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Diet study of the tiger (*Panthera tigris tigris*) in Chitwan National Park, Nepal, with specific focus on the buffer zone and the surrounding areas, in relation to human-wildlife conflicts

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Cover photo: Pugmark of a Bengal tiger (Panthera tigris tigris) in the research site of Chitwan National Park, photographed by S. Kelchtermans

Abstract

Habitat destruction, prey depletion and human-carnivore conflicts are all important factors contributing to the decline of large carnivores. This study intents to analyze the diet of the Bengal tiger (*Panthera tigris tigris*) in Chitwan National Park, Nepal, by identifying 47 prey items from 43 tiger scats. The diet of the tiger was compared between three zones under different management including core area (CA), buffer zone (BZ) and corridor forest (CO). The majority of scats were found in the CA (73.07%). Tigers in CNP fed upon eight different mammal species. Chital (*Axis axis*) was the major prey with a frequency of 57.45% of the tigers' diet, followed by wild boar (17.02%) (*Sus scrofa*). No livestock was consumed by tigers in CNP during this study. A diet comparison of tiger and leopard (*Panthera pardus fusca*), revealed that the diet of leopards consisted of a larger portion of livestock (10%) compared to tigers (0%). This study also focused on the impact of human-tiger conflicts during the last five years in Chitwan National Park, Nepal. The questionnaire-survey indicated that the western section of the buffer zone experienced more livestock depredation, of which tigers are mainly responsible for losses. The majority of attacks occurred during the night (100%), mainly during winter (63.64%). The likelihood of depredation on livestock decreased with increasing distance from the park boundary and, light/fire significantly influenced tiger depredation. The use of protection measures (shepard dog, noise, protection enclosure) appeared not to be significantly influencing the number of attacks. Notable it that regardless of the educational level of local respondents, 93.33% have a positive perception towards large carnivore conservation. To conclude, conflict mitigating measures should prioritize the corridor forest and buffer zone over core area to reduce the economic loss, inflicted by livestock depredation. The conservation actions on the long term can only be effective if enforcement of regulations is combined with education and the active involvement of local communities.

Keywords: Bengal tiger, diet, human-tiger conflict, Chitwan National Park

Public summary

Growing human populations and associated impacts such as forest degradation and overexploitation of wildlife resources, are a rapidly growing threat to Asian wildlife. This increased pressure of local communities on wildlife resources, will potentially lead to an increase in human-carnivore conflicts. The main threats of carnivores residing in close proximity to local communities are habitat loss, human disturbances and potential changes in their prey species dynamics. Additionally retaliatory killings by locals due to depredation of their livestock poses an additional threat towards their conservation.

These conflicts have intensified over the past decades in Chitwan National Park (CNP), Nepal. Therefore the aim of this study is to analyze the natural diet and prey preference of tigers in the core zone (CA), buffer zone (BZ) and, corridor forest (CO) of CNP. The study also compared the diet of tiger and leopard to prioritize areas for conflict mitigation measures. Additionally, it aims to analyze the degree of human-tiger conflict (HTC) in CNP, to understand the perception of local communities and, to assess which conflict mitigation measures are currently applied. Essential for current tiger conservation, is to integrate the data to gain deeper insight in the identification of factors that contribute to the intensification of the conflict.

The findings of this study indicate that tigers are more active in the core region of the park and less involved in livestock raiding compared to leopards. The latter are mainly active in the periphery of the park, where they are responsible for the depredation of livestock. With increasing distance from the park boundary, the likelihood of depredation on livestock decreased. The use of protection measures (shepard dog, noise, protection enclosure) appeared not to be significantly influencing the number of attacks. Regardless of the educational level, the majority of the respondents have a positive perception towards the conservation of large carnivores.

This project is a collaboration between NTNC Nepal (National Trust for Nature Conservation), Leiden University in The Netherlands, Antwerp University in Belgium and Leo Foundation in The Netherlands.

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Abbreviations

CNP	Chitwan National Park
TAL	Terai Arc Landscape
HTC	Human-tiger conflict
CO	Corridor forest
CA	Core area
BZ	Buffer zone
NTNC	National Trust for Nature Conservation
PA	Protected area

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Figure 1.1: On the left a pugmark of a tiger and on the right a pugmark of a leopard (pen length: 14 cm).

Figure 1.2: Scratch mark of a tiger (pencil length: 17cm).

Chapter 1
Introduction

1.1 Anthropogenic pressures and threats

Growing human populations and their associated impacts on the ecosystem, such as forest degradation and overexploitation of natural resources, constitute a fast-growing threat to Asian wildlife (IUCN, 2017). Large carnivores worldwide are threatened by habitat destruction, prey depletion, retaliatory killing and illegal trade (Inskip and Zimmermann 2009). Some authors describe large carnivores as '*keystone species'*: species that have an impact on other species and ecosystem functioning (Simberloff 1998). Others have described them as '*flagship species*', whose main role is to attract the attention of the public, or '*umbrella species',* area-demanding species that represent a wider range of biodiversiy with more modest area requirements (Lambeck 1997). Globally large carnivores are declining as a result of habitat destruction, prey depletion, and human wildlife-conflicts. Increasingly, it is being realized that this decline is a global conservation concern (Sillero 2015).

The survival of large carnivores, in human-dominated landscapes, is conservation dependent (Karanth and Chellan 2009), conservation strategies in these landscapes should focus on the protection of core breeding areas (Kenney *et al.* 2014). The Terai Arc Landscape (TAL) in Nepal and India is such a landscape in which both protected areas and the surrounding buffer zones are important for the conservation of large mammals including top-predators tigers and leopards (Chanchani *et al*. 2014). In this landscape, high densities of threatened large mammals occur naturally such as tigers, CNP in Nepal is one of the most important parks in TAL. However it faces several threats, such as the high number of tourists, invasive species such as *Mikania micrantha*, flooding's, rapid population growth and, increasing conflict with communities (Dhungana *et al.*, 2017; Thapa, 2018). With the ongoing fragmentation of human dominated landscapes, wildlife populations become more isolated and many species become confined to protected areas (Brüner *et al.*, 2001). Due to the encroachment of human settlements and illegal activities into these protected areas, many wildlife species are now forced to live in close proximity with people, thereby increasing risks of conflict (Inskip and Zimmermann 2009). To secure the survival of large carnivores, it is crucial to prevent and mitigate these conflicts between carnivores and humans.

1.2 Ecology of Bengal tigers *(Panthera tigris tigris)*

There are nine subspecies of tigers identified and four of them are already extinct, which include the Bali tiger (*P. tigris balica*) found in Bali island of Indonesia which went extinct in the 1940s, followed by the Caspian tiger (*P. tigris virgata*) extinct in 1970s, the Javan tiger (*P.tigris sondaica*) in early 1980s and the South China tiger (*P.tigris amoyensis*) in 1990s (Seidensticker, 2010). The remaining subspecies are categorized as Endangered on the global IUCN Red List (Luo *et al.*, 2004; IUCN, 2019). However, Wilting *et al.* (2015) supports recognition of only two distinct evolutionary groups of tigers representing two subspecies of tiger, e.g. the Sunda tiger (*P. tigris sondaica*) and the continental tiger (*P. tigris tigris*). The Sunda tiger included *P. tigris sondaica, P. tigris balica* and *P. tigris sumatrae* whereas, the continental tiger included *P. tigris tigris, P. tigris altaica, P. tigris amoyensis, P. tigris corbetti, P. tigris virgata* and *P. tigris jacksoni* (Wilting *et al*. 2015).

Being the top predator, conservation of tigers is often understood in the context of the conservation of the whole ecosystem and its components (Seidensticker 2010). Even though the tiger is regarded as a cultural icon over much of its range, it has been continually threatened by habitat loss, fragmentation of populations, poaching and hunting, the depletion of its prey base, and by human-wildlife conflicts (Dinerstein *et al*. 2007). However, conservation of the tiger is vital for ecological health, but its conservation in a human-dominated landscape is demanding as it requires large and undisturbed areas for ensuring its long-term survival (DNPWC 2018b). The species is enlisted in CITES Appendix I and classified Endangered on the global IUCN Redlist, due to a high threat of extinction in the wild globally (Robinson *et al*., 2015; DNPWC, 2018b; IUCN, 2019).

Historic ranges of the tiger once covered Turkey, Tibetan plateau, Manchuria and the Sea of Okhotsk in South and Southeast Asia (Luo *et al*. 2004). Since 1990, this species has already lost more than 50% of its historic range due to habitat fragmentation and degradation by human activities (WWF, 2018). An assessment of the global tiger population in 2015 estimates that 5000 to 7000 tigers may still survive in the wild (J. Goodrich *et al*. 2015). In 2017, there were as few as 3,890 tigers left, suggesting a rapid overall decline in tiger numbers (WWF, 2020). A recent estimate shows 235 tigers present in Nepal, of which a high density resides within CNP (DNPWC 2018b). Tigers are generally solitary and prey density is the most important factor influencing tiger density, territory size, breeding performance and survival of cubs and juveniles (Quigley 2016). Adult female home ranges rarely overlap, whereas male home ranges typically overlap with 1–3 females, a common felid pattern of social organization (Goodrich *et al*. 2015). The lower limit of female territory size in CNP is around 15-20 km^2, set by social intolerance (Sunquist, 2009). Male and female tigers establish territories which they will defend against intruders. Territory size may change during the breeding season as males try to access female territories, often leading to violent confrontations with other males (Sunquist, 2009).

Nepal is one of the collaborators of the "Global Tiger Recovery Programme, (NTRP; 2010-2022)" which was endorsed in the St. Petersburg Declaration on the Tiger Summit held in St. Petersburg, Russia on November 21-24, 2010 (S. K. Upadhyaya 2019). The declaration aims to double the number of tigers across its distribution range by 2022. The major activities for tiger conservation conducted in CNP are tiger monitoring, anti-poaching operations, habitat management and public awareness (DNPWC 2018b).

1.3 Carnivore interactions

Tigers (*Panthera tigris tigris)* and leopards (*Panthera pardus fusca)* are known to be sympatric carnivores across most of their range, they are present in the same geographical area and may encounter one another (Prasad and Pavel, 2012; Upadhyaya, 2019). Tigers and leopards have substantial dietary overlap (Lovari *et al*. 2015). Both predators are predating on small, medium and large-sized ungulates, which could create competition between the two species (Odden, 2007). Theoretically, if the availability of shared resources is not a limiting factor, species would coexist without competition (Lovari *et al.* 2015). Conversely, if the availability of resources is limited, competition is expected to occur. In this case one species, the 'inferior' competitor, may be affected by the other, the 'superior' competitor, through resource exploitation or interference (Putman, 1996). Ecological theories predict that sympatric species should avoid competition through spatial and/or temporal partitioning and avoidance (Andheria *et al.*, 2007). Smaller species are expected to differentiate their diet from that of larger, dominant ones, to reduce the risk of competition and potentially lethal encounters (Mondal *et al.* 2012; Lovari *et al*. 2015; Odden, 2017). Smaller carnivores may also show active spatial or temporal avoidance towards larger carnivores (S. K. Upadhyaya 2019). Because of this co-existence, the temporal and spatial interactions of these carnivores are relevant for conservation. Some authors hypothesize that leopards are pushed towards park boundaries when the number of tigers inside a park increases, thereby contributing to more human-leopard conflicts (Upadhyaya, 2019). This theory is confirmed by several studies, which indicate that leopards show spatial and temporal avoidance of tigers in the core zone (Subodh K.U., 2019; Upadhyaya, 2019; Lamichhane, 2019).

1.4 Diet study

The tiger is an ambush predator and its activity pattern is predominantly crepuscular and nocturnal while they rest during the day (Karanth and Sunquist, 2000). They are mostly preying upon the largest ungulates in all the ecosystems in which they occur (Biswas and Sankar 2002). Although they can potentially hunt prey varying from small mammals to the largest of the bovids, the mean weight of species hunted is around 60 kg (Bhattarai and Kindlmann, 2012). Prey is obtained predominantly from deer species, which contribute up to 75% of the prey biomass requirement of the tiger in most parts of its range (Sunquist *et al*., 1999). The major prey species of tigers include medium to large size prey such as Sambar (*Rusa unicolor*), Chital (*Axis axis*), wild boar (*Sus scrofa*) and musle deer (*Moschus sps*.) (Bhattarai and Kindlmann, 2012; Bhandari, M.K. and Pokheral 2017). However, it was indicated that with increasing distance from the core area, tigers killed more livestock in comparison to wild prey, possibly because livestock were more easily accessible than wild prey (Kolipaka 2018). This author also found that male tigers killed a higher percentage of livestock than female tigers with increasing distance from the core area. Several studies indicate varying degrees of livestock raiding by tigers in CNP. In the study of Biswas and Sankar (2002) livestock is only present in a very small proportion of tiger scats compared to leopard scats. This is in accordance with the findings of Bhattarai, (2012) and Upadhyaya *et al*. (2018) who also found a very low percentage of livestock in tiger scat. Whereas other studies report a higher frequency of livestock in tiger scats (Seidensticker, 1976; Wang & Macdonald, 2009; Kolipaka *et al*., 2017).

Factors affecting prey choice in tigers differ across its distributional range and need to be understood in the local context. Such an understanding has been proven to be important for effective conservation planning (SUNQUIST & SUNQUIST, 1989). Thus, studying the food habits of tigers concerning their prey base is essential for better management of tigers and their habitats. The results of a diet study may support future conservation practices to reduce human-wildlife conflict.

1.5 Human-wildlife conflicts

Across much of the tiger's range, there is considerable information about the magnitude of human-tiger conflicts (HTC) (Nowell & Jackson, 1996; Helalsiddiqui, 1998; Nyhus *et al*. 2004). These conflicts arise when the requirements of people and wildlife overlap, potentially creating costs to both (Inskip and Zimmermann 2009). Conflict with people and their livestock is a significant source of mortality for large carnivores and there is an urgent need to characterize and develop measures to mitigate and reduce these conflicts (Nowell & Jackson, 1996; Linnell, 1999). The retaliatory killing of large carnivores after conflicts contributed to global declines of large carnivores (Lindsey and Symon 2007).

HTC is generally expressed in three forms, i) tiger attacks on humans, ii) tiger attacks on livestock iii) and threats to human safety (Goodrich, 2010; Lamichhane, 2019). These human-tiger conflicts, in combination with a lack of habitat connectivity, have been identified as common persistent threats for tigers in Nepal (Dhakal *et al*. 2014; DNPWC 2018a). A study in CNP showed a general increase in HTC during 2003-2017 (Thakur *et al.* 2016). During 1979-2006, 88 humans were killed by tigers in CNP (Gurung *et al.,* 2008). Apart from these human casualties, livestock depredation also causes conflicts. Between 2007 and 2014, an average of 44 head of livestock were killed by tigers annually (Dhungana *et al*. 2017). These conflicts reduce support for tiger conservation among local communities (Goodrich, 2010) In CNP, a compensation-/relief scheme for wildlife victims (either human or economic loss) was established in 1999, to compensate for losses. These compensation-/relief schemes generally also result in higher tolerance of local communities to livestock losses (Lamichhane 2019). Along with legal and institutional protection of endangered species such as tigers (*Panthera tigris tigris*), support is needed from local communities living inside or close to the protected areas (Inskip *et al*., 2014).

1.6 Aim of the study

Human-wildlife conflicts are increasing worldwide as a result of the increasing human populations living in close proximity to parks. This study aims to analyze the natural diet and prey preference of tigers in the surroundings of CNP, with a specific focus on the buffer zones. Additionally, this study aims to analyze the degree of conflict in CNP and its buffer zone and to understand the perception of local communities living in the vicinity of tiger habitat. The intend of this study is to integrate the data and to contribute to an assessment of the conflict and its potential solutions.

1.6.1 Research objectives

1) What is the overall diet of tigers in Chitwan National Park and buffer zone/ corridor and surrounding fragmented areas?
    a. What is the species composition?
    b. What is the overall contribution of livestock in the diet composition?
    c. Are there any specific prey preferences?
    d. Is there a significant difference in prey species when we compare the natural diet of tiger and leopard?
2) What is the spatial and temporal distribution of human-tiger conflicts?
    a. What is the distribution of conflicts in the buffer zone/ corridor?
    b. Which factors influence these conflicts?
3) What is the perception and attitude of local communities regarding the tiger and what measures are taken to manage and prevent human-tiger conflicts?

1.6.2 Research hypothesis

I) Because of a high density of tigers inside the core area, leopards are pushed to the buffer zone and corridor forest and become more involved in livestock raiding.

II) Scat of both leopard and tiger collected in the core area (CNP) contains a smaller proportion of livestock compared to scat collected in the buffer zone and corridor forest.

III) People who reside near the park border will experience more livestock depredation.

Figure 2.1: Old scat (>2 weeks) of a tiger, potential prey species: Spotted deer.

Figure 2.2: Collected scats after washing with sieve (1 mm), drying in full sun.

Chapter II

Material and methods

2.1 Background study area

This study was conducted in CNP (27°16.56’- 27°42.14’N and 83°50.23’ - 84°46.25’E) in Nepal and in its buffer zone, including the Barandabhar Corridor Forest (Fig. 2.3; Fig 2.4; Fig 2.5). It was designated as Nepal’s first protected area in 1973, and covers 932 km^2 in south-central Nepal, on the border with India. It is a part of the Terai Arc Landscape (TAC), a priority tiger conservation landscape (E. Wikramanayake *et al.* 2004). It is a UNESCO World Heritage Site since 1984, and considered to be a global biodiversity hotspot, especially since the park holds the largest population of tigers in the country (Karki and Pandav, 2013; Dhakal *et al*., 2014). Due to the presence of this population, CNP is considered an important area for tiger conservation globally (E. D. Wikramanayake *et al.* 1998).

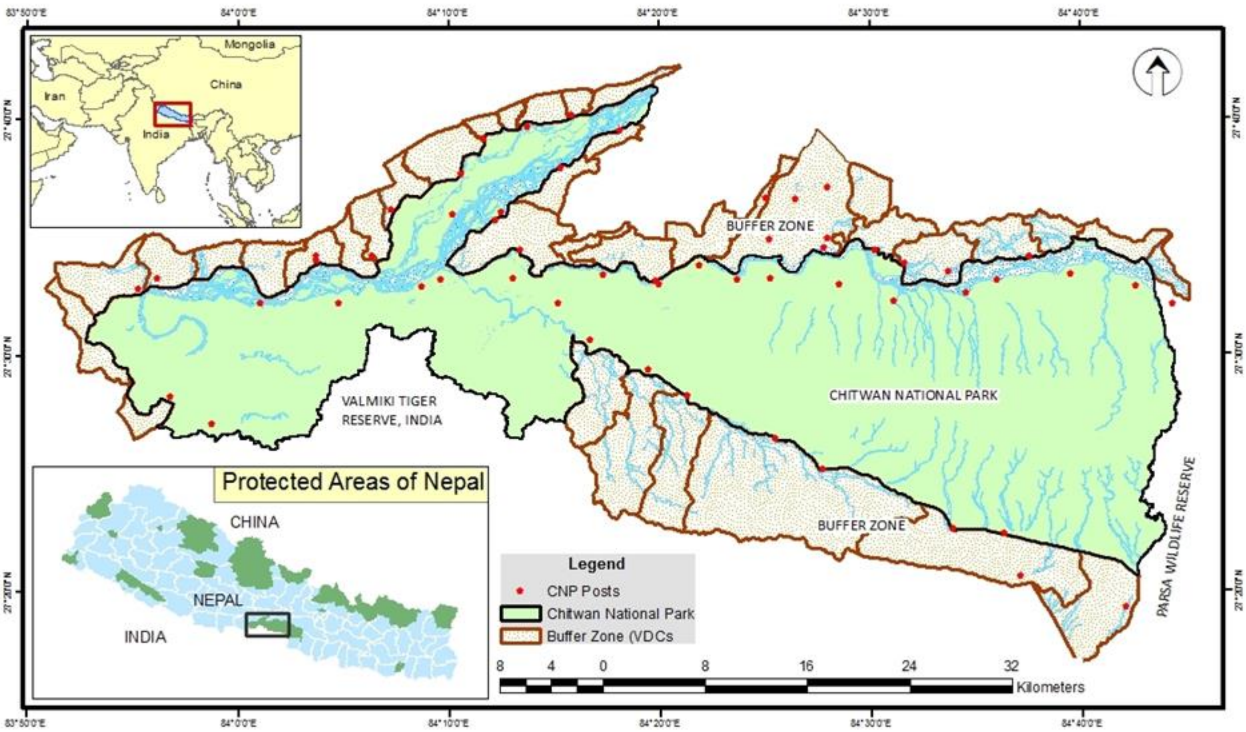

Figure 2.3: Map indicating Chitwan National Park and its buffer zone (Source: NTNC, 2017).

CNP accommodates 50 mammal species, over 526 bird species, 49 reptiles and amphibians, and 120 species of fish (Karki, 2011). The park is dominated by forest (80%) with a majority of sal (*Shorea robusta*) forest, followed by riverine forest and mixed hardwood forest (Thapa, 2016). Also, there are grasslands (12%), exposed surface (5%) and water bodies (3%) (Thapa, 2011). CNP holds the second largest population of greater one-horned rhinoceros (*Rhinoceros unicornis* Linnaeus, 1758) in the world with the latest estimate of around 600 individuals (Subedi *et al.* 2017). Other important species present are the Indian elephant (*Elephas maximus indicus* Linnaeus, 1758), Gaur (*Bos gaurus* C. H. Smith 1827), Sloth bear (*Melursus ursinus* Shaw, 1791), Great hornbill (*Buceros bicornis* Linnaeus, 1758) and Gharial crocodile (*Gavialis gangeticus* Gmelin in Linnaeus, 1789) (Bhattarai & Kindlemann, 2012; CNP, 2015).

For this thesis, the corridor forest (CO) is considered part of the Barandabhar corridor forest which is situated outside of the buffer zone (Fig 2.4). The park consists of a core area with a total surface area of 932 km², surrounded by a buffer zone which covers a surface area of about 750 km² (Bhattarai & Kindlmann, 2012). The different zones (CA, CO, and BZ) are expected to experience different degrees of human disturbances (Gurung, Nelson, and Smith 2009). The CA experiences the smallest degree of human disturbances, mostly in the form of tourism, such as guided walking tours or car tours. However, these touristic activities do not cover the entire park they cover, only a small proportion, leaving the core area undisturbed. In this zone grazing practices and fodder collection are prohibited (some exceptions: e.g. elephant owners). In the BZ, which functions as a transition zone, sustainable livestock grazing and fodder collection are allowed under certain conditions (Nepal and Weber, 1994; Gurung, Nelson and Smith, 2009). The CO is surrounded by villages, and sustainable grazing practices, as well as fodder collection, are allowed (Gurung, Nelson, and Smith 2009), this zone is expected to experience the highest degree of human disturbance.

2.2 Data collection

2.2.1 Diet study

To determine the diet of the tiger, a non-invasive microscopic analysis of prey hair morphology obtained from scat was applied (Ramakrishnan *et al.*, 1999). The scats were collected and analyzed over a period of 3 months fieldwork (October-December 2019), in three areas: the core area (CA), the buffer zone (BZ) and corridor forest (CO). For each field visit, technicians of NTNC accompanied and assisted me in the identification of the signs in the proximity of the scats.

Since leopards and tigers are more likely to defecate on forest tracks or grassy areas just bordering the tracks (Sunquist, 1981; Johnsingh, 1983; Norton *et al.*, 1986; Karanth and Sunquist, 1995), scats were collected along forest tracks. Two samples were collected from each fresh scat: one for genetic analysis

(DNA) and another for prey identification. The samples for DNA analysis were taken to analyze the field identification accuracy. Only the outer muscular layer was collected using a swap and sealed into a vial, containing 95% ethanol. Afterwards these labelled vails were stored in a fridge for its later extraction. The samples for prey identification were sealed in plastic zip-bags and labelled for location, GPS coordinates, habitat type, age of scat, scat composition, predator, potential prey species and date.

Transects were walked or covered by motorcycle, based on existing knowledge of field experts and accessibility by distance. This studies main focus was the collection of samples in the buffer zone of CNP, e.g. the region with potentially the highest degree of conflict. However, due to extremely low encounter rates in the buffer zone, the core area was later also included into this study. Searching effort was maximised in the buffer zone (> ±25 days), and a minimal amount of time was invested in searching the core area (< ±5 days). Daily transect length varied from 12.7 km to 19.16 km, with an average of 16.87 km. The low encounter rate was mainly due to the extremely high vegetation (> 2m), which made it challenging spotting any wildlife signs. Additionally, performing the fieldwork in another season (February-May) would potentially have increased the encounter rate due to lower vegetation. Also, the period of fieldwork was a limiting factor, a longer period would have potentially increased the number of samples collected.

Differentiation between tiger and leopard scats were based on the size and shape of the scats, signs in the proximity of the scat and the conformation by local expert technicians (Odden and Wegge, 2010). The signs included length of scratch marks (Fig 1.2), pugmarks (Fig 1.1), smell or other deposits. Usually, scats of tigers have a lower degree of coiling and relatively larger distance between two successive constrictions within a single piece of scat in comparison with leopard scat (Biswas and Sankar, 2002).

The collected scats were first dried in open air, followed by washing using a sieve (pore size: 1 mm) to separate the hairs, feathers, and bones from the organic matter. These samples were then dried in the sun during a period dependent on each scat (Fig 2.2), afterwards, the samples were inserted in newspapers and folded into little packages for further drying.

2.2.2 Prey species density

Prey species densities were estimated to analyze the potential prey preference of tigers. These estimates were based upon data from wildlife population assessment reports available at NTNC. For a comparison between the three zones, data of previous years were consulted. The latest survey of prey species density conducted in the core- and buffer zone of CNP, was in June 2019. However, the disintegrated data had not yet been analyzed. The second most recent survey for the core area dates back to April 2016. For the buffer zone and corridor forest the data used dated back to May 2017. To use this data, the assumption was made that the prey composition did not change significantly over time. For the core zone a line transect of ± 21 km was used to study the prey density in the Eastern sector of CNP, in 2016. Each transect was surveyed twice at periods were animals were active (morning/ late afternoon). Count data were used and extrapolated to the area to represent the relative prey availability. Similar methods were used for the buffer zone and corridor forest.

2.2.3 Human-tiger conflict

The study was conducted in the buffer zone of CNP, including 2 Village Development Committees situated in the Easter- (Tikauli buffer zone community forest user group) and westerner section, respectively (Fig 2.4). To obtain specific quantitative and qualitative information from the different zones, a pre-formatted questionnaire was developed with simple open- and closed questions about past incidents, the loss of livestock and possible prevention methods (Annex I). The questionnaire developed by Dr. Babu Ram Lamichhane (NTNC, biodiversity conservation center) and PhD student Simon Reynaert (UAntwerp) was used for comparison.

For this survey, it was opted to interview the household heads. Household heads were sometimes temporarily absent, in which case another person of the same household was selected for the interview. The households were semi-randomly selected based on the proximity to the border of the park and distribution over the different zones of the park (focus on east- and west zone) and accessibility by bicycle. The questionnaire considers only the Chitwan district. In total, sixty households were interviewed. In each zone at least 10% of the households were interviewed, the starting point was chosen at random, leaving 5 households between consecutive interviews.

Data were collected on human casualties and incidents of livestock depredation, that occurred during the last years (≤ 5 years). The human casualty data included type (killed or injured) and, date (season, day/night). The livestock depredation data included livestock type and the number of loss (buffalo, duck/chicken, cow/ ox, goat, sheep, pig), date (season, day/night), methods of protection (light, noise or shepherd dog) and the enclosure method of the livestock (no shed, temporary with fence, temporary without fence, permanent without fence or permanent with fence). Coordinates of surveys were recorded using a hand-held global positioning system (GPS) unit.

2.3 Data analysis

2.3.1 Scat analysis

After the scats were washed and dried, the procedure following Ramakrishnan *et al.* (1999) was used for the preparation of the microscopic slides. First of all, the morphological features of the prey hairs were analyzed and photographed (Canon EOS 200D). And for each sample signs of bone fragments and small skulls were recorded. Secondly, approximately 20 hairs were randomly taken from each scat for slide preparation. Before mounting the hairs on the slide, they were first briefly washed in ethanol and dried using filter paper. Meanwhile, the slides were cleaned and were polished with a thin layer of clear nail polish. The mounted hairs were removed after ± 10 minutes using forceps, leaving an imprint. The mounted slides were then examined using a microscope under 400X magnification where the medullary pattern was matched with the patterns in the reference collection book. Lastly, pictures of each hair imprint were taken of the medial part of the medullary pattern with a Coslab Digital Camera (model: MDCE-5C). The majority of prey species identification was largely performed at the University of Antwerp, based on the pictures (Fig 3.1).

Prey species were classified into three different classes in terms of their mean body weight, following Lovari *et al.* (2015). Average weights of prey species were obtained from Dinerstein (1980), Wegge *et al.* (2009) and Narasimmarajan and Parida (2014). Species with a mean weight between 5 and 25 kg were classified as 'small prey' (barking deer, common langur, Indian porcupine), between 25 to 100 kg as 'medium prey' (chital and wild boar) and >100 kg as 'large prey' (sambar deer, gaur and sloth bear).

2.3.2 Statistical analysis of diet study

For the diet study, all statistical analyses were performed using the software RGui version 3.5.1 ("Feather Spray"). Data were first tested on normality with RGui software, and test results were assumed significant for levels of $p < 0.05$. Tiger prey preferences were determined following the methods used to determine the prey preferences of other large predators (Hayward *et al.*, 2006; Lyngdoh *et al.*, 2014). A Jacobs' Index was used to determine the prey selectivity of tigers in the different zones (CA, CO & BZ) using the formula:

$$E = \frac{r-p}{r+p}$$

E= Jacobs Index

r = % prey species in diet

p = % available prey in the environment

This index generates a value between -1 and 1, where the latter represents a strong preference for the considered prey species. Additionally, Chi-square tests were applied to analyze differences in the overall diet between tigers. To test for significant differences in diet between the different zones as well as between tiger and leopard, generalized linear models (GLM, family='binomial') were constructed. Two by two comparisons were performed utilizing posthoc tukey tests to find significant differences. The diet data matrix was split up to obtain two dependent factors consisting of wildlife and livestock. All prey species presences and absences (1 or 0) in the data matrix were assigned to one of these two classes.

Predator (tiger or leopard) and location (core area, buffer zone or corridor) were considered as independent factors explaining the variation in the model.

2.3.3 Statistical analysis of human-tiger conflict

To define the fraction and distribution of livestock lost due to depredation, analysis and visualization were performed in Microsoft Excel and QGis. In order to test the hypothesis that distance to the park influences the number of livestock attacks/loss by tigers, a statistical analysis was performed in RGui (version 3.5.1 "Feather Spray”). Tests were deemed significant when p-values were smaller than 0.05. Based on the article by Bommel *et al*. (2007), independent variables responsible for livestock loss were selected out of the data gathered with the questionnaire. The variables were tested to study if they were normally distributed with a Shapiro Wilk test, which was not the case. A General Linear Regression was used to quantify the factors explaining the loss by depredation. The explanatory variables were the distance from the communities to the park boundary, zone (east/west), number of livestock owned, education, season and protection measurements (protection enclosures, noise, light or Shepard dog). Seasons were defined as summer (February-June), monsoon (June-October) and winter (October-February). The Spearman correlation test allowed me to study the data for correlated dependent variables which could not be incorporated in the same General Linear Model (GLM). To avoid multicollinearity in the model, correlated parameters were never included in the same model. As a preliminary test, a full factorial GLM was executed with all possible interactions. This was merely a test since the inclusion of all interactions results in overfitting of the model. Hereafter, several versions of the custom GLM were carried out using reversed stepwise selection, starting from a full model using the elimination of the least significant parameters and by applying the AIC-criterium.

Within the questionnaires, different statements about wildlife conservation were presented to the respondents. They were given the option to either agree with, disagree with, or indicate neutrality towards different statements. This allowed for reporting on the division of perceptions among the population. The results were visualized using Microsoft Excel.

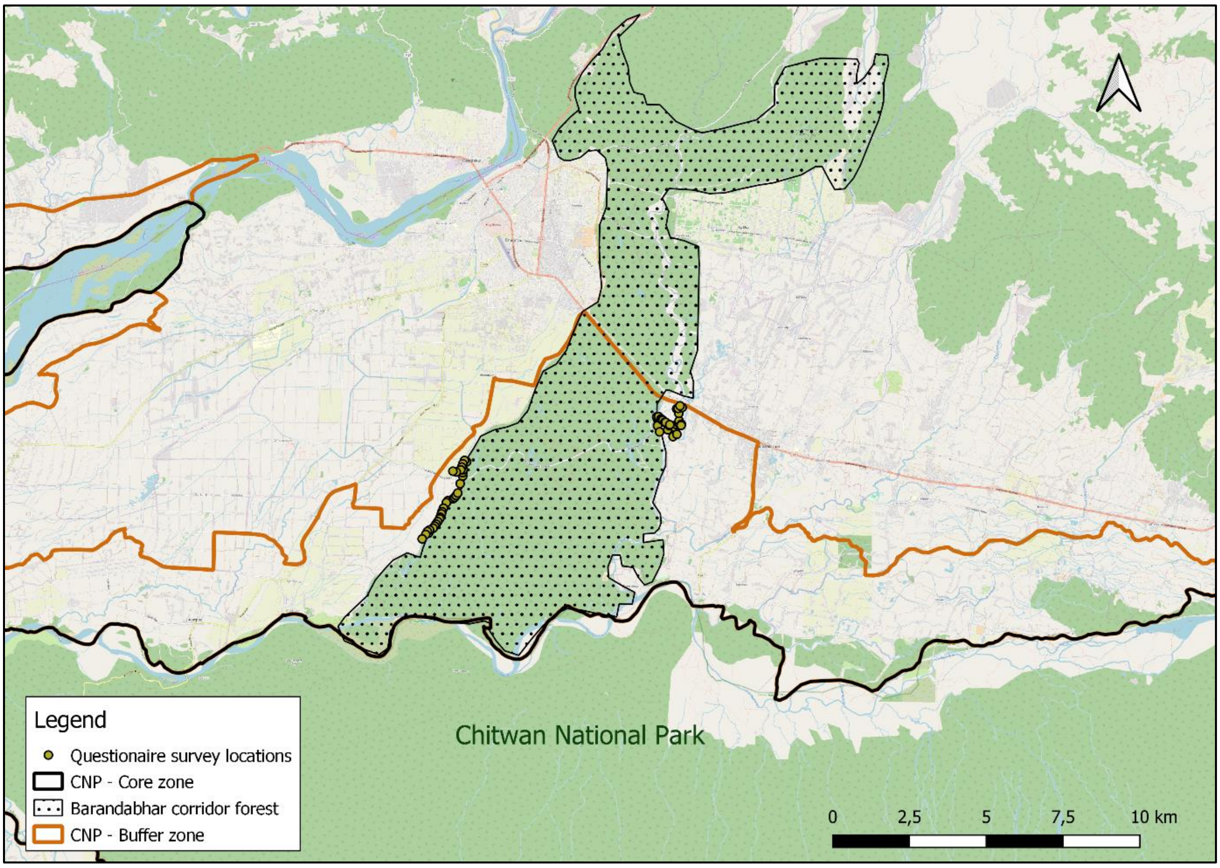

Figure 2.4: Visualization of corridor forest and buffer zone. Yellow points represents the locations of the household-questionnaire survey (n=60). Map constructed in QGis (version 3.12).

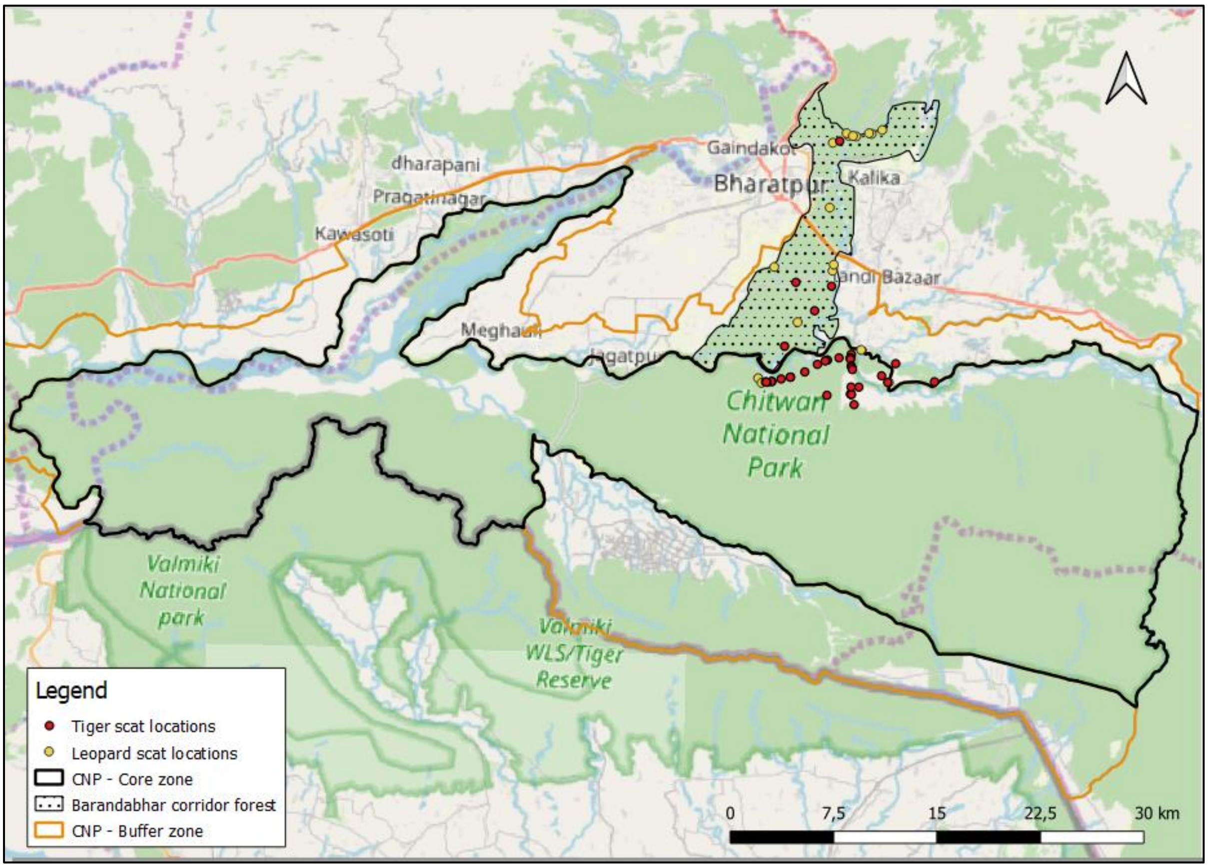

Figure 2.5: Visualization of CNP with red dots representing the scat locations of tigers and, yellow dots represent leopards scat locations. Map constructed in QGis (version 3.12).

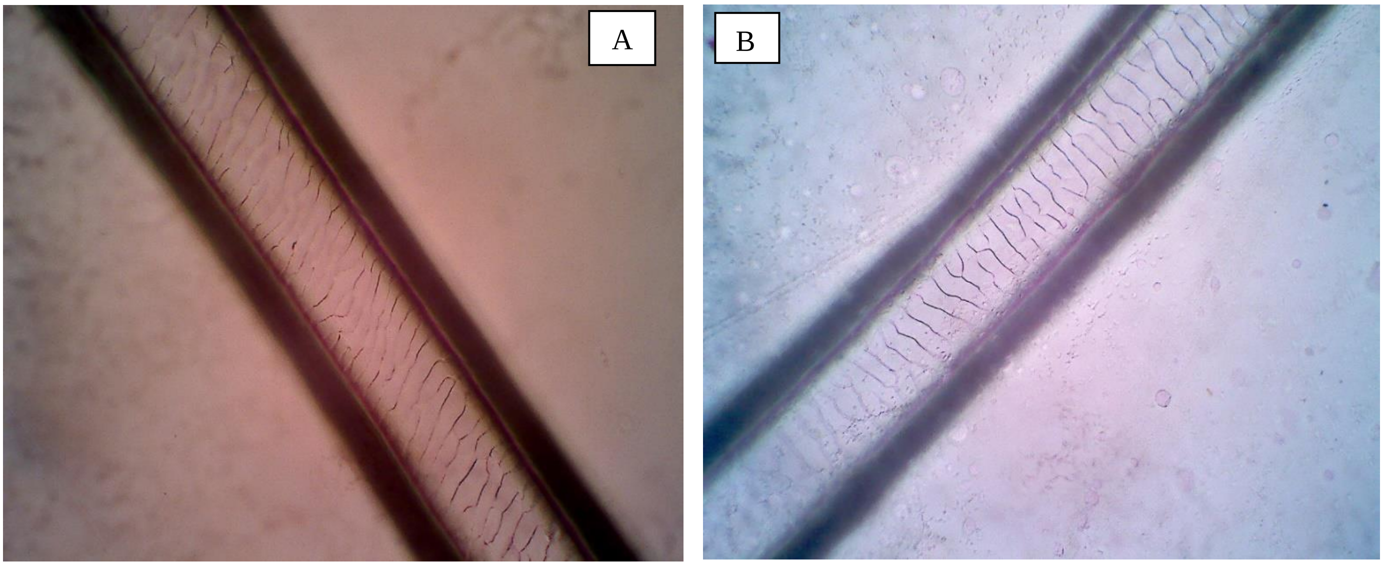

Figure 3.1: Pictures taken by Coslab digital camera of hair imprints on the microscopic slides. (A,B) medial cuticular pattern of guard hair, both identified as spotted deer (Chital (*Axis Axis)*).

Figure 3.2: Major prey species of tigers in CNP, with exception of sloth bear.

Chapter III

Results

3.1 Diet study

3.1.1 Diet composition

In this study, a total of 47 prey items of eight different prey species were identified in the 43 tiger scats (Table 3.1, Table 3.2). The number of tiger scats collected was 34, 8 and 1, for the CA, BZ, and CO, respectively. The distribution of scats across the three zones differs significantly (χ^2 = 23.927, df = 4, p-value = 8.263e-05; Table 3.1, Fig 3.4). The majority of tiger scats were found in the CA (73.07%). Thirty-nine tiger scats (90.70%) consisted of a single prey species and four scats (9.30%) consisted of two prey species. Chital (57.45%) was the dominant prey species hunted by the tigers in CNP (Table 3.2, Fig 3.3). The second was wild boar (17.02%), followed by sambar deer (10.64%). Not all of the prey of CNP were found in the scats and, livestock was absent in this study.

Table 3.1: General overview of number of scats found in each area of CNP belonging to either tiger or leopard.

	Core area	Buffer zone	Corridor forest	Total per species	Total used
Tiger	34	8	1	43	43
Leopard	4	18	2	24	21
Total per area	38	26	3	67	64

Table 3.2: Number (No.) of prey items belonging to tiger scats obtained within CNP.

Common name	Scientific name	No. of prey items	Percentage (%)
Chital	*Axis axis*	27	57.45
Sambar deer	*Rusa unicolor*	5	10.64
Barking deer	*Muntiacus*	3	6.38
Wild boar	*Sus Scrofa*	8	17.02
Common langur	*Semnopithecus entellus*	1	2.13
Gaur	*Bos gaurus*	1	2.13
Indian porcupine	*Hystrix indica*	1	2.13
Sloth bear	*Melursus ursinus*	1	2.13
Total		47	100

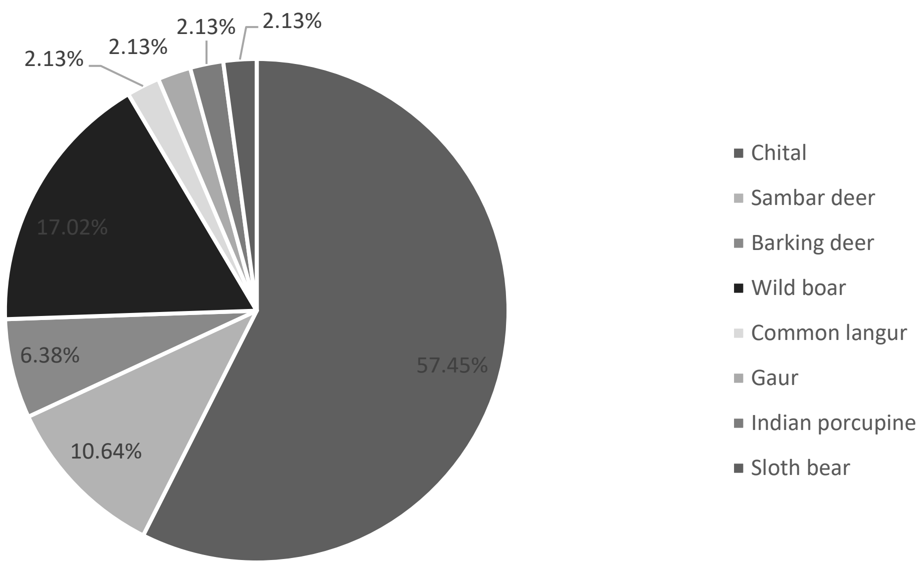

Figure 3.3: Visualization of the percentage of prey items (n=47) obtained from the tiger diet in CNP, combing the CA, CO and the BZ.

Fig 3.3 complements Table 3.2, indicating that the majority of tiger diet consists of chital (57.45%). Wild boar is also considered as an important prey item in the tiger diet (17.02%).

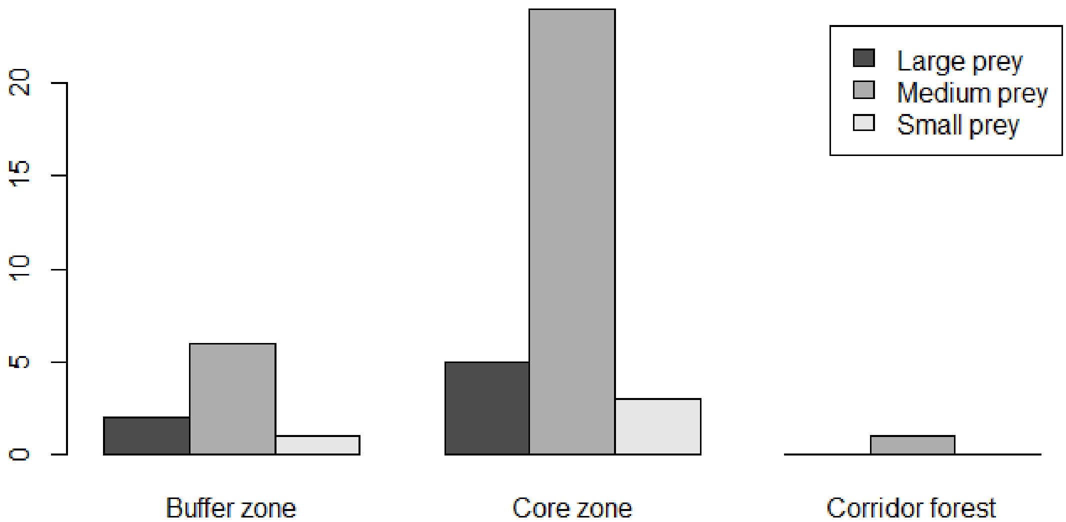

Figure 3.4: Barplot representing the tiger diet in relation to the amount of wild prey per category (small-, medium- and large prey) distributed across the different zones, note prey items are in terms of counts.

Fig 3.4 concludes that most prey items in the category of 'Medium prey' are obtained from the core zone. Logical, following the prey availability according to the latest wildlife assessment survey (2016), which indicated that medium prey accounts for 71.01% of the total wildlife assessment survey (Table 3.3). Additionally, 'Medium prey' is the most common category across all of the three zones, with 94.14% for both BZ and CO (according to the wildlife assessment survey (2016), Table 3.4/ Table 3.5).

3.1.2 Prey species preference

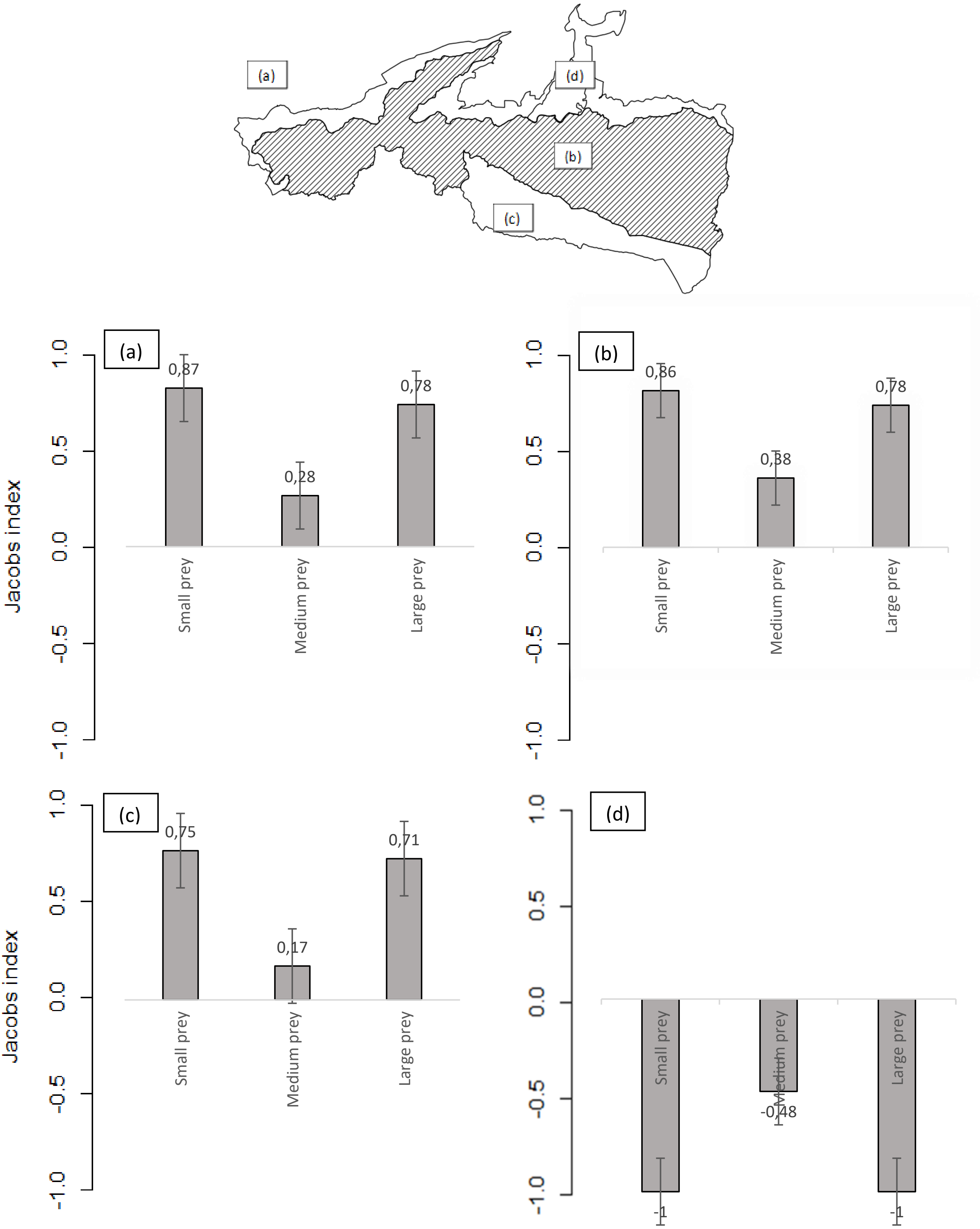

Figure 3.5: Jacob's Index indicating the mean and standard error of tiger prey preference in the different prey classes for (a) CNP, (b) core area, (c) buffer zone and (d) corridor forrest.

The mean Jacob's Index and standard error for the prey class preference in accordance to CNP and the three different zones is represented in Fig 3.5. In general, CNP reflects a strong preference for wild boar (0.74), common langur (1), gaur (1), sambar (0.59) and sloth bear (0.75) (Table 3.3). Similar results are obtained in the core area, e.g. wild boar (0.85), common langur (1), gaur (1), sambar (0.85), etc. (Table 3.4). Chital, although abundant, is not preferred by tigers in CNP, including the core- and the buffer zone. For CNP in general, as for the core area, the results indicate a strong preference for the small prey category (5 – 25 kg), based on the mean Jacobs Index (Fig 3.5: a, b).

Table 3.3: Overview of prey availability in Chitwan National Park (Source: NTNC wildlife assessment report, 2016/2017), diet contribution (%, n=43) and potential prey preferences obtained by the Jacobs' Index. The category 'others' contains species such as peacock, hog deer, e.g. species that were not present in the diet of tigers in this study.

Tiger – CNP					
Prey species	Count	Availability (%)	Diet contribution (%)	Jacobs index	Preference
Chital	1379	84.45	57.45	-0.19	No
Sambar deer	45	2.76	10.64	0.59	Yes
Barking deer	26	1.59	6.88	0.62	Yes
Wild boar	41	2.51	17.02	0.74	Yes
Common langur	0	0	2.13	1	Yes
Gaur	0	0	2.13	1	Yes
Porcupine	0	0	2.13	1	Yes
Sloth bear	5	0.31	2.13	0.75	Yes
Others	137	8.39	0	-1	No
Total	1633	100	100		

Table 3.4: Overview of prey availability in the core zone (Source: NTNC wildlife assessment report, 2016), diet contribution (%, n=34) and potential prey preferences obtained by the Jacobs' index. The category 'others' contains species such as peacock, hog deer, e.g. species that were not present in the diet of tigers in this study.

Tiger – Core zone					
Prey species	Count	Availability (%)	Diet contribution (%)	Jacobs index	Preference
Chital	353	69.63	57.14	-0,10	No
Sambar deer	3	0.69	8.57	0.85	Yes
Barking deer	8	1.58	5.71	0.57	Yes
Wild boar	7	1.38	17.14	0.85	Yes
Common langur	0	0	2.86	1	Yes
Gaur	0	0	2.86	1	Yes
Porcupine	0	0	2.86	1	Yes
Sloth bear	5	0.99	2.86	0.49	Yes
Others	131	25.84	0	-1	No
Total	507	100	100		

Within the buffer zone, tigers reflect a strong preference for sambar (0.71), barking deer (0.75) and wild boar (0.57), but neutrality towards gaur (0) and sloth bear (0) (Table 3.5). According to the mean Jacobs Index tigers in this zone also prefer the small prey category (Fig 3.5: c), similar as in the core area. Within the corridor forest there is a very small preference towards chital (Table 3.6), but no specific preference for a prey category class, however due to the small sample size, the results are biased (Fig 3.5; d).

Table 3.5: Overview of prey availability in the buffer zone (Source: NTNC wildlife assessment report, 2017), diet contribution (%, n=8) and potential prey preferences obtained by the Jacobs' index. The category 'others' contains species such as peacock, hog deer, e.g. species that were not present in the diet of tigers in this study.

Tiger – Buffer zone					
Prey species	Count	Availability (%)	Diet contribution (%)	Jacobs index	Preference
Chital	513	91.12	55.56	-0.24	No
Sambar deer	21	3.73	22.22	0.71	Yes
Barking deer	9	1.60	11.11	0.75	Yes
Wild boar	17	3.02	11.11	0.57	Yes
Common langur	0	0	0	0	Neutral
Gaur	0	0	0	0	Neutral
Porcupine	0	0	0	0	Neutral
Sloth bear	0	0	0	0	Neutral
Others	3	0.53	0	-1	No
Total	563	100	100		

Table 3.6: Overview of prey availability in the corridor forest (Source: NTNC wildlife assessment report, 2017), diet contribution (%, n=1) and potential prey preferences obtained by the Jacobs' index. The category 'others' contains species such as peacock, hog deer, e.g. species that were not present in the diet of tigers in this study.

Tiger – Corridor forest					
Prey species	Count	Availability (%)	Diet contribution (%)	Jacobs index	Preference
Chital	513	91.12	100	0.046	Yes
Sambar deer	21	3.73	0	-1	No
Barking deer	9	1.60	0	-1	No
Wild boar	17	3.02	0	-1	No
Common langur	0	0	0	0	Neutral
Gaur	0	0	0	0	Neutral
Porcupine	0	0	0	0	Neutral
Sloth bear	0	0	0	0	Neutral
Others	3	0.53	0	-1	No
Total	563	100	100		

3.1.3 Diet comparison

Leopard and tiger diet are represented in Table 3.7. The number of leopard scats collected was 4, 18 and 2, for the CA, BZ and CO, respectively. In comparison with the number of tiger scats collected: 34, 8 and 1, for the CA, BZ, and CO (Table 3.1). The major difference in the diet between the species is the presence of livestock (10%) in the diet of leopards (Fig 3.7). Additionally, 42.86% of the samples of leopard scat and, only 9.30% of the samples of tiger scats consisted of two prey-species.

Table 3.7: Diet comparison of leopards and tigers in CNP.

Common name	Scientific name	No. of prey items		Percentage (%)	
		Tiger	Leopard	Tiger	Leopard
Chital	*Axis axis*	27	15	57.45	50
Sambar deer	*Rusa unicolor*	5	1	10.64	3.33
Barking deer	*Muntiacus*	3	3	6.38	10
Wild boar	*Sus Scrofa*	8	4	17.02	13.33
Common langur	*Semnopithecus entellus*	1	1	2.13	3.33
Gaur	*Bos gaurus*	1	0	2.13	0
Indian porcupine	*Hystrix indica*	1	0	2.13	0
Sloth bear	*Melursus ursinus*	1	0	2.13	0
Hog deer	*Axis porcinus*	0	2	0	6.67
Domestic goat	*Capra aegagrus hircus*	0	3	0	10
Bird	*Unknown*	0	1	0	3.33
	Total	47	30	100	100

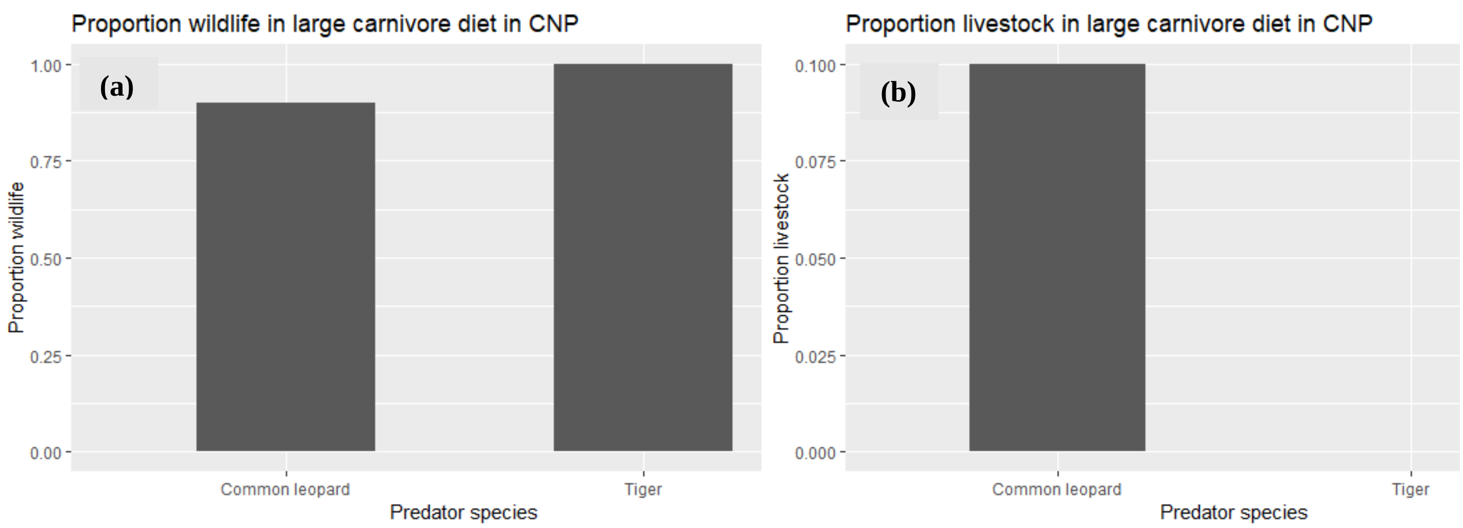

Figure 3.6: (a) Proportion of wildlife found in the diet of both carnivores. (b) Proportion of livestock found in the diet of both carnivores.

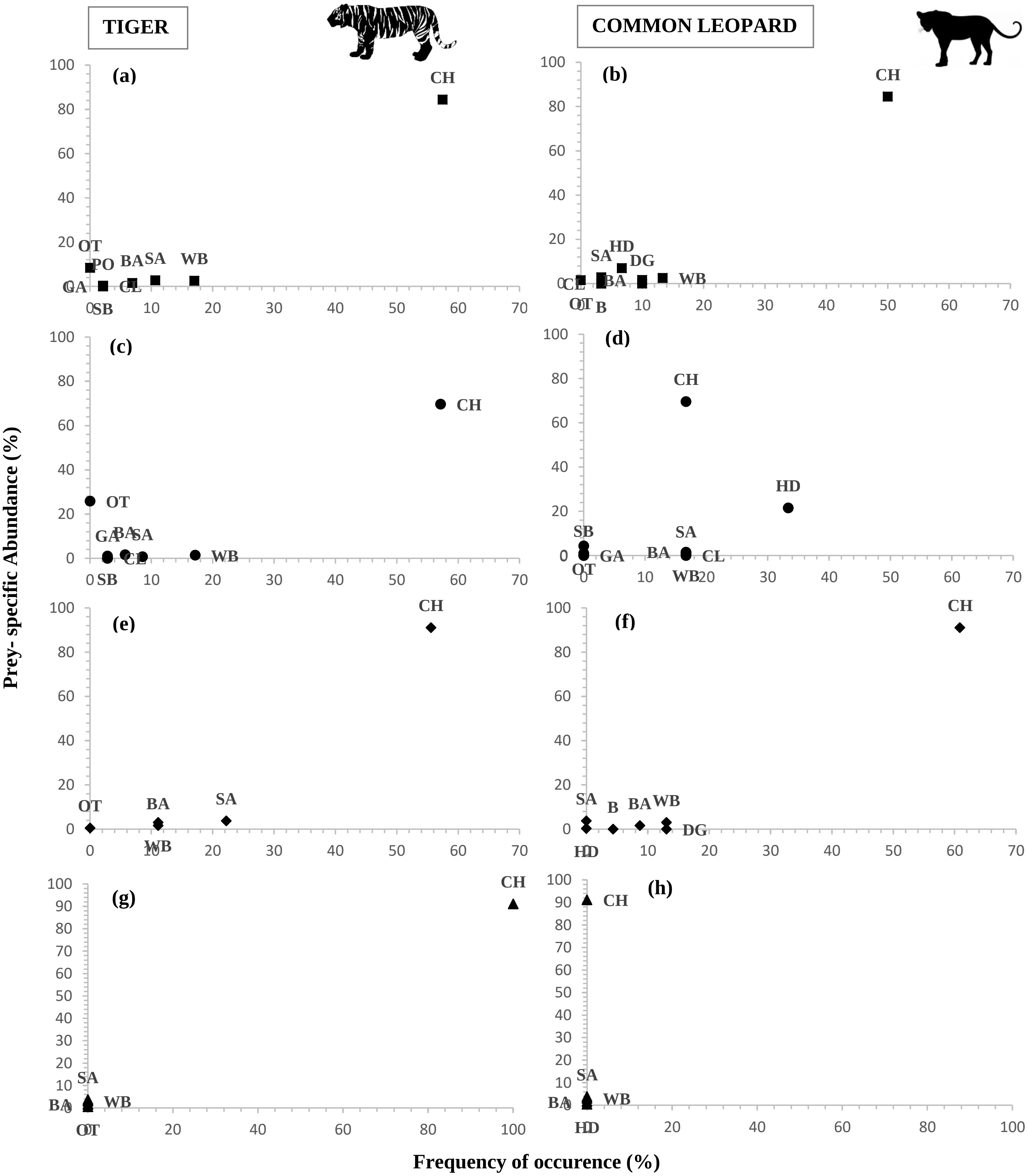

Figure 3.7: Feeding strategy diagram. Prey-specific abundance plotted against frequency of occurrence of prey items in the diet of the tiger (n=47) (a,c, e & g) and the diet of the common leopard (n=30) (b,d,f & h). Prey items: (CH) chital, (HD) hog deer, (GA) gaur, (WB) wild boar, (SB) sloth bear, (BA) barking deer, (SA) sambar deer, (DG) domestic goat, (B) bird, (OT) others. ■ represent the diet in CNP ● represents diet in the core zone, ◆ represents diet in the buffer zone, ▲ represents diet in the corridor forest of CNP.

For both tigers and leopards in CNP, several less abundant prey species are clustered in the lower left quadrant of the feeding strategy diagram, representing items with low contribution to the diet in terms of prey-specific abundance (Fig 3.7). Chital was dominant in the diet of both predators in CNP, projecting their similar utilization pattern. Although abundant in availably and in contribution to the predator diet, chital was not preferred by either tiger or leopard in CNP.

There is some variation in the contribution of livestock and wildlife to the diet of tiger versus leopard as well as between the different areas (Table 3.1/ Table 3.7/ Fig 3.6 / Fig 3.7/ Fig 3.8). To find if any of these variations are statistically significant, p-values were computed using GLM's. For neither wildlife, livestock nor birds a significant interaction between species and location was found. Scats obtained from the CA contain a significantly higher proportion of wildlife (1.00) than those found in the buffer zone (0.90) (GLM, z-value = 2.69, p-value = 0.007, df = 2, Fig 3.7). No significant difference was found in CA and the CO in wildlife prey items. The diet of leopards in CNP consists of a significantly larger proportion of livestock compared to the tiger diet (GLM, z-value = -2.42, p-value = 0.016, df = 1).

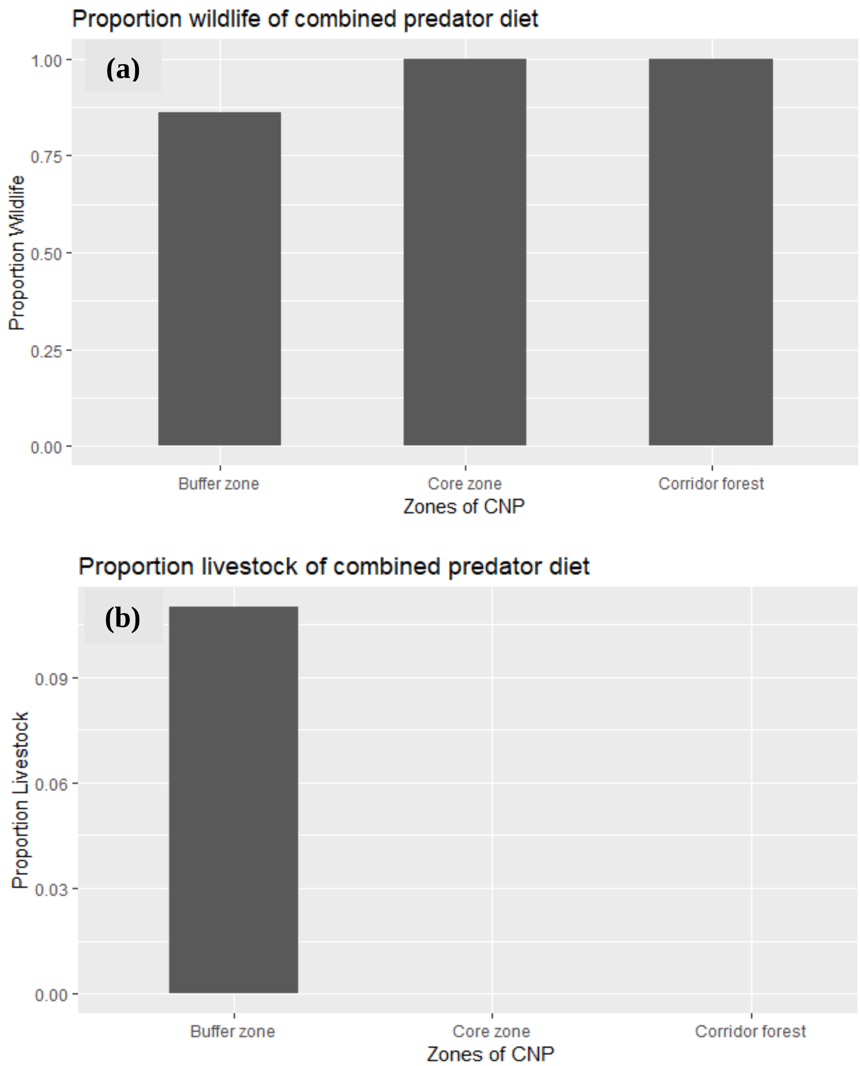

Figure 3.8:

(a) Differences in the proportion of wildlife found in scats of tiger and leopard between the three different zones.

(b) Differences in the proportion of livestock found in scats of tiger and leopard between the three different zones.

Scats obtained from the core zone and corridor forest only contain wildlife, whereas a few scats of the buffer zone contain livestock.

3.2 Human-tiger conflict

3.2.1 Fraction and distribution of livestock lost to large carnivores

Table 3.8 indicates the fraction of livestock that is believed to be lost to carnivores, in relation to the number of livestock owned based on the questionnaire survey. The questionnaire focused on the conflict in the BZ, attacks are displayed per zone and separated into tiger attacks and other large carnivores attacks (e.g. leopard, crocodile, phyton, jackal). The latter are not normally distributed (W = 0.50744, p-value = 6.903e-13), and deviation from normality is assumed.

Table 3.8: Fraction of Livestock lost to large carnivores in relation to the number of livestock owned in the different zones of the BZ in CNP, based on interview survey (n=60).

	Tiger attacks on livestock (%)	**Attacks of other large carnivores on livestock (%)**
Zone within the BZ		
East	0.72	2.17
West	7.25	5.31
Total	4.64	4.06

The fraction of livestock loss is based on the estimate of livestock depredation by respondents during recent years (≤ 5 years), in relation to the number of livestock they own. In the eastern district of the BZ, the combined households owned a total of 138 animals, of which they only lost 4 due to depredation over the past five years. Table 3.8 indicates that tigers were responsible for 1 loss (0.72%), and 3 additional losses (2.17%) occurred due to other carnivores, respectively.

In the western district of the BZ, the combined households owned a total of 207 animals, of which they lost 26 due to depredation over the past five years. Tigers were responsible for 15 losses (7.25%), and 11 losses (5.31%) were contributed by other carnivores.

The data show that tigers are responsible for 4.64% of the attacks on livestock as a percentage of the total number of livestock. The pastoralists lose an additional 4.06% of all livestock to other carnivores. Based on the data collected within this survey, the mean loss over the past five years is 0.06 animals per household that was interviewed. Of the 60 respondents, only 2 reported having problems with tigers, and only 4 reported having problems with other carnivores in the area (e.g. leopards, crocodile, phyton). Most of the respondents (n=52) reported problems with herbivores and omnivores that caused crop-raiding, such as wild boars (n=30), spotted deer (n=6), rhino’s (n=8) and wild elephants (n=8). The latter species were also reported as problem species due to occasional human casualties caused by unexpected encounters between humans and wild elephants.

3.2.2 Factors that influence the frequency of attacks

During the questionnaire survey, all respondents were asked to specify, for every attack, the place, time (night or during the day), and season during which the attack took place. Table 3.9 displays the results for each of the large carnivores.

Table 3.9: Circumstances of the attacks on livestock around CNP by the different large carnivores in percentage of total attacks (n=60, with attacks n=21: n=11 for tigers, n=6 for leopard, n=4 for others).

	Tiger	**Leopard**	**Others**
At night (%)	100	100	100
During the day (%)	0.00	0.00	0.00
Monsoon (%)	18.18	16.67	0.00
Summer (%)	18.18	33.33	50
Winter (%)	63.64	50	50

Table 3.9 shows that all the attacks that were reported during this survey occurred during the night. In general, the majority of the attacks occurred during the winter (16 October – 15 February), 63.64% for tiger and, 50% for leopard and others, respectively. Fig 3.10 indicates that households with larger herds of livestock don't necessarily experience more frequent predation by large carnivores, including predation by the tiger.

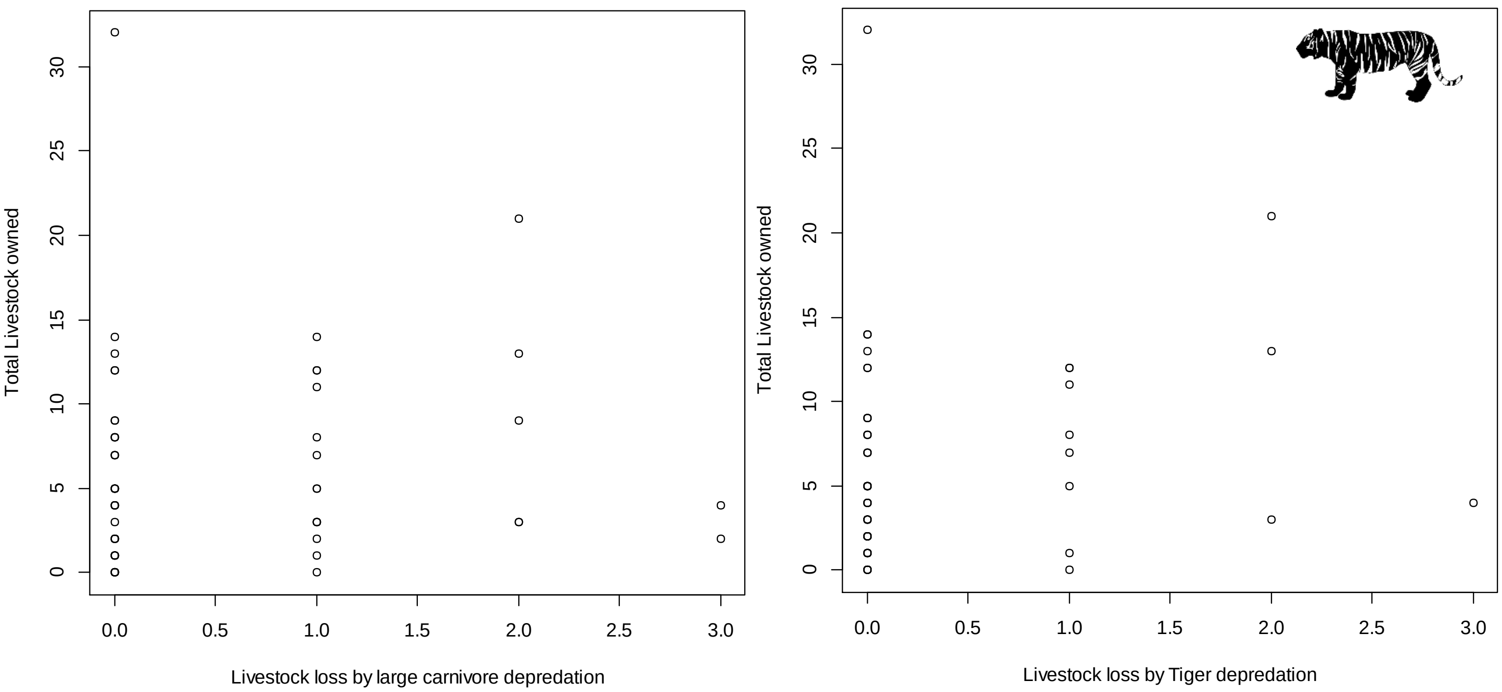

Figure 3.9: Number of livestock lost by large carnivores (e.g. Leopard, tiger, phyton, etc.) (n=14) vs. total livestock owned (n=345) and number of livestock lost by tiger depredation (n=16) vs. total livestock owned (n=345).

A Spearman correlation test was implemented to test the data for correlated dependent variables (Table 3.10), the outcome revealed a number of correlated parameters. The use of light to repel wildlife is significantly correlated with two variables, protection enclosures (0.38, p<0.01: Table 3.10) and Shepard dog (-0.46, p<0.001: Table 3.10), respectively. Additionally, the number of livestock owned is also significantly correlated with the protection enclosure (0.56, p<0.001: Table 3.10), a higher number of livestock present per household results in better protection.

Table 3.10: Outcome of the Spearman's rank correlation test, correlation is significant at *P < 0.05; **P < 0.01; ***P < 0.001. Variables are light (L), distance to the park (D), protection enclosure (PE), Shepard dog (SD), noise (N), education (E), number of livestock owned (LO), summer (S), monsoon (M) and winter (W).

Spearman's rank correlation rho

	L	D	PE	SD	N	E	LO	S	M	W
Light			**	***						
Distance										
Protection enclosure	**						***			
Shepard dog	***									
Noise										
Education										
Livestock owned			***							
Summer										
Monsoon										
Winter										

Correlation is significant at **P < 0.05; **P < 0.01; ***P < 0.001.*

In order to address other variables or factors that can explain or influence the depredation by tigers, several GLM-models were created in RStudio (final model: Annex II). To prevent multicollinearity in the model, it was based on the outcome of the non-parametric test (Table 3.10).

At individual household level it was found that distance to the park boundary (GLM, z-value=9.8006, p-value=0.00285, df=55) and the use of light/fire (GLM, z-value=5.6497, p-value= 0.02348, df=55) were highly associated with livestock losses. With increasing distance to the park boundary, the likelihood of depredation on livestock decreased for the households, visualized in Fig 3.10. The logistic model suggests that the reported attacks are not significantly higher in households with a larger number of livestock (GLM, z-value=0.9884, p-value=0.34337, df=55), as indicated in Fig 3.9. The use of protection measurements (shepherd dog, protection enclosure) appears not to be significantly influencing the number of attacks.

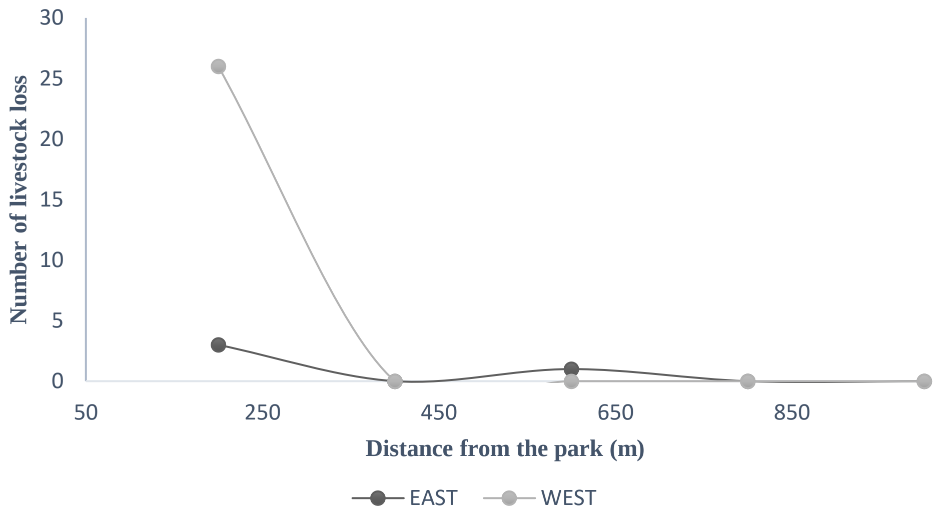

Figure 3.10: Number of livestock loss plotted against distance to park boundary (m).

3.2.3 Perception of locals towards the conservation of large carnivores

Regardless of the educational level (no education/ primary- or secondary level/ college/ university) 93.33% of the households have a positive perception towards conservation, the remaining 6.67% is neutral towards it (Fig 3.11). There is no significant difference between the perceptions and the educational level (χ^2=4.0944, df = 4, p-value=0.3934: Fig 3.11). Additionally, there is also no significant difference in perception between male and female respondents (χ^2=0.14469, df = 1, p-value=0.7037).

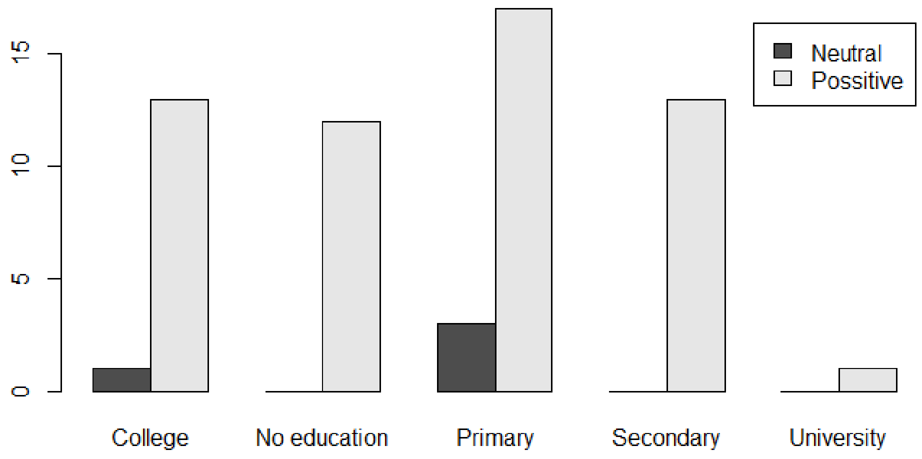

Figure 3.11: Perception of residents (n=60) towards carnivore conservation based on their educational level.

Fig 3.12 states that 93.33% of the population living in the BZ of CNP recognizes the need for large carnivore conservation. Furthermore, 81.67% agrees that wildlife attracts tourists and that the local communities benefit from this practice. Fig 3.12 also indicates that 83.33% is satisfied with the current wildlife management strategies and 83.33% also agrees that the national park authorities play a positive role in the conflict mitigation between humans and wildlife. However, 16.67% of the population living in the BZ of CNP is not satisfied with the current wildlife management strategies. And furthermore, 6.67% agrees with the fact that tigers should be eradicated.

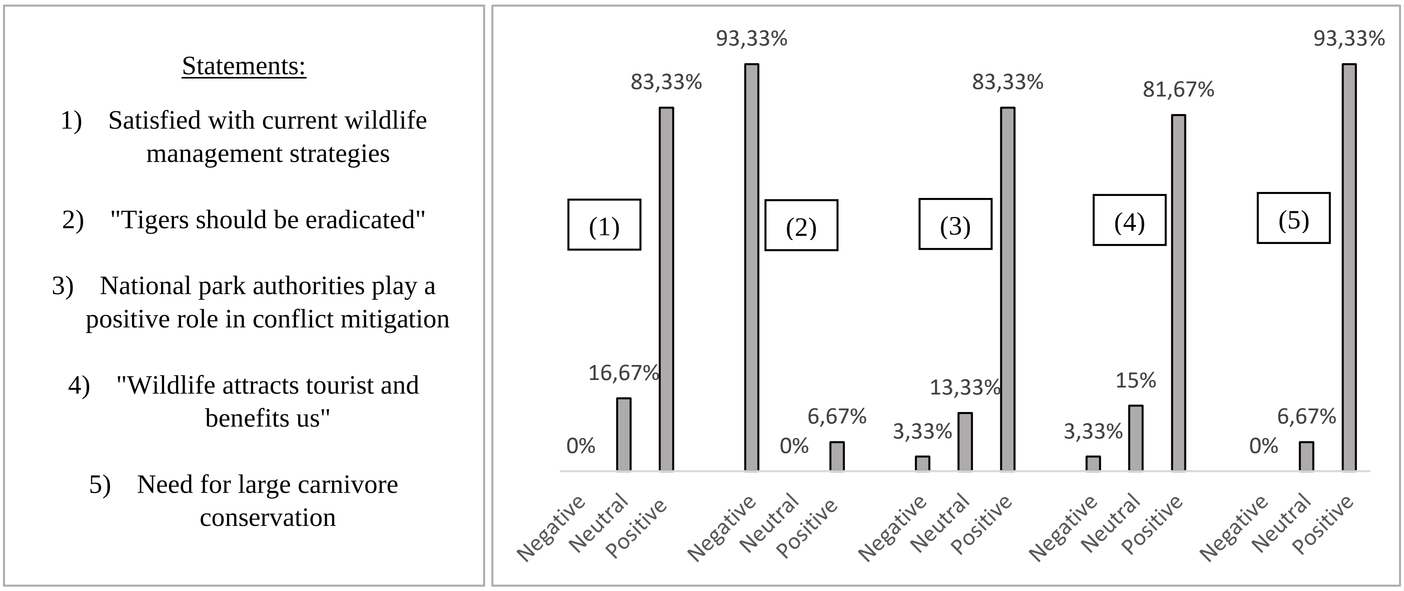

Figure 3.12: Statements related to the different perception of local respondents towards wildlife conservation (n=60).

Fig 3.13 indicates that the majority of the household suggests that education and training (47%) is the most important mitigation strategy to reduce HTC's. Additionally, investment in infrastructure such as better fencing (32%) is indicated as the second most important strategy. And monitoring (13%) and compensation for losses (8%) are considered less important.

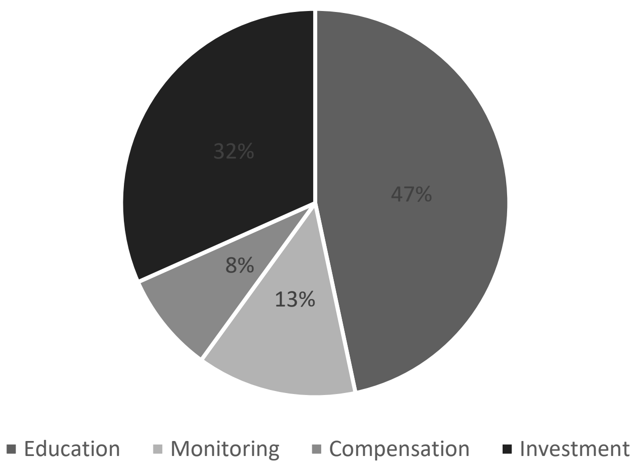

Figure 3.13: General overview of conflict mitigation strategies that are in placed within CNP and perceptions of local households.

3.2.4 Mitigation and protective measurements

The following visualizations reflect the measures taken to prevent/reduce HTC's in CNP. Fig 3.14 (A) presents the different techniques used around CNP to keep livestock herds together. For the protection of the livestock, 1.67% of the respondents reported the use of permanent sheds without a fence. 41.67% used temporary sheds with a fence, 45% used temporarily without a fence and, 11.67% didn't use any enclosure method.

During the questionnaire survey, 51.67% of the respondents stated to use light/fire to scare away carnivores. Shepard dogs were also frequently used, by 16.67% of the respondents. Another measure used to protect their livestock is the use of noise, but only 5% of the households reported the use of this measurement as represented in Fig 3.14 (B).

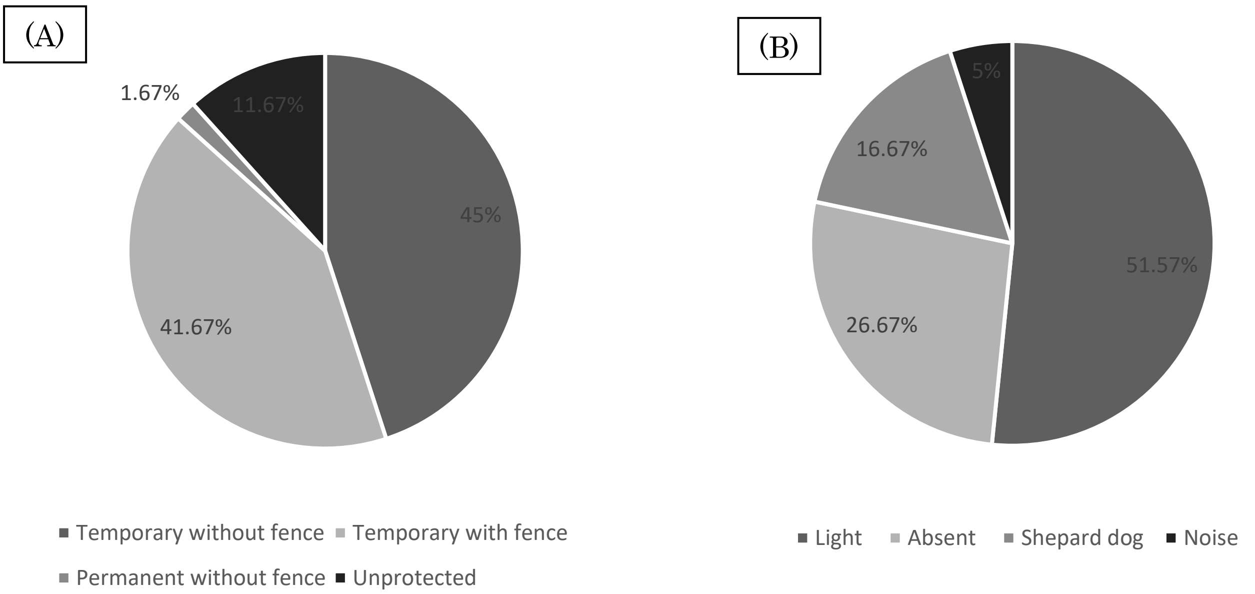

Figure 3.14: (A) Local husbandry practices in the BZ (n=60), (B) Additional methods of protection of the livestock in BZ (n=60).

Figure 4.1: Pictures of leopard and tiger were shown before the start of the questionnaires to indicate whether or not the respondents could correctly identify the species causing conflict.

Figure 4.2: Fence build to protect the nearby communities living in close proximity to the border of park in the BZ.

Chapter IV

Discussion

4.1 Diet study

For this part of the study, data were collected using transect surveys, with identification of scats based on signs in proximity and through conformation by technicians. Upadhyaya et al. (2019) indicated that the field identification of carnivore species by technicians was found to be ‘fairly accurate’ (96%, n=101). This suggests that results based on morphological scat identification are reliable, even without the use of DNA analysis. Scat collection during this study was quite challenging due to several environmental factors. Due to the small sample size and the fact that only fractions of the three zones were surveyed, a caution approach must therefore be maintained when extrapolating these findings towards the entire tiger population in CNP.

4.1.1 Tiger distribution

The results suggest that tigers are more active in the core region of the park and less involved in livestock raiding than leopards, which only occurred in the buffer zone of the park. These findings are in agreement with Lamichhane (2019), who found that leopards predate more on livestock compared to tigers. In addition, this is also in agreement with Bhattarai (2012), who found that leopards predate more livestock in areas with a higher degree of habitat disturbance, e.g. buffer zones. The findings of Lamichhane (2019) also indicate that the contribution of livestock is lower than previously reported by Bhattarai (2012). Reduced availability of livestock in forests due to grazing restrictions in the park and community-managed buffer zone forests may have led to lower encounters of livestock by tigers which is reflected in their diet (Gurung, Nelson and Smith, 2009). As the relative presence of leopard scats compared to tiger scats is higher in the buffer zone this seems to confirm the findings of Odden and Wegge, (2010) who suggested that tigers displace leopards to the edge zones of parks. The total number of scats collected in CNP for tigers (43) is twice the number of collected leopard (21) scats. This results in a scat ratio of 2:1 for tigers compared to leopards. This is in accordance with Thapa (2011), who found that tiger density was 2-3 times higher than leopard density in CNP.

Eight prey species (e.g., chital, sambar, barking deer, wild boar, common langur, gaur, Indian porcupine, and sloth bear) contributed to the diet of tigers in CNP. These findings are similar to the findings of Andheria et al. (2007), who reported that chital, sambar and wild pig constituted 96% of the diet of tigers. Additionally, the composition of tiger diet, which overlapped in space but not time, was broadly similar to Kapfer *et al.* (2011). Similar to other studies of tiger diet (Miquelle *et al.*, 1996; Bagchi, Goyal and Sankar, 2003), tigers in Chitwan preyed heavily on medium- to large-sized cervids. But my findings also indicate that after chital, the second most consumed prey species is wild boar. It has been suggested that tigers include more species, as well as smaller species, in their diet when their primary prey (cervids) are unavailable (Harsha et al., 2018). However, owing to enhanced protection, cervid populations were most abundant during the study in CNP (NTNC wildlife assessment surveys, 2016/2017) suggesting this was not the case. A possible explanation is given by Miquelle *et al.* (1996), who also indicated that wild pig is regularly preyed upon by tigers over most of its distribution because there is a high degree of overlap in the habitats between both species. For example, the occurrence of fresh areas of soil plowed up by wild pig together with a large number of tracks of tigers in many parts of the study area also indicates the overlap in habitats between tiger and wild pig. The presence of the remains of sloth bear in tiger scats is probably because they live in the same habitat. However, sloth bears are not considered a regular prey of tigers (Biswas and Sankar, 2002).

4.1.2 Diet in space

The prey species preference differs across the three zones in CNP. Although chital is the most abundant prey in all three zones, it is only preferred by tigers in the corridor. This is in accordance with the findings of Bhattarai and Kindlmann (2012) who reported that chital was underutilized by tigers based on their availability. Additional findings are also similar to the latter study, medium prey is the most consumed category by tigers in every zone within CNP. Despite this, the medium prey category is not preferred by tigers in CNP. Individual prey species belonging to this category may have relatively high scores on the Jacobs Index scale. But the mean values of each prey category indicate a profound preference for the small prey category in all zones. It must be considered that the high mean preference for small prey category in CNP, as is the preference for species in the BZ and CO, may be due to the lack of enough data instead of reflecting an actual preference. My findings are inconsistent with previous studies. Bhattarai and Kindlmann (2012) indicated that tigers have a strong preference for/and are selective for medium prey. Similar results were recorded by Biswas and Sankar (2002) in Pench National Park, India. However, Karanth and Sunquist (1995), and Andheria et al. (2007), recorded tigers selectively preying on large-bodied prey in South India. Hence, it is likely that prey selection by predators depends on prey availability and structure of wildlife communities, which differs in time, different geographic locations and habitats.

Livestock was not part of the tiger diet in this study. However, it was previously reported in the diet in CNP (Bhattarai, 2012; Lovari *et al.*, 2015; Bhandari, M.K. and Pokheral, 2017; Lamichhane, 2019). These studies all indicate that the fraction of livestock in the diet is relatively small, 15% and 3%, for leopard and tiger, respectively (Lamichhane, 2019). These studies also indicate that leopards are more frequently involved in livestock raiding compared to tigers. These findings are consistent with my own results, leopards (10%) consume more livestock than tigers (0%). Notable is also the fact that a higher frequency of scats containing livestock are obtained in the buffer zone, and rarely in the core area (Bhattarai, 2012). This possibly indicates that both carnivores consume more livestock in disturbed human dominated areas, with a high degree of anthropogenic pressure. Bhattarai & Kindlmann (2012) suggested that the abundance of mainly large natural prey species in the buffer zone is low due to their high sensitivity for human disturbance. This results consequently in a shift in tiger and leopard diet towards other more available prey, including livestock.

Interspecific differences in the feeding strategy diagram indicates that there is some degree of dietary overlap. Resulting in potential competition between tiger and leopard. The maintenance of substantial populations of wild prey species populations of both tiger and leopard is therefore essential to maintain viable populations of wild cats in CNP. According to Bhandari et al. (2017), the latter can also potentially reduce the economic losses caused by human-carnivore conflicts: loss of wild prey may result in more livestock depredation.

4.2 Human-tiger conflict

For this part of the study, the majority of the data have been collected through questionnaire surveys. There are several potential weaknesses when relying on this technique, potentially affecting the data quality. The research was performed in cooperation with technicians of NTNC and occasionally assisted by the head of the community where surveys were conducted. We insisted that the respondents were not forced to participate in the survey and that they were free to answer the questions truthfully. However, circumstances were such that respondents might have been reserved in giving honest answers.

4.2.1 Factors influencing the frequency of attacks

The results indicate that tigers are responsible for the largest fraction of livestock losses during the past five years. Nevertheless, it must be kept in mind that these numbers were gathered using interviews, which are nor objective nor scientifically substantiated. It is logical that, when asking for the number of incidents in the timespan of the last 5 years, people are unable to precisely pinpoint each event in time. Additionally, livestock owners may mistakenly identify the wrong carnivore species due to the inability to recognize (the kill of) different carnivores (Caruso *et al.*, 2016). Even though at the beginning of each interview, the majority of respondents correctly identified the pictures of both carnivores (Fig 4.1), the results should still be handled with caution.

The mean loss over the past five years found in the study (0.06 animals per household) is relatively low compared to predation rates reported elsewhere (Bagchi and Mishra, 2006; Wang and Macdonald, 2006; Tamang and Baral, 2008; Madhusudan and Foundation, 2014; Bhattarai, 2014b). Possibly indicating the implemented grazing restrictions in CNP seem to be successful. The opportunistic killing of livestock by tigers is common as domestic animals are easy prey. Key persons in the study area considered grazing of livestock in tiger habitat, a decline of natural prey, habitat loss and physical impairment to have a significant effect on livestock depredation by tigers. This was also found by Karki and Barlow (2008). Although low in absolute terms, predation rates amount to a loss of 4.64% of total number of livestock (≤ 5 years), with additional 4.06% of all livestock by other carnivores. Given that most households are poor and are dependent on subsistence agriculture the economic effect of predation may be high and prompt retaliation killings (Bagchi and Mishra, 2006).

The western section of the BZ experiences significantly more attacks by both tigers as by other predators, compared to the eastern section. This can be explained by the fact that this section is less densely populated which suggests that tigers try to avoid areas with more anthropogenic influences. The results also indicate that all attacks (100%) which were reported in this study occurred during the night. Similar observations were quoted in the study of Miller and Jhala (2015), they confirmed that most attacks by large carnivores occur in the early evening. An additional explanation is that tigers have a preference for nocturnal hunting which is probably caused by their improved night vision compared to their prey (Mallick, 2009).

The majority of livestock depredation occurred more often during winter (October-February; 63.64%) compared to other seasons. Nepal is a predominately an agricultural country with 65% of the population involved in largely subsistence farming (CBS, 2012). Livestock is an integral part of subsistence agriculture. So during winter, these agricultural activities are generally at a peak with paddy harvesting in the BZ of the study area (Lamichhane, 2019). Therefore, livestock is more likely to be left free to graze and browse due to the diminished human resources available to guard livestock, increasing the probability of being taken by tigers. Similar observations of greater livestock loss during the peak cropping season were reported by Sangay and Vernes, (2008) and Bhattarai, (2014). The size of herds of livestock appears not to be relevant for the number of attacks and larger herds don't necessarily experience more frequent predation by large carnivores. However, it has to be kept in mind that the data were extracted from a limited number of households, which could generate biased results. Contradictory evidence was extracted from several studies. Bommel *et al.* (2007) observed an increase in the risk of livestock depredation by lions, with an increase in the percentage of villagers owning livestock, e.g. livestock attracts predators (Singh and Kamboj, 1996).

The results from the GLM-model indicate that the use of light to repel carnivores and the distance from the park boundary are important variables which significantly influence tiger depredation. Consistent with the hypothesis, with increasing distance from the park boundary, the likelihood of depredation on livestock decreased for the households. Similar observations were reported by Bommel *et al.* (2007). This study found a high predation rate by lions in close proximity to the park borders and a sharp drop in predation losses with increasing distance from the borders. The same observation also justifies human casualties: higher percentages close to forest boundary (Karki and Barlow, 2008).

4.2.2. Perception of locals

Regardless of the educational level, the results suggested that 93.33% of the households have a positive perception towards the conservation of large carnivores. Additionally, 93.33% of the respondents are satisfied with the current management strategies implemented in CNP. This is in accordance with Nepal and Spiteri (2015), who suggest that individuals who perceive benefits from CNP are more likely to recognize that these benefits, and, in turn, their livelihood, are directly tied to the integrity of the park and its resources. This study might have oversimplified the anthropogenic perceptions. As the study of Struebig *et al.* (2018) indicated that tolerance towards tigers is driven by a number of complex factors that include spirituality, as well as the risk of actual attack. Additionally, tiger support and positive perceptions towards tiger conservation can be influenced by the number of human casualties. This is in accordance with the findings of Bhattarai (2014a), were local people were willing to tolerate some loss of livestock but no human casualties. This kind of conflict can cause retaliatory killings. A questionnaire-survey indicated that in such an event of a tiger killed by the hand of an angry mob, 39.90% of the respondents feel relieved and are satisfied with the action (Sadath, 2017). No significant relationship was found between education and perceptions. However, several studies indicate that education has a significant influence on perceptions. With the people supporting tiger conservation generally having a higher level of education than those with a negative attitude (Bhattarai, 2014b).

My findings indicate that approximately 81.67% of the respondents believe that wildlife tourism in the study area is associated with local benefits. These findings are in accordance with Karanth and Nepal (2011) where residents' views on tourism were very favorable in Nepal. Employment from tourism is often suggested as a benefit for residents, but the study of Karanth and Defries (2011) found that tourism employed <0.001% of the population living within 10km of Indian PAs. Outsiders largely owned these tourist facilities, and although residents comprised 76–90% of employees they were in lower paid positions (gardening, housekeeping, etc.) and seasonal jobs (October to April). Spiteri and Nepal (2014) also indicate that while benefits are recognized by the residents, village distant from the main tourist entry point to the park where costs associated with conservation are highest recognize few benefits. Additionally, an individual's level of participation in tourism also affects the benefits received, with those directly employed in tourism receiving the most benefits (Nepal and Spiteri, 2015). Wildlife tourism continues to grow in protected areas (PAs) (Karanth and Defries, 2011). Previous research indicates that numbers of visits to PAs are declining in wealthy countries (United States, Japan) while foreign visitation is increasing in less wealthy countries (Balmford *et al.*, 2009; Buckley, 2009).

4.2.3 Mitigation and protective measurements

My questionnaire survey revealed that the majority of locals indicated that education and training is the most important mitigation strategy to reduce HTC's. The local communities are generally deprived of good education and socio-economic opportunities. So logically these people are also the ones most affected by the conflict. It is therefore important for future management to improve the livelihood of these communities through capacity building programs. The remaining respondents indicated that investment in infrastructure such as better fencing is important to mitigate the conflict. The study of Lamichhane (2019) indicated that the construction of fences and awareness programs practiced by buffer zone communities have reduced human-wildlife interaction ultimately resulting in a lower incidence of conflicts. As have monitoring and compensation payments for losses, however only a small fraction of the respondents considered these mitigation strategies as priority.

As indicated in the result, the use of light to repel wildlife is a significant variable influencing the number of attacks, which is in accordance with Kerley, Wilson, and Balfour (2018). Goodrich (2010) also confirmed that the use of fire/light can successfully thwart attacking tigers. The use of other protection measurements (shepherd dog, protection enclosure, noise) appears not to be significant, but several studies indicate that these measurements can indeed assist in reducing HTC's. Shepard dogs have a relatively high success rate in detecting tigers and alarming the owners to respond (Khan, 2008). Additionally, fencing is generally the first line of defense that is employed to exclude predators from certain areas (Fig 4.2, Sillero-zubiri and Switzer, 2014; Kerley, Wilson and Balfour, 2018; Kolowski and Holekamp, 2019).

Figure 5.1: The conservation triangle of CNP, representing all parties involved in successful wildlife management.

Figure 5.2: An awareness-raising event for local communities. Source: Lamichhane 2019.

Chapter V

Conclusion

Human-wildlife conflict is a complex facet of wildlife management, and in Chitwan as elsewhere, careful management will be required if the goals of wildlife conservation and economic livelihood for communities are to be met. Therefore, the success of any predation mitigation measures requires the full engagement of communities in wildlife management (Sangay & Vernes, 2008). On the long-term conservation actions can only be effective if enforcement of regulations is combined with the education and the active involvement of local communities (Inskip & Zimmerman, 2009).

- Accurate knowledge of the diet of a species is important for effective conservation and, proper management of wild prey is essential for balancing potential conflicts within an acceptable range. Management plans of wild prey populations are already in place and proven relatively successful in CNP (Lamichhane, 2019). My own findings acknowledge the latter, the majority of tiger and leopard diet in CNP consists of wild prey. It is now advised that future management should mainly focus on the social aspects of the conflict.

- According to the signs and scats of both predators, it can be concluded that tigers are more active in the core region of the park, whereas leopards are more active in the periphery of park. The latter was also more involved in livestock raiding (10%) compared to tigers (0%). Wegge et al., (2018) showed that even when a certain amount of livestock depredation cannot be avoided, educating and informing local communities can result into a positive perception towards large carnivores (Fig 5.2). Thereby, reducing the chance of aggressive retaliation in reaction to livestock depredation. Future management should adopt strategies to increase prey density and reduce livestock depredation in buffer zones or outside forests to reduce potential conflict with humans.

- The questionnaire-survey indicates that the tiger is the dominant livestock predator in the BZ of Chitwan. This is a factor that is probably related to their numerical abundance. High and stable densities of tigers in the core areas of CNP in recent years may have increased recruitment of tigers and thus resulted in higher rates of dispersal (Lamichhane, 2019). A result may be that more tigers are attempting to occupy buffer zone forests, which are in closer proximity of human settlements. In these areas, measures should be taken to protect the local communities and their livestock, in order to mitigate the potential future conflicts.

- These communities, living in the buffer zone, are generally deprived of good education and socio-economic benefits. Therefore, it is important that future management focusses on the improvement of local capacity building programs, providing education and training. Conservation organization can plan an important role in this aspect. Additionally, regular monitoring of wildlife, especially in the fringe areas, will help improve understanding of the interactions between carnivores and humans. And future research that assess the effectiveness of implemented conservation measures are essential to guide the decision making that contributes to the mitigation of human-wildlife conflicts and ultimately the long-term conservation of tigers.

Chapter VI

Annex

Annex I – Questionnaire

DATE: / /

Household Information

1) Age : Gender:
2) Education : a) School b) Collage
3) District : Distance from park boundary: GPS location:
4) Have you migrated here? a) yes b) no
    a) If yes: How long ago?
5) Livelihood source:
    A) Agriculture B) Livestock c) Business d) Others
6) If your livelihood source is based on livestock:
    - Which kind of livestock do you own?
      a)Buffalo b)Pig c)Duck/chicken d)Cow/Ox f)Goat d)Sheep
    - How you feed your livestock?
      a)Stall fed b) Grazing in CF c) Grazing in the park d) Grazing in private land
    - How you keep your livestock?
      a)No shed b) Temporary with fence c) Temporary without fence
      d) Permanent with fence e) Permeant without fence
    - Presence of guard dogs yes: No:

Experience with wildlife

1) According to the photos, can you distinguish between tiger and leopard yes: No:
2) Have you experienced conflict with leopard/tiger in the past 5 years : Yes: No: Both:
3) If yes:
    - Cause of conflict: a) Leopard b) Tiger c) Others
    - Number of livestock loss:
    - Season the conflict occurred:
    - Have tiger/leopard ever attacked on you or a family member (If yes, place, time, date, sex and age of victim, injury or death)
        - Place and date:
        - Gender and age of victim:
        - Severity of attack:
    - Are you happy with the conflict compensation measures

- If no, what should be done?

4) Have you done or heard of livestock insurance? If yes, are you willing to pay?
5) Which are the most problematic wildlife species in your area?
6) Do you think tiger/leopard population has increased or decreased over past 10 years?
   a) Highly increasing b) Increasing a bit c) highly decreasing a bit d) Decreasing a bit e) No change Increasing a bit

Communities perception towards wildlife

7) Do you think tiger/leopard need conservation ?

Agree	Neutral	Disagree

   a) If 'Agree' why?
      I. Religious belief (Iconic species) II. Endangered species III. Revenue from tourism VI. Beautiful appearance

8) Wildlife attracts tourist and benefits us.

Agree	Neutral	Disagree

9) I'm aware that if I live close to the forest, I am more at risk of conflict with wild animals, but it is my responsibly to avoid it.

Agree	Neutral	Disagree

10) National Park authorities are playing a positive role for human wildlife conflict mitigation.

Agree	Neutral	Disagree

11) Do you think tiger/leopard should be eradicated ?If yes why?
    a) Threats to human safety b) Livestock degradation

12) What do you think is the best strategy to minimize the conflict?
    a) Education/training
    b) monitoring/alarming
    c) compensation of loss
    d) Investment in infrastructure (such as better fencing)

Annex II – General linear regression

Table 6.1: General outcome of the logistic regression of tiger depredation against the explanatory variables.

General linear regression: Tests of Between-Subjects Effects			
Response variable: Depredation by tiger			
	β	X^2	p
Intercept	-0.0005236		0.99864
Distance	-0.0284600	9.8006	0.00285 **
Noise	-0.0626347	0.0884	0.77693
Light	0.2318704	5.6497	0.02348 *
Livestock owned	0.0078852	0.9884	0.34337
Variables are significant at **P < 0.05; **P < 0.01; ***P < 0.001.*			

Chapter VII

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