार, मेसजाली), समस्या दिने वन्यजन्तुको समयमै नियन्त्रण, सुरक्षित खोर जस्ता कार्यक्रमसँगै जनचेतनाका कार्यक्रमहरु र जँगलमा निर्भरता कम गर्ने जिविकोपार्जनका कार्यक्रमहरुको सँचालनले गर्दा क्षति नियन्त्रण गर्न सहयोग पुगेको देखिन्छ।

निचोडको रुपमा मानव-वन्यजन्तुको सह-अस्तित्वको बारेमा यस अध्ययनको केही संकेत गरेको छ। यहाँ सह-अस्तित्वलाई 'एउटै भू-परिधिमा मानव र वन्यजन्तु सँगसँगै बस्ने क्रममा वन्यजन्तुको दिगो सुनिश्चितता गर्दै, वन्यजन्तुबाट हुने क्षति समुदायले स्वीकार गर्नसक्ने मात्रामा राख्ने र सन्तुलन कायम राख्ने संस्थागत संरचना कायम रहेको' अवस्थाको रुपमा परिभाषित गरिएको छ। ठूला मांशहारी प्रजातिसँग यस्तो सह-अस्तित्व कायम गर्न तीनिहरुको जैविक आवश्यकताहरुको ख्याल गर्दै यी जनावरहरु प्रति सामाजिक शहनशीलताको विकास गर्नुपर्ने देखिन्छ। दह्रिलो कानुनी व्यवस्थासँगै प्राकृतिक सम्पदाप्रतिको सम्मान गर्ने सामाजिक र सांस्कृतिक मुल्यमान्यता समेत जरुरी पर्दछ। वन्यजन्तुप्रतिको सामाजिक शहनशिलता विकासका लागि वन्यजन्तुबाट हुने क्षति नियन्त्रणका लक्षित कार्यक्रमहरु लागु गर्ने, वनमा निर्भरता नहुने जीविकोपार्जनमा प्रेरित गर्ने तथा वन्यजन्तुबाट हुने क्षतिको तत्काल राहतको व्यवस्था गर्न सकिन्छ। स्थानीय समुदायलाई प्याराईकोलोजिस्टको रुपमा सहभागी गराई मानवबस्ती आसपासको जँगल क्षेत्रमा बाघ, चितुवाको नियमित अनुगमनको व्यवस्था गरिए तीनिहरुको अन्तरसम्बन्धबारे थप गहिरो गरी बुझ्न र सह-अस्तित्व कायम गर्न सहज हुने देखिन्छ। साथै, समस्या दिने बाघ तथा चितुवाको पहिचान गरी समयमै नियन्त्रण तथा स्थानान्तरण गरी तिनीहरुबाट हुने क्षति कम गर्न सकिन्छ।

Curriculum vitae

Babu Ram Lamichhane was born on 10th April 1985 in the remote village of Gorkha, Nepal. He studied environmental sciences for his diploma from the Tri-Chandra College in Kathmandu during 2002 to 2005. He was involved in various environmental campaigns around Kathmandu valley during his study of environmental sciences. After obtaining his diploma he worked as a school teacher for a year before starting his Master's study on Natural Resources Management and Rural Development at the Tribhuvan University, Institute of Forestry in Pokhara (Nepal). After this study he started a job as a research officer at the National Trust for Nature Conservation, a quasi-government organization actively involved in nature conservation initiatives in Nepal. He has been involved in various wildlife conservation and research activities in Nepal primarily in the southern Terai region since 2009. After the visit of Prof. Dr. Hans de Iongh to Chitwan National Park in 2013 it was decided that Babu Ram could start his PhD project. In 2014, with a small grant provided by the Himalayan Tiger Foundation (a Dutch NGO), Babu Ram visited to University of Antwerp, Belgium to develop the PhD proposal under supervision of Prof. Dr. Herwig Leirs and Prof. Dr. Hans H. de Iongh. He submitted the proposal to University of Antwerp and Leiden University. University of Antwerp approved the PhD proposal in 2015 and PhD was accepted at Evolutionary Ecology Group, Department of Biology. Louwes Fund for Research on Water and Food at Leiden University funded the PhD project. Babu Ram was also registered as PhD student at Institute of Cultural Anthropology and Development Sociology, Faculty of Social and Behavioral Sciences, Leiden University with Prof. Dr. Gerard Persoon as his supervisor. His PhD is thus a joint degree of the University of Antwerp and Leiden University. In Nepal the National Trust for Nature Conservation (NTNC) has supported this research. During this research project Babu Ram continued to work for NTNC as a wildlife research officer.

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