STATUS AND DISTRIBUTION OF PREY SPECIES OF BIG CATS IN THE BRANDABHAR CORRIDOR OF CHITWAN VALLEY, NEPAL.

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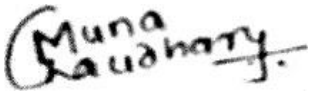
Declaration

I, Muna Chaudhary, hereby declare that this project paper entitled "**Status and distribution of prey species of big cats in the Brandabhar corridor of Chitwan Valley, Nepal**" is a project paper report based on primary work and all the sources of information used are duly acknowledged. This work has not been submitted to any other university for any academic award. All the research activities done in this study meet terms and laws of National trust for Nature conservation –Biodiversity Conservation Center.



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Letter of Acceptance for Project Paper

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Letter of Acceptance for Project Paper

The project paper attached hereto entitled **"Status and distribution of prey species of big cats in the Brandabhar corridor of Chitwan valley, Nepal"** submitted by **Muna Chaudhary** in the partial fulfillment of the requirements for the degree of **Bachelor of Science in Forestry** is hereby accepted.

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Acronyms

AIC:	Akaike Information Criterion
BaNP:	Banke National Park
BNP:	Bardiya National Park
BCC:	Biodiversity Conservation Center
BCFs:	Brandabhar Corridor Forests
BZFs:	Buffer Zone Forests
CITES:	Convention on International Trade in Endangered Species of Wild Flora and Fauna
CNP:	Chitwan National Park
DNPWC:	Department of National Parks and Wildlife Conservation
ESW:	Effective Strip Width
GoN:	Government of Nepal
GPS:	Global Positioning System
GTRP:	Global Tiger Recovery Program
MoFE:	Ministry of Forest and Environment
NFs:	National Forests
NRDB:	National Red Data Book
NTNC:	National Trust for Nature Conservation
PAs:	Protected Areas
PNP:	Parsa National Park
ShNP:	Shuklaphanta National Park

Abstract

Information on the density, abundance and biomass of their prey are crucial for proper managing dispersing big cats (tigers and common leopard) in the Brandabhar corridor. This study was carried out in the Brandabhar corridor consisting of Buffer zone forests and National forests of Chitwan valley, which provides he prime habitats for dispersing tigers and leopards. We estimated the population density, abundance and biomass of wild prey. A total of 28 line transects ranging from 1.27-5.96 km length with in an interval 300 m were randomly with help of ArcGIS covering all available habitat types in the intensive study area. The study was conducted from March 15 to June 6, 2020. We used program DISTANCE 6.0 to estimate the overall and species wise density of wild prey. A 111.79 km^2 intensive study area was surveyed using two methods 1) transect surveyed on elephant back and 2) transect surveyed on foot. All prey species density of 184.1 and 333.23 individuals km^{-2} were estimated in 59.13 $km^2$of buffer zone forests and 16.16 km^2 of National forests respectively using elephant back method. And using foot method of survey, overall density of 90.51 individuals km^{-2} was estimated in 52.66 km^2 of National forests. Total area (75.29 km^2) surveyed on elephant back estimated 169.39 individuals km^{-2} and 144.04 individuals km^{-2} of overall density and spotted deer density respectively. When the density figures were multiplied by the average weight of spotted deer, biomass of 7634.12 kg km^{-2} was obtained. Based on prey density, elephant back method of survey estimated highest abundances than foot method. On the basis of observation of prey species, spotted deer was found to have highest abundance followed by rhesus, wild boar, sambar, barking and langur in Sal forests. Based on detection rate of prey species on elephant back, average detection rate was found to be highest in buffer zone forests than national forests of Brandabhar corridors.

Key words: Abundance, biomass, line transect survey, prey density.

शोध साराँश

आहारा प्रजातिको घनत्व, प्रशसता र बायोमास जस्ता जानकारीहरुको माध्यमले छरिएर आएका ठूला बिराला (पाटे बाघ र चितुवाहरु) को उचित रुपमा व्यवसथापन बरन्डाभार कोरिडरमा महतवपुर्ण देखिन्छ। छरिएर आएका पाटे बाघ र चितुवाहरको प्रमुख वासस्थान रुपमा रहेकोले यो अध्ययन चितवन उपत्यकामा पर्ने बरनडाभार कोरिडरमा रहेका मध्यवर्ती र राष्ट्रिय वनहरुमा गरियो । हामीले यस अध्ययनमा डिस्टान्स स्यामपलिङ अधारित लाईन ट्रान्जेकट सर्वेक्षण हातीमा चढरे र हिडने विधि प्रयोग गरी जनसँखया घनत्व, प्रशसता र बायोमास अनुमान गरियो। आर्क जि.आई.एसको माध्यमबाट जम्मा २८ वटा लाईन ट्रान्जेकटहरुमा १.२७ देखि ५.९६ कि.मी लम्बाई रहने गरी सबै प्रकारका वासस्थानमा समावेश हुने गरी ३०० मिटरको अन्तरालमा अनियमित रुपमा अध्ययन क्षेत्रमा राखियो । यो अध्ययन मार्च १५, २०२० देखि जुन ६, २०२० सम्मको अवधिमा पुरा गरियो। हामीले यस अध्ययनमा डिस्टान्स ६.० सफटवेयर कार्यक्रमबाट सबै आहारा प्रजातिहरु समावेश गरिएको घनत्व र प्रत्येक आहारा प्रजातिको घनत्व निकालियो । जम्मा १११.७९ वर्ग कि.मी को अध्ययन क्षेत्रमा दुईवटा विधि हातीमा चढेर र हिडेर सर्वेक्षण गरियो। हातीमा चढने विधि प्रयोग गरी सबै आहारा प्रजातिहरु समावेश गरिएको घनत्व क्रमशः १८४.१ र ३३३.२३ जनावर प्रति वर्ग कि.मी मध्यवर्ती वनमा (५९.१३ वर्ग कि.मी) र राष्ट्रिय वनमा (१६.१६ वर्ग कि.मी) अनुमान गरियो । यसै गरी हिडने विधि प्रयोग गरी सबै आहारा प्रजातिहरु समावेश गरिएको घनत्व ९०.५१ जनावर प्रति कि.मी राष्ट्रिय वनमा (५२.६६ वर्ग कि.मी) अनुमान गरियो। जम्मा ७५.२९ वर्ग कि.मी अध्ययन क्षेत्रमा हाती चढेर सबै आहारा प्रजातिहरु समावेश गरिएको घनत्व १६९.३९ जनावर प्रति वर्ग कि.मी र चितल प्रजातिको घनत्व १४४.०४ जनावर प्रति वर्ग कि.मी अनुमान गरियो। चितल प्रजातिहको घनत्व औसत जिवित चितलको वजन सँग गुणन गरी चितल प्रजातिको बायोमास ७६३४.१२ के.जी प्रति वर्ग कि.मी अनुमान गरियो । आहारा प्रजातिको घनत्वको आधारमा हिडने विधिको तुलनामा हाती चढेर गरेको विधिमा बढि जनावरको प्रशसता अनुमान गरियो । सर्वेक्षणमा देखिएको आहारा प्रजातिहरुको संखयाको आधारमा साल वनमा चितलको प्रशसता बढि र कम अनुसार असामी बादर, बदेल, जरायो, रतुवा र लङगुरमा देखियो । हातीमा चढेर गरिएका सर्वेक्षणमा देखिएको आहारा प्रजातिहरुको डिटेकसन दरको आधारमा राष्ट्रिय वनको तुलनामा मध्यवर्ती वनमा औसत डिटेकसन दर बढी देखियो ।

सार शब्दहरु : प्रशसता, बायोमास, लाईन ट्रान्जेकट सर्वेक्षण, आहारा प्रजातिको घनत्व।

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CHAPTER -I

INTRODUCTION

1.1 Background

Big cats are among the most recognized and admired animals, at the top of food chain so, they are at the top of the hunting pyramid and require a great deal of meat. They have always been fewer in number than the small cats, which are more easily able to find sufficient food for their needs. Out of 12 wild cats found in Nepal, the Royal Bengal Tiger and Common Leopard are the most amazing big cats that are found in corridors and non-protected forests of Chitwan valley. The tiger (*Panthera tigris)* is sympatric with the leopard (*Panthera pardus)* throughout much of its range in Asia because both cats are large in size and share the same prey species primarily ungulates (Andheria et.al., 2007).

Population of big cats in the recent year are in declining rate, mainly due to extreme human disturbances and activities like habitat loss, poaching and depletion of prey populations (Karanth & Stith, 1999; Seidensticker et al., 1999; Karanth et al., 2003). Among total eight sub-species of tiger, only five are surviving today's world and remaining three subspecies has gone extinct (Winkramanayake et al., 1998). Royal Bengal Tiger (*Panthera tigris tigris*) is one of the living sub-species of tiger found in small, isolated protected areas of Nepal (Bagale, 2005). The Bengal tiger (*Panthera tigris)* is an Asia's largest top predator considered as umbrella and charismatic species in the world (Seidensticker and Mc Dougall, 1993). However due to loss of habitats, poaching and trade of tiger body parts made decline in population across its range, it is listed as Endangered species on the IUCN Red List, enlisted on the Appendix I of the CITES and listed as protected species in National Parks and Wildlife Conservation Act (1973). Density of tiger is appeared to be primarily dependent upon the density of wild prey population (Karanth and Nicholos, 2002; Karanth et. al., 2004).

Among nine sub-species of leopard, the common leopard (*Panthera pardus fusca*) (Meyer, 1794) is one of the most widely distributed felids across the forested landscapes of the Indian subcontinent (IUCN, 2010; IUCN, 2017). The Leopard (*Panthera pardus)* is categorized as a Near Threatened species by the IUCN Red List of Threatened species (Henschel et. al., 2008; IUCN, 2010). It is also enlisted in the Appendix I of Convention on International Trade in Endangered Species of wild fauna and flora (CITES) as a highly threatened mammal. It is also included as a susceptible mammal in the National Red Data Book (NRDB, 1995). But it is not a protected mammal of Nepal under Department of National Parks and Wildlife Conservation Act, 1973 (DNPWC, 1973). It is also one of the most vulnerable species because of its killing behavior to large number of domesticated animals; however least concern in terms of its conservation given in Nepal.

Wild ungulates are considered as major parts of Carnivores diet (Schaller, 1967; Seidensticker, 1976; Johnsingh, 1983; Karanth & Sunquist, 1995; Karanth & Nichols, 1998; Biswas & Sankar, 2002; Bagchi et al., 2003; Wang, 2010; Thapa, 2011). The ungulates species such as chital (*Axis axis*), sambar (*Rusa unicolor*), wild boar (*Sus scrofa*), hog deer (*Axis porcinus*), barking deer (*Muntiacus muntjak*) and guar (*Bos gaurus*) comprised about 70% of biomass in the diets of tiger and leopard (Johnsingh, 1992; Thapa, 2011), therefore, their conservation is essential for sustaining viable populations of predators. Medium to large sized ungulates comprise the bulk of the tiger's diet, of which spotted deer and sambar constitute approximately 55%–65% (Karanth and Sunquist, 1995). The viable and healthy population of different size class of ungulates are the determining factor for the feasible population of carnivores like big cats (Schaller, 1967; Sunquist, 1981; Karanth, 1995; Karanth & Sunquist, 1995; Karanth & Nichols, 1998; Carbone & Gittleman, 2002; Karanth et al., 2004). Tiger abundance is positively associated with the abundance of prey, particularly wild ungulates (Karanth and Stith, 1999; Smith et al., 1998; Sunquist et al., 1999). The larger species (Biswas and Sankar, 2002) are preferred by tiger to hunt ranging from medium to large sized wild ungulates (John Singh, 1983). The four deer species (barking deer- Muntiacus muntjac, hog deer- *Axis porcinus*, spotted deer- *Axis axis*, and Sambar- *Rusa unicolor*, two antelope species (four horned antelope-*Tetracerous*

quadricornis, blue bull- Boselaphus tragocamelus), two primates (hanuman langur-Semnopithecus entellus, rhesus Monkey-*Macca mullata*), gaur (*Bos gaurus*) and wild boar (*Sus scorfa*) are the prey species of Bengal tiger in Nepal (Karki et al., 2012; Lamichhanne and Jha, 2015). The sympatric carnivore of tiger such as leopard shows preference for large ungulates to small rodents and even arthropods (Bailey, 1993). The small and medium sized species like chital, smaller domestic and small wild animals are the main prey in all season whereas wild boar and birds are other important preys of Common leopard in the dry season (Eliassen, 2003).

Out of the total combined density of prey (all prey per km2) varied between 8.1 and 77.5 animals per km2 across the sites, prey base species monitoring indicated that the combined prey density per km2 in CNP and adjoining forest is 70.7 (MoFE, 2018). However, prey density estimates marginally declined from 73.63 to 70.7 (SE 7.49) in CNP (P=0.8) across the survey sites as compared to 2013 (Dhakal et al., 2014). Time frame, line transect survey concentrated only in Terai lowland, poaching outside park, bisecting of corridors by national highway and road, road kills and large-scale human disturbances might be reasons for decline in prey density estimates (DNPWC, 2019). Available habitat, distribution of water sources, and human disturbance were the most common variables influencing spatial distribution of prey at different spatial scales. Due to high prey occupancy and tiger habitat use suggested that the Churia is valuable habitat for ungulates and tigers (Thapa and Kelly, 2017).

Adjoining corridor of Chitwan National park and non-protected forest of Chitwan valley has extensive riparian forests and tall floodplain grasslands regulated by annual floods where ungulates can reach their highest densities. Corridors are connections between isolated areas of similar habitat (Bolen and William, 1995) and geographical extensions, whose function is to connect separate areas and facilitate the movement of animals and provide natural conditions for their conservation (Rivera et al., 2002). Some adverse effects on habitat are minimized with help of corridor (linear corridor or stepping stones) through dispersal of individuals between isolated patches, assisting for the long-term genetic interchange and recolonization of the patches from which populations have been locally

extirpated (Bond, 2003). The abundance of hog deer is closely associated with areas of tall grassland and floodplains, while that of other ungulate species are associated with that of forests and short grasslands but primates are mainly abundant in riverine and mixed forests however abundances of most species, except hog deer and wild pig, are more closely associated with areas of forests than with open areas (Bhattarai and Kindlmann, 2013).

The scientifically coherent, analytical and logical methods employed for deducing information on the prey abundance are important for monitoring prey populations (Karanth, 1995), but some limitations such as spare population, peculiar habitat requirements, and lack of scientifically valid studies makes their conservation and management difficult (Karanth & Sunquist, 1992). Earlier studies lack strong statistically validity for estimation of ungulates population as those researches have generally focused on ecology and behaviour (Karanth & Sunquist, 1992; Buckland et al., 1993). Despite of above extremities, scientists developed the statistically valid and broadly used method-DISTANCE sampling for estimating density of biological populations (Buckland et al., 1993, Karanth & Sunquist, 1992). Distance sampling-based line transect is regarded as a practical and relatively less expensive method for assessing status of wild animals (Burnham et al., 1980, Buckland et al., 1993, Thomas et al., 2009). In south Asia including Nepal, it is also considered as standard, practical and economical monitoring tool for wild prey species of tiger (Karanth and Sunquist, 1995; Karki, 2011). Using this sampling methods, it will provide logical and statistically valid data on the density and abundance prey species.

The recent national tiger survey (2018) revealed estimate of the highest number of tigers (93 out of 235) in CNP and adjoining forests (DNPWC, 2019). With the increasing tiger population in PAs, not only the young tigers but also the leopards, the other co-predator, may be pushed out in marginal habitats outside (Lamichhane et al. 2019). The National Tiger Survey (2018) recorded that four tigers (2male and 2 female) were captured in Brandabhar Corridor (CNP- BZ). The tiger survey revealed that tigers are dispersing outside core-tiger bearing PAs (DNPWC, 2019) i.e. known tiger distribution range (or unoccupied habitat) in the buffer zone, corridors and adjoining non-protected forests. But

prey density is very low in the forests outside PAs, which is a challenge for survival of dispersing tigers (Shrestha, 2004). Therefore, current estimated data on the abundance of wild prey species in the corridors and non-protected forests in Chitwan valley will be useful for the management and conservation of carnivore species like big cats. The information on status and distribution of prey species will be helpful for habitat suitability modeling of big cats along with sympatric carnivores in and outside protected areas as well as important for habitat conservation and management of endangered and vulnerable ungulates and primates.

1.2 Statement of problem

Beside several conservation efforts invested in Chitwan National Park and adjoining forest areas, doubling tiger by 2022 committed by Government of Nepal is great challenge and opportunities (DNPWC, 2014) and being in the mainstream of the biodiversity, the tiger should have a suitable habitat and well availability of prey within and outside the protected areas (PAs). Being the tiger as an umbrella species, its effective conservation enhances survival prospects for other forms of biodiversity (Karanth, 2003) such as increase in abundance of prey species of the sympatric predator like Common Leopard (Selvan et.al., 2013). However, the non-protected forest (National and Community forests) outside the PA is not widely concerned on the information on wild prey (prey density of big cats, their abundance and biomass). Study about status, distribution and the abundance of prey and habitat suitability outside the core area should be made in an intensive scale otherwise this may jeopardize the commitment of government.

It is a great news that population of tigers recovering from near extinction grew and took over the optimal habitats of the park but this has made decline in Leopard density in the areas taken over by tiger resulting shift of many leopards to tiger-free areas outside the park where they then fed on domestic livestock. This will increase consequences of human wildlife conflict. Recent National Tiger and Prey survey highlights that tigers are dispersing outside forests with increasing tiger population in protected areas of Nepal, which may also displace leopards in existing in those forests to marginal habitats (Odden

and Fredrksen, 2010). Several studies reported that intra-guild predation between some of the predators such as tiger predation on leopard is reported from Chitwan National Park (Seidensticker 1976). It has been great challenge to conservationist on effect of intra-guild predation on ecological balance. Killing and displacement of leopards by tigers thus appears to have important ecological consequences.

In the forests outside Pas, wild prey density is very low, which is a challenge for survival of dispersing tigers (Shrestha, 2004). Some of the prey ungulates like hog deer and swamp deer are endangered whereas prey species like barking deer, sambar deer, blue bull and spotted deer are vulnerable (Jnawali, 2010). Availability of sufficient prey is vital for the use of corridors by dispersing tigers and leopards. Free grazing is common practice in these forests. Herding cattle is not allowed in the core area of CNP in Nepal, but it is allowed under certain conditions in both the buffer zone and the Brandabhar corridor forest (Gurung, Nelson, & Smith, 2009; Gurung *et al.,* 2008; Nepal & Weber, 1994). There is a threat of habitat loss resulting scarce of wild prey of big cats. If prey is scarce in the corridor, human-tiger conflict can rise in terms of increased livestock depredation and human casualties in and around the corridor. In result, people may kill tigers/leopards in retaliation. The study is necessary to estimate general status and abundance of the prey base (wild ungulates) within the corridor and non-protected forests to hold the population of dispersing tiger along with sympatric predator Common leopard.

Land base supporting of increasing and dispersing tigers and leopard in CNP as well as depletion of prey base are considered as the most significant challenges. Understanding distribution and prey base abundance of carnivores will in turn facilitate development of management strategies and implementation of conservation action plan that looks for sustaining increased and dispersed tigers and leopards by increasing land base supporting of these big cats and sympatric carnivores in the corridors and non-protected forests. Therefore, it is necessary to conduct research on status and distribution of prey of big cats in the corridors and non-protected forests of Chitwan valley to initiate conservation and management of habitats of wild prey outside PAs to sustain the tiger population growth and achieve national target. It will also help to predict chance of increased level of

interference competition among sympatric carnivores like leopard as well as chance of encounter rates with human. Research findings will also help to study and understand intra-guild predation as well as suitability of coexistence of both big cats in corridors and non-protected forests of Chitwan valley. Finally, understanding status and distribution of prey base is important for carnivore conservation like big cats and their sympatric carnivores like leopard.

1.3 Research questions

i. What is the status and distribution of wild prey species of big cats in corridors and non-protected forests of Chitwan valley?

ii. What are the habitats/vegetation inhabited by wild prey species comparing with their abundance in the study area?

iii. What is the wild prey biomass available in study area for dispersing tigers and sympatric carnivore like leopard from park?

1.4 Objectives

The general objective of the current study was to assess the status and distribution of prey species of big cats (Bengal tiger and Common Leopard) in the corridors and non-protected forests of Chitwan valley.

The specific objectives were:

i To assess the prey base abundance in the study area having different forest management regimes.

ii To assess wild prey biomass available for dispersing big cats in the study area.

iii To explore the habitat types used by prey species of sympatric big cats.

1.5 Significance of study

i. The study provides the estimate of wild prey density of big cats and their distribution in the study area.

ii. It also helps to understand ecology of prey and predator in the corridors and adjoining national forests.

iii. The research findings will further help to assess habitat quality of corridors and non-protected forests outside the park for dispersing big cats.

iv. The information from research will also help to formulate the conservation action plan for big cats.

1.6 Limitations

i. The study area was invaded by invasive species like *Mikenia micrantha, Lantana camara Urtica diocia* (Sisno) *etc.* and high bushes which created difficulties for carrying out prey base survey in transects of national forests of Brandabhar corridor using foot method of survey.

ii. Prey base line transect survey were carried out on Elephant back in inaccessible and unsecured area (animal danger) instead of transect walk for better observation in high bushes and shrubs of buffer zone forests of Brandabhar corridor.

iii. Noise pollution created by vehicles on east to west national highway and Padampur road hampered better sighting of animal in Brandabhar corridor forests.

iv. The time variation in data collection using both elephants back and foot method was main temporal limitation of the study.

v. Unequal distribution of different length of line transects in different sites was the main spatial limitation of this study. However, it was designed to cover overall habitat types/vegetation.

CHAPTER –II

2. LITERATURE REVIEW

2.1 Big Cats in Nepal

Cats are possibly the most beautiful and graceful of all animals which are sleek, with fine fur that is often strikingly marked with spots or stripes, and elegant heads with pointed ears and large eyes. Both the wild cat and the domestic cat belong to one family, the Felidae. There are four groups within the cat family: the small cats, which includes 28 different species including domestic cats and cats as diverse as the small black-footed cat and the large puma; the large cats (the lion, tiger, jaguar, leopard, and snow leopard); and two groups consisting of only one cat each, the cheetah and the clouded leopard.

12 species of wild cats are recorded in Nepal. They are as Royal Bengal tiger (*Panthera tigris tigris*), Common leopard (*Panthera pardus*), Clouded leopard (*Neofelis nebulosa*), Snow leopard (*Panthera uncia*), Leopard cat (*Prionailurus bengalensis*), Jungle cat (*Felis chaus*), Palla's cat (*Otocolobus manul*), Rusty spotted cat (*Prionailurus rubiginosus*), Marbled cat (*Pardofelis marmorata*), Fishing cat (*Prionailurus viverrinus*), Asiatic golden cat (*Catopuma temminckii*) and Eurasian lynx (*Lynx lynx*) (NTNC, 2019). There are seven large cats found all over the World, which include tigers, lions, leopards, cougars (puma), jaguars, cheetahs and snow leopards (Sunquist and Sunquist, 2017).

Out of seven large cats of the World, Royal Bengal tiger, Common leopard and Snow leopard are considered as big cats of Nepal having character like stealthy, strong and fierce as the best predator with breathtaking beauty (Ghimirey, 2006). The Royal Bengal Tiger and Common Leopard are co-existing big cats inhabited in CNP, Buffer zone, Brandabhar corridor and National forests of Chitwan valley. Density of these two big cats are dependent on the prey availability in their co-existing habitats.

2.1.1 Royal Bengal Tiger

The Royal Bengal tiger (*Panthera tigris tigris*), one of the world's most magnificent mammal, is nationally and globally endangered and faces extinction in future if present trends poaching and habitat degradation continues (DNPWC/MoFSC/GoN, 2007). It is the largest of the living felids, easily recognizable as the only striped cat. It is the apex predator of the food chain as well as an indicator of healthy ecosystem. Being umbrella and charismatic species, conservation of tiger means the conservation and balancing of the whole ecosystem. Among 8 sub-species of *Panthera tigeris*, Bengal tiger (*Panthera tigris tigris*), Sumatran tiger (*Panthera tigris sumatrae*), Amur tiger (*Panthera tigris alatica*), Indo-china tiger (*Panthera tigris corbetti*) and South china tiger (*Panthera tigris amoyensis*) are living sub- species whereas Caspian tiger (*Panthera tigris virgate*), Javan tiger (*Panthera tigris sondaica*) and Bali tiger (*Panthera tigris balica*) have gone extinct.

The heaviest Bengal tiger on record was a male that weighted 227 kg in Nepal. Adult male tigers in Nepal and India weigh 180 to 258 kg, and adult females weigh 100 to 160 kilograms. The tiger's coat pattern of black stripes against dark gold background looks very conspicuous even in in semi-coated habitat. Tigers are solitary and ambush hunters requiring >5 kg of meat per day (Sunquist 1981). The tiger diets are largely comprised of deer species (about 75% in most parts of its range), although it kills prey ranging from medium to large sized animals like gaur (*Bos gaurus*). Among the different factors threatening tiger populations, reduction in prey populations was concluded as the cause for observed decline in tiger numbers (Karanth and Stith, 1999; Karki et al., 2009). Prey densities should be monitored closely for the survival of tigers (Karanth and Stith, 1999). Apart from wild animals, tigers also readily prey on livestock when they are available (Sunquist, 1981).

Tiger is territorial animal which found in variety of habitats from tropical rain forest and boreal forest to dry savannas (Bhattarai, 2009). Dense forest and grasslands are generally preferred by tigers. Tigers are often found bathing in ponds, lakes, and rivers (DNPWC, 2007). They have adapted to living in each different habitat and therefore prey on a wide

variety of animals. They generally feed predominately on large deer species and wild boar but occasionally they predate larger prey species such as wild cattle, elephant and rhino calves. They are also opportunistic and will kill monkeys, birds, reptiles and fish as well as more unusual prey such as crocodiles and leopards. Males have been known to kill cubs fathered by other tigers (Sunquist, Karanth, & Sunquist, 1999).

Tiger is listed in Appendix I of CITES and classed as Endangered category in Appendix I of Red Book of IUCN. In Nepal, it is listed as protected under NPWC Act 1973 (DNPWC/MoFSC/GoN, 2007). Reduction of prey base (Karanth and Stith, 1999; Ranganathan et al., 2008), loss of habitat and fragmentation (Wikramanayake et al., 1998; Dinerstein et al., 2007), poaching (Nowell and Jackson, 1996; Chapron et al., 2008) and conflict with humans (Gurung et al., 2008) are considered as main reasons for the global decline of tiger populations. Census conducted in 1999/2000 and 2005 resulted 340-350 and 360-370 adult tigers respectively (DNPWC/MFSC/GoN, 2007). But following census conducted in 2009, 2013 and 2018 resulted an increased population in isolated habitat of tigers (five protected areas) in Nepal.

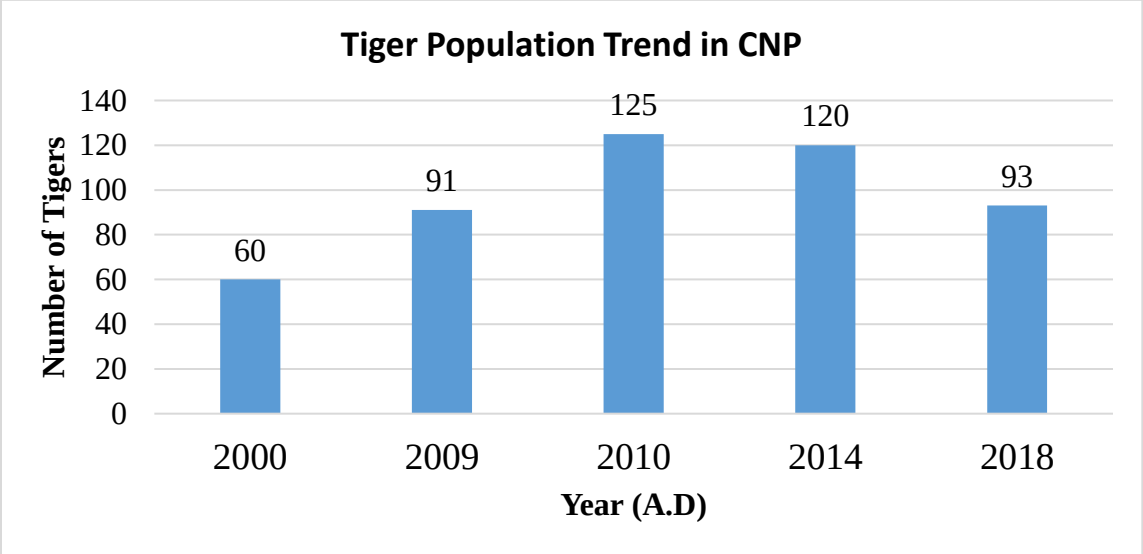


Figure 1. Tiger population trend in Chitwan National Park (DNPWC, 2018; Acharya, 2019)

2.1.2 Common Leopard

Panthera pardus (Leopard; Linnaeus, 1758) is one of the most widely distributed, solitary and adapted Wild cats of genus *Panthera* (Nowell and Jackson, 1996; Myers, 1986) and also considered as the fourth largest of the seven large cats family Felidae and order Carnivora (Stein and Hayssen, 2013), occupying an array of habitats, from rainforests to deserts and from the fringes of urban areas to remote mountain ranges such as in Asia and Africa (Achyut and Kreigenhofer, 2009; Harihar and Pandav, 2012; Nowell and Jackson, 1996; Kitchener. 1991). Nepal is the habitat for three species of Leopard: Common Leopard *Panthera pardus*, Clouded Leopard *Neofelis nebulosa* and Snow Leopard *Uncia uncia* (Ghimirey, 2006). Out of these three species, it is most common one having large dark rosettes spots known as Forest Leopard which is restricted only to forest or heavy cover (Prater 1998). It has distribution range extending as high as 4000m (KMTNC, 1998), up to 3500m (Shah et al., 2004) and 5200 (Jackson et al., 1984).

Due to habitat degradation, poaching for its valuable skins bone and persecution as a killer of human and livestock, it is listed as "Near threatened species" by the IUCN throughout its range (Stein and Hayssen, 2013) despite of its wide distributions. The leopard is also placed on Appendix 1 of the CITES, which prohibits trade in any part of the animal in those countries that are members, but smuggling still occurs. Through researches on genetic diversity, nine subspecies are recognized all over the World. These include *P. p. pardus* (Africa), *P. p. nimr* (Arabia), *P. p. saxicolor* (SW Asia), *P. p. melas* (Java), *P. p. kotiya* (Sri Lanka), *P. p. fusca* (Indian sub-continent), *P. p. delacouri* (SE Asia- S China), *P. p. japonensis* (N China) and *P. p. orientalis* (SE Russia, Korean peninsula & NE China) (Stein and Hayssen., 2013; Uphyrkina et al., 2001). *Panthera pardus fusca* is the sub-species present in the study area. The Indian leopard (*Panthera pardus fusca*) is only found on the Indian sub- continent. This subspecies is globally listed as Vulnerable on the IUCN Red List of Threatened Species and only occupies 25-37% of its historic range (Jacobson *et al.*, 2016). Poaching, habitat loss, human- wildlife conflicts and the negative effects of the interaction with tigers have resulted in a decline of most subpopulations across their range (IUCN, 2017). Several subspecies and regional populations are considered Critically

Endangered (Jacobson *et al.*, 2016) It is estimated that there are less than 10,000 individuals left in the wild (IUCN, 2017).

According to study conducted by Eliassen (2003), the leopards generally do not inhabit the prey abundance area if the area has high tiger or other large carnivore density due to social dominancy. General weight of leopard is in the range of 40 to 60 kg but exceptionally large males weighing over 91 kg have also been reported from South Africa (Turnbull and Kemp, 1967). Males inhabit territories of 5 to 40 sq. km, which may overlap with the territories of several females. The study conducted by Odden and Wegge (2005) in RBNP estimates that annual home ranges of the two males were 47 and 48 km2 and had an overlap of only 7%, whereas the overlap between the female's home range (17 km2) and that of one of the males was 56% in Nepal.

The leopards are versatile animals having adaptability to almost every type of environments due to high degree of flexibility in their diet. The leopard can live and thrive in all most all types of habitats including dense forest, rock and scrub (Prater, 1993), grasslands and even on mountain cliffs, where sufficient hideouts and prey species are available (Bailey, 1993; Achyut and Kreigenhofer, 2009), illustrate that they can live wherever there is sufficient cover and adequately sized prey animals. Such a diverse and wide distribution of leopard is mainly due to its highly adaptable hunting and feeding practices and their solitary nature (Bertram, 1999). Their greater adaptability is due to their catholic diet which even includes arthropods, amphibians, rotting carcasses, less dependency on free water and their small size to sustain population and live near to human habitation (Daniel, 1996). The home ranges of leopard are largest when prey availability is relatively low and vice versa (Stein and Hayssen, 2013). It has a variety of space use where presence of competitors, prey size and cover vary. Leopards are more abundant in areas with higher degrees of disturbance and more involved in livestock raiding compared to tigers in areas where both species are sympatric. They can easily survive in human dominated areas by changing their habitats to prey on livestock, dogs and human (Achyut and Kreigenhofer, 2009; Chauhan and Goyal, 2001; Gugginsberg, 1975; Sedeinsticker et al., 1990; Daniel, 1996). Leopards are visual hunters, relying heavily on sight and to a

lesser extent on hearing to detect prey (Sunquist & Sunquist 2002). Leopards are considered to be catholic predators of more than a hundred small (<50 kg) to medium (50-100 kg) sized prey species, but their common kill is between 10 and 40 kg, with an optimum weight of 23 kg (Hayward et al., 2006).

As it is one of the most common large cats found in Nepal, it is distributed every part of our country except high Himalayas. Sufficient studies have not been carried out in Nepal regarding status, distribution and number of leopards. Common leopards are distributed in 73 districts of Nepal (Shah et al., 2004). The study conducted by Poudel (2002) estimated 18-35 individuals of Common leopard in CNP. Outside the park, the leopard concluded lesser density as compared to park. This study also estimated 25-55 common leopards in the Chitwan valley. Research also conducted by Thapa (2011) estimated leopard population in and around CNP to be around 37 and 57 individuals in 2008/09 and 2010 respectively. This data suggests that leopard numbers have slightly increased in CNP from 2008 to 2010 (Thapa, 2011).

2.2 Wild Prey species of big cats (Royal Bengal Tiger and Common Leopard)

Bengal tiger and Common leopard are listed as endangered species in Nepal and known to be sympatric carnivores across most of their range because they are present in the same geographic area and share same prey species (Bhattarai & Kindlmann, 2012; Reynaert, 2018). However, in some areas the nature of their co-existence is conflicting (Odden et al., 2010; Bhattarai & Kindlmann, 2012). *P. pardus* were killed by *P. tigris* in Nepal (McDougal, 1988). Although they coexist, tigers *(Panthera tigris)* restrict the distribution of *P. pardus* in Nepal (Seidensticker 1976; Odden et al. 2010). Wild ungulates are important constituents of faunal assemblage. According to Adhikari and Khadka (2009), size of wild ungulates in Nepal consist of three classes: small sized prey class (barking deer, four horned antelope), medium sized prey class (spotted deer, hog deer) and large sized prey class (sambar, swamp deer, blue bull, gaur).Tiger and leopard have substantial dietary overlap, both predating on small to large sized ungulates (Andheria et al., 2007) but there are differences in prey selection (Karanth & Sunquist, 1995; Odden, 2007). Tiger

prefers medium (50- 100 kg) to large (>100 kg) sized prey whereas leopards show a preference towards small (<50 kg) to medium (50- 100 kg) sized prey resulting in an overlap of preference for medium sized prey (Bhattarai & Kindlmann, 2012). However, these two sympatric predators compete mainly for medium sized prey, but leopard more often predates on small sized prey and domestic animals than tiger. In CNP, the principal prey species of prey of tiger (*Panthera tigris*) and leopard (*Panthera pardus*) are gaur (*Bos gaurus*), sambar deer (*Cervus unicolor*), chital (*Axis axis*), hog deer (*Axis porcinus*), muntjac (*Muntiacus muntjak*) and wild pig (*Sus scrofa*) whereas primates are less preferred by tiger than leopards do (Hayward et al. 2016). Chital, hog deer, barking deer, sambar deer, gaur and wild boar are the principal prey species of tiger in CNP (Lamichhane & Jha, 2015; Bhandari et al., 2017). All ungulate species of CNP except gaur are the wild prey of Brandabhar corridor forest of Chitwan valley (Bhattarai, 2003). According to Bhattarai (2003), the most abundant wild ungulates that are found in this corridor is spotted deer.

2.2.1 Prey of Royal Bengal Tiger

Tigers are solitary top predator having capability of predating wide varieties of varied sized prey from large prey like gaurs (450 kg) to smaller sized prey such as langur (8 kg) (Bhandari et al., 2017). The larger species (Biswas and Sankar, 2002) are preferred by tiger to hunt ranging from medium to large sized wild ungulates such as bovid or cervids (Seidensticker 1976; John Singh, 1983) and also a lesser extent to two species of primates such as rhesus monkey (*Macaca mulatta)* and common langur- Semnopithecus entellus (Bhattarai and Kindlmann, 2012). In South Asia, the main prey species of tigers are spotted deer and sambar deer (Tamang, 1979), and other common prey species include wild pig, gaur and nilgai (Sedeinsticker, 1976). Chital is one of the principal wild preys of the tigers (Karanth and Sunquist, 1995; Stoen and Wegge, 1996). Chital is underutilized by tigers based on their availability (Bhattarai and Kindlmann, 2012; Stoen and Wegge 1996) as well as gregarious nature (Karanth and Sunquist, 1995). In general, sambar is the most abundant prey species for tigers (Karki, 2011; Dhakal et al., 2014). Some researchers also highlight that both large and medium sized prey such as wild boar, sambar and gaur

(Reynaert, 2018) are important for conservation of tiger (Lamichhane & Jha, 2015). The most abundant wild preys of Bengal tiger are four species of cervids (sambar, chital, hog and muntjac), two antelope species (four horned antelope, blue bull) two primates (rhesus monkey and common langur), one bovid (gaur) and one suid (wild pig) in Nepal (Lamichhanne and Jha, 2015; DNPWC, 2019). The major medium sized prey species of CNP include spotted deer, hog deer and wild pig whereas large sized prey includes sambar deer, gaur and blue bull (Bhattarai & Kindlmann, 2012). It has been recorded that tiger preys more frequently upon elephant calves (Karanth and Sunquist, 1995) and rhino calves (Seidensticker, 1976) than do leopards. A recent study on tiger diets in CNP suggests that predation of medium sized domestic animals is higher when abundancy of large prey species is low (Bhandari et al., 2017).

Felids like tiger generally raise predation on livestock to survive when there is scarce of wild prey, mainly medium and large-sized ungulates due to seasonal migration, population shrinkage and human disturbances (Sunquist, 1981; Baker et al., 2008; Zhang et al., 2013; Khorozyan et al., 2015; Bhandari et al., 2017). Due to such ecological behaviour, retaliation and preventive persecution has made decline in populations of tiger. Tigers mostly predate upon wild prey for its subsistence in the Chitwan National Park, but will also sporadically kill livestock in some extent (Bhattarai and Kindlmann, 2012; Bhandari et al., 2017).

2.2.2 Prey of sympatric carnivore (Common leopard)

Leopards *Panthera pardus* have a catholic diet and are generally thought to prey on medium-sized ungulates like barking deer and hog deer (Hayward et al., 2006; Reynaert, 2018) however they preferentially prey upon species within a weight range of 10–40 kg. The leopards generally focus hunting on locally abundant medium sized ungulates species in the 20-80 kg range. (Seidensticker 1991; Bailey, 1993). Karanth and Sunquist (1995) found that leopard focused on prey having weight 30-175 kg. At least 92 prey species (Bailey, 1993) and 30 different prey species (Henschel et al., 2005) have been documented so far.

In the absence of large competitors like tigers, it may feed on larger prey (Stein, 2008) whereas it tends to select smaller prey when inhabiting areas with larger competitors (Karanth and Sunquist 1995, 2000). Leopards prefer to prey within this body mass range, which occur in small herds, in dense habitat and afford the hunter minimal risk of injury during capture. It primarily feeds on small to medium-sized ungulates, but has a varied diet including fish, reptiles, birds, pangolins, hyraxes, hares, snakes and small mammals like rodents (Hamilton, 1976; Stein and Hayssen, 2013). The leopard shows preference for large ungulates like sambar (Wang and Macdonald, 2009) to small rodents and even arthropods (Bailey, 1993). The leopard also prefers to hunt primates like langur- *Semnopithecus entellus* (Mukherjee and Mishra, 2001) more frequently than tigers (Karanth & Sunquist, 1995). Eliasson (2003) also found that leopards generally used to predate small and medium sized species in Nepal. The small and medium sized species like chital (Odden *et al.*, 2010) and muntjac (Wang and Macdonald, 2009), smaller domestic like dog- *Canis lupus familiaris* (Mukherjee and Mishra, 2001) and small wild animals are the main prey in all season whereas wild boar and birds are other important preys of Common leopard in the dry season (Eliassen, 2003). The leopard predates more on livestock, small mammals and birds in areas where both predators are present (Bhattarai & Kindlmann, 2012; Odden et al., 2010). Leopards also feed upon variety of small vertebrates and invertebrates in area of scarce resources where large prey species are absent (Hayward et al., 2006; Stuart and Stuart, 1993). Leopards have been recorded preying on species as small as birds and rodents (Ott, 2004) and hares (Mitchell, Shenton & Uys, 1965). During summer season and even more so major or preferred prey is not readily available, smaller mammals are considered as an important component of predator diets (Zhirjakov 1990). When major prey species is not readily available then in such situation, alternate prey in the form of smaller animals become very important component in common leopard's diet. Due to grouping behaviour of prey species as anti-predatory strategy and dry season, common leopard shifts dietary and predation strategy towards the smaller mammals and reduces predation on the other prey species (Achyut & Kreigenhofer 2009).

Støen and Wegge (1996) reported in BNP that in spite of the high prey biomass and diversity, leopards are displaced to the outside forests, suggesting that interspecific predation rather than food competition excluded coexistence with tigers. Interference competition is stronger between both sympatric carnivore when the abundance of prey species is low and the overlap in diets increases (Odden et al., 2010).

2.3 Status and distribution of wild prey species of big cats

2.3.1 Status of wild prey species

In Nepal, several researches have been conducted for estimating prey base abundance of tiger and leopard using line transect survey and diet analysis. The study conducted by Reynaert (2018) under different management regimes and areas including core area, buffer zone and corridor forest has compared the diet and prey preference of tiger and leopard. Some researchers have also estimated the abundance of prey species of big cats in Chitwan valley (Seidensticker, 1976; Tamang, 1982).

Wild prey species of tiger recorded using distance sampling based transect survey are four deer species (spotted deer, sambar, hog deer, barking deer), two antelope species (blue bull and four horned antelope), wild boar, gaur and two primate species (rhesus macaque and langur) (DNPWC, 2019). All wild prey species except blue bull, gaur and four horned antelope are found in Brandabhar corridor of Chitwan valley (DOF, 2016). Wild prey populations are also declining and restricted in small isolated populations in Nepal due to extreme human disturbances, poaching and habitat degradation. Wild prey species like spotted deer, barking deer blue bull, wild boar and rhesus monkey are listed as least concern (LC) whereas gaur, four horned antelope and sambar deer are listed as vulnerable species (V). However, prey like hog deer is listed as endangered species whereas langur is listed as near threatened (NT) (Admin et al., 2018; Jnawali et al., 2011; Thapa, 2014).

Several nationwide survey and researches have been conducted to estimate the prey density in tiger bearing protected areas of Nepal. The first, second and third nationwide assessments has been conducted on status of tiger and prey in 2009, 2013 and 2018

respectively. Those three nationwide tiger and prey survey has provided reliable estimates of prey density of tiger using distance sampling-based line transect survey in five tiger bearing protected areas and adjoining forest of Nepal. Research conducted by Giri and Karki has estimated 5.5 animals km^{-2}, 62.6 animals km^{-2}, 67.8 animals km^{-2} and 82.6 animals km^{-2} density of wild prey species in Parsa Wildlife Reserve (PWR), Chitwan National Park (CNP), Bardiya National Park (BNP) and Shuklaphanta Wildlife Reserve (SWR) respectively (Giri 2018; Karki et al., 2011). The second nationwide assessments on status of tiger and prey has estimated the highest prey density in BNP (92.6 animals km^{-2}) followed by SWR (78.62 animals km^{-2}), CNP (73.63 animals km^{-2}), PWR (25.33 animals km^{-2}) and BaNP (10.27 animals km^{-2}) respectively (DNPWC, 2013). The third 2018 nationwide tiger and prey status assessment conducted in five tiger bearing protected areas and adjoining forests has estimated wild prey density 22 (SE 3.8), 70.7 (SE 7.5), 8.1 (SE 1.6), 77.5 (SE 6.6) and 68 (SE 7) in PNP, CNP, BaNP, BNP, and ShNP, respectively (DNPWC, 2019). The recent survey conducted in 2013 and 2018 shows that wild prey density has been increased significantly in CNP as compared last estimates in 2009 A.D.

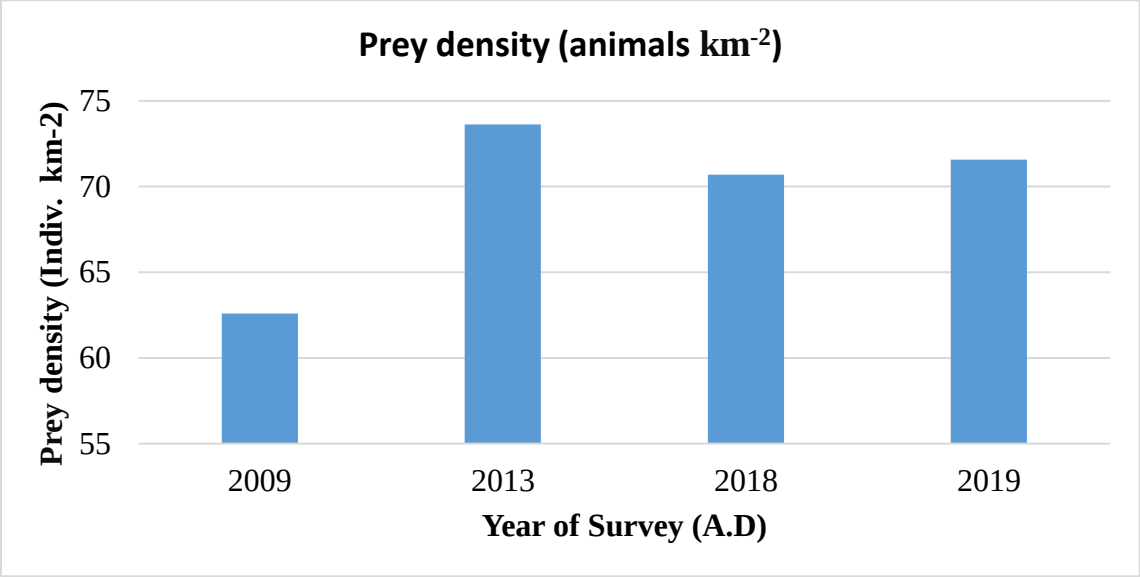


Figure 2. Prey density estimates in Chitwan National Park (DNPWC, 2009; 2013; 2018: 2019)

Out of total 73.63 animals/km2 prey density of small to large sized prey species in CNP, the previous survey conducted in 2013 estimates that spotted deer had the highest prey density (44.75) followed by wild boar (4.43), sambar (4.02), barking deer (3.65) and hog deer (3.28) (Dhakal et al., 2014; DNPWC, 2013). The prey density estimates of overall species were derived except two primates (Rhesus macaque and Langur). The combined density of wild prey (overall prey per km2) considering only CNP was the main limitation of previous survey. But the recent 2018 survey estimated the combined prey density 70.7 (SE 7.49) in CNP and adjoining forests (DNPWC, 2019). Out of this total combined prey density estimates, spotted deer had the highest prey density (43.85) followed by hog deer (13.4), sambar deer (9.96), barking deer (3.84) and wild boar (3.8). In comparison to 2013 survey, 2018 survey indicates that there is increase in prey density of endangered species like hog deer, vulnerable species like sambar deer and least concern species like barking deer in park and adjoining forests. But there is decrement in prey density of least concern species like spotted deer and wild boar in CNP and adjoining forest.

2.3.2 Distribution of wild prey species

CNP and adjoining forests have extensive riparian forests and tall floodplain grasslands regulated by annual floods where ungulates can reach their higher densities. The associations between the abundance of the prey of tiger with habitat, topographic, predator and human disturbance variables were also studied (Bhattrai and Kindlmann, 2013).

Density of tiger is believed to be primarily dependent upon the density of its prey population (Karanth and Nicholas, 2004). But human disturbances such as competition from domestic livestock for similar resource requirements, subsequent effects of overgrazing (Bhattarai and Kindlmann, 2011) and habitat degradation have led to the greatest threats in the abundance of wild ungulates in their natural habitats (Bhattrai and Kindlmann, 2013; Kittur et al., 2010). Drastic reduction in the cover of shrubs, which is mainly used as shelters (Patton, 1992) has resulted the deterioration of their forest habitat due to human activities. Such covers as shelter is significantly important for the survival

of small and declining populations (Caughley, 1994; Dinerstein, 1979; Karanth et al., 2004) such as sambar and gaur.

Chital, hog deer, barking deer, sambar deer, wild boar, rhino and wild elephant are the main ungulate species that are found in Brandabhar corridor forest of Chitwan valley (Bhattarai, 2003; DOF, 2016; Kandel, 2012). The abundance of hog deer is closely associated with areas of tall grassland and floodplains, while that of other ungulate species is associated with that of forests and short grasslands but primates are mainly abundant in riverine and mixed forests. However, abundances of most species, except hog deer and wild pig, were more closely associated with areas of forests than with open areas (Bhattarai and Kindlmann, 2013).

Spotted deer (chital) mostly prefer newly burned phatas as feeding habitats (Moe, 1993) and rest in forest habitats during the middle of the day (Naess and Anderson, 1993). It also prefers open grasslands during winter and more forested patches during summer when grass is scarce (Schaller, 1967). Overall in Nepal, chital was reported as the most important abundant prey having wide distribution and high density (Bhandari et al., 2017). Sambar deer is a generalist grazer and browser (Schaller, 1967) dependent on shrubs and water and distributed in wide variety of habitats due to its high adaptability. Their food consists of grass, leaves, and various kinds of wild fruit (Prater 1998). Hog deer has a much wider distribution than chital and covers the area throughout the alluvial grassland extending eastward to southern Nepal (Prater, 1998). It is also specialist prefers to inhabit in floodplains and tall grasslands (Dhungel and O'Gara, 1991). In Nepal, hog deer are mainly concentrated in favored habitats like tall grasses along the riverbanks and open phantas of Chitwan, Karnali-Bardia and Shukla Phantas (Mishra 1982). Likewise, both open areas and forests are preferred by gaur, wild pig and barking deer (Prater, 1980). Barking deer is the smallest deer of Brandabhar Corridor Forest which is most common in dense forest habitats and graze in open forest edges and is fairly diurnal (Prater,1998). Wild boar is distributed throughout the southern part of Nepal living in variety of habitats like wooded grassland, swampy areas, forests and dense bushes are preferred habitats, and they build shelters of grass, reeds or brush. The wild boars are omnivorous, eating crops, roots, tubers,

insects, snakes etc. (Prater, 1998). Gaur has wider distribution and spend most of the year in the less accessible Churia hills in south of CNP. However, they descend into grassland and riverine forests to graze and browse when bush fire ease off in spring time and lush grasses start growing up again (CNP, 2016).

2.4 Distance sampling

Distance sampling-based line transect survey is statistically valid, preferred and widely used method for estimating dispersed wildlife population abundance through visual detection of animals like deer and other prey species of big cats like tiger and sympatric carnivore like common leopard (Anderson et al., 1979; Burnham et al., 1980; Buckland et al., 1993; Lancia et al., 1994; Buckland et al., 2005). Now, it is becoming the standard monitoring tool of prey species in all tiger range countries of South Asia including Nepal (Karanth & Sunquist 1995, Varman & Sukumar, 1995, Khan et al., 1996, Biswas & Sankar, 2002, Sankar & Johnsingh, 2002, Bagchi et al., 2003, Jathanna et al., 2003, Karanth et al., 2004, Harihar et al., 2009. Paliwal, 2009; Malla, 2009; Wegge & Storaas 2009; Thapa, 2011; Karki, 2011). This method estimates the absolute density of prey population based on the observer to animal's distance (Buckland et al., 1993). It will be an efficient and frugal mehod furnishes rigorous estimates of abundance if all assumptions are strictly followed (Buckland et al., 2001; Nomani et al., 2008). The assumptions (Buckland et al., 2001; Williams et al., 2002) which are strictly pursued by this method are:

a. Transect lines are randomly positioned with respect to the distribution of objects (or objects are randomly distributed in space.
b. Objects are directly detected on the transect lines with certainty.
c. Objects are detected at their initial locations and the location of objects are not influenced by the observer's presence or observation process.
d. Detection of individuals are independent events and
e. Measurements are exact.

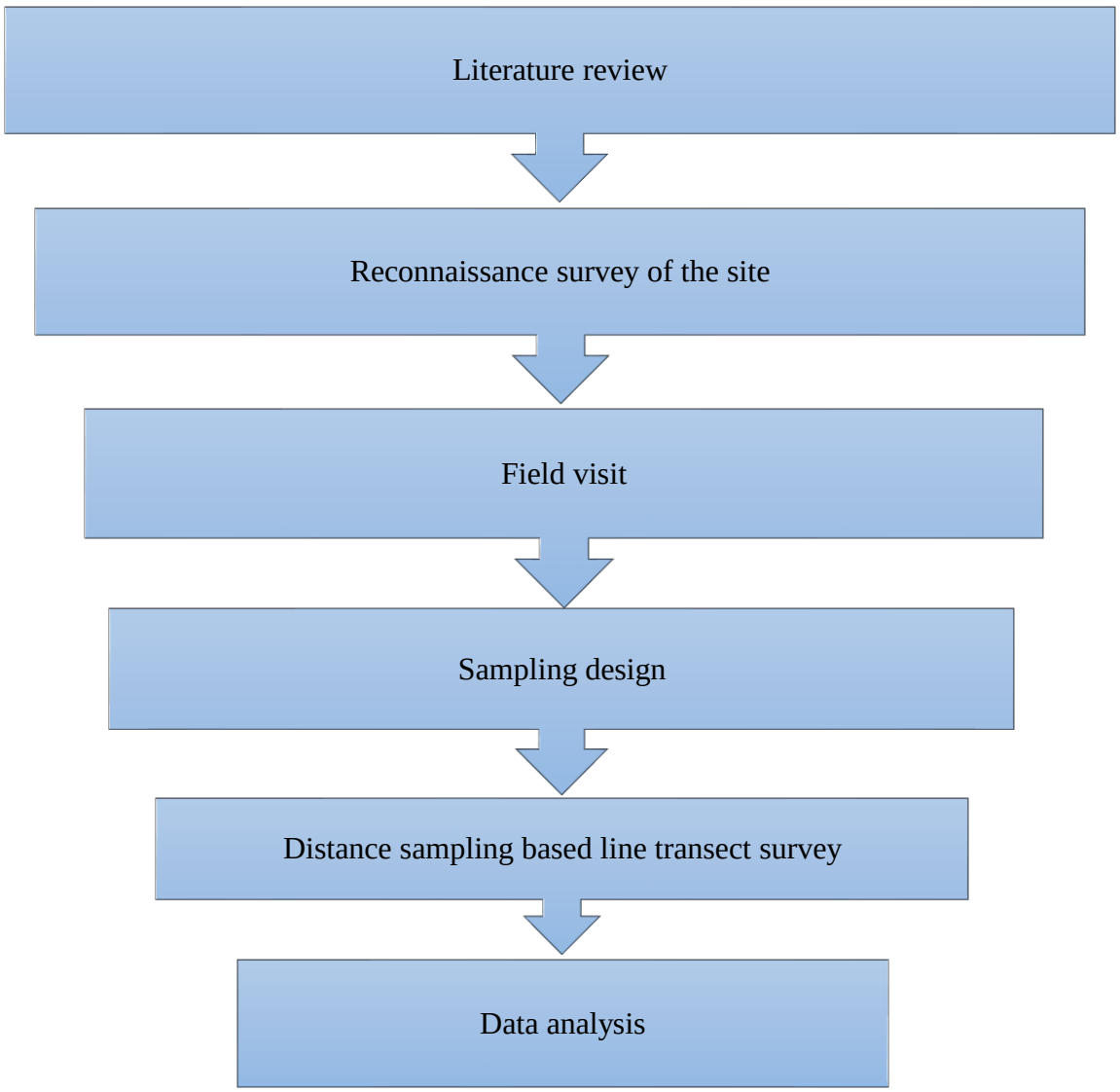
Therefore, if above given assumptions are exactly met then it provides unbiased estimates of abundance. However, knowledge on the total length, layout and the number of transects influence accuracy and precision of estimates of densities as well as spatial distribution pattern and density of objects as an influencing factor (Nomani et al., 2008). The method involves observers moving along straight trails called 'transects' and counting animals seen on either side. It is useful in flat and open areas but violates many assumptions of undulating terrain however the very steep terrain in Churia requires the transect length to be no more than 1 km to maintain a straight line. In this case, the transect length needs to be shortened relative to the others (2 km) due to an expected lower prey encounter rate. The following information recorded on line transect data sheet are as given below:

i. Date, survey location, observer's name, transect by walk/elephant, transect number and weather.
ii. Time (start and end time of transect survey, prey sighting time of each individual).
iii. GPS locations (start and end of transect as well as individuals prey sighting on each transect).
iv. Species identity and the total number of individuals of each species sighted from direct observation (chital, sambar, barking deer, wild boar and primates).
v. Group size (cluster size of each detection from line transect).
vi. Age and sex compositions (age: adult, sub-adult, yearling, young; and sex: male, female and unidentified).
vii. Radial distance i.e. distance to the centre of the group or single individual from line transect using digital range finder.
viii. Sighting angle i.e. radial angle to the centre of the group or single individual from line transect using Silva compass.
ix. Line transect bearing i.e. bearing which is laid down using Silva compass.

CHAPTER -III

3. MATERIALS AND METHODS

3.1 Conceptual Framework



3.2 Study Area

The study was conducted in the forests of the northern Chitwan valley (27°35'1.40" to 27°40'41.35"N latitude, and 83°51'27.97"E to 84°30'20.42"E longitude) in Brandabhar corridor and non-protected forests outside of the Chitwan National Park (CNP). Dispersing tigers and leopards from CNP come to these forests and some of them settle their territory. These forests play a crucial role by providing refuge habitats for dispersing tigers and also act as a wildlife corridor for carnivores (tiger and leopard) and alternative/seasonal as well as temporal habitats for others wild animals (Litvaitis et al., 1996). The Brandabhar forest covers an area of 87.9 km^2 and bisects the Chitwan District in east and west Chitwan (Lamichhane et al., 2018). The corridor, a 29 km long forest patch is bisected by a busy National Mahendra highway nearly at the middle, resulting in the southern part comprising a 56.9 km^2 area managed under the buffer zone of RCNP and the northern part comprising 31 km^2 is managed under Divisional forest office, and recently declared as protected forests. However, the study was carried out in area 111.79 km^2.

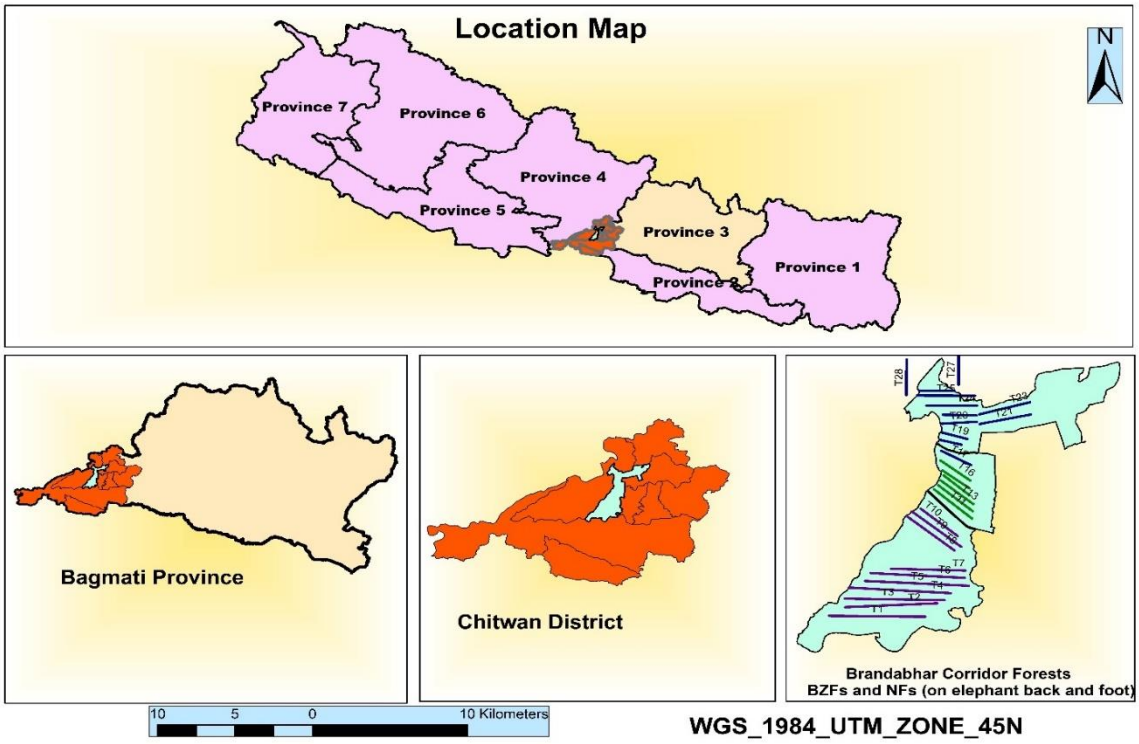


Figure 3. Location Map showing study area

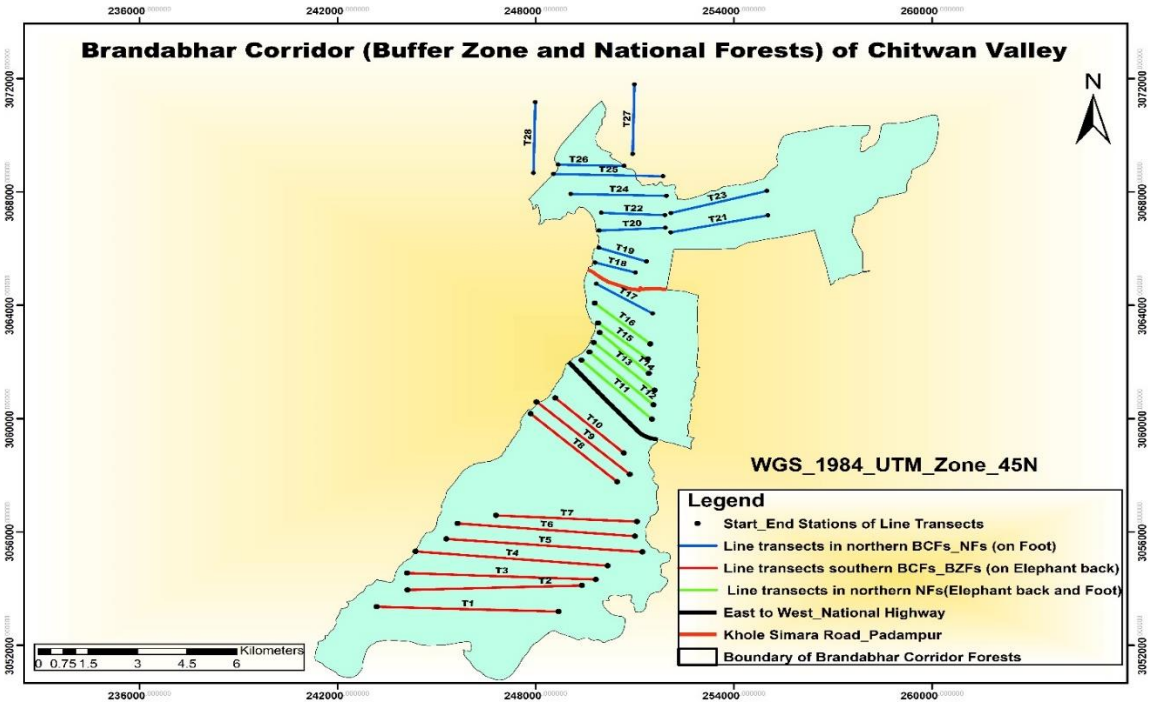


Figure 4. Map indicating Line transects in Brandabhar Corridor (BZFs and NFs)

The Brandabhar Protected Forest is a biological corridor between Tarai Arc Landscape (TAL) and Chitwan Annapurna Landscape (CHAL) connecting Chitwan National Park and Mahabharat foothills in Nepal's Inner Tarai. The corridor serves as a highly potential alternative habitat to enable wildlife to move up to Mahabharat foothills mainly during the rainy season (Kandel, 2012). The buffer zone on the north side lies adjacent to Brandabhar Corridor Forest, dominated by Sal forest, grassland and a few large water bodies. The Buffer zone of BCF holds 48.016 km^2 forest, 5.018 km^2 grassland, 3.276 km^2 shrub lands and 0.5 km^2 of water bodies collectively called Bishazari Lake (Bhattarai, 2003). The forest has range of climate season- winter, spring and monsoon with subtropical climate. The monsoon begins at the end of May and continues until September and the mean annual rainfall was 192 mm and highest in July (604.8 mm), lowest in January (0.9 mm) and no rainfall in December.

The flora of Brandabhar forest is dominated mainly by Sal forest and partly by riverine, tall grassland and short grassland. The percentage of vegetation of Chitwan Valley consists

of (70%) Sal forest (a moist deciduous type), grassland (20%), Riverine forest (7%) and Sal with chir pine (3%).

Table 1. Types of vegetation/habitats available in the Brandabhar Corridor Forests.

S. N	Types of Vegetation/habitat	Descriptions
1.	Sal Forest	Sal (*Shorea robusta*) is dominated species in Sal forest and the associated species with sal are *Semecarpus anacardium*, *Terminalia bellirica* and *Terminalia tomentosa*. A large number of other trees, shrubs, creepers, ferns, flowers and grasses grow among or under the Sal.
2.	Riverine Forest	Higher canopy species Simal (*Bombax ceiba*), sissoo (*Dalbergia sissoo*), and Bhellar (*Trewia nudiflora*) and in the lower canopy *Clerodendrum viscosum* and *Zizyphus mauritiana* are common species in riverine forest. These species grow along watercourses. The composition of these vegetation varies greatly from place to place in riverine forests.
3.	Tall Grassland	Tall grassland is dominated by Kans (*Saccharum spontaneum*), and distributed along the Rapti and Budhi Rapti riverside. The alluvial flood plains support a luxuriant growth of grasses interspersed with patches of riverine forest. These tall and dense stands of grasses are popularly called 'elephant grass'.
4.	Short Grassland	Brandabhar forest is very important for short grassland, which is mainly dominated by Siru (*Imperata sps*.).

Brandabhar corridor dominated by Sal forest comprised of 22 species of mammals including tiger, leopard, rhinoceros, Asian elephant, sloth bear, wild boar, sambar deer, spotted deer, hog deer, barking deer and 280 species of birds including giant hornbill, hill myna, and storks. It is also considered as a critical habitat for many species of migratory birds (e.g., Siberian crane), aquatic birds, and mugger crocodile. More than 45 species of herpeto-fauna represented by frog, toad, lizards, python and crocodile are found in Brandabhar Corridor Forest (Resource Himalaya, 2000 and KMTNC, 2002).

The Brandabhar forest in the north of CNP is a well-known corridor with possible linkages of CNP to the Mahabharat mountain habitats (up to Annapurna) in the North (MOFSC 2015) and is partly protected as a Ramsar site due to the presence of 328 bird species that live in proximity of the large water bodies (Lamichhanne et al., 2018). Usage of underpasses by wildlife has been documented in Brandabhar corridor. Frequent use of the corridors by tigers and leopards has also been documented. The presence of tigers in Brandabhar corridor forests suggests that the forests outside protected areas play a vital role in managing tigers as meta-population in TAL. Therefore, a landscape approach is critical to the long-term conservation of tiger populations. Forest connectivity of these forests continues through Churia hill forests up to Bardiya in 350 km west. The recent survey shows that 3 to 4 tigers and more leopards in the Churia hill forests detected tigers 100 km west of CNP, dispersed through these forests.

In both Brandabhar corridor and non-protected forests of Chitwan valley, regulated human use is allowed. The corridor forest is surrounded by villages on all sides, except for two small sections in the North and South. Sustainable grazing practice as well as fodder collection are allowed (Gurung et. al., 2009). A large part of these forests has been handed over to the communities for management (the community forests). The communities are responsible for the management and sustainable utilization of the forest resources. The members of the community forests (CF) frequently use these forests for fodder, grazing, collection of edible vegetables, NTFPs and sometimes for fuel wood/timber. Such activities increase the chances of interaction between humans and tigers/leopards in these forests. Such high degree of human disturbances leads to challenges for conservationist for

managing habitats of dispersing tiger and leopards from park in the corridors and non-protected forests. Therefore, managing existing habitats for wild preys in these forests by minimizing human disturbances will be helpful for conserving and increasing population of big cats in Nepal.

3.3 Methods

3.3.1 Sampling Design

A total of 28 line transects were randomly placed in all possible directions with help of ArcGIS 10.3 covering all available habitat types in the intensive study area (Brandabhar corridor and non-protected forests of Chitwan valley). Line transects of varying length ranging from 1.27-5.96 km were laid and traversed on elephant back and foot method of survey with in an interval 300 m except in undulating and hilly terrain so as to adhere to the straight-line assumption of distance sampling (DNPWC, 2017).

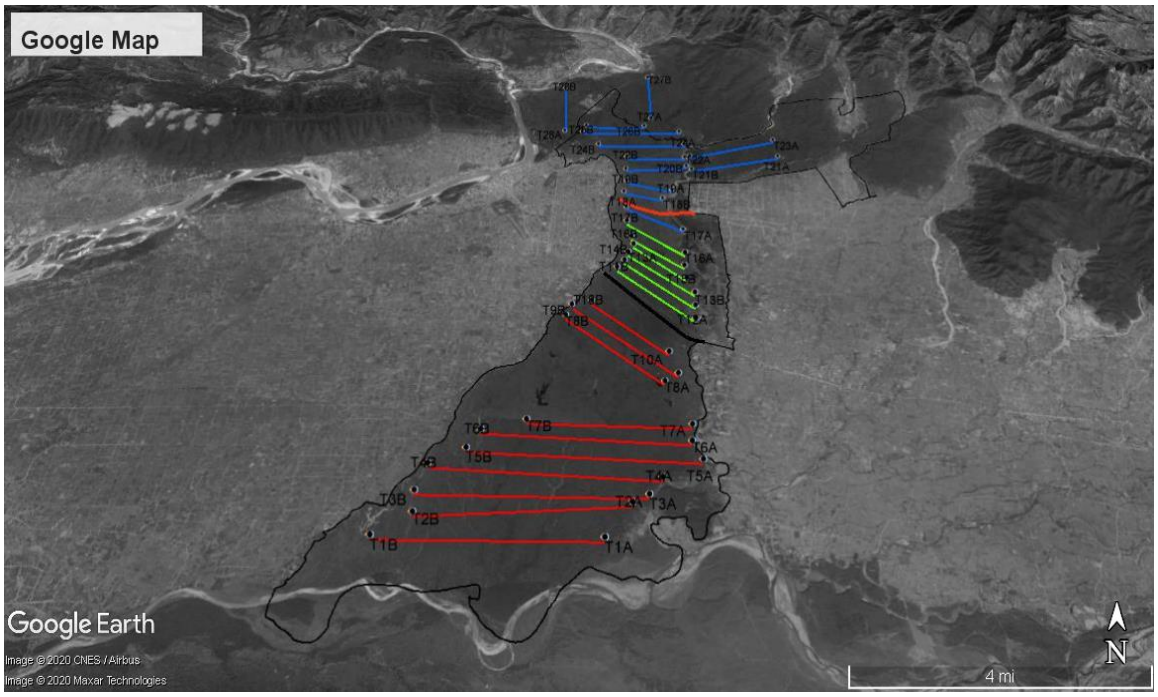


Figure 5. Line transects laid in Google Map showing Brandabhar corridor of Chitwan valley.

3.3.2 Field Methods (Data Collection)

3.3.2.1 Distance Sampling Based Line Transect Survey

Prey species of big cats were assessed using distance sampling-based line transect survey (Buckland et al. 2001)**.** Each transect was surveyed only once by two people during early morning (07:00-10:00 hrs.) or late afternoon (15:00-18:00 hrs.) when wild prey species were active.

The traversing of the transect line was done on foot or on elephant back (Wegge and Storaas 2009). Two methods of survey (Elephant back and Foot) were carried out in the Buffer zone forests and National forests of Brandabhar corridors. Out of 28 line transects, 16 line transects were traversed on elephant back in inaccessible and unsecured areas of corridor forests (buffer zone and transects laid in national forests) below Kholesimara road of Padampur. Within elephant back method of survey, line transect survey was carried out in two sites (buffer zone forests and national forests). Three to four observers along with trained wildlife technicians of NTNC-BCC in a group were used to sample line transects on elephant back which was conducted from March 15, 2020 to March 21, 2020. 18 line transects laid in whole northern national forests were also traversed on foot with assistance of two groups. However, foot/transect walk method of survey covered transects inaccessible for elephant walk which was carried out from May 24, 2020 to June 6, 2020.

At least 100 km transect survey efforts were carried out representing different habitat types and vegetations. The method involved observers moving along transects, counting animals seen on either side. When animals sighted, records of species, group or clusters size/composition, bearing, sighting distance and GPS coordinates was noted on the data sheet. Range finder and Silva compass were used to measure the sighting distance and bearing. GPS was used to measure the location of start and end points of each transects as well as location of individuals sighted on each transect.

The habitat types and habitat characteristics used by different prey species were recorded and GPS coordinates was noted during the transect survey.

3.3.2.2 Field Equipment used in the survey

S. N	Equipment	Purpose
i.	Global Positioning System (GPS): Etrex Garmin	To record start and end GPS Coordinates as well as location of prey sighting.
ii.	Digital Range Finder	To record radial distance to centre of group or single prey from transect line.
iii.	Silva Compass	To record radial angle to centre of group or single prey from transect line.
iv.	Binoculars (Olympus 10*50 DPS I)	To observe or sight prey as well as record species, cluster size, sex, age etc.
v.	Camera (Nikon DSLR)	To capture the photo of prey and their predators.
vi.	Data Sheet (Line Transect Survey)	To collect data measured from above equipment during survey.

Table 2. Equipment used in the field survey

3.3.3 Data Analysis

After the field work, collected data was entered into excel spreadsheet and exported as tab-delimited text file. The line transect data was imported and analyzed using DISTANCE 6.0 Program (Thomas et.al. 2009) to estimate prey species density, abundances, mean group size and encounter rate. This software modeled a detection function by species, representing the probability of detecting an individual (or group) as a function of distance to transect line. It allowed correcting the number of detected animals for those that are missed and provides absolute density estimate. In this study likelihood measure, minimum Akaike Information Criterion (AIC) values, Chi- square goodness-of-fit tests generated by DISTANCE, model robustness, relative estimate precision and detection function shape etc. were used to select the model for generating density estimates after correcting evidence of evasive movement before detection, 'rounding' and 'heaping' of data. Parameters such as animal density, cluster density, mean cluster size, abundance, encounter rate, confidence intervals etc. were estimated. The density estimates and abundance of the overall prey species encountered on transects will be calculated by Effective Strip width (ESW). For the species wise density, number of detections or observation will be the main criteria for estimation.

The mean biomass of wild prey (Kg/km^2) in the study area was also estimated by multiplying mean ecological density by its average unit live weight. (Tamang, 1982; Wegge et. al., 2009). The unit weight was taken from the published data on live body weights (Wegge and storass, 2009).

Formula for calculation of Biomass of wild prey species:

Mean Biomass= D* average unit live weight

Where, D=mean ecological density

CHAPTER - IV

4. RESULT AND DISCUSSION

4.1 Result

4.1.1 Sampling efforts:

A total of 144 number of detections of six species of wild prey were recorded in total sampling efforts of 105.4 km. The survey was carried out in two management regimes (Buffer zone and National forests of Brandabhar Corridors forests) surveyed using two methods of survey (on elephant back and foot).

Management regimes	Methods of Survey	Survey efforts	No. of transects	No. of observations
Southern BCFs (Buffer zone Forests)	Elephant back	48.3 Km	10	75
Northern BCFs (National Forests)	Elephant back	14.5 Km	6	37
Whole Northern National Forests	Transect walk/Foot	42.6 Km	18	32
Buffer zone and National Forests	Elephant back	62.8 km	16	112

Table 3. Sampling efforts in management sites using two method of survey

4.1.2 Prey Species Encountered:

A total of 1047 individuals in 144 observations of six different species of wild prey (spotted deer, sambar deer, barking deer, wild boar, rhesus and langur) were encountered during the line transect survey in Brandabhar corridor of Chitwan valley, of which species wise

density estimate was possible only for chital due to sample size constraints (the minimum of 30 detections). One male hog deer was detected outside line transects (in grasslands).

S. N	Species (Common name)	Scientific name	No. of detections	Total Number of animals detected
1.	Spotted deer (Chital)	*Axis axis*	80	838
2.	Sambar deer (Jarayo)	*Rusa unicolor*	24	38
3.	Barking deer (Ratuwa)	*Muntiacus muntjak*	17	20
4.	Wild boar	*Sus scrofa*	17	46
5.	Rhesus macaque	*Macaca mulatta*	5	103
6.	Langur	*Semnopithecus entellus*	1	2
	Total		**144**	**1,047**

Table 4. Species summary detections from all transects in BCFs

4.1.3 Detected number of animals with in and out of transect: It does not represent total population of wild prey in whole study area.

i. According to management regimes:

Management regimes	No of observed animals
Southern BCF-Buffer zone Forests (on elephant back)	508
Northern BCF- National Forests (on elephant back)	320
Whole Northern National Forests of BCF (on foot)	219
Study area (out of transect)	173
Total	**1220**

Table 5. Number of detected animals based on management regimes

Southern BCFs i.e. Buffer zone forests (elephant back) was found to have high number of observed animals (sample abundance) followed by northern BCFs (national forests) and whole northern national forests of BCFs. Study area (outside of transects) has minimum number of observations of prey.

ii. According to species wise:

Species	No of observed animals	M	F	U	Y
Barking deer	20	9	6	5	0
Spotted deer*	838+154*	160+33*	476+49*	50+30*	152+42*
Sambar deer	38	15	16	2	5
Wild Boar*	46+2*	3	5	17+2*	21
Hog deer*	1*	0	1*	0	0
Rhesus*	103+16*	0	0	103+16*	0
Langur	2	0	0	2	0
Total	**1047+173***	**183+33***	**503+50***	**179+48***	**178+42***

Table 6. Number of observed animals based on species wise

- *Prey species observed out of line transects*

Spotted deer was highly detected prey (greater number) followed by rhesus, wild boar, sambar and barking deer. Langur and hog deer were less detected prey in whole study area. It did not represent the total population of each prey species.

4.1.4 Prey density:

The numbers of detections/observations were generally very low (spotted deer 80, barking deer 17, sambar deer 24, wild boar 17, rhesus monkey 5 and langur 1) in whole study area. Prey species must meet the recommended minimum of 30 detections to confirm the underlying assumptions of model fitting to estimate density and abundances (Burnham et al., 1980; Buckland et al., 1993).

Overall prey species density was estimated for the sites traversed with two survey methods due to fulfillment of minimum detections 30. Detection of all species except spotted deer (n=71 out of total 80 chital detections) on elephant back method was well below the minimum of 30 observations. Therefore, species specific density estimates were only possible for spotted deer detected on elephant back and models were fitted to estimate prey density. Based on comparison of AIC values and Chi- square goodness-of-fit tests generated by DISTANCE, key functions were fitted overall prey data to select the model after correcting evidence of evasive movement before detection, 'rounding' and 'heaping' of data and detection probability curve of individual animals or clusters were derived to describe the results correctly.

i. **Overall prey species density detected in combined BZFs and NFs regimes using elephant back method:** Based on comparison of AIC values, half normal-cosine key function fitted overall prey data.

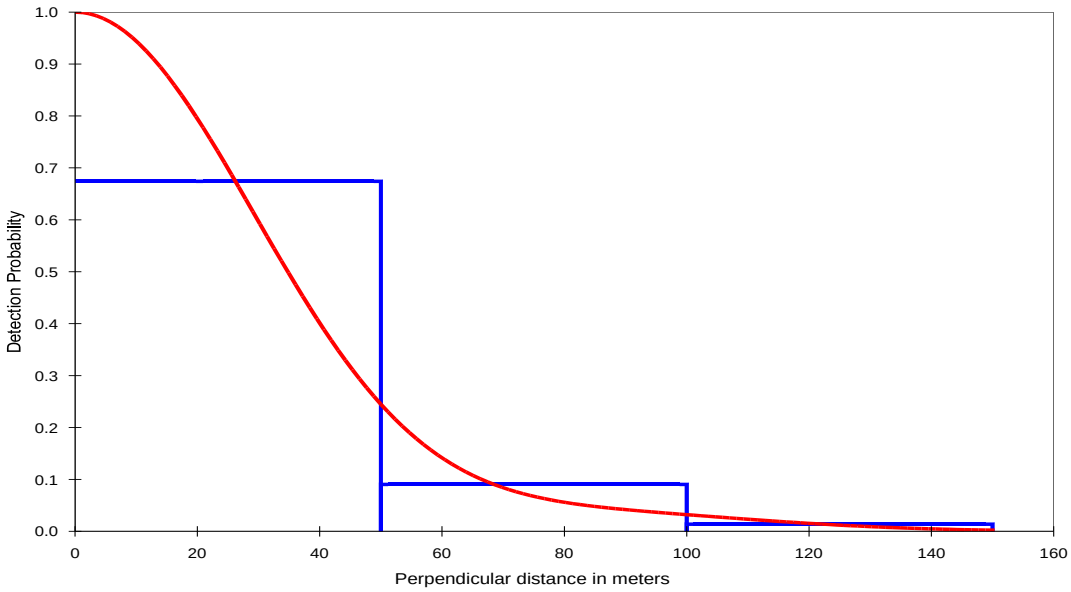


Figure 6. Detection probability Curve (Half-Normal Key-Cosine) of overall prey species in combined BZFs and NFs using elephant back method.

The density of clusters (Ds) and density (D) of all prey species combined were estimated to be 22.91 clusters of animals km^{-2} and 169.39 animals km^{-2} respectively. The mean size of clusters E(S) in the population was 7.39 animals per group.

Point Parameter	Standard Estimate	Standard Error	Percent Coef. Of variation	95% Percent Confidence Interval
D(S)	22.913	3.4639	15.12	16.883-31.189
E(S)	7.39	0.88043	11.91	5.8437-9.3528
D	169.39	32.6	19.24	115.74-247.91

Table 7. Summary of density estimates of overall prey species detected in combined BZFs and using elephant back method.

ii. **Overall prey species density in Buffer zone forests Southern BCFs using elephant back method:** Based on comparison of AIC values, hazard rate cosine key function was fitted overall prey data.

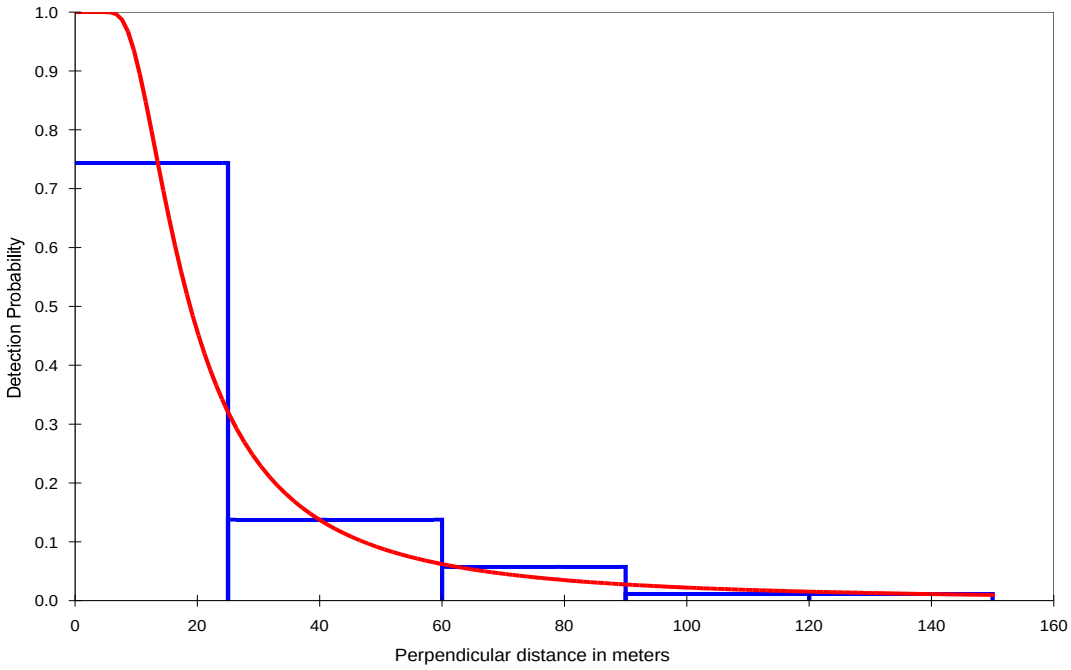


Figure 7. Detection probability Curve (Hazard Rate Key-Cosine) of overall prey species in Buffer zone forests of Southern BCFs using elephant back method.

The density of clusters (Ds) and density (D) of all prey species were estimated to be 30.07 cluster of animals km^{-2} and 184.10 animals km^{-2} respectively. The mean size of clusters E(S) in the population was 6.12 animals per group.

Point Parameter	Standard Estimate	Standard Error	Percent Coef. Of variation	95% Percent Confidence Interval
D(S)	30.067	10.413	34.63	15.386-58.754
E(S)	6.1231	1.04	16.99	4.3752-8.5693
D	184.1	71.013	38.57	88.034-385.01

Table 8. Summary of density estimates of overall prey species in Buffer zone forests of Southern BCFs using elephant back method.

iii. **Overall prey species density in National forests of Northern BCFs using elephant back method:** Based on comparison of AIC values, half normal-cosine key function was fitted overall prey data.

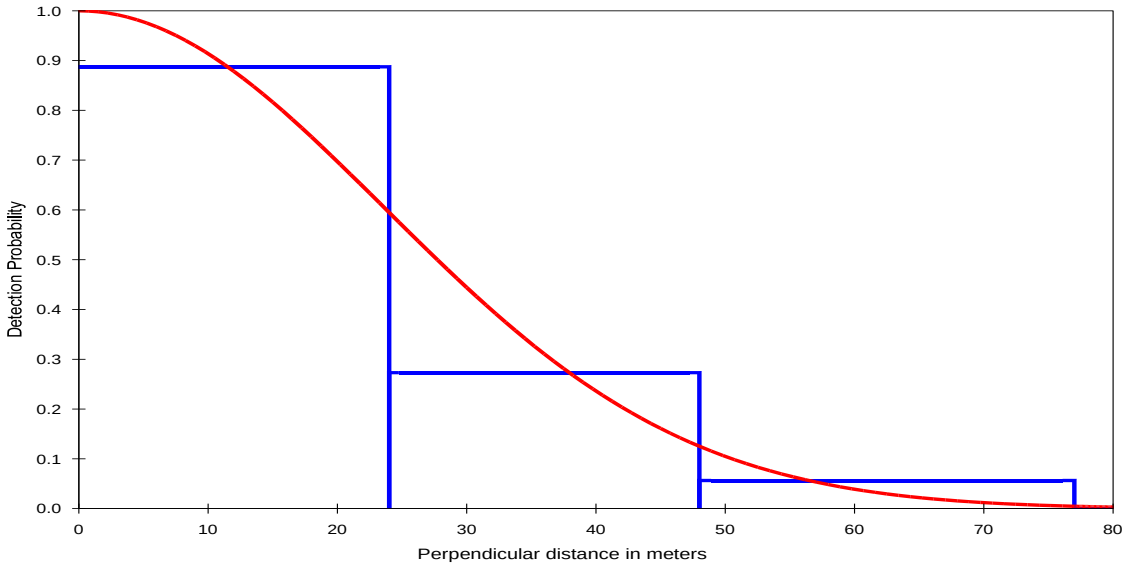


Figure 8. Detection probability Curve (Half-Normal Key-Cosine) of overall prey species in National forests of Northern BCFs using elephant back method.

The density of clusters (Ds) and density (D) of all prey species were estimated to be 42.09 cluster of animals km^{-2} and 333.23 animals km^{-2} respectively. The mean size of clusters E(S) in the population was 7.92 animals per group.

Point Parameter	Standard Estimate	Standard Error	Percent Coef. Of variation	95% Percent Confidence Interval
D(S)	42.093	11.803	28.04	22.357-79.249
E(S)	7.9167	1.6156	20.41	5.2535-11.930
D	333.23	115.57	34.68	164.09-676.74

Table 9. Summary of density estimates of overall prey species in National forests of Northern BCFs using elephant back method.

iv. **Overall prey species density in whole Northern National Forests of BCF using foot method:** Based on comparison of AIC values, half normal-cosine key function was fitted overall prey data.

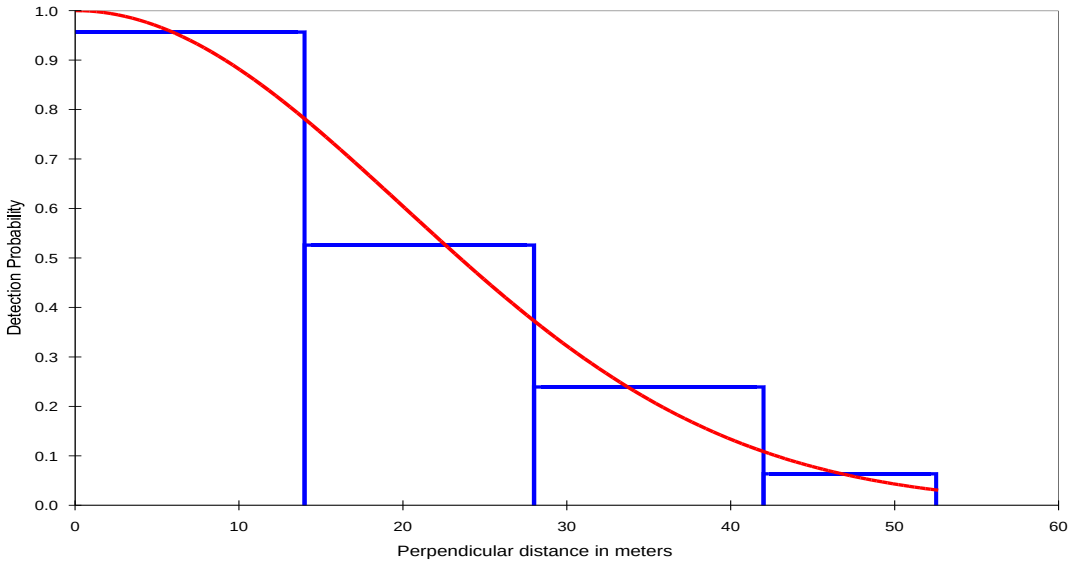


Figure 9. Detection probability Curve (Half-Normal Key-Cosine) of overall prey species in Whole Northern National forests of BCFs using foot method

The density of clusters (Ds) and density (D) of all prey species were estimated to be 17.53 clusters of animals km^{-2} and 90.51 animals km^{-2} respectively. The mean size of clusters E(S) in the population was 5.16 animals per group.

Point Parameter	Standard Estimate	Standard Error	Percent Coef. Of variation	95% Percent Confidence Interval
D(S)	17.529	4.158	23.72	10.889-28.218
E(S)	5.1631	1.5714	30.44	2.8144-9.4819
D	90.505	34.923	38.59	42.933-190.79

Table 10. Summary of density estimates of overall prey species in whole Northern National forests of BCFs using foot method.

v. **Spotted deer density detected in combined BZFs and NFs using elephant back method:** Based on comparison of AIC values, half normal-cosine key function fitted spotted deer data.

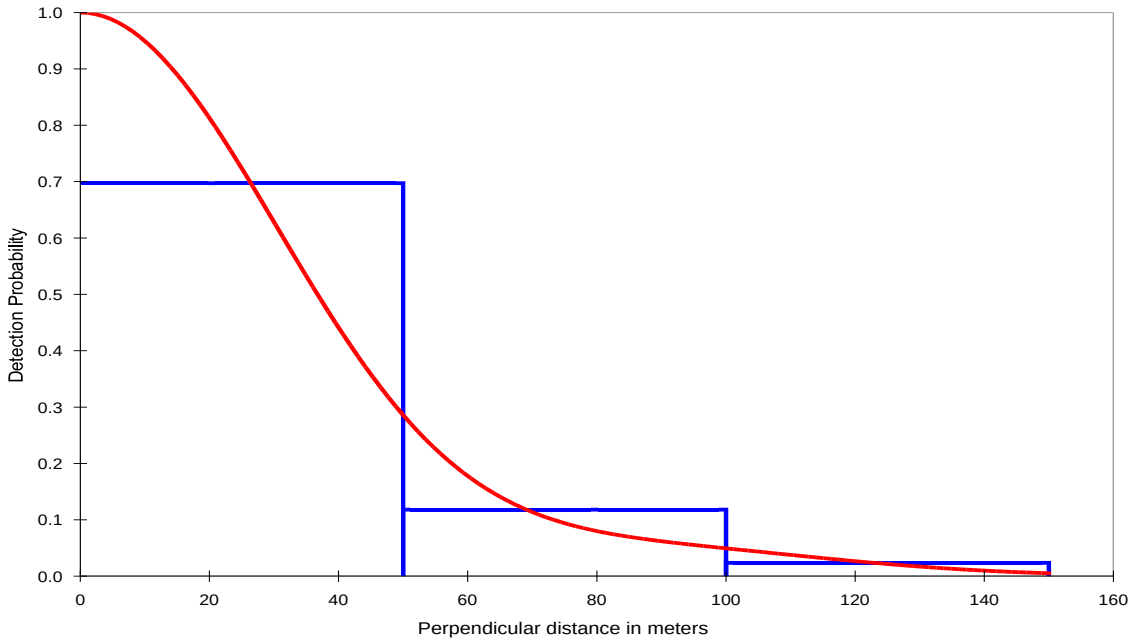


Figure 10. Detection probability Curve (Half-Normal Key-Cosine) of spotted deer detected in combined BZFs and NFs using elephant back method.

The density of clusters (Ds) and density (D) of all prey species were estimated to be 13.47 cluster of animals km^{-2} and 144.04 animals km^{-2} respectively. The mean size of clusters E(S) in the population was 10.69 animals per group.

Point Parameter	Standard Estimate	Standard Error	Percent Coef. Of variation	95% Percent Confidence Interval
D(S)	13.474	2.4305	18.04	9.3612-19.395
E(S)	10.690	1.2257	11.47	8.5112-13.427
D	144.040	30.788	21.37	94.377-219.85

Table 11. Summary of density estimates of spotted deer in combined BZFs and NFs using elephant back method.

4.1.5 Prey biomass density:

Due to high number of observations of spotted deer in comparison to other prey species detected on elephant back method survey, spotted deer density was estimated to 144.04 individuals km^{-2}. However, the survey conducted on foot and elephant back recorded low detection of all species except spotted deer and did not confirm underlying assumptions (minimum of 30 observations) for the model fitting Therefore, specific species wise density estimates were not possible for other species due to limit number of detections.

The live weight of spotted deer was taken as 53 kg (Wegge and Storass, 2009). When the density estimate of each prey species was multiplied by its live weight, a biomass density would be estimated. The study area survey on elephant back method of survey harbored biomass of spotted deer to be 7634.12 Kg km^{-2}.

4.1.6 Abundance of prey species:

a. **Based on the estimated wild prey density**: It represents the total abundance of wild prey in whole study area.

Management regimes	Method of survey	Species	Prey density (animals km^{-2})	Abundances
Southern BCF (BZFs)	Elephant back	Overall prey	184.1	10886
Northern BCFs (Sample NFs)	Elephant back	Overall prey	333.23	5385
BZFs and Sample NFs	Elephant back	Spotted deer	144.04	10845
	Elephant back	Overall prey	169.39	12753
Whole Northern NFs	Foot	Overall prey	90.51	4766

Table 12. Abundance of Prey species estimated from prey density

On the basis of prey density (animals km^{-2}) and abundance calculated from DISTANCE 6.0, survey conducted on elephant back method estimated the higher abundance than survey conducted on foot. Though the prey density in southern BCFs (BZFs) was lower than the density in 16.16 km^2 northern BCFs (Sample NFs), buffer zone forests estimated the higher abundances than sample northern NFs. The estimated abundance of spotted deer

detected in combined BZFs and sample NFs using elephant back method was 10,845 number of individuals.

b. Predicting abundance of prey based on sampling efficiency (through detections rate) on elephant back method of survey (BZFs and NFs):

Management Sites	Transects	Detection rate (detections/km)					
		Length	Overall species	Spotted deer	Sambar deer	Barking deer	Wild boar
Southern BCF (Buffer zone forests)	T1	5.51	0.907	0.544	0.363	0.000	0.000
	T2	5.28	1.893	1.325	0.000	0.379	0.189
	T3	5.72	1.399	0.875	0.175	0.350	0.000
	T4	5.78	2.421	2.075	0.000	0.173	0.173
	T5	5.96	2.518	1.343	0.672	0.168	0.336
	T6	5.37	1.862	0.931	0.372	0.000	0.559
	T7	4.27	0.702	0.234	0.000	0.234	0.234
	T8	3.56	0.562	0.281	0.281	0.000	0.000
	T9	3.81	1.313	1.313	0.000	0.000	0.000
	T10	2.87	1.045	1.045	0.000	0.000	0.000
Northern BCF (National forests)	T11	2.98	4.364	2.350	1.007	0.336	0.671
	T12	2.77	2.887	1.083	1.443	0.000	0.361
	T13	2.44	1.229	1.229	0.000	0.000	0.000
	T14	2.13	1.412	0.941	0.000	0.000	0.471
	T15	1.97	1.015	0.000	1.015	0.000	0.000
	T16	2.18	3.663	2.747	0.458	0.000	0.458

Table 13. Summary of detection rate of overall species detected on elephant back method survey.

The average detection rate (overall species) estimates in southern BCF (Buffer zone forests) and Northern BCF (National forests) were 1.462 and 2.428 detections per km respectively. Though using same method of survey (elephant back) and higher number of detections (n=75) as compared to Northern National forests, average detection rate was less in southern BCF (Buffer zone forests). It means sampling efficiency was high in Northern BCF (National forests). It was mainly due to variation in number of transects and length of line transects resulting greater difference in survey efforts. The number of transects, length of transects and survey efforts were lesser in northern BCFs i.e. national

forests (k=6; length 1.97-2.98 km; L=14.5 km) as compared to southern BCF i.e. buffer zone forests (k=10; length 2.87-5.96 km; L= 48.3 km).

4.1.7 Habitats inhabited by wild prey species based on observation.

Line transects were designed to cover all habitat types but most of line transects were located in sal dominated forests of BCFs. Most preferred habitat of prey i.e. short grasslands were generally situated outside the line transects near river banks and village area. Observations of animals outside the line transects were recorded to assess habitats inhabited by wild prey species.

Species	No. of observed animals	S/F	M/F	R/F	W	S/G
Barking deer	20	19	1	0	0	0
Spotted deer*	838+154*	804+2*	0	34	0	152*
Sambar deer	38	37	0	0	1	0
Wild Boar*	46+2*	46+1*	0	0	0	1*
Hog deer*	1*	0	0	0	0	1*
Rhesus*	103+16*	71	32	16*	0	0
Langur	2	2	0	0	0	0
Total	**1047+173***	**979+3***	**33**	**34+16***	**1**	**154***

Table 14. Summary of number of observed species in different habitats

- represents species found outside line transects

Habitats inhabited by wild prey species were determined on the basis of observation within the study area. Spotted deer were mostly observed in Sal forest followed by short grassland and riverine forests. Similarly, sambar deer were also observed in Sal forest but very numerous near wetlands. Barking deer were highly observed in Sal forest and very numerous in mixed forest whereas wild boar was also observed in Sal forest and very numerous in grasslands. Only one male hog deer was sighted in grasslands outside line transects. Rhesus monkeys were highly observed in Sal forest followed by mixed forest, riverine forests and near wetlands. Langurs were found to be mostly inhabited in Sal forest and mixed forest.

4.2 Discussion:

Distance sampling based on line transect sampling is scientifically coherent, logical and widely method for estimating density, abundances and biomass of wild prey species. The density of all prey species detected on elephant back (Southern BCF-Buffer zone and Northern BCF- sample area of National forests) and on foot (Whole National forests) as well as spotted deer (elephant back) have been estimated using line transect sampling in Brandabhar Corridors forests. Therefore, the information on the density, abundance and biomass of prey species are essential for management of wild prey species as diet for dispersing big cats (tiger and common leopard) from core area of park to adjoining corridor like Brandabhar corridor forests (BCF). It will also help to understand predator ecology. Knowledge on habitats types inhabited by prey species on the basis of observation somehow helps to predict ecology of wild prey species in Corridor forests.

However low or inadequate detection of prey species except chital was general limitation of this study. Number of line transects were not distributed equally and spatially coverage was not similar in two method of survey (k=16 on elephant back and k=18 on foot/transect walk method. Within elephant back method of survey, number of lines transects was distributed in buffer zone (K=10) and national forests (k=6) to compare density in forests under different protection management strategies (Buffer zone community forests under park and community forests under Divisional Forest Office). Conducting survey in different months (elephant back method of survey on month of March and foot/transect walk method of survey on month of May and June) was temporal limitation in this study.

All wild prey species was inadequately detected during this survey due to inadequate temporal replication and detection of some prey living in large herds such as spotted deer and wild boar. Prey were less detected on foot method as compared to elephant back method of survey. It was mainly due to high detectability of individual animal or cluster of animals to a greater distance while surveying on elephant back. Noise pollution created by high traffic on national highway bisecting corridor, collection of fuel and fodder, collection of edible vegetable by village people, fishing in the river and wetlands, collection of sand and gravel from river near forests etc. were mid-level of disturbances. Movement of large

herds of spotted deer in the grasslands outside the line transects during early morning or late evening survey may be possible reasons of less detection of prey on transect walk/foot.

Management regimes	**Southern BCF (BZFs)**	**Northern BCF (Sample NFs)**	**BZFs and Sample NFs**		**Whole Northern NFs**
Method of survey	Elephant back	Elephant back	Elephant back	Elephant back	Foot
Surveyed area (km^2)	59.13	16.16	75.29	75.29	52.66
Efforts (No of Transect)	48.3 km (10)	14.5 km (6)	62.8 km (16)	62.8 km (16)	42.6 km (18)
Prey Species	Overall prey	Overall prey	Spotted deer	Overall prey	Overall prey
No. of Observations	75	37	71	112	32
Model	Hazard rate-Cosine	Half Normal-Cosine	Half Normal-Cosine	Half Normal-Cosine	Half Normal-Cosine
P-hat	0.172	0.368	0.279	0.259	0.47
ESW (SE)	25.88 (8.126)	29.49 (3.878)	41.95 (4.41)	38.91 (3.015)	24.77 (3.29)
E(S)	6.12	7.92	10.69	7.39	5.16
CV% E(S)	16.99	20.41	11.47	11.91	30.44
DS (Cluster km^{-2})	30.07	42.09	13.47	22.91	17.53
CV% (DS)	34.63	28.04	18.04	15.12	23.72
D (animals km^{-2})	184.1	333.23	144.04	169.39	90.51
CV% (D)	38.57	34.68	21.37	19.24	38.59
Abundance (animal No.)	10886	5385	10845	12753	4766
Encounter rate (detections/Km)	1.55	2.48	1.13	1.78	0.86
CV% (Encounter rate)	14.15	24.77	14.65	12.98	19.65
Biomass (Kg km^{-2})	-	-	7634.12	-	-

Table 15. Estimated summary prey densities in BCFs

P - hat = Detection probability, ESW = Effective strip width, DS = group density, D = individual density, CV % (DS) and CV % (D) = coefficient of variation on estimate of DS

and D respectively and the 95% Confidence Interval (95 % CI) on the estimate of individual density, BZFs=Buffer zone forests, NFs=National forests.

Within elephant back method of survey, detections of specific prey species in southern and northern BCFs were less than minimum of 30 observations. Therefore, density of overall prey species was estimated for these two sites. Overall prey densities estimated in northern BCF-National Forests (D=333.23) was high as compared to estimation in southern BCF-Buffer zone forests (D=184.1). Smaller study area representing a smaller number of transects (k=6) and less survey efforts (L=14.5 km) in northern BCF (NFs) are the possible reasons for high density as compared to southern BCF (BZFs). Increase in density is also due to detections of large herds and concentration of prey near highway. As National highway has bisected BCF into southern and northern area, it has led high concentration of large herds of prey like spotted deer in surveyed area of northern national forests as compared to southern buffer zone forests. Large herds and high concentration of wild prey like chital and wild boar has increased its density by 149.13 animals per km2. There was no possibility to compare species wise density in two management practice sites (buffer zone and national forests) due to minimum detections of prey.

Detections of all prey species except chital on elephant back method were less than minimum 30 number of observations Therefore, there was only possibility to estimate species wise density of spotted deer. But estimation of other species wise density for foot method of survey were not possible due to very low detection of prey. However, overall prey density for elephant back and foot method of survey was estimated due to higher number of observations 112 and 32 respectively. All prey density estimated on elephant back was the highest (D=169.39) but density estimated on foot/transect walk survey was minimum (D=90.51). Greater visibility on elephant back in high and dense bushes, high detectability of single animal or cluster of animals to the greater distances, longer length of transects leading to increase in survey efforts (L=62.8 km), survey area managed as protected forests (BZFs under park) and non-protected forests (NFs under DFO), medium level of human disturbances etc. are the possible spatial reasons for higher prey density on

elephant back method of survey. Elephant back method of survey carried out on March as the best season for sighting of prey was temporal reason for high density of prey (Achyut & Kreigenhofer, 2009). During that period, forests were open having dry and burnt low bushes, sprouting young shoots, and used elephant for survey that substantially maximize observer height for sighting and minimize the prey disturbance (Wegge & Storaas, 2009). However, foot/transect walk method of survey was conducted in whole northern national forests on month of May and June. In that period, there was high and dense bushes barrier to visibility and lead to low detection of prey. The area surveyed on transect walk had also less managed and less protection strategies as compared to area surveyed on elephant back. Low level of protection and management as well as intense disturbances are possible reasons for low detection of prey and finally minimizing its density. Within elephant back method of survey, biomass of spotted deer was estimated to 7634.12 Kg km^{-2}. The biomass was only estimated for spotted deer detected on elephant back.

Table 16. Comparison of estimated biomass (Kg km-2) of spotted deer from different studies in the Protected Areas of Nepal Terai.

Location/PAs	**Biomass of spotted deer**
CNP (Thapa, 2011)	4695.66
BNP (Malla, 2009),	4521.96
SWR (Yadav, 2006)	3001.32
SWR (Adhikari and Thapa, 2013)	4266.00
SWR (Karki, 2011)	1565.46
Dry season lowland in Nepal (Støen & Wegge, 1996)	467085
Pench National Park (Biswas & Sankar, 2002)	4441.25
Kalakkad- Mundantherai Tiger Reserve (Krishnakumar et al., 2020)	117.5

The estimated biomass of spotted deer from this study was found to have highest biomass as compared to Biswas & Shankar (2002), Yadav (2006), Malla (2009), Karki (2011), Thapa (2011) and Krishnakumar et al. (2020). However, the study conducted in dry season lowland in Nepal (Støen & Wegge, 1996) estimated highest biomass of chital as compared to our study. Therefore, the study has estimated highest biomass of chital than above national park and reserve of India except dry season lowland in Nepal.

Prey Habitat/PAs	Overall Prey Species Density D±SE	Chital Density D (SE)	Survey Method
Brandabhar Corridors (Bhattrai, 2003)	-	136	-
CNP- 1976 (Seidensticker, 1976)	-	17.3	-
CNP-1982 (Tamang, 1982)	-	16.8	-
CNP-2008,2009 (2010)	113.8	86.3±10.1	Elephant back and foot
CNP-2009 (DNPWC, 2009)	62.6	-	Elephant back and foot
CNP-2014 (Dhakal et al., 2014; DNPWC, 2013)	73.63	44.75	Elephant back and foot
CNP-2018 (DNPWC, 2019)	70.7±7.49	-	Elephant back and foot
Chitwan-Parsa Complex (DNPWC, 2020)	71.58	-	Elephant back and foot
A case study from Padampur, CNP (Khadka et al., 2016)	132.01 ± 19.20	88.22 ± 25.84	Elephant back
SWR TAL- 2015 (Karki et al., 2015)	144.8±22.8	79.0±19.0	Elephant back
SWR-2013 (Adhikari and Thapa, 2013)	72.71 (17.70)	28.99 (7.84)	Elephant back and foot

Dry Season lowland in Nepal (SWR)-2010 (Lovari et al., 2015)	130.8	25.9	Elephant back
Dry Season lowland in Nepal (SWR)-2011 (Lovari et al., 2015)	174.8	41.0	Elephant back
Sub-topical Lowland (BaNP and SWR)-2010 (Pokheral, 2013)	130.94	25.88	Elephant back
Sub-topical Lowland (BaNP and SWR)-2011 (Pokheral, 2013)	175.14	40.97	Elephant back
Karnali-BaNP-1976 (Dinerstein, 1980)	-	33.9	-
Karnali-BaNP-2009 (Malla, 2009)	-	50.5	-
BNP-2016 (Karki et al., 2016)	56.3±6.5	29.3±4.3	-
BNP-2009 (Wegge and Storass, 2009)	287.8	267 (38.30)	Elephant back
Nalkeri Reserved Forest within Naga-rahole National Park- (Karanth & Sunquist, 1995)	91 ±0.0	49.1±0.0	Foot
Pench National Park (Biswas & Sankar, 2002)	90.3	80.7	Foot
Tropical deciduous forest – Satputra and Milkal landscape (Narasimmarajan et al., 2014).	69.5±8.5	-	Foot
Western Terai Arc Landscape, India (Harihar, 2011)	73.40	59.03	Foot
Kalakkad- Mundantherai Tiger Reserve (Krishnakumar et al., 2020)	101.27	2.5	Foot

Table 17. Comparison of prey density (Indi.km-2) SE published in different article.

Some PAs and reserves of India had estimated overall prey density detected on transect walk between 69.5 to 101.27 individual km^{-2}. This study has estimated the lower overall species density as compared to Krishnakumar et al. (2020), approximately same as compared to Biswas & Sankar (2002) and Karanth & Sunquist (1995) and the higher as compared to Harihar (2011) and Narasimmarajan et al. (2014). However, with in Nepal, PAs and some lowland areas had estimated overall prey density on elephant back ranging between 130.8 to 287.8 individual km^{-2}. The study has estimated the lower density of species combined as compared to Wegge and Storass (2009), 2011- Pokheral (2013) and 2011-Lovari et al. (2015) and the higher as compared to 2012- Pokheral (2013), 2012-Lovari et al. (2015), Karki et al. (2015) and Khadka et al. (2016). Previous study conducted in Nepal on elephant back estimated spotted deer density ranging between 25.9 to 267 individual km^{-2}.

Our study has resulted the lower density of spotted deer as compared to Wegge and Storass (2009) but the higher density as compared to Bhattrai (2003), 2011- Pokheral (2013), 2011-Lovari et al. (2015), 2012- Pokheral (2013), 2012-Lovari et al. (2015), Karki et al. (2015) and Khadka et al. (2016).

Elephant back method estimated the higher abundance than foot method due to higher detectability resulting the higher density. Within elephant back, BZFs was found to higher abundance than national forests due to its greater survey area and connectivity of survey area with park. This study reveals the higher abundance of spotted deer in sal forests followed by riverine forests. But the previous study in corridor (Bhattrai, 2003) had shown the higher abundance in tall grass flood plain followed by riverine and sal forests.

CHAPTER - V

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion:

i. Among two methods of field survey, elephant back survey estimated the higher and more reliable estimates of prey density than survey on foot.

ii. Within elephant back survey, national forest of northern BCFs had the higher all prey density than buffer zone forests of southern BCFs.

iii. Based on the abundance estimated from prey density, southern BZFs had the higher abundance than northern NFs surveyed on elephant back method. Obviously, survey on elephant back estimated the higher and more reliable abundances than survey on foot.

iv. Based on observed prey species detected within and out of transects, spotted deer was found to be more abundant followed by rhesus, wild boar, sambar and barking deer. Hog deer and langur were found to be less abundant in the study area. However, it does not indicate total abundance of prey.

v. Based on observed prey detected in different habitats, sal forest was found to have the greater number of detected animals followed by short grassland outside transects, riverine and mixed forest. Minimum number of animals were detected in wetland.

vi. In the current context, abundance and density of prey population are likely to support dispersing big cats (tigers and sympatric large predators like common leopard) in Brandabhar corridor.

vii. Buffer zone and national forest have a good potential to hold dispersing big cats in terms of availability of prey (density and biomass). These management regimes were estimated to have greater population of preferred medium sized prey species like spotted deer.

viii. Collection of fuel, fodder and vegetables, excavation and collection of sand and gravel, fishing in wetlands etc. were level of human disturbances spotted in national forests management regimes (community forests).

ix. National highway restricts movement of big cats and its prey from buffer zone to national forests and vice versa. Therefore, it has played role to create isolated populations big cats and its prey.

5.2 Recommendation:

i. Less coverage of grasslands and further in shrinkage condition due to invasive alien species in Brandabhar corridors are a great challenge to maintain suitable habitats for wild prey. Therefore, management interventions should be implemented and executed for further increase of prey species and big cats in the corridor.

ii. The management activities such as annual grass cutting facilities to manage the grasslands and controlled burning to increase the growth the young grasses which in turn help to increase the density and biomass of prey population as a diet for dispersing big cats in the corridors of Chitwan valley. The large mammalian predators like tigers and leopards have been known to respond to prey biomass and densities (Carbone & Gittleman, 2002; Karanth *et al*. 2004).

iii. Conservation of prey population requires habitat management, regulation of encroachment created by livestock and human, and removal of alien invasive species.

iv. If we consider and reduce the limitations occurred in spatial and temporal context, prey base surveys in future ensure an adequate number of detections for robust estimation of density in Brandabhar Corridor and national forests through increasing survey efforts and sampling design.

v. Robust estimation of prey abundance in different habitats can be done by recording of observed prey species in certain distance of equal interval.

vi. The sampling design and frequency of monitoring needs to be improved by increasing spatial and temporal replicates as well as selection of suitable season for field survey to maximize visibility.

vii. The length of line transects should be increased covering the grasslands which was not considered in the recent survey for increasing number of detections and survey efforts.

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APPENDICES:

Annex-I: Datasheet (Line Transect Survey)

Observer Name: ……..… Block No: ……. Transect No: ……..

Transect Bearing: …. Location Name…… Weather: …… Habitat Type: ……...

Start GPS: E ……..… N ……. End GPS: E……...…….…. N …….……

Date: …..... Start Time: …. End Time: ……. Transect on Foot/Elephant back: ….....

S. N	Time	Species	M	F	Y	Un-ID	Total No.	Animal Bearing	Angular Sighting Distance	Habitat Type	GPS
											N: **E:**
											N: **E:**
											N: **E:**
											N: **E:**
											N: **E:**
											N: **E:**
											N: **E:**

Habitat type*:* SF - Sal forest, MF - Mixed Forest, RF - Riverine Forest, TG - Tall Grassland, SG – Short Grassland, W-Wetland, S – Streamed

Annex II: Permission Letter from NTNC-BCC, Sauraha, Chitwan

राष्ट्रिय प्रकृति संरक्षण कोष

जैविक विविधता संरक्षण केन्द्र

च.नं. २६८ /०७६/७७

मिति: २०७७/०२/

श्रीमान् डिभिजनल वन अधिकृत ज्यू,
डिभिजन वन कार्यालय, चितवन

विषय: <u>बाघ/चितुवाको आहरा प्रजाति अध्ययन सम्बन्धमा</u>

उपरोक्त सम्बन्धमा यस राष्ट्रिय प्रकृति संरक्षण कोष, जैविक विविधता संरक्षण केन्द्र मार्फत वरण्डाभार जैविक मार्गमा नियमित रुपमा वन्यजन्तुको अनुगमन गरिँदै आएको यहाँमा विदितै छ। यस वर्ष पनि त्यस क्षेत्रमा बाघ/चितुवाको आहरा प्रजातिको अवस्थाको बारेमा लाईन ट्रान्सेक्ट विधिबाट नियमित अनुगमन गर्ने र बाघ/चितुवा दिशाबाट आहराको अध्ययन गर्नुपर्ने भएकाले यस केन्द्रका वन्यजन्तु प्राविधिक श्री तिर्थ लामाको नेतृत्वमा खटिएको पाँचजनाको टोलीलाई उक्त कार्य सँचालनको लागि आवश्यक अनुमति र त्यस क्षेत्रमा पर्ने सब-डिभिजन वन कार्यालय, रेञ्ज पोष्ट र सामुदायिक वन कार्यालयहरुलाई जानाकारी गराई सहयोग गरिदिनुहुन हार्दिक अनुरोध गर्दछु।

राम कुमार अर्याल
नि. कार्यालय प्रमुख

रत्ननगर-६, सौराहा, चितवन, नेपाल ।
फोन : ९७७-५६-५८०१५३, ९७७-५६-५८००१२, ५८०२८८
फ्याक्स : ९७७-५६-५८०१३०

पो. ब.नं. ३७१२, काठ...
फोन : ९७७-१-५...
फ्याक्स : ९७७-१-...
वेबसाइट : http://...

Annex III: Permission Letter from Division Forest Office, Chitwan

प्रदेश सरकार
उद्योग, पर्यटन, वन तथा वातावरण मन्त्रालय
वन निर्देशनालय
वागमती प्रदेश

डिभिजन वन कार्यालय, चितवन

प स :- २०७६/०७७ (योजना)
च. नं. :-

वेब साइट :- www.dfochitwan.gov.np
ई-मेल :- info@dfochitwan.gov.np
फोन नं:-०५६-५२०२१५/फ्याक्स: ०५६५-२७५५७

मिति : २०७७/२/५

विषय:- बाघ/चितुवाको आहारा प्रजाति अध्ययन सम्बन्धमा ।

श्री भरतपुर सब डिभिजन वन कार्यालय, भरतपुर ।
श्री हरिपुर सब डिभिजन वन कार्यालय, हरिपुर ।
श्री खगेडी सब डिभिजन वन कार्यालय, पदमपुर ।

उपरोक्त सम्बन्धमा राष्ट्रिय प्रकृति संरक्षण कोष, जैविक विविधता संरक्षण केन्द्र मार्फत बरण्डाभार जैविक मार्गमा नियमित रुपमा वन्यजन्तुको अनुगमन गरिँदै आएको यहाँमा विदितै छ । यस वर्ष पनि यस क्षेत्रमा बाघ/चितुवाको आहारा प्रजातिको अवस्थाको बारेमा लाईन ट्रान्जेक्ट विधिबाट नियमित अनुगमन गर्ने र बाघ/चितुवा दिशाबाट आहाराको अध्ययन गर्नुपर्ने भएकोले यस केन्द्रका वन्यजन्तु प्राविधिक श्री तिर्थ लामाको नेतृत्वमा खटिएको पाँच जनाको टोलीलाई उक्त कार्य सञ्चालनको लागि आवश्यक अनुमति र त्यस क्षेत्रमा पर्ने सब डिभिजन वन कार्यालय र सामुदायिक वन कार्यालयहरुलाई जानकारी गराई सहयोग गरिदिनुहुन भनी श्री राष्ट्रिय प्रकृति संरक्षण कोष, जैविक विविधता केन्द्रको च.नं. २७८ मिति २०७७/२/४ को पत्रबाट लेखि आएको हुँदा सो सम्बन्धमा आवश्यक सहयोग गर्नुहुन साथै आ-आफ्नो कार्यक्षेत्रमा पर्ने सम्बन्धित सामुदायिक वनहरुलाई जानकारी गराईदिनुहुन अनुरोध छ ।

06.02.04
पदमराज नेपाल
डिभिजनल वन अधिकृत

बोधार्थ:-
श्री राष्ट्रिय प्रकृति संरक्षण कोष, जैविक विविधता केन्द्र,
सौराहा, चितवन ÷ आवश्यक समन्वय गरी कार्यसम्पादन गर्नुहुन ।

Annex IV: List of Participants involved in the prey base line transect survey

S. N	Name	Professions	Organizations
1.	Kapil Pokherl	Wildlife Technician	NTNC-BCC, Sauraha, Chitwan
2.	Tirtha Lama	Wildlife Technician	NTNC-BCC, Sauraha, Chitwan
3.	Tikaram Tharu	Wildlife Technician	NTNC-BCC, Sauraha, Chitwan
4.	Rajbansi Dhami	Wildlife Technician	NTNC-BCC, Sauraha, Chitwan
5.	Binod Darai	Wildlife Technician	NTNC-BCC, Sauraha, Chitwan
6.	Ganesh Lama	Wildlife Technician	NTNC-BCC, Sauraha, Chitwan
7.	Shiv Mahato	Wildlife Technician	NTNC-BCC, Sauraha, Chitwan
6.	Palla Mardania	Hattisar/Prakirtikali Elephant	NTNC-BCC, Sauraha, Chitwan
7.	Punte Gurau	Hattisar/Prakirtikali Elephant	NTNC-BCC, Sauraha, Chitwan
8.	Pappu Chaudhary	Hattisar/Prakirtikali Elephant	NTNC-BCC, Sauraha, Chitwan
9.	Harendra Chaudhary	Hattisar/Mankali Elephant	NTNC-BCC, Sauraha, Chitwan
10.	Ram B. Gurung	Hattisar/Mankali Elephant	NTNC-BCC, Sauraha, Chitwan
11.	Sushil Kumal	Hattisar/Mankali Elephant	NTNC-BCC, Sauraha, Chitwan
12.	Jogendra Gurau	Hattisar/Junekali Elephant	NTNC-BCC, Sauraha, Chitwan
13.	Prabhu Kacchadia	Hattisar/Junekali Elephant	NTNC-BCC, Sauraha, Chitwan
14.	Upendra Kachhadia	Hattisar/Junekali Elephant	NTNC-BCC, Sauraha, Chitwan
15.	Hira Chaudhary	Hattisar/Kirtikali Elephant	NTNC-BCC, Sauraha, Chitwan
16.	Hansa Raj Chaudhary	Hattisar/Kirtikali Elephant	NTNC-BCC, Sauraha, Chitwan
17.	Pramod Chaudhary	Hattisar/Kirtikali Elephant	NTNC-BCC, Sauraha, Chitwan
18.	Ram Bahadur Gurung	Forest Guard	Sub-Div. Forest Office, Chitwan

19.	Rishi Ram Ranabhatt	Forest Guard	Sub-Div. Forest Office, Chitwan
20.	Bikash Kunwar	Forest Guard	Sub-Div. Forest Office, Chitwan
21.	Nishant Adhikari	Nature Guide	Gaida Hotel, Sauraha

Annex V: Advisor Committee

Name	Position	Organization	Role
Dol Raj Thanet	Assistant Professor	Tribhuvan University, Institute of Forestry, Hetauda	Advisor
Dr. Babu Ram Lammichane,	Research Officer (Wildlife)	National Trust for Nature Conservation-Biodiversity Conservation Center, Sauraha, Chitwan	Co-Supervisor

Annex VI: Photo Plates

a. Transect survey on Elephant back

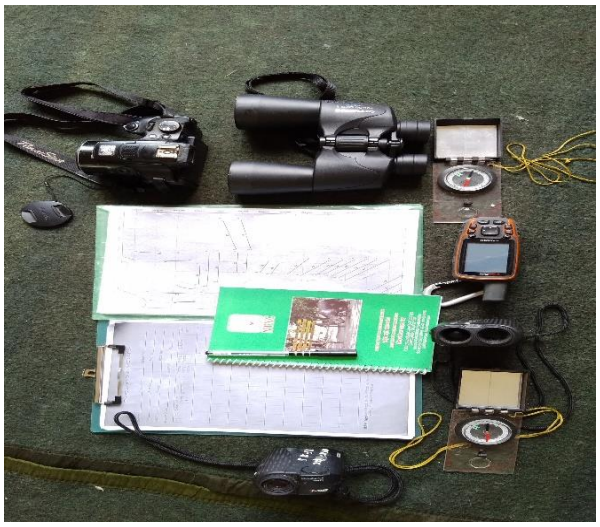
b. Hattisar and Wildlife technician of NTNC- BCC

c. Line transect made by NTNC-BCC

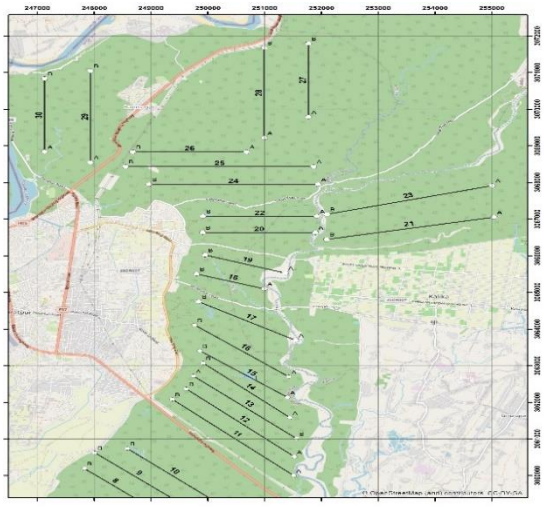
d. Transect station tagged with plate Number

e. Transect stations marked by Paint

f. Sighting of Prey on Elephant back



g. Equipment used for transect traversing



h. Transect map used for transect survey

i. Sal Forest

j. Short grassland

k. Wetland (Rhino Tal)

l. Clusters of Spotted deer (*Axis axix*)

m. Cluster of females spotted deer

n. Male spotted deer

o. Male Sambar deer (*Rusa unicolar*)

p. Barking deer (*Muntiacus muntjak*)

q. Hog deer (*Axix porcinus*)

r. Carcass of deer

s. Group for Transect survey

t. Wildlife technicians and Nature guide

u. carrying out transect survey

v. Human disturbances (Fodder collection

w. Fishing in Rhino Tal

x. Fishing by village people

xi. Pellet of deer

xii. Scat of Bengal tiger

xiii. Foot mark of Bengal tiger