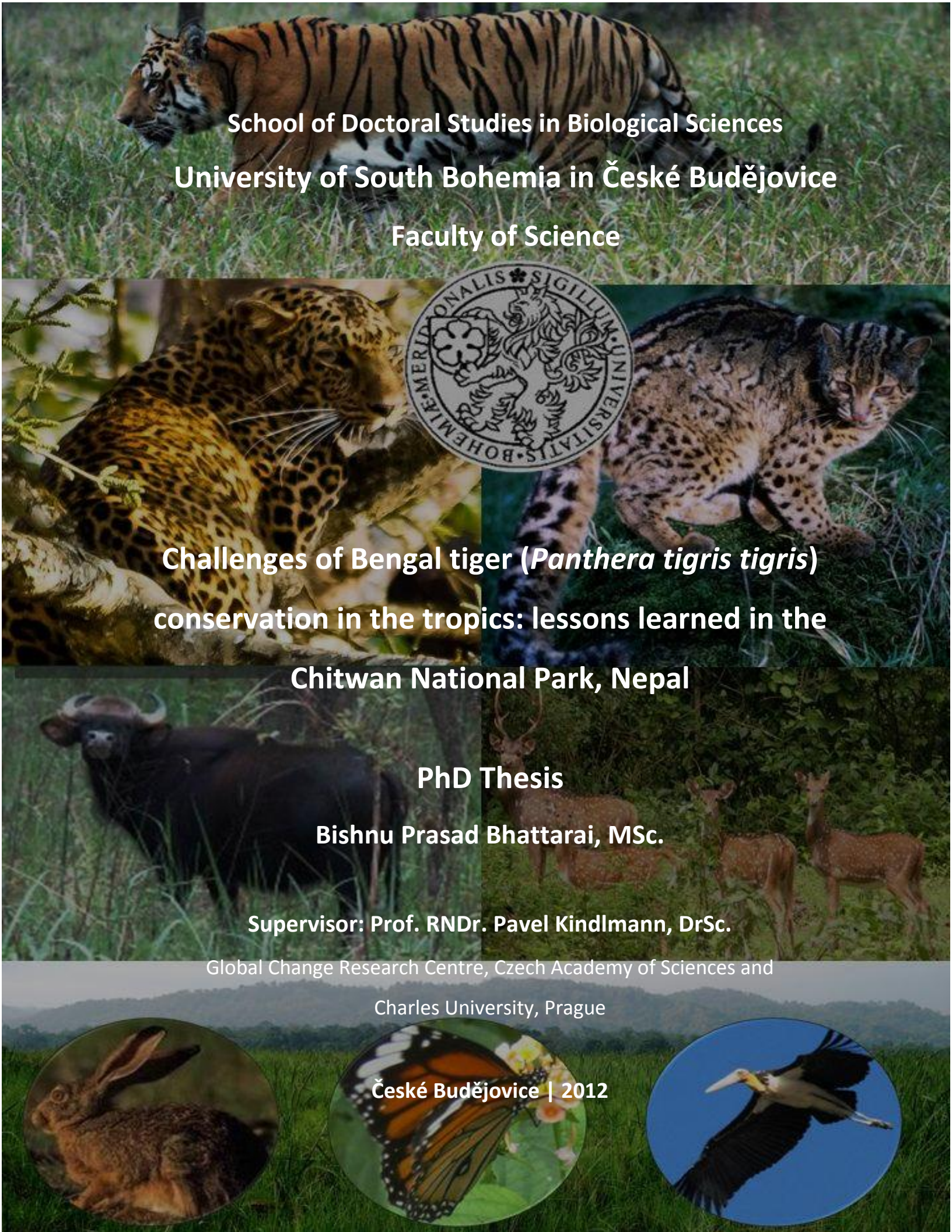

School of Doctoral Studies in Biological Sciences

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Challenges of Bengal tiger (*Panthera tigris tigris*) conservation in the tropics: lessons learned in the Chitwan National Park, Nepal

PhD Thesis

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This dissertation is dedicated to

DNPWC – Department of National Parks and Wildlife Conservation

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for their support and contributions in this research

Annotation:

Bhattarai, B.P., 2011: Challenges of Bengal tiger (*Panthera tigris tigris*) conservation in the tropics: lessons learned from the Chitwan National Park of Nepal. Ph.D. Thesis, in English – 51 pp. + Appendices 255 pp., Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic.

This research deals with the challenges of the conservation of tiger (*Panthera tigris tigris*) in the Chitwan National Park of Nepal and aims to be a model for tiger conservation in the tropical areas of other tiger range countries. Despite the high level of public concern and major investments during the last few decades for conservation, wild tigers continue to be under grave threat, and their preservation now requires, more than ever before, using reliable ecological knowledge for their conservation interventions. In this dissertation, I investigated various factors that affect on tiger conservation in this park: population status of prey, dietary patterns of tiger and its impact on sympatric carnivores (e.g., leopard) and increasing human-wildlife conflicts, effects of habitat structures and human disturbances on prey and predator species abundance and distribution.

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‘Unless poor farmers living in proximity of wildlife saw the benefits of conservation, species could not be saved’

–Pralad Yonzon

Author contribution statement

Bishnu P. Bhattarai, author of this Ph.D. thesis, is the first author of five papers (manuscripts) and four chapters in a book. Most of the raw data processing, as well as most of the statistical analyses were performed by him.

Pavel Kindlmann participated in all the papers and as a supervisor helped with all necessary things. Prakash Kumar Paudel participated in "Conservation of Biodiversity: An Outline of the Challenges" (Paper I) and first author of "An Overview of the Biodiversity in Nepal" (Paper II).

All co-authors hereby consent the publication of the papers in the PhD thesis of Bishnu Prasad Bhattarai and support it by their signatures:

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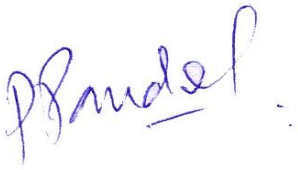
Prakash Kumar Paudel 

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GENERAL INTRODUCTION

The tiger (*Panthera tigris*, Linnaeus 1758) is considered as one of the world's most magnificent and icon species of wildlife community in all ecosystems wherever it occurs. So that conservation of the tiger is referred as the conservation of whole ecosystem and wildlife community, including their prey (Nowell & Jackson 1996). Of the nine sub-species of the tiger (Luo et al. 2004), three were extinct: Bali tiger (*Panthera tigris balica*), Javan tiger (*P. t. sondaica*) and Caspian tiger (*P. t. virgata*); one sub-species has not been observed in the wild since the 1970s and possibly extinct: South China tiger (*P. t. amoyensis*: Southern China). However, fortunately, five species still exist: Malayan tiger (*P. t. jacksoni*: Peninsular Malaysia), Bengal tiger (*P. t. tigris*: Indian sub-continent), Amur tiger (*P. t. altaica*: Russian Far East and north-eastern China), Northern Indo-Chinese tiger (*P. t. corbetti*: Indochina north of the Malayan peninsula) and Sumatran tiger (*P. t. sumatrae*: Sumatra).

Distribution and habitat: The Bengal tiger (*Panthera tigris tigris*) occurs primarily throughout the Indian sub-continent, in the southern Nepal (155 individuals), India (1706 individuals), Bangladesh (440 individuals), and Bhutan (75 individuals) (Tamang 1993; WWF 2001; Sunquist & Sunquist 2002; Chundawat et al. 2011). In Nepal, tigers primarily live in the five protected areas (PAs): Parsa Wildlife Reserve, Chitwan National Park (CNP), Banke National Park, Bardia National Park and Suklaphanta Wildlife Reserve (DNPWC 2011) however, they are rarely recorded outside of these protected areas.

The basic habitat requirements of the Bengal tiger include the thick cover of forest, proximity to water and undisturbed large area with an abundance of large and medium-sized prey. However, it inhabits in a wide range of forest types, including evergreen, semi-evergreen forests of Assam and eastern Bengal; the mangrove forests of the Sundarbans; the deciduous forests of Nepal, and dry thorny forests of the Western Ghats (Sunquist & Sunquist 1989; Seidensticker & McDougal 1993; Nowell & Jackson 1996). It has also been reported to about 4000 m altitude in the mountains of Bhutan (Pralad Yonzon pers. comm.) and south-eastern Tibet (Matthiessen 2000). In the

recent period, wild tigers inhabit less than 5% of the 1.5 million km^2 of forest habitat available (Karanth 2001), which is due to the lack of wild prey base and continuous human disturbances in their natural habitats that limit the existence of wild tigers in most of the forested areas. In Nepal, tigers exist mainly in the tarai region with the rich alluvial grasslands and riverine forests in a series of valleys "duns" and climax *Shorea* forest on the slopes of the Siwalik range. Ample rainfall and rich alluvial soils of the duns support the mosaic of habitats such as tropical-moist deciduous, riverine, and upland forest, interspersed with tall grasses (Stainton 1972). Historically, the lowland forests in the duns run the entire length of Nepal, and this area was a rich in large-mammal fauna including some of the highest densities of tigers on the Indian subcontinent (Smythies 1942), but it has become highly fragmented due to expanding human populations, increased development, and road construction. The isolated dun valleys created an increasingly isolated metapopulation structure of tigers (Smith et al. 1998).

Social organization: tigers are usually solitary and large territorial mammals, except for females with cubs, but they are not anti-social (Nowell & Jackson 1996; Sunquist & Sunquist 2002). Usually, males associate with females during mating period and also observed with females and cubs when feeding or resting (Schaller 1967; McDougal 1977; Sunquist 1981). Sometimes tigers travel in groups for example, in Kanha National Park of India Wright (1989) reported that a mature male was greeted by a female with cubs and by a sub-adult male, thought to be from a previous litter.

Territory and dispersal capabilities: tigers occupy large territory as compared to other mammals through its dispersal capabilities. The dispersal capabilities depend upon the shape and size of the natural habitat and frequency of human disturbances, for example in the fragmented landscapes of Nepal their dispersal distance is low as compared to un-fragmented and large landscapes of India (Sunquist 1981). However, Smith (1993) in the CNP reported that male tiger had dispersal capabilities about three times higher than females; most females were philopatric, settling next to their mothers. The average dispersal distance for male was 33 to 65 kms, and for female was slightly less than 10 to 33 kms in the CNP. The home ranges of adult tigers varied with sexes and season of the

year (male: 27 – 42 km^2 and female: 10 – 17 km^2) due to forest cover, grass availability, prey availability and human disturbance (Sunquist 1981). Exceptionally, Sunquist (1981) mentioned an evidence of a sub-adult male from Chitwan travelled 150 kms to the Trijuga-Koshi-Tappu area in eastern Nepal. There is also the variation in the age of dispersal within the same area, e.g. in CNP some young leaving their natal area at 19 months, while others stayed to 28 months (Smith 1993). The tiger disperses and establishes a new territory based on availability of prey and suitable habitat.

1. Challenges of tiger conservation in the tropics: an example from Nepal

Tiger conservation is a global challenge, as the number of wild tigers has decreased from an estimated 100,000 in the early 1900s to around 3,600 adults scattered as small populations across the range (Global Tiger Recovery program- GTRP 2010). The lack of enforcement (Sanderson et al. 2006) is the major threat of tiger conservation, followed by hunting of tiger prey, low tiger population size, hunting of tigers, lack of habitat connectivity, habitat degradation, national policies and efforts and wildlife-people conflict vs. people's perception and its impact on tiger conservation.

Habitat loss and landscape fragmentation: In a list of the conservation messages from IUCN (Vié et al. 2009) implied that the loss, alteration and fragmentation of the habitat remain the primary threat to most species, including tiger. About, 93% of the tiger's original range has been lost in the past 150 years. Furthermore, its numbers and distribution range continues to decline as the current range of the tiger encompasses some of the densest human populations on Earth (Sanderson et al. 2006). Human pressure on habitats continues to grow and impact negatively on tigers throughout their range, leading to fragmentation and decline in populations of tigers and their prey (WWF 2002). The largest remaining tiger population is in the Indian subcontinent, where only 11% of original habitat remains and continue to be fragmented and degraded (Dinerstein et al 2007; Wikramanayake et al., 2010). The loss, homogenization (loss of

habitat heterogeneity) and fragmentations of the tiger habitats are the prime challenges to protect tiger and their prey species.

Habitat loss and landscape fragmentation in Nepal has started in the 1950s. Before this period, there were large forested areas throughout the country mostly in Tarai. The Tarai region was inhospitable for people due to malaria, but after the eradication program in 1954, these fertile flatlands became an attractive destination for the people from the hilly regions (Spillet & Tamang 1966). This mass migration of people triggered habitat fragmentation, which has divided tiger's community into three separate populations in Nepal (e.g. Chitwan-Parsa, Banke-Bardia, and Suklaphanta) with very limited opportunities for interaction between and among these isolated units (Smith et al. 1998). Tiger population in Trijuga forest was extirpated, and tiger numbers declined across the Tarai forest in the 1970s (Smith 1993; Gurung 2002). The conversion of natural habitats around the landscapes separated the PAs into different isolated units (DeFries et al. 2005). The Chitwan population of the tiger is isolated from the western population (Bardia) by a strong dispersal barrier at the city of Butwal and in the eastern part it is isolated at the Bagmati River gorge, where cultivation extends from the Gangetic Plain to the base of the Siwalik Hills (Smith et al. 1998). Besides these eastern and western barriers, the Siwalik Hills are highly degraded and heavily settled, and no tigers or tiger signs have been recorded further to the east of the Bagmati River gorge (Smith et al. 1998). The recent study of Sharma et al. (2011) showed that Chitwan population of the tiger constitutes a tiger population genetically different from other parts of Tarai Arc Landscape (TAL), concludes the consequences of habitat isolation. Population viability models using field data from Indonesia also show that maintaining connectivity between tiger populations in larger landscapes can offset losses from poaching and increase population persistence (Sanderson et al. 2006; Linkie et al. 2006; Wikramanayake et al. 2011). However, a scenario projecting habitat loss in tiger conservation landscapes shows a possible 43% reduction during the next decade (Wikramanayake et al. 2010).

However, the National Park Act of 1973 created a network of protected areas; it did not stop degradation of critical habitats of tiger outside the PAs. The protected areas in Nepal and across most of the tiger range, does not support population of tigers of adequate size to ensure long-term viability due to isolation (Smith et al. 1987; Dinerstein & Wikramanayake 1993; Smith et al. 1998; Smith et al. 1999; Ahearn et al. 2001). Existing forest outside protected areas presents a great potential to link threatened wildlife populations in protected areas and increase regional population viability but forests outside protected areas are in multiple-use (Ahearn et al. 2001). Connectivity restoration could be possible by managing these lands under a landscape approach which in turn facilitate a higher probability of long-term survival of flagship wildlife (e.g., tiger, elephant and Rhinoceros) populations in the wild. Improving connectivity within and between landscapes will also provide a hedge against the impacts of climate change, when habitat and climatic shifts could result in corresponding shifts by another biodiversity and by people (Wikramanayake et al. 2011).

Poaching and illegal trade of body parts of tiger: The demand for tiger-based medicines by the traditional medicine is the major cause of tiger poaching. International trade in wildlife and its products likely making it the world's third largest illegal trade behind drugs and arms, continue to be an untamed and lucrative business worth an estimated five to ten billion U.S. dollars annually (Cheung 1995). The weak side is that we have still notoriously unreliable records of wildlife trade (Blundell & Mascia 2005). To cope with this problem, we need accurate data on wildlife trade, which is essential for bio-security (Gerson et al. 2008). Despite a greater role played by CITES to ban the international trade in tiger parts along with the strict laws for domestic trade in most of the tiger range countries, illegal trade continues. The domestic trade of tiger body parts is illegal, but still common in Bhutan, Laos, North Korea, China, Cambodia, Indonesia, Myanmar, Thailand, and Vietnam. While in North Korea, trade in tiger parts and their derivatives is still legal. Surprisingly, in Cambodia, a macabre method of poaching tigers is widespread: even land mines are used to kill the animals. The hotspots of tiger trade countries are located in East Asia, Southeast Asia, North America, and in parts of

Western Europe (WWF 2002). In the developing countries like Nepal, the problem of wildlife trade is directly correlated with demographic factors, potentials for profit and lack of adequate resources for law enforcement (HMGN/MFSC 2002). Nepal has the too little local market as compared to international market, and it is not regarded as the consumer country but its territory acts as a safe passage or transit point for the transportation of wildlife products to Tibet and India (Shakya 2004; Aryal 2004). China is a popular country for traditional medicine, and ornaments made up of from wildlife and the major sources of these products are found in India, Nepal and other south Asian countries. In these trends, Nepal has been affected both from the transit point and from the source point, as it is located in between two big countries (Yonzon 2006).

Wildlife poaching is a great problem in most of the protected areas of Nepal, as the market value of wildlife products increases, mainly for the endangered species like tiger and rhinoceros in tarai region and snow leopard and musk deer in the high mountain (DNPWC 2001; HMGN/MFSC 2002). In Nepal, there is a lack of reliable data on poaching of tigers. However, the reliable data available only for the Asian one-horned rhinoceros which is due to its high profile after decades of conservation efforts (Murphy et. al. 2005). There was a loss of 157 rhinoceroses from CNP between the years 2000 to 2005 in which 94 were confirmed to have been killed by poachers (Shrestha & Joshi 2007). Likewise, the officials of Nepal seized 41 tiger skins, one tiger skull, 165 pieces and 5 sacks of tiger bones, 587 leopard skins, six jungle cat skin and 660 otter skins in 2003 and 2004 from the northern and southern border of the country (GTF 2004; ADB and ICIMOD 2006; Oli 2006). By evaluating such data, it can be concluded that poaching is endemic in Nepal, and it is a serious challenge to protected area managers and conservationists (Yonzon 2004).

Poachers need extensive local knowledge of wildlife distribution to kill them in the wild. For this, local villagers are the key weapon for them, as most of the local people at the periphery of the PA are poor and uneducated. Poachers give them more money, as compared to their annual income from their farm. In such situation, local people see less benefit and little value in protecting the wildlife (Haynes 1998). So it is

the combination of poverty, lack of education and demands in the international market, which triggers poaching in the PAs. Furthermore, the inaccessible areas in the protected areas are more vulnerable to hunting and poaching. For example, the Churia range of the CNP and BNP can also be temporary home for poachers.

National policies and efforts for tiger conservation: The National Park and Wildlife Conservation Act 2029 in 1973 (NPWCA) provided the legislation for the protection of PAs only (DNPWC 1973; Heinen & Kattel 1992). Besides this, Nepal has adopted and implemented various national and international policies, acts and rules for conservation and to control poaching and illegal trade on mega-fauna (e.g. rhinoceros and tiger) and also committed it by signing CITES and preparing CITES bill for implementation. The NPWCA act also defines the penalty (NRs. 50,000 -100,000, or imprisonment of 5-15 years, or both) for a person involved in the poaching of a tiger, or in trade of its parts. This Act clearly indicates that tiger is strictly protected wild animal in Nepal, and it helps in tiger conservation. Furthermore, the country has also established anti-poaching units (APUs) in the PAs in collaboration with local people and various organizations to control such activities (Asian Development Bank & ICIMOD 2006). However, strict penalties and APUs cannot function well because of the high demand for tiger body parts in the international markets and weakness in the implementation of law.

The government of Nepal prepared many acts and regulations related to nature protection. However, there is a lack of explicit arrangements in the law (e.g., buffer zone regulations 1995) for the controlling mechanism of illegal wildlife trade and poaching and even more the “forest act 1993” has not explicitly defined wildlife as a forest product. The Bufferzone Management Guidelines in 1999 gives importance to protect the core habitat of national parks and their wildlife, which can help to conserve the tiger and it also, serve both the objectives of developments and conservation (HMGN/MFSC 2002). The act defines the rights of local people to use resources in the buffer zone areas while strictly banned in the core areas (Budhathoki 2004). However, most of the bufferzone forests are degraded and local people continue using forest products inside the core area of the CNP. It can also cause problems to the park security personnel to

discriminate between poachers and local people. It means that only paper based law is not enough to protect the wildlife. Therefore, the implementation of law in the field is urgent to cope with emerging illegal trade of wildlife.

The challenges to protect mega species are evolving and growing day by day as their demand in the international market in increasing. However, security institutions like TRAFFIC, police, army and conservation agencies like WWF, National Trust for Nature Conservation (NTNC) and CITES secretariat are involving to control illegal trade of wildlife by providing training for the custom officials and authorities (DNPWC 2001). Nepalese army is involved in the security inside the PAs and Nepal police is involved outside the PAs (Heinen & Shrestha 2006) but there is still lack of professional knowledge and skills. The limitation in tiger conservation is the lack of well trained personnel, accessibility, equipment, funds and long-term data (Asian Development Bank & ICIMOD 2006). For example, in the CNP, most of the security posts are located in the lowlands nearby the villages and there is no security post in the Churia range, which is due to inaccessibility and funds for management (CEPF 2005). The proper distribution of security posts, defining monitoring routes in vulnerable areas and reliable information on poaching are necessary in the PAs to strengthen tiger conservation efforts and planning.

Most of the tiger range countries are not in proper stage of tiger conservation, as these countries have problems with educational, social and economic issues. The lack of funds in the developing countries like Nepal has serious problems to implement the legislative requirements needed for tiger conservation (DNPWC/MoFSC/GoN 2007; Yonzon & Hunter 1991; Fox et al. 1996). In the developing countries, government cannot afford funds regularly to protect wildlife because most of their annual budgets go to the management of the basic needs of people, health problems, education and political conflict and instability (DNPWC/MoFSC/GoN 2007). Therefore, international cooperation is needed to support conservation in a sustainable way. The gap in international cooperation is another problem of illegal trade of wildlife, as most of the world's prime tiger habitats straddle international borders and also for the effective

implementation of CITES depends on networking among tiger range countries, transit, and consumer countries (Dinerstein et al. 2007). The hampers in the cooperation give safe land for poachers and smugglers to kill and transport the wildlife products (Smith et al. 2003; Yonzon 2006; DNPWC/MoFSC/GoN 2007). Hence, international cooperation is a fundamental part of tiger conservation, as it can support effective exchange of technology between countries.

Wildlife-people conflict vs people's perception and its impact on tiger conservation: Most of the earlier research findings revealed that the human pressure in the core habitats of the tiger is the main obstacles of tiger conservation as tiger distribution is limited to the lowland tarai region of Nepal, and this area possesses the highest densities of people in the country. The human and their livestock intervention inside the park is one of the major sources of human-wildlife conflict, as it affects the natural pattern of distribution of wildlife and reduces the quality and quantity of forages of wild ungulates. The Chitwan NP is surrounded by lots of settlements and is also the major tourist destination in the country, which causes continuous pressure inside the park. Local peoples' perception towards wildlife and park depends on the benefit and harm from the wildlife. Benefits (e.g., revenue from tourism) increase the positive attitudes towards wildlife and harm (e.g., loss of livestock, and human live from wildlife) cause the opposite (Nepal & Weber 1995). Recently, there appeared compensation schemes for wildlife damage, but they are still ineffective and it is doubtful, whether the local authorities consider people more vulnerable than park wildlife. Also, most of the local people want a free land inside the park to graze their livestock and collect forest products like fuel wood, timber, NTFPs and grass. Hence, these villagers are not satisfied with the park legislations. Nepal and Weber (1995) found that negative attitudes on wildlife triggered illegal activities. These negative attitudes also enable them to continue the poaching activities of valuable wildlife like tiger and rhinoceros from which they get more financial benefits than their farm. Therefore, wildlife-people conflict and negative attitudes towards wildlife are the major threats to tiger in the PAs.

After the declaration of the buffer zone area in the PAs, the condition of forest also improved a bit and large animals like tiger and rhinoceros started to use these areas. This caused closer distances between wildlife and people in the surrounding communities (Dinerstein et al. 1998), which ultimately increased the number of incidents with wildlife. For example, the number of human killed by tiger increases from an average of 1.2 (±1.2) persons/year before 1998 to 7.2 (±6.9) persons/year between 1998 to 2006 (Gurung et al. 2008). From these data, one can conclude that human-tiger conflict is also a major challenge to protect tigers. The compensation provided by conservation agencies is not well enough. There is also partiality among the local communities in the involvement of the income-generating activities. The person who lost their family members, livestock and crops (e.g., poor farmers) are also treated as the same groups that are not affected so much by wildlife (e.g., people involved in tourism business). If they are not able to take part in income-generating opportunities, negative attitudes towards wildlife could increase and as a result, such people pursue poaching as a self-compensatory, retaliatory and livelihood coping strategy (Kideghesho et al. 2005). Hence priority should be given to the most affected communities followed by the least.

2. Importance of natural prey availability for tiger population viability and persistence in the wild

Most of tiger diet consists of ungulates, the rest of primates and domestic animals. The average weight of prey killed by tigers can be quite variable; for example, in the CNP a tiger needs 5-6 kg of meat per day for maintenance (Sunquist 1981; Sunquist et al. 1999), which means 1825-2190 kg/year of meat per tiger. However, 30% of each carcass is inedible, so that a tiger needs to kill 2373-2847 kg/year (2610 kg/year in average) of meat. It means that the 155 tigers (DNPWC 2011) in the CNP need 404,550 kg meat per year.

The main prey species for tigers in Nepal are sambar deer (*Cervus unicolor*), swamp deer (*Cervus duvauceli*), chital (*Axis axis*), hog deer (*Axis porcinus*), barking deer

(*Muntiacus muntjak*), wild boar (*Sus scrofa*), gaur bison (*Bos gaurus*), nilgai (*Boselaphus tragocamelus*) and sometimes primates, such as langur (*Semnopithecus entellus*) and rhesus monkey (*Macaca mulata*). Among these prey, swamp deer and nilgai are not found in the diet of tiger and leopard in CNP. Tigers kill animals from a broad range of age classes, not just the old or the very young (Sunquist & Sunquist 2002). Moreover, they readily eat carrion (Schaller 1967). There was also a record that tigers attack young elephants (*Elephas maximus*) (Nowell & Jackson 1996) and rhinoceros (*Rhinoceros unicornis*), and also take smaller species like birds, reptiles and fish. Heptner and Sludskii (1972) reported that tigers sometimes prey upon leopards and their own kind, as well as other carnivores, including bears (this study), weighing up to 170 kgs.

The population density of the tiger is positively related to abundance of prey, particularly wild ungulates (Smith 1984; Karanth & Stith 1999; Sunquist et al. 1999). The ungulate assemblages with no large or medium-sized prey (cervids or bovids) in many parts of the tiger's range could not support viable tiger density and also the reproduction rate declines in a poor habitat with low prey base (Karanth & Stith 1999). Quantitative studies on the tiger prey base in national forests are very rare as compared to protected areas in Nepal (Seidensticker 1976a; Dinerstein 1980; Mishra 1982; Smith 1984; Dhungel & O'Gara 1991; Stoen & Wegge 1996; Smith et al. 1999). Besides, there is also too little information of abundance and densities of tiger prey species on the landscape level in the protected areas. It is important to monitor and analyse landscape changes and evaluate the impact of these changes on tiger and its prey species, for example, habitat heterogeneity and landscape connectivity are essential to maintain the prey communities and connected tiger populations for local to regional conservation planning in the focal landscape (WWF 2002; Seidensticker 1976b; Smith et al. 1998; Smith et al.1999).

3. Consequences of the interactions between sympatric carnivores: tiger and leopard as a case study in the Chitwan National Park

Tiger and leopard coexist in most of the tiger range countries under certain conditions. They inhabit thick vegetation and are sympatric in most of their ranges. Tigers are four times bigger than leopards. However, leopards are not common in habitat where tiger density is high, i.e., allopatric (Schaller 1967). In such condition, leopards are more prevalent on the peripheries of the park i.e. the area between prime tiger habitat and village where they are usually dependent on both natural prey and livestock. Tigers, as well as humans, contribute to leopard mortality (McDougal 1988).

Studies of the interactions between large carnivores and between large carnivores and people belong to the main issues in conservation, as large carnivores are usually among the most endangered species. The ecological densities of tigers and other sympatric predators in the Indian subcontinent are governed mainly by the structure (abundance of different size classes of prey) of their prey community (Karanth & Sunquist 1995). Under these predictions, the tigers and leopards can occur sympatrically, if both large and medium-sized prey is abundant where tigers would select large prey enabling the coexistence of leopards at high densities. But if there is a shortage of large prey then tigers would switch to medium-sized prey and reduce leopard densities through competition. Furthermore, if both large and medium-sized prey is scarce, leopards would be relatively more abundant because of their ability to survive on smaller prey such as primates.

The higher level of competition occurs among the large carnivores for food, if there is a decline in the abundance of their prey due to its consumption by other carnivores, habitat degradation and hunting by local inhabitants (Smith et al. 1999; Weins 1993; Brodie 2009). Furthermore, large carnivores tend to resort to feed on livestock or even people when there is a shortage of food. Retaliatory killing of such carnivores by farmers increases the likelihood of these predators becoming extinct (Smith et al. 1999; Gurung et al. 2008; Sangay & Vernes 2008). Such sequence of causally dependent events can be likened to a vortex that may eventually lead to

extinction of the large carnivores. Such situation is especially common in isolated small patches of protected areas (Smith et al. 1987). The balance on the different size classes of prey plays a crucial role for the coexistence of tiger and its sympatric predators in the same natural habitats (Schaller 1967, Johnsingh 1983; Seidensticker & McDougal 1993; Karanth & Sunquist 1995; Tamang 1993; this study).

SCOPE OF THE THESIS

In this dissertation, I investigated challenges for tiger conservation in the Chitwan National Park: population status of prey, prey preference of tiger and its impact on sympatric carnivores (e.g., leopard), factors associated with human-wildlife conflicts, effects of habitat structures and human disturbances on prey and predator species abundance and distribution.

Paper I deals with the status of the protected areas of Nepal, and the challenges faced by the government to protect them. **Paper II** presents the overview of the biodiversity of Nepal, including the eco-regional distribution of the flora and fauna in different physiographical regions of the country.

Paper III studies the consequences of the interactions between two sympatric carnivores: tiger and leopard. These two predators compete mainly for medium-sized prey. However, leopard relies more on small prey and livestock than tiger. Leopard is shifted towards the periphery of the park and preys upon domestic animals which increase the conflict with local people. The predators prey upon domestic animals or even people in the areas where there is low abundance of wild prey and higher level of human disturbance.

Paper IV deals with the abundance and habitat preference of the prey species and their association with the habitat heterogeneity. The abundances of the principal prey species were positively correlated with habitat heterogeneity. The habitat, which contributes significantly to the heterogeneity of the landscape, is grassland in large patches of forest, which is in decreasing order due to encroachment of forest. This paper highlights the importance of habitat heterogeneity to support the large population of prey species and suggested the restoration of heterogeneity in the landscape as the best way to manage the habitats in the CNP.

Paper V deals with the impact of human disturbance on prey species of tiger and leopard. Species were less affected by environmental factors as compared to disturbances. Bufferzone is designed to minimize human impacts in the core areas.

However, it could not function well to protect the core area of park as all the parts of the park possess some level human impacts because of the degradation of the most of the forests in bufferzone. This study suggested restoring the bufferzone forests and minimizing the human disturbance in the CNP.

Paper VI concentrates on the population structure and social organization of the wild ungulates and the factors that determine the grouping patters of these species. Human disturbance and predator played the greatest role in determining the grouping patterns of ungulates in this park.

Paper VII deals with the effect of human disturbance on the habitat and prey preference of the tiger. Tiger strongly preferred prey-rich areas and strongly avoided areas subject to human disturbance. It preyed upon domestic animals in the areas, where there was low abundance of wild prey and high disturbance.

Paper VIII presents the impact of livestock grazing on the vegetation and wild ungulates. Standing biomass was lower in grazed areas, as compared with the ungrazed ones. Grazing also affected on the species composition of herbaceous plants and grasses.

Paper IX deals with the distribution and diversity of storks. These species also have minor contributions in the diet of tiger and leopard. The CNP provides good habitat for residential and migratory storks. However, their population was quite low and threatened by human impacts and wetland habitat degradation.

SUMMARY OF METHODS

The study area was divided into seven blocks depending on the location and incidence of human disturbance (B1 to B7−Fig. 1a, Table 1 in paper III). Most of the data collected in the transects. Distance sampling was used to estimate the abundance of eight major species of prey (e.g., gaur bison, sambar, chital, hog deer, muntjac, wild boar, common langur and rhesus monkey) in the study area, as this method is practical, efficient and inexpensive (Buckland et al. 2004). In transects, we recorded the numbers and size of each herd of any of the aforementioned prey species encountered, sighting angle and sighting distance. From these data, prey population densities were estimated using the Multiple Covariates Distance sampling (MCDS) method of DISTANCE 6.0 (Thomas et al. 2009; Buckland et al. 2004).

To study the status of habitats, Every 100 m along a transect, we recorded the dominant habitat type within a circle with 200 m radius, and classified it into six types: sal forest, mixed hardwood forest, riverine forest, tall grassland, short grassland and flood plain. In transects, we also recorded the status of human disturbance, presence signs and number of livestock and people. To prepare the habitat map, we classified the Landsat TM image of 2010 by using the information obtained from transect walks.

To obtain information on predators, we examined and collected signs of presence of tiger and leopard during walks along transects and their immediate vicinity following their signs, such as footprints, scrapes, scratch marks and so on. Tiger and leopard prefer to use forest roads and tracks as travel routes, along which they deposit scats, which serve them also for territory marking (McDougal 1977; Smith et al. 1989; Sunquist 1981). To determine the food habits of tiger and leopard, we used their scats for further analysis.

SUMMARY OF RESULTS AND DISCUSSION

Papers **I** and **II** give an overview and challenges of the biodiversity conservation in Nepal. The country supports 3.96% of mammals, 8.92% of birds, 0.99% of reptiles, 2.47% of amphibians, 1.87% of fish, 3.72% of butterflies, 0.49% of moth and 0.44% of spiders of the world. Nepal is divided into different physiographical regions from lowland tarai to the highland of the Himalayas that supports tropical to alpine climate. The pattern and distribution of biodiversity are described in terms of eco-regions. The protected areas of Nepal are divided into five categories: strict nature reserve, national park, wildlife reserve, hunting reserve and conservation area and bufferzone. The declaration of the Ramsar sites for wetland conservation, and Tarai Arc Landscape (TAL) and Sacred Himalayan Landscape (SHL) are the practices of the landscape-level conservation in Nepal. Besides these, these two papers also highlighted the conservation challenges, which range from forest encroachment to illicit trade of wildlife. The widespread prevalence of poverty and economic insecurity are the major obstacles of conservation of biodiversity in Nepal.

The study of interaction between tiger and leopard in Chitwan (Nepal), by comparing prey utilization (dietary patterns with the aid of scat analysis) and availability (prey abundance), found that the preference of medium-sized (30-175 kg) prey by tiger, while the leopard prefers small-sized (5-30 kg) prey, but also often eats medium-sized prey. Tiger utilized sambar deer more often than its availability, which might result in local extinction of sambar deer in the future. Leopard utilized more domestic animals (especially small ones) as compared to tiger. These two predators compete mainly for medium-sized prey, while the leopard relies more on small prey and livestock than tiger. These predators killed livestock and even people in areas where there was a low density of wild prey and high level of human disturbance. The conflict between humans and carnivores is the most serious challenge threatening the conservation of carnivores, which depend on the abundance of different-sized prey and little human disturbance. Hence, restoring large populations of prey and reducing the level of human disturbance

are the key measures necessary for the effective conservation of tiger and leopard (**Paper III**).

The study of the relationship between habitat heterogeneity and abundance of prey species of the tiger showed that the abundance of the principal prey species of the tiger was positively correlated with habitat heterogeneity. Among the prey, chital was the most abundant prey species in the CNP. Habitat preference indices of prey revealed that short grassland, mixed forest, and riverine forest were the most preferred habitats. And the results also indicate that larger species of deer tend to be found in more diverse habitats than small species, excluding muntjac. In Chitwan, the grasslands in large patches of forest contribute significantly to the heterogeneity of the landscape. The ongoing increase of forest cover in the CNP has led to a reduction in the area of grassland, which may negatively affect the abundance of the prey species of the tiger. Hence, it is suggested that the restoration of landscape heterogeneity is the best way to manage the habitats in the CNP (**Paper IV**).

The results of the impact of human disturbance on prey of tiger and also their associations with predators and habitats show that the abundance of hog deer was positively associated with presence of tall grasslands and floodplains, while that of other ungulate species and primates were associated with presence of forests and short grasslands. Abundances of all species except hog deer and wild boar were more closely associated with the presence of forests than with open areas, because those used by the latter were mainly occupied by humans and livestock. Prey species were not closely associated with topographic variables. However, ungulates were found closer to waterholes than primates. The positive correlations between human disturbance and abundances of primates and muntjac explained that these species are more tolerant and adapted to human disturbance. However, the major prey species of the tiger were negatively associated with human disturbance. As a consequence, human disturbance may also affect on tigers, existing in smaller populations, and the lack of prey could result in their extinction in the Chitwan NP. The increase of human population and forest resource demand accelerated the gap in the ecological integrity of the park. The

degradation of the bufferzone forest is the major upcoming problem as it cannot fulfil the demand of people. This puts tremendous pressure in the core area of park. Therefore, in terms of the conservation and management of the park, minimizing human disturbance with a special emphasis on restoration of the bufferzone forest of southern, far western and far eastern parts of park should be the prime objective (**Paper V**).

Paper VI highlights the factors affecting the grouping characteristics and population structure of chital (*Axis axis*), sambar (*Cervus unicolor*), hog deer (*Axis porcinus*), muntjac (*Muntiacus muntjak*), wild boar (*Sus scrofa*) and gaur (*Bos gaurus*) in the Chitwan National Park. Mean group sizes were highest for chital (winter: 13.76 and summer: 11.01), followed by wild boar (winter: 6.89 and summer: 8.51), hog deer (winter: 5.52 and summer: 6.66), gaur (winter: 4.36 and summer: 5.81), sambar (winter: 1.86 and summer: 2.45) and muntjac (winter: 1.44 and summer: 1.46). Wild boar population possessed the highest proportion of young individuals and the least in gaur population. The habitat structures, presence of predators and the human disturbances were the major determinants of the variations of the grouping patterns of ungulates in this area. The larger groups of ungulates were found in the open areas with low disturbance and high predatory pressure, while smaller groups and solitary individuals were found in the forests of more disturbed areas in order to escape from the disturbances and predatory pressure.

Paper VII shows the effect of human disturbance on habitat and prey preferences of tiger. Tiger preferred early successional forest and grasslands and avoided *Shorea* forests and floodplains as compared to availability. Prey-rich areas were the most preferred sites for tiger, and it usually avoided areas subject to human disturbance. Tiger attacked domestic animals only in highly disturbed areas with a low abundance of wild prey. For the effective and natural pattern of the use of habitat and prey, a predator like tiger needs undisturbed wilderness. The existing continuous human pressure in the habitats may change the behaviour of the tiger dramatically, which consequently increases the conflict with people and a decline in prey populations. These

results suggested that the human disturbance is the major determinant of habitat and prey preferences of the tiger in human-dominated landscapes like Chitwan.

The impact of livestock grazing in the wildlife habitats is the critical part of wildlife management in tropical regions. In Barandabhar Corridor Forest, lies in the bufferzone area of the CNP, as much as 73% of the area was grazed by livestock, which resulted in competition between the livestock and wild ungulates for food. Livestock grazing affected both species composition and community structure of grasslands. There was a higher proportion of the standing biomass in the ungrazed areas and the lower proportion of barren ground as compared with the grazed areas. Livestock grazing also affected the species composition of herbaceous plants and grasses. In order to restore these degraded grasslands, the grazing by livestock needs to be reduced by establishing public grazing areas for the local people **(Paper VIII)**.

The **paper IX** deals with the distribution and diversity of storks in the adjoining areas of the CNP. There is also minor contribution of birds like storks in the diet of carnivores. This study recorded four species of storks in this area, the lesser adjutant stork (52 individuals); black stork (6); woolly-necked stork (148) and Asian open bill stork (363). Three species of the stork are residential in this park while the black stork is migratory and only present in winter. Storks were recorded mainly around lakes and ponds followed by marshy and swampy land, grassland, paddy-fields, rivers and streams. Storks were confined to the paddy fields when many of the wetlands in and around the Chitwan National Park dried out in summer. The major threats to these species were degradation of aquatic ecosystems, overuse of pesticides in croplands and over-fishing of rivers and lakes using poisons and electricity.

GENERAL CONCLUSIONS

Paper I & II provides a glimpse of biodiversity status and conservation challenges in context of Nepal. The country has protected more than 40% of the area. It has undertaken both the model of conservation- species and ecosystem. These models recognize the role of guardianship of local people in conservation. However, conservation challenges still continuing and are more serious than before. Nepal's great biodiversity is attributed to its diverse topography and climate. The fertile flat lands of the Tarai region possess a mosaic of sal and riverine forests with large patches of tall grassland. Likewise, the landscape heterogeneity from subtropical to alpine regions provides a mosaic of habitats and a great diversity of flora and fauna.

Paper III indicates the consequences of the interactions between tiger and leopard for the same prey and habitats. The competition between tiger and leopard was mainly for medium-sized prey, but the leopard relies more on small prey and livestock than tiger. The low abundance of large species of prey, like sambar deer and gaur, force tiger to feed on medium-sized prey, which does not occur in habitats, where there is an abundance of all types of prey. These predators killed livestock and even people in areas where there was a low density of wild prey and high level of human disturbance. In Chitwan, people graze their livestock (goats, cattle and buffaloes) at the periphery of the park and even in the core area. Leopards are adapted to venture to these peripheral areas, which are close to the human settlements. It also relieves leopards from competition with tigers for prey, as tiger rarely forages in the peripheries. Therefore, leopard is more responsible for wildlife-people conflict than tiger and retaliatory killing of leopard by aggrieved farmers could be more common than tiger.

Paper IV. It is concluded that habitat heterogeneity strongly affects the abundance of wildlife and in particular, the principal prey of tigers. Therefore, maintaining spatial heterogeneity in the CNP should be an important conservation goal.

Paper V. The prey of the tiger was much more affected by disturbance than by small-scale variation in the environment of the CNP. The abundances of ungulates, which are

the principal prey of the tiger, are negatively affected by disturbance, as compared to the primates. Such impact may result in the local extinction of the tiger in this area. The increase of human population along with forest resource demand accelerated the gap in the ecological integrity of Chitwan National Park. The degradation of the bufferzone forest is the major upcoming problem as it cannot fulfill the demand of people. This puts tremendous pressure in the core area of park.

Paper VI indicates that population structures in ungulates are influenced by the habitat, predators and human disturbances. In the disturbed areas, ungulates resorted into the small groups in the forest areas to escape and hide from the human influences. These species make larger groups in the open areas with less human disturbances. Likewise, in the predator rich areas, they were found in the large groups mainly in open areas and small groups in forests, which are considered as an antipredatory strategy. So it can be concluded that the population structure and social organisation in ungulates were mainly governed by the different level of human disturbance and predatory pressure.

Paper VII implies that habitat and prey preference of tigers was greatly influenced by human disturbance and prey abundance. Tiger presence was positively associated with prey abundance and negatively with human disturbance. Domestic animals occur most frequently in the diet of tigers in highly disturbed areas. Human disturbance affects the abundance of prey and so for the abundance of the tiger. In conclusion, prey abundance is the main determinant of tiger abundance only in large and relatively undisturbed areas.

Paper VIII. Livestock grazing is one of the foremost threats to the conservation of wildlife in Chitwan. Their grazing not only reduces the quality and quantity of the forages for wildlife, but also results in the transmission of various livestock diseases to wildlife, when livestock and wildlife share the same habitat.

Paper IX revealed that the migratory black stork is very rare, the lesser adjutant stork is rare; the woolly-necked stork is common, and the Asian open bill stork is the most abundant species of the family Ciconiidae in the study area. The major threats faced by Ciconiidae are disturbance of their habitats, food scarcity and excessive use of

agrochemicals in the fields. The area and quality of the wetlands are also decreasing due to eutrophication and human encroachment. Human encroachment (fishermen, hunters, and large numbers of tourists), livestock pressure and collection of natural products like fish and snails from the habitat of storks negatively affected the distribution and diversity of storks.

CONSERVATION IMPLICATIONS

Paper I and **II** highlights the conservation pattern in Nepal, in which conservation is mainly on the protection of flagship species, the protected areas for which are mostly located in the southern and northern part of the country. However, the Midhills and Mahabharat are underrepresented in the protected area system. Hence, we recommend the necessity to initiate conservation programs in the Mahabharat and Midhills in order to improve the interconnectedness of the eco-regions. Furthermore, such conservation approach will also provide the altitudinal connectivity for the seasonal migratory animals and more space for the large territorial mammals like tigers. The poverty and economic insecurity in the country also increase the challenges for conservation so that conservation needs to be integrated with community well being.

Paper III. The undisturbed, intact habitats with high populations of all kinds of prey are required for effective and sustainable conservation of carnivores in the CNP. Increase of population sizes of large wild prey is the first priority in their conservation and simultaneous reduction of domestic prey by imposing conservation measures like demarcation of grass-cutting zones and livestock grazing areas within the buffer zone of the CNP. At present, both the buffer and core zones are the prohibited zones to graze domestic animals and collect grass; it means the local people have no alternative, which forces them to collect grass and graze their animals illegally anywhere. Demarcation of grass-cutting zones and livestock grazing areas in some degraded parts of the buffer zone, which are not important for wildlife, would reduce the human interference in the core zones. Also, education of local inhabitants towards nature conservation awareness and active cooperation in wildlife protection, which is rather neglected at present, would lower the frequency of their penetration into the core zones of the CNP. Many examples from other parts of the world clearly demonstrate the importance of cooperation between local communities and park management authorities so that conservation of large predators in the Chitwan National Park cannot be successful

without this. This can be achieved by subsidies to local people from the park authorities who in turn help in maintaining wildlife population in the park.

Paper IV focuses on the importance of habitat heterogeneity in a landscape as it strongly affects the abundance of wildlife, particularly the principal prey of tigers. Therefore, maintaining spatial heterogeneity in the CNP should be an important conservation goal, and it could significantly affect the abundance of prey species. Further study of the mechanisms that create heterogeneity in the landscape is needed as the spatial distribution of grasslands (especially short grasslands) might be crucial for the long-term conservation of especially, small- to large-sized ungulates. Therefore, management of tall grassland by burning or ploughing and restoration of short grasslands by removing trees can significantly increase the proportion of the area of forage suitable for the majority of prey species of the tiger.

Paper V recommends the conservation and management of the CNP by minimizing human disturbance with a special emphasis on restoration of the bufferzone forest of southern, far western and far eastern parts as well as trainings and subsidies for alternative income generating programs for local people.

Paper VI recommends the regular monitoring of the population dynamics of the major prey species of the tiger, particularly wild ungulates in relation to human disturbances, is important by adopting rapid assessment techniques to achieve the changes in demographic structures and facilitate to make the long-term conservation strategies in this park.

Paper VII also suggests the need of the balances in the abundances of small to large-sized prey of tiger and low human disturbance. The human disturbance should be minimized by delineating a core area of park as a strictly prohibited zone and the buffer zone areas as the only zone to which local people have some level of access.

Paper VIII focuses on the adverse effects of livestock grazing on wildlife and suggests the following changes in management: (1) the non-buffer zone area of the Barandabhar corridor forest should be added to the buffer zone of the Chitwan National Park; (2) livestock grazing zones should be clearly demarcated, and the local people encouraged

to avoid grazing pedigree stock there and, most importantly,(3) community-based programs, such as community forestry, agro-forestry and biogas, need to be implemented in the Barandabhar corridor forest, so that even the poorest people in the region have alternative ways, of achieving their basic needs.

Paper IX suggests the long-term management plan to protect the endangered birds like storks: (1) minimizing human disturbance and over extraction of food of storks (e.g., fish, snails, crabs) and excessive use of agrochemicals in the fields; (2) restoration of degraded (e.g., wetlands covered by invasive alien species) and lost wetlands (e.g. dried wetlands, lost by flood) by launching cleaning campaign in collaboration with local people and refilling and damming of the lost wetlands and (3) establishing commercial fish ponds for the wetland dependent communities like Chepang, Darai, Bote, Majhi, and Tharu communities.

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APPENDICES

ABSTRACTS OF THE PAPERS

Paper I

Bhattarai, B. P., Paudel, P. K. & Kindlmann, P. (2012). Conservation of biodiversity: an outline of the challenges. In: Pavel Kindlmann (Ed.). *Himalayan Biodiversity in the Changing World*, Springer, Dordrecht, pp. 41–70.

The conservation of biodiversity is an important issue in developing countries like Nepal. Subsistence agriculture, including livestock rearing, is the main occupation of the majority of the people in rural areas. This puts an ever-increasing demand on the forest as the human population increases. Consequently, many forests are either badly degraded or encroached by people seeking essential resources for their survival. Thus, conservation challenges in Nepal are of anthropogenic origin and the result of an unsustainable extraction of biological resources. The challenges get more complicated as the human population grows, thus the conservation strategies need to effectively harmonize human and conservation needs.

Keywords: *Conservation challenges • Threats • Biodiversity • Nepal • Protected areas*

Paper II

Paudel P. K, **Bhattarai B. P,** & Kindlmann, P. (2012). An overview of the biodiversity of Nepal. In: Pavel Kindlmann (Ed.). *Himalayan Biodiversity in the Changing World*, Springer, Dordrecht, pp. 1–40.

Nepal is a mountainous country in the central Himalayas, which occupies about one third of (800 km) of the entire length of the Himalayan mountain range. Nepal alone claims eight out of the top ten tallest mountains in the world, including Mount Everest (8,848 m). Apart from the mountains, deep gorges, river valleys and the flat lands it provides a unique

assemblage of very different habitats and a great biodiversity within a small geographical area. The 147 181 km^2 that make up Nepal is slightly less than 0.1% of the global land mass, but contains a disproportionately large diversity of plants and animals. The country's 118 ecosystems harbour over 2% of the flowering plants, 3% of the pteridophytes and 6% of the bryophytes in the world's flora. Similarly, the country harbours 3.9% of the mammals, 8.9% of the birds and 3.7% of the world's fauna of butterflies.

Keywords: *Nepal • Biodiversity • Physiography • Ecoregion • Himalaya*

Paper III

Bhattarai, B. P. & Kindlmann, P. (2011). Interactions between Bengal tiger (*Panthera tigris*) and leopard (*Panthera pardus*) – implications for the conservation of these species. Submitted to *Biodiversity and Conservation*.

Bengal tiger and common leopard belong to endangered species in Nepal and elsewhere. They share their prey species, thus one affects prey availability of the other, which may contribute to decline in numbers of these carnivores. However, data on these interactions are very rare. We studied diet composition of tiger and leopard in Chitwan (Nepal), by analyzing remnants of prey in scats of these two species and comparing abundance of prey species in scats with prey abundance recorded along line transects. We found that tiger prefers medium-sized (30-175 kg) prey, while leopard prefers small-sized (5-30 kg) prey, but also often eats medium-sized prey. Domestic animals (especially small ones) are more often eaten by leopard, compared with tiger. Consequently, these two predators compete mainly for medium-sized prey, but leopard relies more on small prey and livestock than tiger. Tiger utilized sambar deer more often than expected from sambar deer availability, which might result in local extinction of sambar deer in the future. We found that prey preferences of tiger and leopard also depend on the degree of habitat disturbance. Predators killed livestock and even people in areas where there was a low density of wild prey. The conflict between humans and carnivores is the most important challenge threatening the

conservation of carnivores, which depend on the abundance of different-sized prey and little human disturbance. Hence, restoring large populations of prey and reducing the level of human disturbance are the key measures necessary for the effective conservation of tiger and leopard.

Keywords: *Carnivores • Interaction • Diet overlap • Prey preference • Predation*

Paper IV

Bhattarai, B. P. & Kindlmann, P. (2012). Habitat heterogeneity as the key determinant of the abundance and habitat preference of prey species of tiger in the Chitwan National Park, Nepal. *Acta Theriologica* **57**: 89–97. DOI: 10.1007/s13364-011-0047-8

Studies on the relationship between habitat heterogeneity and animal abundance are essential for understanding what determines biodiversity. Transect-based direct observations of eight principal prey species of tiger in the Chitwan National Park (CNP) were used to determine their abundances and habitat preferences. Chital was the most abundant prey species of tiger (*Panthera tigris*). Each of the prey species had significantly different habitat preferences except sambar deer and chital. Habitat preference was measured using Manly' s preference index, which revealed that short grassland, mixed forest, and riverine forest were the most preferred habitats of the prey species. The results indicate that large species of deer tend to be found in more diverse habitats than small species, except muntjac. The abundance of the principal prey species of tiger was positively correlated with habitat heterogeneity. The habitat, which contributes significantly to the heterogeneity of the landscape, is grassland in large patches of forest. The ongoing increase of forest cover in the CNP has led to a reduction in the area of grassland, which may negatively affect the abundance of the prey species of tiger. Hence, it is suggested that the restoration of landscape heterogeneity is the best way to manage the habitats in the CNP.

Keywords: *Ungulates • Prey • Heterogeneity • Habitat selection • Abundance • Preference • Resource selection*

Paper V

Bhattarai, B. P. & Kindlmann, P. (2011). Impact of human disturbance on the prey species of tiger in the Chitwan National Park- implications for Park management. Submitted to *Journal of Environmental Management.*

Chitwan National Park is surrounded by large settlements of people, which share the space with tigers and their prey. In this study, we measured the associations between the abundance of the different prey of tiger with habitat, predators and human disturbances, using canonical correspondence and discriminant function analyses. We show that the abundance of hog deer is closely associated with presence of tall grasslands and floodplains, while that of other ungulate species is associated with presence of forests and short grasslands. Primates were mainly abundant in riverine mixed forests. Abundances of most species except hog deer and wild boar were more closely associated with the presence of forests than with open areas, because those used by the latter were mainly occupied by humans and livestock. The presences of the species studied were not closely associated with topographic variables. Proximity of water holes was more closely associated with presence of ungulates than with that of primates. There were positive interactions between human disturbance and abundances of primates and muntjac, which explained that these species are more tolerant and adapted to human disturbance. However, the major prey species of tiger were negatively associated with human disturbance. As a consequence, human disturbance may also affect on tigers, existing in smaller populations, and the lack of prey could result in their extinction in the Chitwan NP. Therefore, in terms of the conservation and management of the park, minimizing human disturbance of wildlife habitats and restoration of bufferzone forest should be the prime objectives.

Keywords: *Human disturbance • Ungulates • Conservation • Habitats • Predators*

Paper VI

Bhattarai, B. P. & Kindlmann, P. (2011). Factors affecting population structure and social organization of the wild ungulates in the Chitwan National Park of Nepal, Submitted to *Journal of Mammology*.

We investigated the factors affecting group sizes and population structure of chital (*Axis axis*), sambar (*Cervus unicolor*), hog deer (*Axis porcinus*), muntjac (*Muntiacus muntjak*), wild boar (*Sus scrofa*) and gaur (*Bos gaurus*) in the Chitwan National Park in southern Nepal. Mean group sizes were largest for chital (winter: 13.8 and summer: 11), followed by wild boar (winter: 6.9 and summer: 8.5), hog deer (winter: 5.5 and summer: 6.7), gaur (winter: 4.4 and summer: 5.8), sambar (winter: 1.9 and summer: 2.5) and muntjac (winter: 1.4 and summer: 1.5). The age and sex ratio of all these species of ungulates were biased towards females. The highest proportions of young individuals were recorded in wild boar and lowest in gaur. Group sizes of the ungulates in this area are strongly associated with habitat structure, presence of predators and human disturbance. Large groups of ungulates were mainly recorded in less disturbed open areas where there were predators and small groups and solitary individuals in highly degraded area of forest. In order to improve the long-term conservation of ungulates in the Chitwan National Park we recommend that the current level of human disturbance in the park be greatly reduced and changes in the demography of ungulate populations be regularly monitored.

Keywords: *Ungulates • Predators • Population Structure • Gregarious • Conservation • Disturbance*

Paper VII

Bhattarai B. P. & Kindlmann, P. (2011). Effects of human disturbance on habitat and prey preferences of Bengal tiger in Chitwan, Nepal. Submitted to *Animal Conservation*.

We studied habitat and prey preferences of tiger in relation to human disturbance by walking along transects at different sites in the Chitwan National Park, Nepal. Tiger preferred early successional forest and grasslands and avoided *Shorea* forests and floodplains. Similarly, it strongly preferred prey-rich areas and strongly avoided areas subject to human disturbance. Scat analysis showed that tiger preferred medium-sized prey and avoided small and very small prey and domestic animals. Tiger attacked the latter only in highly disturbed areas with a low abundance of wild prey. The low preference for large prey and high preference for medium-sized prey might be due to the low availability of large prey (e.g., sambar, gaur) and comparatively high availability of medium-sized prey (e.g., chital, wild boar) in this area. For the effective use of habitat and prey, a predator like tiger needs undisturbed wilderness. Regular disturbance by humans may cause dramatic changes in the behaviour of these predators, which consequently increases conflict with people and a decline in prey populations. Hence, habitat and prey preferences of tiger do not only depend on prey abundance, but also on the degree of habitat disturbance in human-dominated landscapes like Chitwan. Proper management of this park by delineating a core area as a prohibited zone and only a buffer zone area with free access for local people could help minimize the effect of human disturbance.

Keywords: *Tiger • Preference • Prey • Chitwan • Conservation • Disturbance*

Paper VIII

Bhattarai, B. P. & Kindlmann, P. (2012). The impact of livestock grazing on the vegetation and wildlife ungulates in the Barandabhar Corridor Forest, Nepal. In: Pavel Kindlmann (Ed.). *Himalayan Biodiversity in the Changing World*, Springer, Dordrecht, pp. 157–175.

We investigated how livestock grazing inside the Barandabhar corridor forest (lowland in the south-central part of Nepal) affects plant community structure and standing biomass of grassland in this area. There were 2,432 domestic animals regularly grazing inside the natural habitats. As much as 73% of the area is grazed by livestock, which resulted in competition between the livestock and wild ungulates for food. Grazed areas differed from ungrazed in species composition and community structure. In the ungrazed areas, the standing biomass was higher, the proportion of barren ground smaller and the number of plant species larger compared with grazed areas. Livestock grazing also affected the species composition of herbaceous plants and grasses. In order to restore these degraded grasslands, the grazing by livestock needs to be reduced by establishing public grazing areas for the local people.

Keywords: *Grazing • Livestock • Nepal • Ungulates • Grasslands*

Paper IX

Bhattarai, B. P. (2012). Distribution and diversity of storks in the adjoining areas of Chitwan National Park, Nepal. In: Pavel Kindlmann (Ed.). *Himalayan Biodiversity in the Changing World*, Springer, Dordrecht, pp. 97–114.

The Barandabhar corridor forest (BCF) has a very high biodiversity and in terms of wildlife is globally significant. This study on the status of Ciconiidae (storks) in the BCF was conducted by means of direct observation along bird routes, line transects, roads, man-made tracks

and riversides. A seasonal count was used to determine the actual status of the storks. Four species of the family Ciconiidae, the lesser adjutant stork (52 individuals); black stork (6); woolly-necked stork (148) and Asian open bill stork (363) were recorded during the course of this study. The population of storks was highest in the rainy season. Among the species studied, the Asian open bill stork, woolly-necked stork and lesser adjutant stork were resident in the area, whereas the black stork is migratory and only present in winter. Storks were recorded mainly around lakes and ponds (675 individuals) followed by marshy and swampy land (325), grassland (293), paddy fields (251), rivers and streams (187). The most abundant species is the Asian open bill stork, followed by the woolly-necked stork, lesser adjutant stork and black stork. All the diversity indices values showed that the Asian open bill stork was the dominant species in the study area, followed by the woolly-necked stork, lesser adjutant stork and black stork. Many wetlands inside the Chitwan National Park and the Barandabhar corridor forest dry out in summer, which directly affects the survival of these birds, as they are confined to protected areas in the dry season, when there is no water in the paddy fields. Degradation of aquatic ecosystems, overuse of pesticides in fields and over-fishing of rivers and lakes using poisons and electricity, are the major threats to these species.

Keywords: *Storks • Corridor • Birding Routes • Biodiversity • Pesticides • Threats*