ESTIMATING THE DENSITY OF PREY SPECIES OF TIGER (*Panthera tigris tigris*) IN SHUKLAPHANTA WILDLIFE RESERVE, NEPAL

Pradeep Adhikari
T.U. Regd. No: 5-1-48-60-2001
Roll No: 13065
Batch: 2066/67

A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Zoology with special paper Ecology and Environment

Submitted to

Central Department of Zoology
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu
Nepal

August, 2013

ESTIMATING THE DENSITY OF PREY SPECIES OF TIGER (*Panthera tigris tigris*) IN SHUKLAPHANTA WILDLIFE RESERVE, NEPAL

Pradeep Adhikari

T.U. Regd. No: 5-1-48-60-2001

Roll No: 13065

Batch: 2066/67

A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Zoology with special paper Ecology and Environment

Submitted to

Central Department of Zoology

Institute of Science and Technology

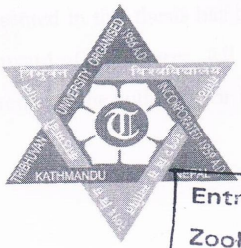
Tribhuvan University

Kirtipur, Kathmandu

Nepal

August, 2013

ESTIMATING THE DENSITY OF PREY SPECIES OF TIGER (*Panthera tigris tigris*) IN SHUKLAPHANTA WILDLIFE RESERVE, NEPAL



Pradeep Adhikari
T.U. Regd. No: 5-1-48-60-2001
Roll No: 13065
Batch: 2066/67

A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Zoology with special paper Ecology and Environment

Submitted to

Central Department of Zoology
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu
Nepal

June, 2013

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author (s) or institution (s).

Date. 10./07./2013.

.....
Pradeep Adhikari

☎ 01-4331896

TRIBHUVAN UNIVERSITY

and Technology

CENTRAL DEPARTMENT OF ZOOLOGY

Kirtipur, Kathmandu, Nepal.

RECOMMENDATION

This is to recommend that the thesis entitled "Estimating the density of prey species of Tiger (*Panthera tigris tigris*) in Shuklaphanta Wildlife Reserve, Nepal" has been carried out by Mr. Pradeep Adhikari for the partial fulfillment of Master's Degree of Science in Zoology with special paper Ecology and Environment. This is his original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

Date. 11 /07/ 2013

Dr. Tej Bahadur Thapa
Associate Professor
Central Department of Zoology,
Tribhuvan University,
Kirtipur, Kathmandu, Nepal

RECOMMENDATION

This is to recommend that the thesis entitled "Estimating the density of prey species of Tiger (*Panthera tigris tigris*) in Shuklaphanta Wildlife Reserve, Nepal" has been carried out by Mr. Pradeep Adhikari for the partial fulfillment of Master's Degree of Science in Zoology with special paper Ecology and Environment. This is his original work and has been carried out under my co-supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

Date 26/07/2013

.....Hemant.....

Mr. Hemanta Kumar Yadav
Conservation officer/ Office chief
National Trust for Nature Conservation/
Suklaphanta Conservation Programme,
Kanchanpur, Nepal

☎ 01-4331896

TRIBHUVAN UNIVERSITY

CENTRAL DEPARTMENT OF ZOOLOGY

Kirtipur, Kathmandu, Nepal.

Ref.No.:

LETTER OF APPROVAL

On the recommendation of supervisor "Dr. Tej Bahadur Thapa" this thesis submitted by Mr. Pradeep Adhikari entitled "Estimating the density of prey species of Tiger (*Panthera tigris tigris*) in Shuklaphanta Wildlife Reserve, Nepal" is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Ecology and Environment.

Date 14./7./2013...

.....

Prof. Dr. Ranjana Gupta
Head of Department of Zoology,
Tribhuvan University,
Kirtipur, Kathmandu, Nepal

☎ 01-4331896

TRIBHUVAN UNIVERSITY

CENTRAL DEPARTMENT OF ZOOLOGY

Kirtipur, Kathmandu, Nepal.

Ref.No.:

LETTER OF APPROVAL

On the recommendation of supervisor "Dr. Tej Bahadur Thapa" this thesis submitted by Mr. Pradeep Adhikari entitled "Estimating the density of prey species of Tiger (*Panthera tigris tigris*) in Shuklaphanta Wildlife Reserve, Nepal" is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Ecology and Environment.

Date 14./7./2013...

.....

Prof. Dr. Ranjana Gupta
Head of Department of Zoology,
Tribhuvan University,
Kirtipur, Kathmandu, Nepal

☎ 01-4331896

TRIBHUVAN UNIVERSITY

CENTRAL DEPARTMENT OF ZOOLOGY

Kirtipur, Kathmandu, Nepal.

Ref.No.:

CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Mr. Pradeep Adhikari entitled "Estimating the density of prey species of Tiger (*Panthera tigris tigris*) in Shuklaphanta Wildlife Reserve, Nepal" has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Ecology and Environment.

EVALUATION COMMITTEE

Supervisor
Dr. Tej Bahadur Thapa
Associate Professor

Head of Department
Prof. Dr. Ranjana Gupta

Dr. Jhamak Bahadur Karki
External Examiner

Mr. Laxman Khanal
Internal Examiner

Date of Examination: 30/07/2013

v

ACKNOWLEDGEMENTS

Really its very difficult for me to find space for mentioning all the good name of many individuals and institutions who have contributed me in innumerable ways by sharing their invaluable time, resources and knowledge without which materialization of the dissertation this form would not have been possible. I am very much excited and give me pleasure from bottom of my heart to express my gratitude to the following personnel.

My deepest gratitude and the sincerest thanks go to my respected supervisor Dr. Tej Bahadur Thapa, Associate Professor at Central Department of Zoology (CDZ) under the auspices of whom I got continuous guidance, encouragement, and intellectual support by sacrificing his invaluable time from proposal development to this stage.

I express my gratitude to Mr. Hemanta Yadav Conservation Officer/ Office chief, National Trust for Nature Conservation (NTNC) - Suklaphanta Conservation Programme (SCP) Wildlife Reserve for his continuous guidance, advice, technical and logistic support during my field study.

I am very much grateful to the NTNC, Khumaltar, Nepal for providing me research grant for this work, Department of National Park and Wildlife Conservation (DNPWC) for providing me permission and Suklaphanta Wildlife Reserve for providing elephant, NTNC- SCP for providing me technical and logistic support. Central Department of Zoology has groomed me to be able to conduct this research.

I would like to thank to the Prof. Dr. Ranjana Gupta, head of Central Department of Zoology for her official support, valuable suggestion during my thesis writing. I also want to thank to the other Professors, and staffs of CDZ specially Mr. Aananda Amatya for their academic and technical support during this study.

I would like to express my sincere thanks to Mr. Naresh Subedi, senior conservation officer of NTNC who has given valuable suggestion and support during the study and provided me literature. I would like to thanks Mr. Yuba Raj Regmi chief warden of Suklaphanta Wildlife

Reserve (SWR), Mr. Nabaraj Chapagain, then senior conservation officer of NTNC, Mr. Kishor Mehata, then assistant warden of SWR, for their support and suggestion during the research. I heartily thank to Mr. Ambika Khatiwada, senior conservation officer of NTNC who continuously provided all kinds of suggestion and support during this study. I am deeply thankful to my field assistant Mr. Dev Raj Joshi wildlife technician NTNC-SCP, Suklaphanta and my colleague Mr. Maniram Banjade for their constant support in the field on various difficulties without them I could not complete my study.

I am grateful to staffs of NTNC - SCP especially Mr. Permananda Garga, Mr. Raju Chaudhary, Mr. Suman Malla, Mr. Pramod Subedi, Mr. Roshan Bhatta, and all the staffs NTNC-SCP for their continue support and co-operation in my field. I can't forget the help of staffs of Suklaphanta, Pipariya, Beldandi posts and Nepal army of Garud Dal Battalion. My great vote of thanks to Surtikali (elephant), Mr. Kala Kumal and Mr. Thaggu Rana for helping to negotiate tall grass lands of Suklaphanta.

I am deeply thankful to Mr. Krishna Prasad Bhandari for his every supports during this period. I would like to extend my thanks to my colleagues Mr. Eka Raj Baral, Mr. Amar Kunwar, Mr. Prakash Gairhe, Mr. Raju Gairhe, Mr. Suraj Baral, Mr. Shreedhar Devkota, Mrs. Saraswoti Paudel, Mr. Saurav Kumar Singh for their moral support that helped towards completion of writing. At last but not least, I am very much grateful to my beloved family especially father Netra Nath Adhikari, mother Chandrakala Adhikari, brothers Pramod Adhikari, and Prabhat Adhikari and wife Tulasi Paudel (Adhikari) for their endless support, encouragement, inspiration and love during the difficult part of my study.

Pradeep Adhikari
pradeep47adhikari@yahoo.com

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of Annexes

ABSTRACT

Tiger population is dependent on a healthy and viable prey population and prey population should be monitored regularly. I estimated population density and structure of major prey species in Shuklaphanta Wildlife Reserve using Distance sampling method. A total of 26 transects covering a total length of 109.25 was monitored for ungulates during February, 2012. Ungulates in the Sal Forest and riverine forest were sampled by walking and in the tall grasses Elephant was used. A total of 132 groups and 2170 individuals of nine prey species (Chital, Barking Deer, Hog Deer, Swamp Deer, Wild Pig, Langur, Rhesus, Peafowl and Cattle) were recorded. The overall density of prey species in SWR was 72.71/km^2 and the densities of Chital, Hog Deer and Primates were 28.99, 8.51 and 6.79/km ^{2} respectively. Biomasses of Chital and Hog Deer were estimated at 1565.46 and 280.83 kg/km^2 respectively. Of the total individuals, 77.64% were classified into age-sex categories. Sex ratios of Chital, Hog Deer and Swamp Deer were female biased, while in Rhesus and Barking Deer were male biased sex ratios were observed. Barking Deer was found mostly solitary, but other species like Chital Wild Pig, Peafowl, Rhesus and Hog Deer occupy intermediate position in terms of sociality with the group size frequencies being distributed among family associations, small groups and medium sized groups. Swamp Deer and domestic Cattle were found in very large herds with more than hundreds individuals in groups. Estimated prey population density of this study was lower than the estimates of 2006 and 2011. However, male- female and young to female ratios represent the good symptoms of future prey population in order to keep long term conservation of Tiger population.

LIST OF ABBREVIATIONS

Abbreviated form		Details of abbreviations
AM	=	Ante Meridian
BZ	=	Buffer Zone
CNP	=	Chitwan National Park
CITES	=	Convention on International Trade in Endangered Species of wild flora and fauna
CV %	=	Percent Coefficient of Variation
D	=	Individual density
DS	=	Group density
DNPWC	=	Department of National Park and Wildlife Conservation
ESW	=	Effective Strip Width
GPS	=	Global Positioning System
Kg	=	Kilogram
Km	=	Kilometer
m	=	meter
max	=	maximum
mini	=	minimum
Mm	=	Millimeter
NP	=	National Park
NTNC	=	National Trust for Nature Conservation
PWR	=	Parsa Wildlife Reserve
RCNP	=	Royal Chitwan National Park
SE	=	Standard Error
Sq	=	Square kilometer
SWR	=	Suklaphanta Wildlife Reserve
TAL	=	Terai Arc Landscape
Temp	=	Temperature
VDC	=	Village Development Committee

1. INTRODUCTION

1.1 Introduction of Tiger

Tiger **(***Panthera tigris*) is one of the most striking flagship species in the world and continuously draws attention to wide diversity of conservation issues (Shrestha 2004). It is an endangered species (Chundawata *et al.* 2011) and listed in Appendix I by Convention on International Trade in Endangered Species of wild flora and fauna (CITES) 2011 (UNEP-WCMC 2011). In Nepal it is listed as a protected species under National Parks and Wildlife Conservation Act 2029 (BS) (DNPWC 2010). Bengal Tiger (*Panthera tigris tigris*) is found in India, Nepal, Bhutan and Bangaladesh. Its adult population is estimated between 1520-1909 in India, 440 in Bangaladesh and 75 in Bhutan (Chundawat *et al.* 2011). In Nepal, a total of 198 Tigers have been estimated (DNPWC 2013). The population of Tiger in Nepal splits into three isolated and vulnerable sub population in Chitwan National Park (CNP), Bardiya National Park (BNP), Shuklaphanta Wildlife Reserve (SWR) complexes (DNPWC 2009).

Tigers are charismatic representatives of the biodiversity within the complex ecosystem where they inhibit. They need large home range to survive. Their conservation will help maintain biological diversity over extensive areas and so help conservation of many other species too (Shrestha 2004) therefore it is considered as an umbrella species (Roberge and Angelstam 2004) whose conservation helps to conserve whole ecosystem as it is lying at the top position of food chain (Steneck 2005). However, in recent years, Tiger population is in declining trend mainly due to loss of habitat, poaching, population fragmentation and reduction in prey populations (Karanth and Stith 1999, Seidensticker *et al.* 1999, Karanth *et al.* 2003, Karki 2011, Thapa 2011).

1.2 Predator prey relationship

Abundance and distribution of carnivores is directly correlated with the density and biomass of prey species (Karanth and Sunquist 1995, Karanth and Stith 1999, Carbon and Gittleman 2002, Karanth *et al.* 2004). Cervidae and Suidae of Artiodactyla and Primates are the main

prey species of Tiger (Karanth & Sunquist 1992), therefore they have key role in the survival of Tiger (Scidensticker 1976). Ungulate depletion is a major factor driving the current decline of Tiger populations (Karanth and Stith 1999). To conserve this threatened species, a healthy and viable prey population therefore needs to maintained (Wegge and Storaass 2009). Tigers always prefer medium to large sized prey species having weights 30- 175 kg (Schaller 1967). Approximately, 47- 65 % of Tiger's diet is composed of medium sized prey like Chital (*Axis axis), Wild Pig (Sus scrofa)* Blackbuck (*Antelope cervicapra*) whereas large sized prey includes Swamp Deer (*Cervous duvauceli*), Gaur (*Bos gaurus*), Samber (*Rusa unicolor*), Nilgai (*Boselaphus trago-camelus*) and domestic Cattle (Schllar 1967, Tamang 1982, Karanth and Sunquist 1995, Biswas and Sankar 2002, Bagchi *et al.* 2003, Johnsingh *et al.* 2004). Barking Deer (*Muntiacus vaginalis*), Hog Deer (*Axis porcinus*), four horned Antelope (*Tetracerous quadricurnis*), Rhesus (*Macaca mulata*), Langur (*Semnopithecus entellus*) having maximum weight up to 30 kg are also consumed by Tiger for its diet (Schllar 1967, Tamang 1982, Karanth and Sunquist 1995). The average kill rate is about 50 ungulates per adult Tiger per year while tigress with large cubs requires 60-73 ungulates per year (Sunquist 1981).

1.3 Prey habitat relationship

Prey species favors various types of habitats. The Chital is found in large numbers in dense deciduous or semi-evergreen forests and open grasslands (Schaller 1967). Their significant dependency is on surface water and partial cover (Schaller1967, Johnsingh 1983). They prefer open grassland during winter and more forested patch during summer when grass is low in abundance (Schaller 1967, Bhat 1993). Hog Deer is mostly found in tall grasslands of floodplain and riverine complexes (Wegge and Storaas 2009). Swamp Deer is a true grazer and they love to live in dry and swampy grasslands. They prefer short grassland of riverine habitat (Khatri 1993, Pokhrel 1996, Wegge *et al*., 2006, 2009). The Barking Deer are mostly seen inhabiting dense forests. Even while grazing, they rarely move into open grasslands and usually remain near the edge of dense forests (Barette 1977, 2004). Sambar are found in habitats ranging from tropical seasonal forests (tropical dry forests and seasonal moist evergreen forests), subtropical mixed forests (conifers, broadleaf deciduous, and broadleaf

evergreen tree species) to tropical rain forests (Schaller 1967, Johnsingh 1983, Timmins *et al*. 2008). In Nepal they are found in sub tropical broad leaf forest around the Churia range and flood plain of river (Wegge *et al.* 2009, Malla 2009). Samber significantly depends on shrubs and water. Wild Pig lives in forest near agricultural fields and its habitat shifts according to change in seasons (Cahill *et al.* 2003). Dinerstein (1980) Eisenberg and Seidensticker (1976) and Karanth & Sunquist (1992) all have shown that the greatest ungulate biomass is reached in areas where grassland and forests form a mosaic with the inter digitations of many different vegetation types. Changing river courses, fire and anthropogenic disturbances have all contributed to increasing the edge habitat, which is preferred by many ungulate species (Sunquist *et al*. 1999).

1.4 Distance sampling and Line transect method

Distance sampling is a widely used technique for estimating the size or density of biological populations (Thomas *et al.* 2009). Karanth (1999) recommended to use line transects and programme DISTANCE (Buckland *et al.* 1993) to estimate the density of Tiger prey species. This method has now become the standard method for estimating the abundance of Tiger prey in protected areas of all Tiger range countries (Biswas and Sankar 2002, Karanth and Nicholos 2002, Bagchi *et al.* 2003, Jathanna *et al.* 2003, Karanth *et al.* 2004). In Nepal, this technique has been adapted in many protected areas of Terai Arc Landscape (Yadav 2006, Malla 2009, Wegge and Storaas 2009, Chalise 2011, Karki 2011, Thapa 2011).

The line transect method (Burnham *et al.* 1980, Buckland *et al*. 1993) is considered to be the most appropriate method for the estimation of herbivore abundance and has been used extensively to determine animal abundance (Eberhardt, 1978, Anderson *et al.* 1979, Burnham *et al.* 1980, Laake *et al.* 1994, Buckland *et al.* 1993, Buckland *et al.* 2001). The distance sampling is based on some important assumptions such as, detection of animals along a line transect decreases with increasing distance from the line, objects should be measured from their initial location, sightings should be independent, the observer must walk faster than the animals, transects should be placed at random with respect to the distribution of the animals, sufficient sightings (>40) are required for the estimation of a detection function or strip (Burnham *et al*. 1980, Buckland *et al.* 1993 Thomas *et al.* 2009). In this technique, all the

individuals cannot be detected during the survey but all individuals which are actually on the line transect should be detected. The key to distance sampling analysis is to fit a detection function to the observed distances, and use this fitted function to estimate the proportion of individuals missed during the survey (Burnham *et al*. 1980, Buckland *et al*. 1993). Line transect sampling is a practical, efficient and relatively inexpensive method for estimating many biological populations (Anderson *et al.* 1979, Burnham *et al*. 1980, Buckland *et al*. 1993). So, this technique has been used to estimate densities of ungulates in the Indian Subcontinent including Nepal (Karanth and Sunquist 1995, Varman and Sukumar 1995, Khan *et al*. 1996, Biswas and Sankar 2002, Sankar and Johnsingh 2002, Bagchi *et al.* 2003, Jathanna *et al*. 2003, Karanth *et al.* 2004, Harihar *et al*. 2007, Edgaonkar 2008, Harihar *et al*. 2009, Paliwal 2009, Malla 2009, Chalise 2011, Karki 2011, Thapa 2011).

1.5 Objectives

The general objective of the research was to estimate the abundance of prey species in Shuklaphanta Wildlife Reserve.

Specific objectives were to:

- Estimate the density and biomass of prey species.
- Determine the population structure of Tiger prey.

Research questions

1. What is the density of Tiger prey?
2. What are the structures of population of Tiger prey?

1.6 Rational of the study

Tiger, a top predator of terrestrial ecosystem of south Asian forests, is an indicator species of healthy ecosystem; therefore its conservation has long term biological implication. Due to several anthropogenic activities like livestock encroachment in the park, illegal trades of forest products, poaching over the Tiger and its prey species, etc. are the main causes of decreasing the population of Tiger drastically in the world (Karnth and Stith 1999, Sunquist

et al. 1999). Government of Nepal with the support of WWF initiated Terai Arc Landscape (TAL) Conservation Project This project aims to link Protected Areas (PAs), corridors and connectives in this region. It aims to conduct the programme of conservation through participation by communities and other stakeholders. It also aims to increase and protect the forest of Terai and successful restoration of prey species. To assess the conservation success, periodic monitoring of prey species is essential. The timely information on abundance, distribution and density of prey species helps to support long term survival of Tiger. In SWR, Pokhrel (2005), Manandhar (2006), Yadav (2006), Shrestha (2008), Chalise (2011), Karki (2011) evaluated the abundance of prey species. Thus, this study aims to obtain updated information of abundance of prey species in SWR and providing the support for conservation planning for Tiger and Leopard (*Panthera pardus*).

1.7 Limitations of the study

- Due to the limitation of fund availability and domestic elephant availability, multiple replications were not done which caused the less detection of animals.
- The forest canopy gave the poor GPS coverage, which has made problem in locating the exact position of sampler's point.
- The study time was winter and the weather was not clear, so visibility problem was there during early hours of the day.

2. LITERATURE REVIEW

Many researchers have estimated population characteristics of prey species of Tiger across their range. They found that the abundance and distribution of large carnivores are regulated by the abundance of different sized ungulate prey (Karanth and Nichols 1998, Ramesh 2010). The low prey density within the habitat leads to lower encounter rates of Tiger (Sunquist and Sunquist 2002) and carrying capacity of breeding female reduces the cub survival rate and diminishes resilience so the viable population of Tiger decreases dramatically (Karanth *et al.* 2002).

Estimation of population parameters of ungulate species were done by many researchers in different time. Earlier studies were focused on ecology and behavior of ungulates but these studies do not have strong statistical validity for estimation of their population (Karanth and Sunquist 1992). Such studies were carried out in south Asia including Nepal (Schaller 1967, Eisenberg and Lockhart 1972, Berwick 1974, Seidentiscker 1976, Dinerstein 1980, Tamang 1982, Johnsingh 1983, Mathur 1991).

In Nepal, Monitoring of prey and predators continued since the establishment of protected areas. Seidensticker (1976) estimated the population composition and density of the ungulates; Chital, *Hog Deer, Samber, Barking Deer, Wild Pig and Rhino (Rhinoceros unicornis).* Density, biomass, grouping characteristics and reproductive activity of wild ungulates were assessed by Dinerstein (1980) in then Royal Karnali- Bardiya wildlife reserve. He determined Chital as the most abundant wild ruminant and Nilgai occupied 88% of the total wild herbivore biomass. In CNP, Tamang (1982) estimated the densities of Chital, Samber, Hog Deer, Barking Deer and Wild Pig and found 16.4, 2.6, 33.0, 5.4 and 5.4 individuals /km^2 respectively in grass land and riverine forest.

Few studies have given emphasis in particular species. Dhungel and Ogara (1991) studied ecology, population structure, morphological feature and behaviour of Hog Deer in CNP and discussed about its narrow home range and diurnal habit. It has strong preference for tall grass and insignificant effect of density-dependent factors in habitat selection (Dhungel and Ogara 1991, Odden *et al.* 2005).

In the past, several direct and indirect techniques have been adopted for the estimation of population parameters. Pellets count is still in practice for population estimation (Dinerstein 1980, Massei *et al.* 1998, Shrestha 2004, Gautam 2005, Pokhrel 2005, Manandhar 2006, Thapa and Lohani 2007, Shrestha 2008, Karki 2009). Karanth (1999) suggested using pellet group counts to obtain indices of Tiger prey abundance only where line transects and direct sightings can not be conducted.

Shrestha (2004) used this technique and determined medium sized prey species (0.6 ± 0.04) more abundant than small (0.04 ± 0.01) and large (0.14 ± 0.02) prey in current TAL area. Bagale (2005) estimated the abundance of ungulates in CNP. His study shows that riverine forest was the most preferred habitat for ungulate. Gautam (2005), Pokhrel (2005), Manandhar (2006), Thapa and Lohani (2007), Shrestha (2008) have all shown that the most abundant species was Chital on their study area. Karki (2009) concluded that grassland and Khair-Sissoo association forest have high quality of habitat for wild ungulate and their predators on the basis of his study in Bardiya- Katarniyaghat corridor forest, Bardia.

In the current context, most appropriate and widely used method for estimating the density of biological populations is DISTANCE sampling (Buckland *et al.* 1993, Karanth and Sunquist 1992). Now, it has become the most standard monitoring tool for prey species in all Tiger range countries of south Asia (Wegge and Storaas 2009). In Nepal, studies are available using DISTANCE sampling. Yadav (2006) estimated overall density of ungulate in SWR 108.32 animals/km^2 with most dominant species, Chital (55.58 individuals/ km^2). In Karnali flood plain with in BNP, Wegge and Storaas (2009) has found population of prey species have increased four times in 1998 (201.9 animals/ km^2) than in 1976. They used radio-collar to monitor Hog Deer and Barking Deer in tall grassland and conducted total counts in different blocks. The political unrest of Nepal from 1996-2006 may have lead to the sharp decline of prey species in BNP due to the poaching of animals for wild meat (Malla 2009). She has got vast difference in density of Chital (85.32 Vs 190.8) compared to Wegge and Storaas (2009). She stressed that prey depletion should be explicitly recognized as a threat to persistence of Tigers apart from habitat loss, structural degradation of habitat and Tiger poaching. Densities of prey species has been estimated by many researchers in different interval of time. Thanet (2010) determined 78.70 animals /km^2 in CNP. Among the various

prey species, Chital was the most frequently encountered (16.7/ km^2) prey species followed by Hog Deer (14.5/ km^2) and Swamp Deer (5.6/ km^2) in SWR (Chalise 2011). Khadka (2011) has conducted a research in Karnali flood plain of BNP and estimated group density and overall density 30.64 and 73.11 animals/ km^2 respectively. Thapa (2011) has recorded higher density of ungulate in summer season than in winter season in CNP. This could be the reason of high visibility in summer. He estimated overall ungulate densities of 123.9, 101.8 and 84.3 animals/ km^2 in Barandabhar, Kasara and Padampur blocks respectively. Karki (2011) carried out similar work throughout the TAL. His results showed that SWR has highest prey density (144.8) fallowed by BNP, CNP and PWR 56.3, 51.7 and 6.6 animals/ km^2 respectively. Distance sampling from elephant back gave more accurate result than sampling on foot or from vehicles in BNP habitat (Wegge and Storaas 2009). Elephant transect helps to reduce prey disturbance and flight but it does not help to know the behaviour of animals (Wegge and Storaas 2009). They revealed that this technique has high accuracy only when the observation of animal is high and accurate density is difficult to obtain for rare species.

This type of study was carried out in several other countries besides Nepal. In India, Karanth and Sunquist (1992), Varman and Sukumar (1995), Khan *et al.* (1996), Karanth and Nichols (1998), Biswas and Sankar (2002), Jathanna *et al.* (2003), Bagchi *et al.* (2003), Gopal *et al.* (2010), Ramesh (2010) used Distance sampling for the estimation of density of prey species in different habitat. In Bhutan, Wang (2010) and in Bangladesh Khan (2012) did such type of sampling. Poaching and livestock grazing were the major problem in South India and thus declined the Tiger prey in Bhadra Tiger Reserve (Jathanna *et al.* 2003). The evaluation of Tiger population in Panna Tiger Reserve revealed that the area has high poaching activity with mean ungulate density 42.4 ± S.E. 8.4/ km^2 (Gopal *et al*. 2010). Ramesh (2010) has determined overall prey density 95.6/km^2 including wild ungulate (42.2/ km^2) in Madhumalai Tiger reserve, Tamilnadu. Wang (2010) noted that Jigme Sigme Wangchuk NP, Bhutan has low ungulate density in comparison to other areas in the Indian sub- continent due to the conflict with farmers and excessive grazing of livestock in park. Reza *et al.* (2002) estimated density of prey species in Sundarbans, Bangladesh.

SWR occupied high biodiversity in far western low land Terai. This reserve is the last strong hold of Swamp Deer and Hispid Hare (*Caprolagus hispidus*) (Shrestha 2008). Weaaver (1991) and Chaudhary (2005) studied on Bengal Florican (*Houbaropsis bengalensis*) and recorded 17 and 7.98 ± 6 individuals/km^2 respectively. Both of these studies have shown the bird as rare for Shuklaphanta grassland. Forty six pairs of Swamp Francolin were counted by Singh (2005) in different swampy areas of lake and river system. The grassland dominated by *Saccharum spontaneum, Imperata cylindrica* was the most preferred habitat for it. Problem of drinking water was seen in dry summer season for wild animals. So, Sharma (2006) suggested that artificial pump should be made in some lakes of SWR in dry summer season. He recorded altogether 14 Lesser Adjutants (*Leptoptilos javanicus*) from Baba Lake, Salgaudi Lake, Kalikech Lake and 26 and 27 pillars of Nepal – India border. Human activities like grazing, grass cutting, poisoning of water, burning and phanta management work of reserve brings the problem in bird's habitat (Singh 2005). Swamp Deer prefers the swampy flat grassland and usually avoid thick- forested area (Schaller 1967, Schaff 1978, Pokhrel 1996). So, they are found in southern belt of SWR. Gyanwali and Jnawali (2005) recorded 1607 Swamp Deer while Maharjan (2006) has got 1501 ± 20 Swamp Deer with relative abundance 1.795. Shortage of food and safe drinking water during hot season, frequent burning of grass lands, competition for food with other wild species, predation by Tiger, flood from Mahakali river and poaching from across the border were the main factors affecting the population of prey species (Bhatta 1998). He has noted 26.48 % reduction occurred in between 1997 and 1998. Subedi (2002) has done feasibility study on relocation of Swamp Deer from RSWR to RCNP. Yadav (2006) estimated pellet density and population density of Hispid Hare at 90.90 and 1.01 per hectare and indicated that the population of Hispid Hare was decreasing there.

3. MATERIALS AND METHOD

3.1 Materials

The scientific instruments used during the field study were

1. GPS (Garmin Etrex7)
2. Range finder (Bushnell 450)
3. Compass (Silva)
4. Camera (Canon,10.0 Megapixel, Zoom lens- 3X1S)
5. Topographic map of study area
6. Binocular (Bushnell 10X42)

3.2 Methods

3.2.1 Study Area

3.2.1.1 Location

This study was conducted in the Shuklaphanta Wildlife Reserve (305 km^2, gazetted in 1973), located between 28^o 45' 48" to 29^o 03' 15" North latitude and 80^o 05' 57" to 80^o 23' 19" East longitude (DNPWC/ PCP, 2004) in Kanchanpur district. The northwestern boundary adjoins agriculture land and settlement of Bhimdatta Municipality. The northeastern boundary goes across the Mahendra highway up to Churia hill. Its eastern boundary is Syali River, and southern and western boundary is bounded by Nepal India border (Figure 1). The buffer zone of SWR covers an area of 243.5 km^2.

3.2.1.2 Topography

The reserve and its surrounding area is comprised of flood plains of various river systems (Mahakali, Bahuni, Radha, Syali, and Chaudhar) and alluvial sandy soils. Its altitude ranges

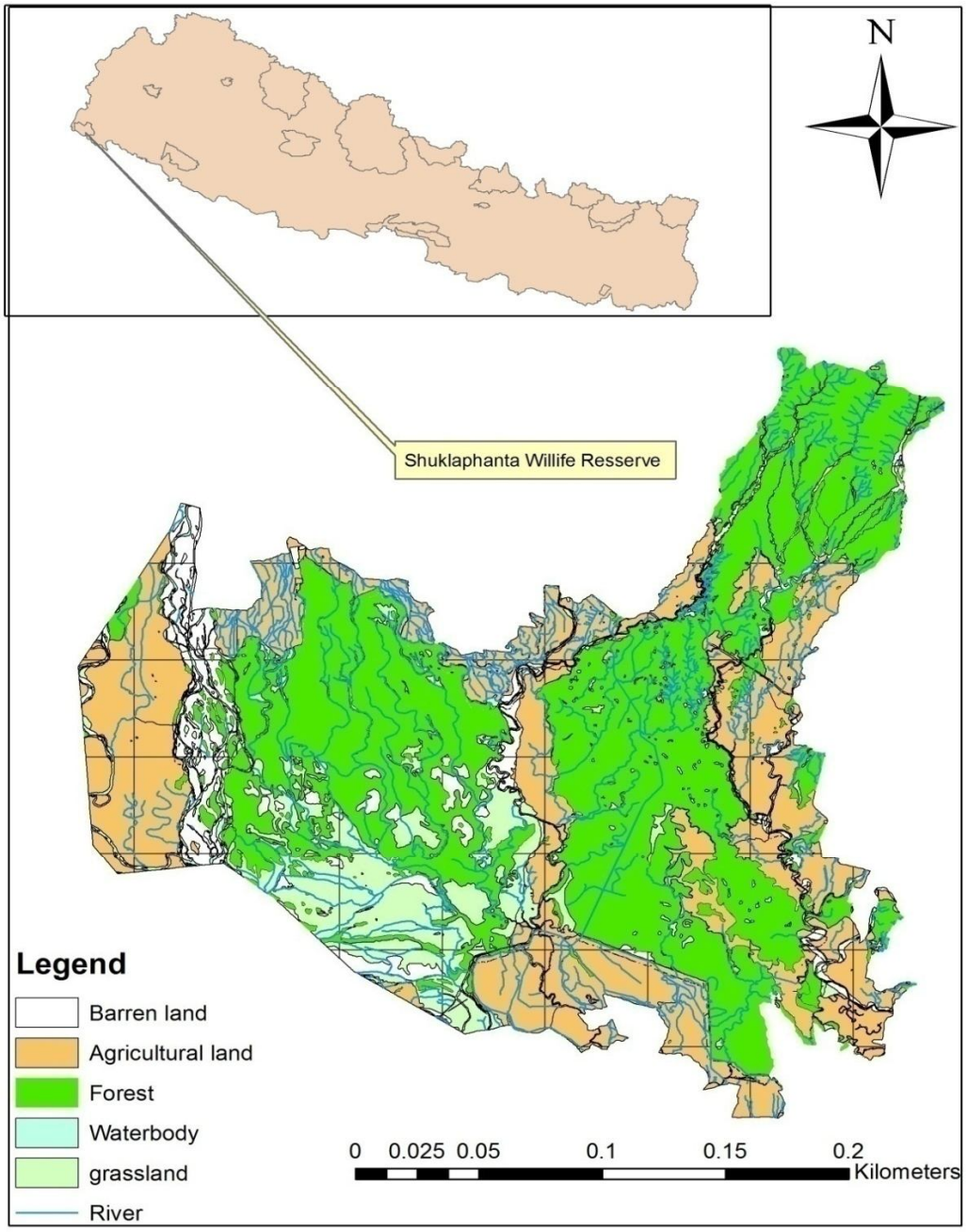


Figure 1: Map of SWR showing study area in Kanchanpur district, Nepal.

between 147 and 1383 m from sea level (DNPWC/ PCP, 2004). Its physiographic region is Terai- Siwalik. The area slopes gently away from the foothills (Churia hills) of the Himalayas in the north. The Siwalik ridge links the hills with the Terai forests by maintaining a natural corridor and allows for vertical migration of wild animals.

3.2.1.3 Climate

The climate is sub-tropical with three seasons. Summer is very hot and dry. It starts from third week of February and lasts up to second week of June. Recorded from 2000 to 2010, May is the hottest month of the year with mean maximum temperature 36.47 ºC (Figure 2). After monsoon season cold winter season starts and temperature decreases continuously. January is the coldest month of the year with average minimum temperature recorded from 2000 to 2010 was 7.31 ºC (Figure 2). During this period sky is covered with heavy fog and land has frost in nights and morning. Little rain occurs which arise from western part of the country during the winter season.

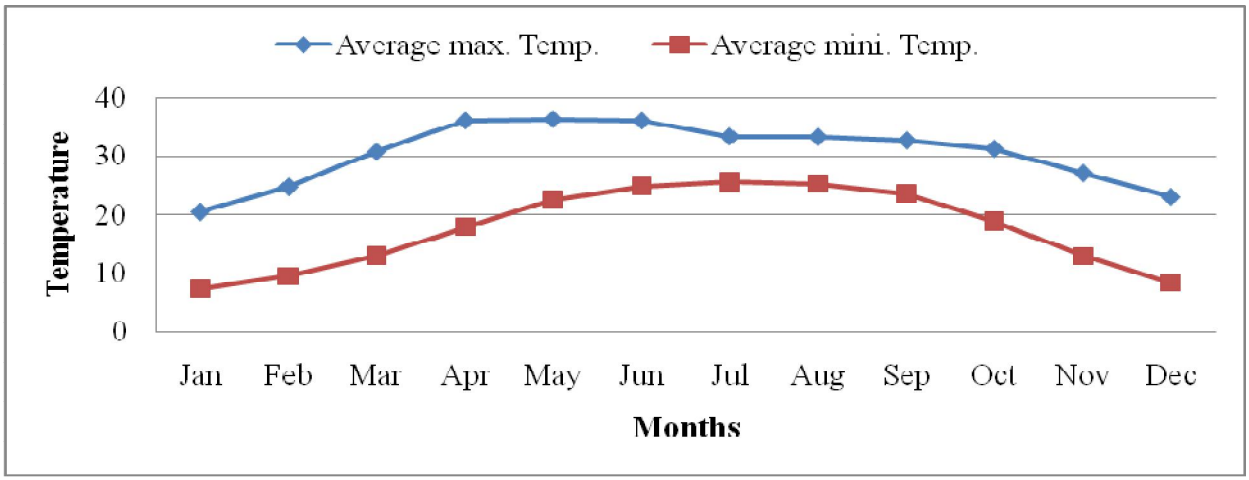


Figure 2: Average maximum and minimum temperature of Kanchanpur district (Mahendranagar station), Nepal (2000- 2010). (*Source: DHM/GOVN*)

Monsoon (Rainy) season starts from mid June to last week of September. Maximum rainfall occurred in August from 2000 to 2011 (Figure 3). The average annual rainfall of the season

from 2000 to 2011 was 1499.73 mm which was the 86.92 % of the total average rainfall of the year.

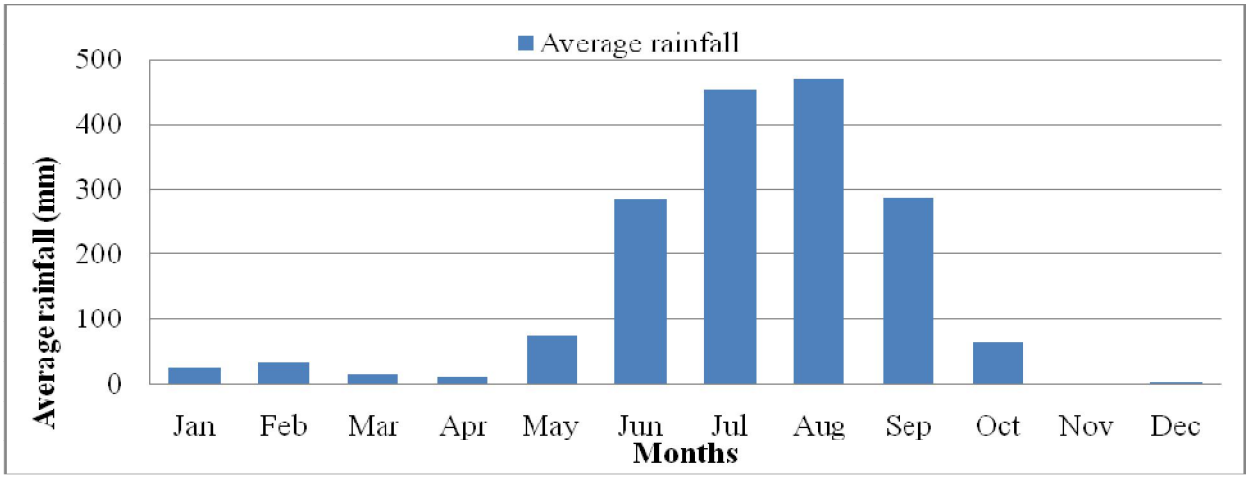


Figure 3: Average rainfall of Kanchanpur district (Mahendranagar station), Nepal (2000-2011). (*Source: DHM/GOVN)*

Relative humidity decreases from the month of April to June. It remains high throughout the year except April to June. Average maximum and minimum relative humidity recorded from 2000 to 2010 were 64.05 in April and maximum 95.29 in January respectively (Figure 4).

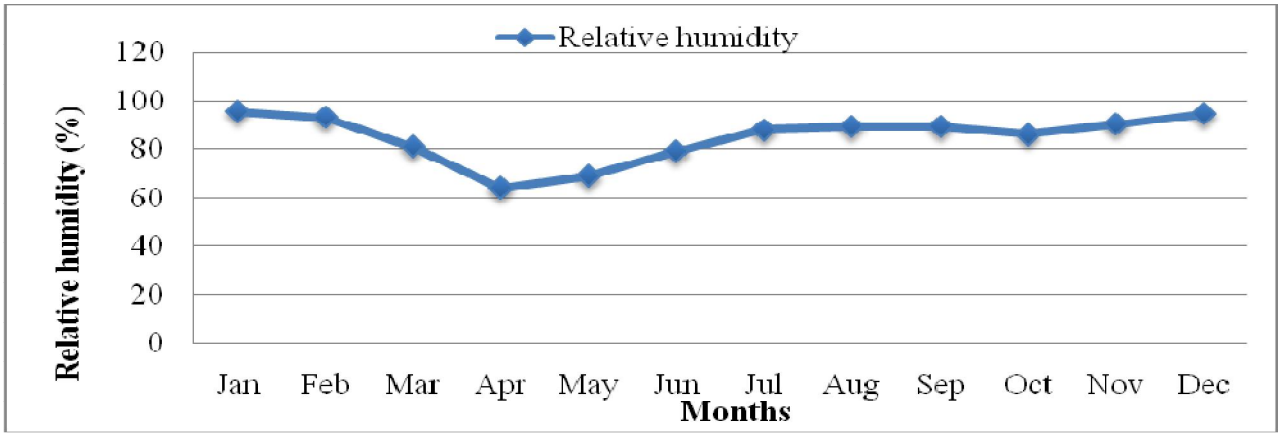


Figure 4: Average relative humidity of Kanchanpur district (Mahendranagar station), Nepal (2000- 2010). *(Source: DHM/GOVN)*

3.2.1.4 Vegetation

The vegetation is sub-tropical type which includes two third of the total area covered by forest and rest one third by grassland (Balson 1976, DNPWC 2011). The aquatic and terrestrial habitat of SWR contains more than 665 plant species belonging to 438 genera and 118 families (DNPWC 2011). Vegetations of SWR are classified into forest, grassland and aquatic habitats. The main vegetation in the forest area is the sal forest (52.5%), mixed deciduous forests (2.5%) comprises *Trewia nudiflora*, *Syzyzium cumini* and *Mallotus philippinensis.* and riverine forest (6.5%) includes *Acacia catechu, Dalbergia sisso* forest near Bahuni and Mahakali flood plains (Balson 1976). The proper phanta of the reserve occupied dense grassland (30.5%) including *Saccharum spontaneum*, *Saccharum bengalensis*, *Narenga spp*, *Vetiveria zizanoides*, *Eulaliopsis binata and Heteropogan contortus* and wetland (10.5%*)* (Schaaf 1978, Yadav *et al.* 2000).

3.2.1.5 Fauna

According to the current checklist SWR contains, 46 species of mammals, 424 species of birds, 12 species of reptiles, 5 species of amphibians and 24 species of Butterfly (DNPWC 2011). Among 46 species of mammals, 18 are listed under different Appendixes of CITES such as the Royal Bengal Tiger, Leopard, Sloth Bear (*Melursus ursinus*), Swamp Deer, Asian Elephant (*Elephas maximus*) and Hispid Hare. Greator one-horned Rhino were translocated from Chitwan National Park to establish a third viable population in the country (Bhuju *et al.* 2007). Its population was 7 (male 2, female 2, unknown adult 2 and unknown young 1) in 2011 (DNPWC 2011). Hog Deer, Chital, Barking Deer, Blue Bull, Wild Pig, Langur, Rhesus, Jackals (Canis *spp*.), Porcupine (*Hystrix indicus*), Jungle Cat (*Felis chaus*), Fishing Cat (*Prionailurus viverrinus*), Large Indian Civet (*Viverra zibetha*), Indian Pangolian (*Manis crassicaudata*) and Chinese Pangolian (*Manis pentadactyla*) are distributed in this reserves. This is the unique habitat for Swamp Deer and its estimated population in 2007 was 1674 (Khadka 2007) but its population became 1743 (male 337, female 1035 and young 371) in 2067 (2010) (DNPWC 2011). The reserve supports the highest population of Bengal Florican in Nepal (Baral and Inskip 2009). Swamp Francolin (*Francolinus gularis*), White Rumped Vulture (*Gyps bengalensis*), Slender Billed Vulture (*Gyps tenuirostris*), Jerdon's Bushchat

(*Saxicola jerdoni*), Hodgson's Bushchat (*Saxicola insignis*), Chestnut-Capped Babbler (*Timalia pileata*) and Jerdon's Babbler (*Chrysomma altirostre*), Yellow-Eyed Babbler (*Chrysomma sinense*), Finn's Weaver (*Ploceus megarhynchus*) and Rufous-Rumped Grassbird (*Graminicola bengansis*) (Baral and Inskip 2009). The globally threatened Mugger Crocodile (*Crocodylus palustris*) and Indian Rock Python (*Python morulus*) have been recorded as well as the Monitor Lizard (*Varanus spp*), Indian Cobra (*Naja naja*), Common Krait *(Bungarus caeruleus*) and Oriental Rat Snake (*Ptyas mucosus*) in SWR (Baral and Inskipp 2009, Majupuria and Kumar 1998).

3.3 Data collection

3.3.1 Site selection

The study area was already divided into six blocks with twenty permanent transects spaced one apart, established and used by Shuklaphanta Conservation Programme of National Trust for Nature Conservation for the regular monitoring of ungulate. I used total 26 transects for prey sampling (Figure 5) adding four more transects in the eastern side of Chahodhar river in the extended part of SWR and their GPS locations of transects are given in Annex two. The study area was characterized by sal forest, riverine forest, mixed forest and tall grass land.

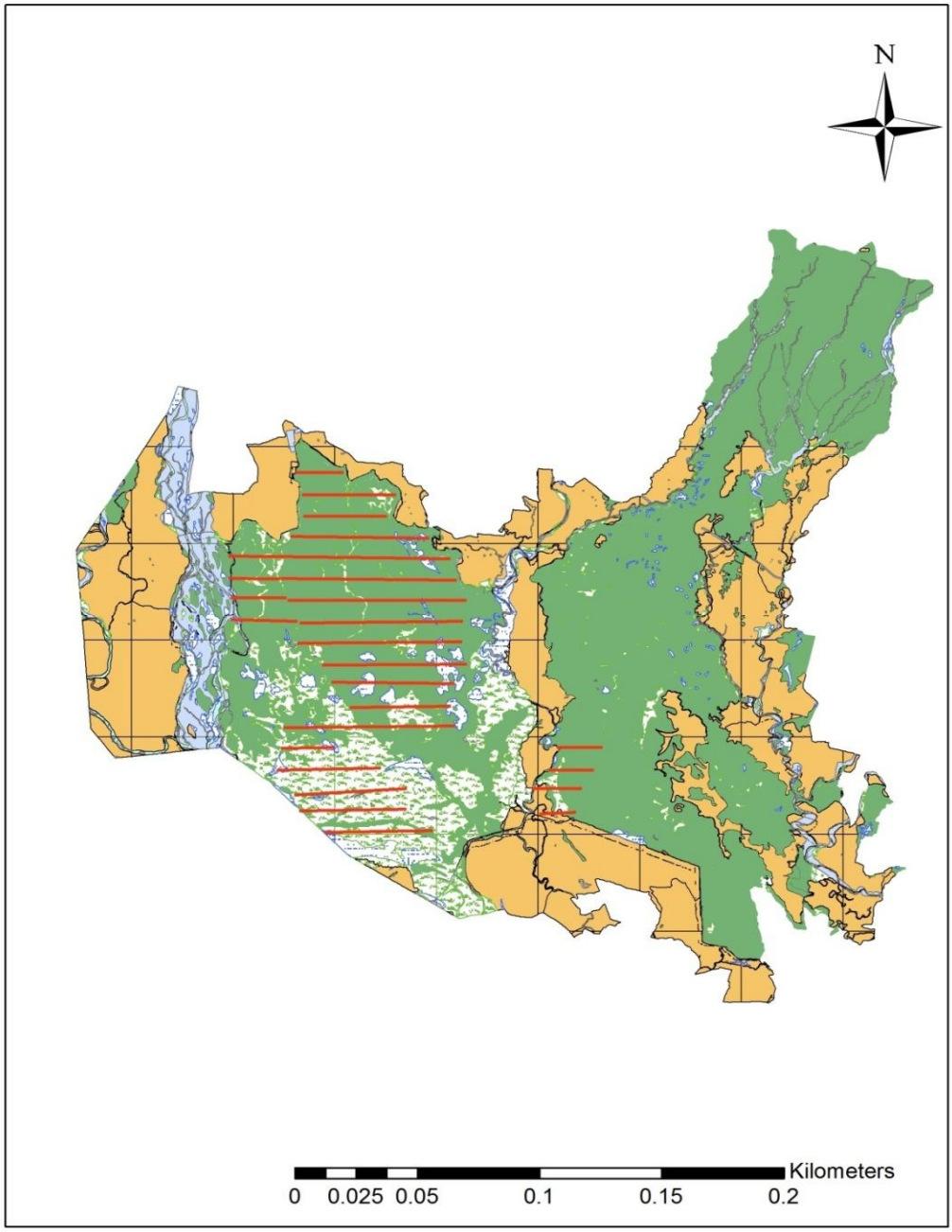


Figure 5: Map showing line transects in the intensive study area within SWR.

3.3.2 Prey sampling

The prey sampling work was conducted between 6th February and 1st March, 2012 and preliminary survey was conducted between 11 -18 January, 2012. Prey population was sampled by walking along the line transects except in the tall and wooded grassland, where domestic Elephant was used. Wegge and Storaass (2009) stated that the density estimates from Elephant did not differ from block counting of ungulate, except in the case of Barking Deer and Swamp Deer. A compass (Silvia) and a GPS (Garmin Etrex 7) were used to make sure that the walk was straight. Start and end points of these transects were recorded using GPS. A fixed bearing was followed until the termination of transect. In each observation of animal, distance from observation point, name of species, number of individuals, their cluster size, cluster composition and age-sex composition were recorded. Distance was measured by range finder (Bushnell 450). Animal or group of animals that were more than 50 m apart were considered separate in the study. Data were collected between 6.30 am and 10.30 am and 109.37 km sampling effort was covered.

3.3.3 Population structure

3.3.3.1 Age and sex- composition

Prey species were categorized into age and sex classes (adult male, adult female, sub adult male, sub adult female and young/juvenile) using combinations of sexually dimorphic physical characteristics, such as morphological configuration, external genitalia, age-specific differences in body size, presence, shape and size of antlers and bone lumps and association with parents (Schaller 1967, Eisenberg and Lockhart 1972, Mishra 1982). Age and sex of the animals were determined to the principal prey species.

3.3.3.2 Group size

Groups of animals were classified according to the number of individuals observed in the cluster size following the method used by Mishra (1982) (Table 1).

Table: 1 Population size range category.

Group size range	Population size category					
1	2-3	4-6	7-10	11-16	16-30	30+
Solitary animal	Family association	Small groups	Moderately small groups	Medium group	Large group	Very large group

Source: (*Mishra 1982*)

3.4. Data analysis

3.4.1 Density estimation

Population density of prey species was estimated using program DISTANCE 6.0 (Thomas *et al.* 2009). Data were arranged by using five cut points in equal interval within 150 m from line transects and discarded all observations beyond 150 m. The software has different detection function models like negative exponential decay, uniform decay, hazard rate and half normal along with cosine, simple polynomial and hermite polynomial key function adjustments**.** The most fitted model of each data set was selected on the basis of the lowest Akaike Information Criteria (AIC) values (Buckland *et al.* 1996, 2001, Burnham *et al.* 1980). The value indicated a compromise between the quality of fit and increased number of model parameters and the goodness of fit tests generated by program DISTANCE (Buckland *et al.* 2001). Once an appropriate model was selected in program DISTANCE, parameters such as encounter rates (n/L), strip width (ESW), average probability of detection (p), cluster size (Y) cluster density (DS), and prey density (D) with the associated coefficient of variance (CV %)

and 95% confidence interval were accessed (Burnham *et al.*1980 and Buckland *et al.* 1993). Chital met the criteria (minimum 40 detections) for the use of DISTANCE software as recommended by Buckland *et al.* (1993) but the densities of Hog Deer and primate were estimated under the same level of resolution (Global and Stratum). Encounter rate, detection function, and cluster size of all these species were estimated by the use of stratum level of resolution and global of detection probability. This type of work has been done by Wang (2008), Malla (2009), Karki (2011).

3.4.2 Bio-mass estimation

I estimated mean biomass (kg/km^2) of each prey species in the study area by multiplying mean ecological density (D) of each species by its average unit body weight derived from published data (Tamang 1982, Wegge *et al.* 2009).

3.4.3 Population structure- Sex ratio

The number of males in 100 females was taken as the sex- ratio. Similarly, young to female ratio was the total number of young/juvenile in 100 females.

4. RESULTS

4.1 Detection of prey species

A total 2170 individuals of nine prey species were detected in 133 clusters. These included Chital, Swamp Deer, Barking, Hog Deer, Wild Pig, Rhesus, Langur, Peafowl (*Pavo cristatus*) and domestic Cattle. A total 109.37 length of 26 transects in five blocks were sampled during this study. Chital, Hog Deer, Wild Pig, Rhesus, Langur and Peafowl were found in small herds whereas Swamp Deer and Cattle were found in large herds but the Barking Deer was recorded mostly in solitary. Number of observations of Chital were high but Barking Deer, Cattle, Wild Pig and Peafowl have low (Table 2).

Table 2: Detection (number of clusters) of prey species in Shuklaphanta Wildlife Reserve, Nepal.

S.N.	Prey species	Number of cluster	Number of individuals
1	Chital	64	511
2	Hog Deer	17	88
3	Swamp Deer	14	1010
4	Rhesus	10	54
5	Peafowl	7	28
6	Wild Pig	6	41
7	Langur	6	25
8	Barking Deer	5	5
9	Cattle	4	408

Preliminary analysis revealed that sufficient detections (>40) needed for analysis in program DISTANCE (Buckland *et al*. 1993) were obtained only for Chital (Table 2). Peafowl, Wild Pig, Langur, Barking Deer and Cattle have less than 10 detections. So, they were not used for separate analysis. Highest percentage of total individuals were occupied by Swamp Deer followed by Chital, Cattle, Hog Deer, Rhesus, Wild Pig, Peafowl, Langur and Barking Deer (Figure 6).

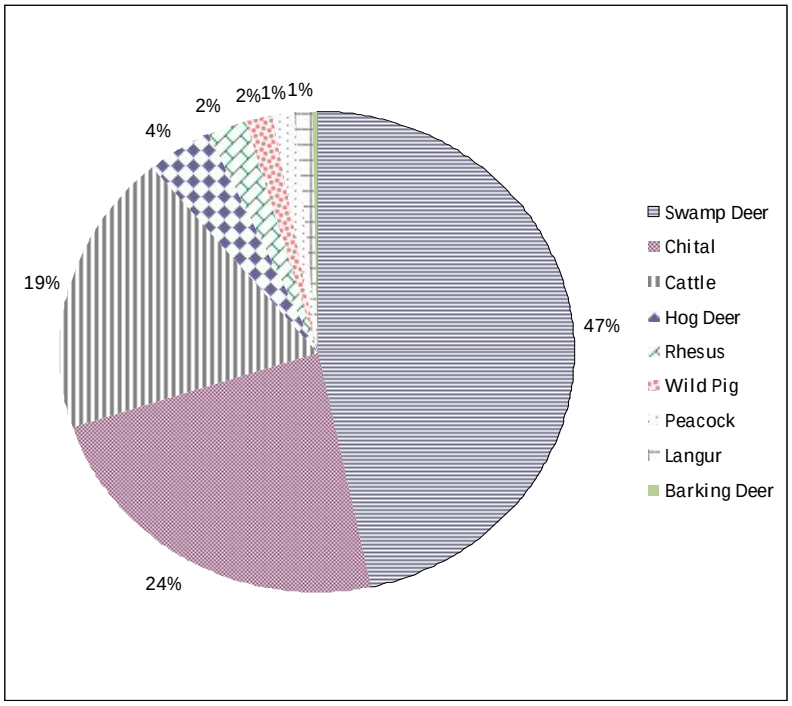


Figure 6: Proportion of individuals of different prey species in SWR, Nepal.

4.2 Densities of Prey Species

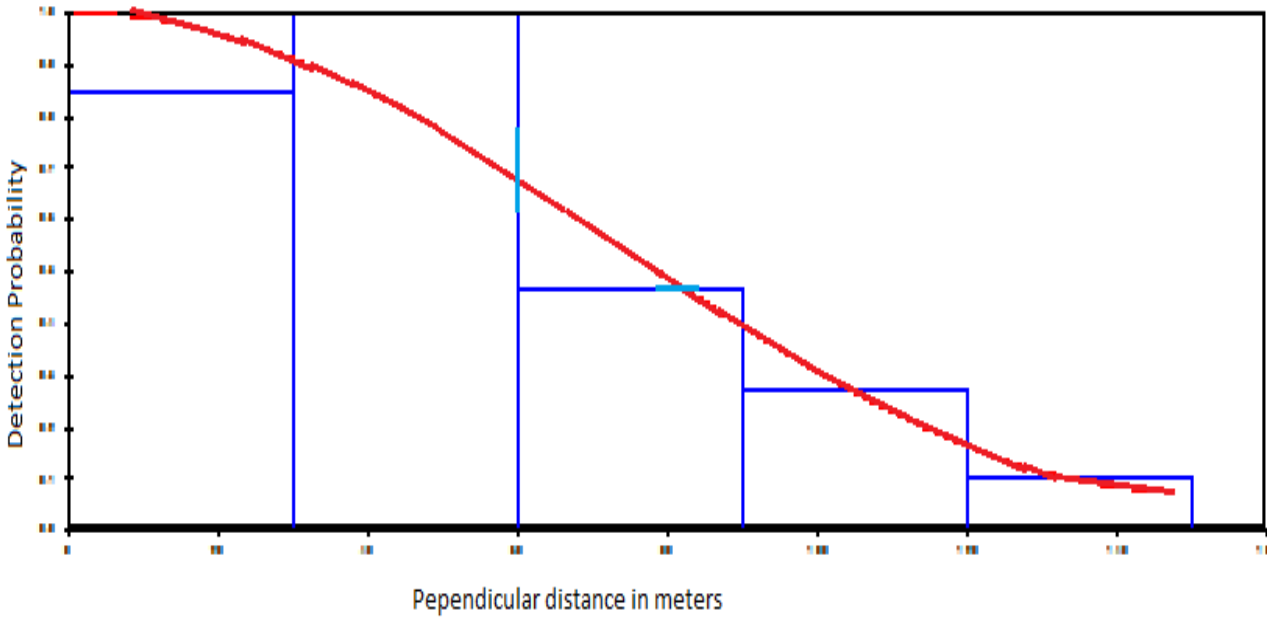


Figure 7: Detection probability curve (Uniform- cosine) for overall prey species in SWR, Nepal.

The overall group and individual densities of ungulate were 7.20/km^2 and 72.71/km^2 respectively (Table 3). A total 7635 individuals were estimated in 105 km^2 with detection probability, encounter rate, mean cluster size and AIC value 3.3, 62.1, 14.81 (3.93) and 359.83 respectively. The percent coefficient of variation of group density and ungulate densities were 19.69 and 24.35 respectively.

Table 3: Density of prey species in SWR, Nepal.

Species	Model	p-hat	ESW (SE)	Cluster	DS	CV% (DS)	D	CV% (D)	95% CI
Overall	Uniform Cosine	3.3	80.64 (3.55)	14.81 (3.93)	7.20 (1.41)	19.69	**72.71** (17.70)	24.35	44.99-117.50
Chital	Uniform Cosine	9.2	87.29 (7.15)	8.11 (1.28)	3.29 (0.74)	22.71	**28.99** (7.84)	27.07	17.03-49.35
Hog deer	Uniform Polynomial	6.0	50.72 (6.52)	5.5 (0.91)	1.44 (0.67)	46.95	**8.51** (4.47)	52.6	3.13-23.10
Primates	Uniform Polynomial	11.1	56.64 (8.29)	4.93 (1.19)	1.29 (0.39)	30.90	**6.79** (2.98)	43.89	2.91-15.87

P - hat = Detection probability, ESW = Effective strip width, Cluster = average cluster size, 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.

Chital was most frequently observed prey species that was detected in 20 out of 26 transects. The detection probability was 9.2 and estimated density was 28.99/km^2 with SE 7.84 and coefficient of variation 27.07 (Table 3).

Hog Deer density was estimated to be 8.51/km^2 with SE 4.47 and high coefficient of variation (Table 3). Hog Deer was found from transect numbers 14 to 18 within block four. Detection probability of this animal was 6.0.

Data of two primate species; the Langur and Rhesus were pooled together for analysis. The probability of detection of primate was 11.1 and density 6.79/km^2 with SE 2.89. It has also high coefficient of variation like Hog Deer (Table 3).

Summing the point estimates from each species that was analyzed separately, resulted in an estimated 4723 individuals of wild prey animals in SWR (does not include Swamp Deer - 14 observations, Peafowl - 7 observations, Wild Pig - 6 observations, and Barking Deer - 5 observations). This is less than the point estimate and confidence interval of the overall estimate of 7,635 wild prey animals in SWR (95% CI= 4,725 - 12, 337).

4.3 Biomass Estimation

Estimated biomass of the Chital and Hog Deer were 1565.46 and 280.83 kg/km^2 respectively calculated in the study area (Table 4).

Table 4: Density and biomass of major prey species in SWR, Nepal.

Species	**Average body weight (kg)***	**Density (Individual/km^2)**	**Biomass (kg/km^2)**
Chital	54	28.99	1565.46
Hog Deer	33	8.51	280.83

**Source: Tamang (1982).*

4.4 Population structure

4.4.1 Age- sex category

All species (Chital, Swamp Deer, Barking Deer, Hog Deer, Wild Pig, Rhesus, and Langur were classified into age- sex category (Figure 8 and 9). Among the observed species 77.64% of them were classified into age- sex category. Swamp Deer had highest population containing 46.54% of total individuals and Barking Deer has lowest population sharing 2.3% of total individuals (Figure 7). I could not classify 90.68% Cattle into their age- sex group which occupied the highest percent of unsexed prey species.

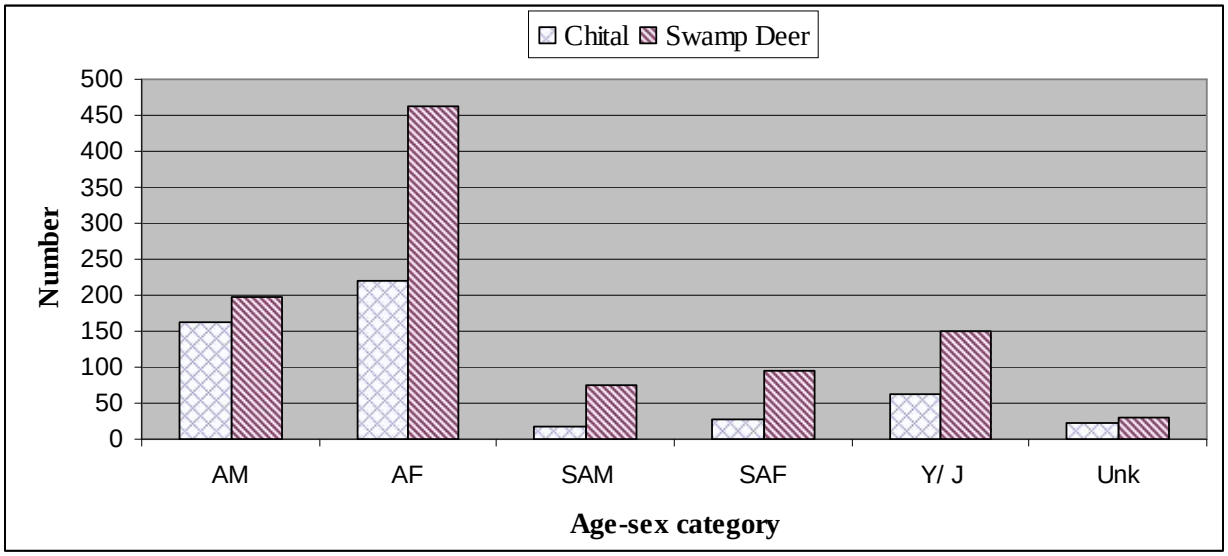


Figure 8: Age – sex category of Chital and Swamp Deer with their number in SWR, Nepal.

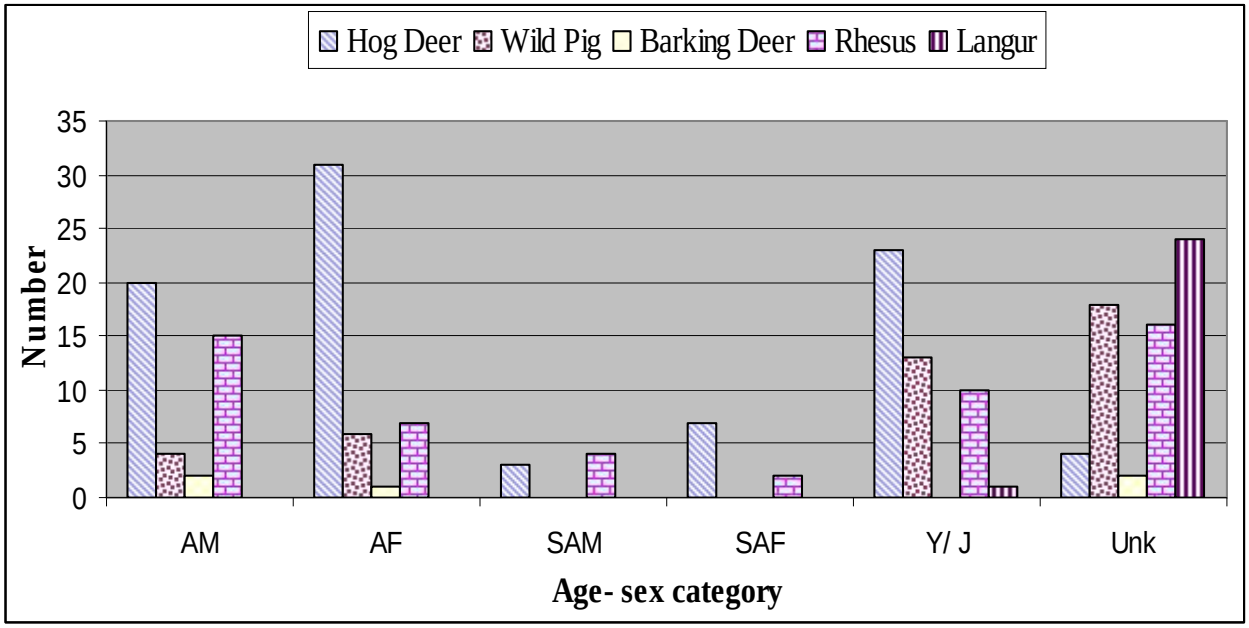


Figure 9: Age – sex category of Hog Deer, Wild Pig, Barking Deer, Rhesus and Langur with their number in SWR, Nepal.

Adult females were dominant in Chital, Hog Deer and Swamp Deer while male domination was recorded in Rhesus and Barking Deer (Figure 8 and 9). Highest percentage of young / juvenile group was recorded for Wild Pig and lowest percentage for Langur (Table 5).

Table 5: Proportion of different age-sex category of prey species in SWR, Nepal.

Species	Total no. of individuals	Percentage (%) of animals in each age- sex category.					
		AM	AF	SAM	SAF	Y/J	Unk
Swamp Deer	1010	19.6	45.84	7.32	9.4	14.95	2.87
Chital	511	31.7	43.05	3.32	5.47	12.13	4.30
Hog Deer	88	22.72	35.22	3.4	7.95	26.13	4.5
Rhesus	54	27.77	12.96	7.4	3.7	18.51	29.62
Wild Pig	41	9.75	14.63	-	-	31.7	43.9
Langur	25	-	-	-	-	4	96
Barking Deer	5	40	20	-	-	-	40

Highest proportion of reproductive group (adult male and adult female) was recorded in Chital which was followed by Swamp Deer, Barking Deer, Hog Deer, Rhesus and Wild Pig respectively (Figure 10).

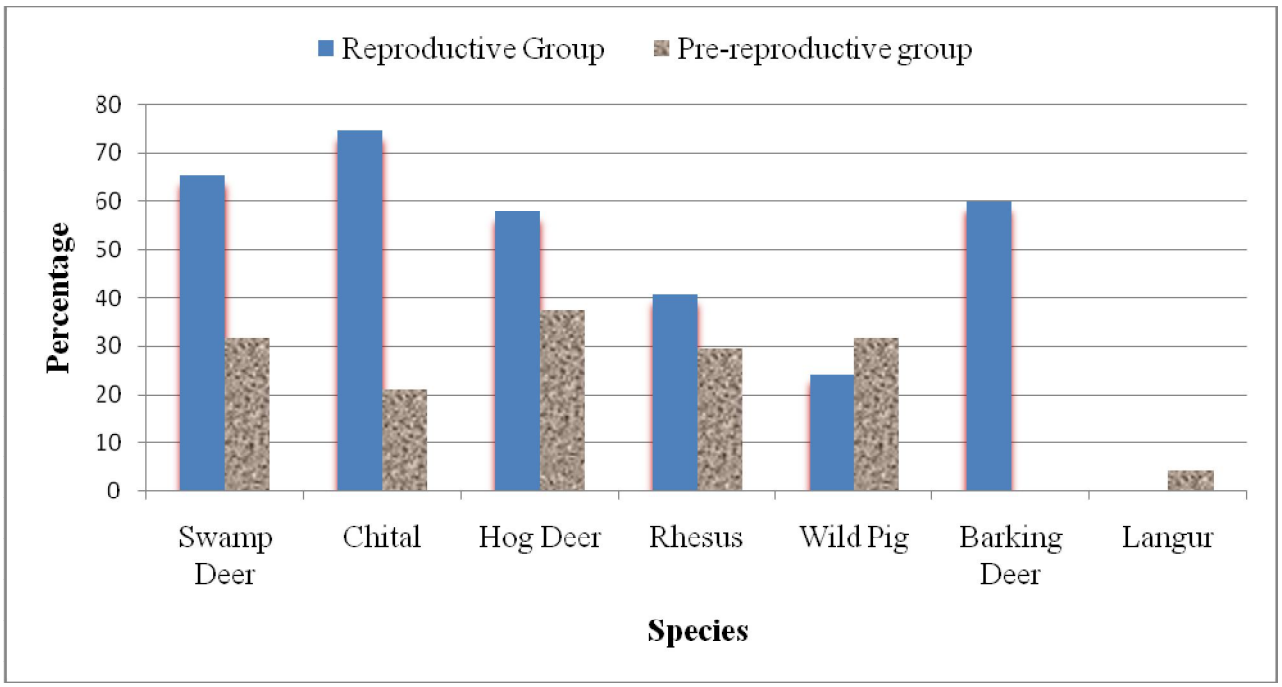


Figure 10: Proportion of pre-reproductive and reproductive age group of prey species in SWR, Nepal.

Similarly, highest proportion of pre-reproductive age group (sub adult male, sub adult female and young / juvenile) was recorded in Hog Deer followed by Wild Pig, Swamp Deer, Rhesus, Chital and Langur respectively (Figure 10). I could not detect reproductive age group of Langur and pre-reproductive age group of Barking Deer.

4.4.2 Group size

The statistics shows the range of group size, number of detection and the proportion (%) of group in each size category (Table 6). From these results it can be seen that Barking Deer is a non-social species which was found 100% solitary. But other species like Chital, Wild Pig, Rhesus and Hog Deer occupied intermediate positions in terms of sociality with the group

size frequencies being distributed among family associations, small groups and medium sized groups (Table 6). Swamp Deer was found in very large herds with more than hundred individuals in groups.

Table 6: Group size and group structure of ungulate and primates in Shuklaphanta WR, Nepal.

Name of Species	Group size range	Percent (%) in each group size category							
		N	Solitary	Family Associ-ation	Small group	Mod. Small group	Medium group	Large group	Very Large group
Chital	1- 61	64	7.8	29.68	23.43	10.93	15.62	6.25	4.68
Hog Deer	1- 14	17	5.88	29.41	11.76	35.29	11.76	-	-
Barking Deer	1	5	100	-	-	-	-	-	-
Swamp Deer	1- 402	14	7.14	-	14.28	28.57	-	14.28	35.71
Wild Pig	1- 13	6	16.67	16.67	33.33	33.33	-	-	-
Langur	1- 5	6	33.33	16.66	33.33	-	16.66	-	-
Rhesus	1- 19	10	20	30	10	30	-	10	-

4.4.3 Sex- ratio

The number of sub adults was added with their respective gender for the determination of sex- ratio. The sex ratios of Rhesus, Chital, Wild Pig, Hog Deer and Swamp Deer were 211, 72.14, 66.66, 60.5 and 48.75 respectively (Figure 11). Similarly, young to female ratios of Rhesus, Chital, Wild Pig, Hog Deer and Swamp Deer were 111, 25, 216, 60.5 and 27.06 respectively (Figure 11). Barking deer has male female ratio of 200 but it has no record of young.

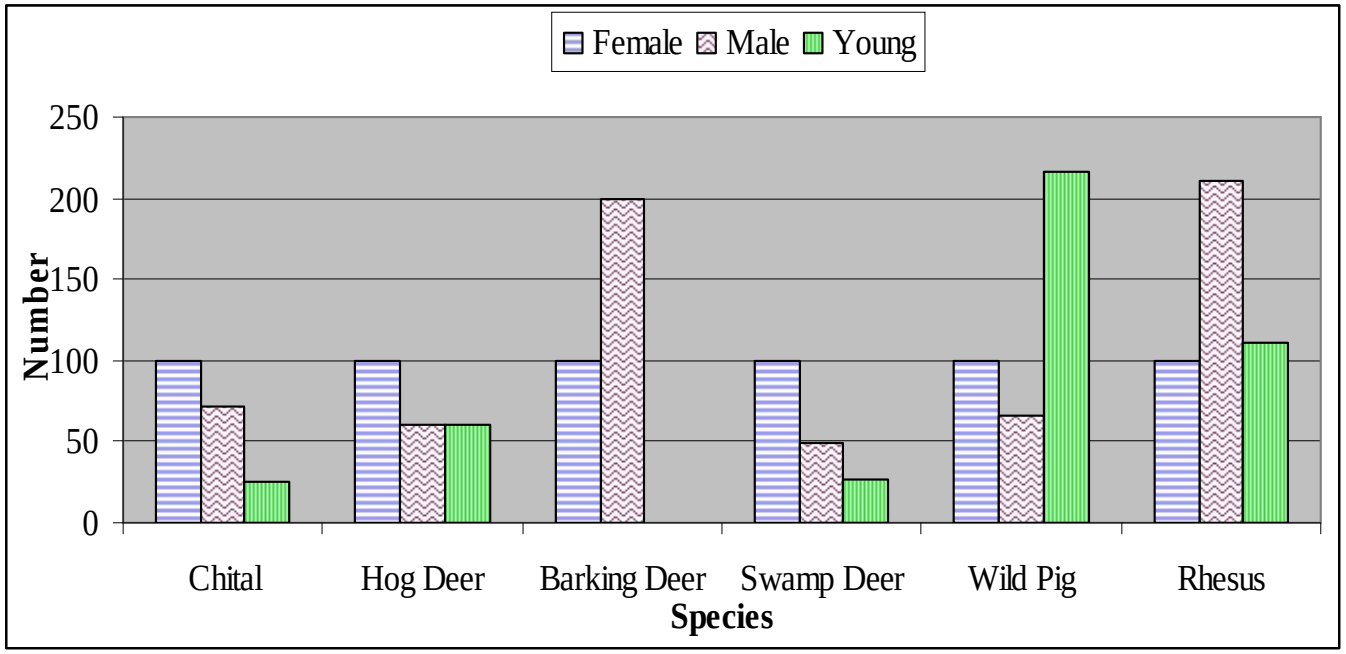


Figure 11: Sex and young to female ratios of prey species in Shuklaphanta Wildlife Reserve.

5. DISCUSSION

5.1 Detection of prey species

This study revealed that Chital was the most abundant prey species in Shuklaphanta Wildlife Reserve which was consistent with many other studies (Yadav 2006, Karki 2011). This species had wider distribution in various habitats such as sal forest with patches of short grass, riverine forest and open grassland with aquatic bodies (Schaller 1967, Mishra 1982). They occurred throughout the study area. I observed their presence in burnt tall grassland and near edges of reserve boundaries showing their preferences towards the cultivated crops. Thus, the detection and density of this animal was higher than other ungulate of SWR. Other species have limited distribution and were recorded only from some particular habitats.

I observed large herds of Swamp Deer in burnt grassland and managed phantas grazing over fresh young grass sprout. Swamp Deer prefers dry and wet swampy grassland as well as riverine forest including patches of short grassland (Khatri 1993, Pokhrel 1996, Wegge and Storaas 2009). Due to availability of such type of habitat in SWR, higher population of Swamp Deer was observed during this study. Although, the observations of the groups (14 groups) of Swamp Deer was lower but total individuals counted was high (1010 individuals). This species was observed only in four transect (14, 15, 16 and 17). This species was found grazing young grasses in small areas of Shuklaphanta around Hattisar, Machan and artificial pond which were growing after burning and cutting. So, the concentration of Swamp Deer was very high in such areas.

Hog Deer was detected only in tall and burnt grassland of Shuklaphanta for getting salty taste of ash. They are sedentary animals in the grasslands where food, water and cover are sufficient (Dhungel and O'gara 1991). In some places, they were recorded together with Swamp Deer.

Barking Deer is a solitary animal rarely observed in tall grassland. Low detection of Barking Deer may be attributed to the selective feeding behavior, territorial mechanism and small body structure (Karanth and Sunquist 1992).

The signs of Wild Pigs were observed throughout the study area but very few animals were directly sighted. Wild Pig is a selective feeder and feeds on foods such as roots, tubers, bulbs, fruits, seeds, insects and carrion of plants and animals. Hence, it has very long range of feeding ground (Prater 1971). Low detections of Wild Pig in study period could be because of its nocturnal habit and wide range of feeding ground (Cahill *et al*. 2003, Karki 2011) and other that due to its behavior, it tends to be underestimated in line transect in tall grassland, forest and shrub land habitat which is dominant in SWR.

Minor prey species like Rhesus, Langur and Peafowl were observed near agricultural field. Cattle were mostly found near reserve boundaries. Due to non-uniform distribution of animals, forest fire, inadequate observations, could be the reasons for less detection of animal clusters.

5.2 Estimation of Densities

The overall group density and individual density were 7.20 and 72.71 individuals/km^2 respectively contributed by Chital, Hog Deer, Swamp Deer, Barking Deer, Wild Pig, Rhesus, Langur, Peafowl and Cattle in the SWR. Densities and biomass of prey species helps in the study of predator ecology (Karanth and Sunquist 1995). Comparison between overall density of prey species of SWR with overall densities of other protected areas of Nepal, revealed that SWR has highest density of ungulate followed by BNP, CNP and PWR (Karki 2011). However, individual density estimate was the lowest in SWR (Yadav 2006, Karki 2011). In contrast to this study, Karki (2011) has sampled prey population during pre-monsoon season after burning grasslands and sprouting young shoots and used elephant for survey that substantially maximize observer height for sighting and minimize the prey disturbance and flight (Wegge and Storaas 2009). Poor visibility during winter season, tall grassland and transect walk on foot were possible reasons for lower density estimates in this study. In addition, multiple replications were not possible for me due to resource constraints.

The density derived from this study showed that Chital was the most abundant of all ungulate species. However the density of this species was lower than BNP and CNP as well as the densities estimated in previous studies in SWR (Yadav 2006, Malla 2009, Thapa 2011, Karki

2011). In SWR, the Chital was observed competing with grazing livestock in several blocks such as Beldandi (block - 6), Khayarbhatti (block - 1) and Pipariya (block - 2) side where domestic dog, people and their kids directly entered into the reserve. I encountered the attack on Chital by dog inside the reserve. Sankar(1994) and Mathai (1999) have reported decreasing ungulate populations in areas with high competition with livestock. I observed many snares and traps fitted on trails to protect cultivated crops from wildlife.

SWR has tall grassland in flood plain of Mahakali River and also has many patches of Riverine complexes. These types of habitats are very suitable for Hog Deer (Wegge and Storaas 2009). The high CV% of Hog Deer in the study (Table 3) could be the sampling error from the elephant as suggested by Naess and Anderson (1993). The estimated density of Hog Deer was greater than the studies of Yadav (2006) and lower than that of Karki (2011) in SWR (Table 7).

Table 7: The density (N/km^2) of animals in SWR, Nepal.

Date	**Chital**	**Hog Deer**	**Primates**
2006 *	55.85	6.5	-
2011**	79	21.6	14.8
2012/13***	28.99	8.51	6.79

*Yadav (2006), ** Karki (2011), *** Present study

Most of the detections of Monkeys were near cultivated land and boarder of the Reserve. Wang (2008) reported that primates prefer to stay near human settlement and agriculture land for securing their food in dry season. Densities of two primate species were estimated together due to the sample size constraints. Pooled density of Langur and Rhesus was lesser than the density estimated by Karki (2011) in SWR (Table 7). Probably, the low detections of primates inside the reserve were due to the scarcity of food in post winter season.

Determination of population structure was difficult due to large herd size of Swamp Deer and inadequate detections for DISTANCE sampling (Buckland et al. 1993). This produced unusual (high) value of CV%, unpredictable number of animals in the specified area and high

range of 95% CI so, the estimated density of Swamp Deer may not be appropriate to consider.

5.3 Biomass

Regular grass harvest and controlled burning over tall grassland helps in growing new generation of young grass which is the most preferred food of wild ungulate and also helps to increase the biomass of available prey population (Karanth and Sunquist 1992). Prey biomass is a fundamental factor for survival and growth of predator population as they directly correlate with each other (Carbone and Gittleman 2002). In SWR, the authorities annually have given permission to the local people for harvesting grass inside the reserve. According to the staff of reserve, they have managed a team for controlled burning in SWR especially in Swamp Deer habitat. These activities help to support incredibly high prey biomass, particularly during winter season.

Individual densities of Chital, Swamp Deer, and Hog Deer have major contribution for the overall prey biomass but biomass of Swamp Deer has not estimated due to the unreliable density. The estimated biomass of prey species was highest in Chitwan (Thapa 2011) followed by Bardia (Malla 2009) and SWR (Karki 2011). Biomass of Chital calculated by Karki (2011) in BNP and CNP was nearly equal to the value of biomass as estimated by this study.

Table 8: The biomass of Chital and Hog Deer in CNP, BNP and SWR, Nepal.

Location and researcher	Biomass of Chital (Kg/km^2)	Biomass of Hog Deer (Kg/km^2)
CNP Thapa (2011)	4695.66	143.44
BNP Malla (2009)	4521.96	133.92
SWR Yadav (2006)	3001.32	214.5
SWR Karki (2011)	4266	712.8
Present study	1565.46	280.83

The calculated biomass of Chital was lesser than the Yadav (2006) and Karki (2011). But the biomass of Hog Deer was found to be increased 30.92% within six years (Yadav 2006). The biomass of Hog Deer was found highest among CNP and BNP (Thapa 2011, Malla 2009).

5.4 Population structure

5.4.1 Age- sex category

I was unable to classify 22.36% of the species into their respective age-sex groups. Tall grassland, whose most of the transects were walked on foot, foggy weather, sensitive nature of animals were made difficult to classify wildlife into age-sex category. Highest percentage of Langur (96 %) could not be classified followed by Wild Pig (43 %), Barking Deer (40 %), and Rhesus (29.62 %). Remaining species have less than five percentage of unidentification. Almost all Langurs were on trees at significant height so, they could not be classified. Similarly, Cattle could not be classified due to the flight distance**.**

5.4.2 Group size

The animals were varying in numbers of individual in group (Table 6). Highest percentage of animal clusters was found in family association and lowest percentage of animal clusters was in very large group (group size more than 30). Karanth and Sunquist (1992) reported Chitals are gregarious and commonly found in medium to large groups. Mishra (1982) recorded highest percentage of cluster was in group size of 5 to 10 (Small group) in Chitwan National Park.

I observed Hog Deer in tall grassland of flood plain and riverine patches as reported by Wegge and Storaas (2009). One to fourteen individuals were observed in a cluster. Hog deer were recorded in solitary to medium sized group. Highest proportion of cluster was recorded in moderately small sized group (Table 6).

Barking Deer is a solitary, forest living species (Barrette 2004). I observed all animals in solitary stage but Johnsingh (1983) recorded up to four individuals in Bandipur. Barrette

(1977) recorded four Barking Deer in a group and they claimed that those groups are temporary. Swamp Deer usually like to stay in large herd (Khatri 1993, Pokhrel 1996). I found one to 402 individuals in a cluster. I recorded highest proportion (35.71%) of cluster in very large group (30+) size category. Availability of resource, protection from the predator could be the possible reasons behind their presence in large herd.

I recorded most of the clusters of Wild Pig in small and moderately small groups whereas least detections were in solitary and family associations (Table 6). I observed maximum 13 individuals in a cluster with female and young together but Johnsingh (1983) has recorded maximum 32 individuals in a single herd in Bandipur, India. Chauhan (2004) reported that the basic social group of Wild Pig includes at least one or more females.

Two species of primates; Langur and Rhesus were observed in different social groups. The group size of primate depends on the food resources. Newton (1987) revealed that the population of Langur is affected by the season, climate and availability of food resources. The mean group size of Langur and Rhesus increases in wet season when plenty of young shoots are there on trees (Jathana *et al*. 2003). I have found that 33.3 % of Langur and 10 % of Rhesus clusters were in small groups (4 – 6) but Karanth and Sunquist (1992) have found that 59 % of Langur and 56 % of Rhesus were in small groups. The risk of predation increases with increase in group size. Probably solitary nature and fragmented population groups of primate was due to the scarcity of food in jungle in mid winter season. In the groups of primates, Rhesus was more available and more social than Langur. Peafowl is a minor prey species mostly found in pairs but few of them were recorded in medium sized group having 11 to 16 individuals in a group. Cattle encroachment was found high in SWR during this study. They were usually found near the edge of the reserve. They have habituated to run away when frightened by security and other persons. So, I could not classify them in their respective age-sex category.

5.4.3 Sex – ratio

I found female biased sex- ratio in Chital, Swamp Deer, Wild Pig and Hog Deer but sex-ratio of Barking Deer and Rhesus were in favor of male (Figure 11). Similar type of sex-

ratio was obtained in principal prey species (Thapa 2011, Karanth and Sunquist1992). Female biased sex – ratio can be interpreted in terms of sexual selection (Clutton- Brock *et al.* 1977). But male biased result may not support to the future prey population because they have chance of predation, intra-specific competition and territorial behavior (Karanth and Sunquist1992). Good young to female ratio was found in Chital, Hog Deer, Swamp Deer and Wild Pig. This represents the good symptom of future prey population.

6. CONCLUSION AND RECOMMENDATIONS

Tiger is an umbrella species. Its abundance and distribution is directly correlated with the densities and biomass of prey species. Healthy prey population helps to support long term survival of Tiger therefore it should be monitored regularly. Distance sampling is one of the best and widely used techniques to determine the abundance of biological population. Now it is becoming important tool for determining the prey population in all Tiger range countries.

This study updated the density of potential prey species in Shuklaphanta Wildlife Reserve using DISTANCE sampling in post winter season. A total of 2170 individuals of nine prey species were detected. Due to some limitations like temporal replication, season, resources, all species (Swamp Deer, Barking Deer, Wild Pig, Hog Deer, Rhesus, Langur) were not sufficiently detected for analysis in the programm DISTANCE except Chital. However density of Hog Deer and Primates were estimated by following Wang (2008), Malla (2009), Karki (2011). As this reserve occupied largest herd of Swamp Deer in Nepal but its density could not estimated due to the cluster constraints. The overall density of ungulate was satisfactory but species wise densities were less in comparison with previous studies. It has very good ratios of male-female and young-female which is representing the symptoms of good future population. In the current context, the abundance of ungulate is likely to support good Tiger density in SWR.

The reserve occupied mosaic habitat of grassland, sal forest, riverine forest and mixed forest. This is a unique place for Swamp Deer. Conservation of ungulate requires management of habitat for successful protection of all prey species. The reserve has high encroachment of human, domestic Cattle and domestic Dog which can bring high competition for resource as well as high chance of disease spreading. Lack of boundary wall and fencing line, wildlife directly enter into the agricultural settlement which has brought high conflict with human. Poaching is another major cause of declining the population of wildlife in SWR (Karki 2011). The reserve is also affected by invasive species, illegal grazing, logging and fires either naturally or induced. B If the current threats are not reduced it will certainly Tiger prey species from their natural habitat.

Finally, SWR has high biodiversity, suitable habitat for wildlife and has possibilities to keep healthy prey population in order to achieve the goal of doubling the Tiger population till 2022.

I would like to suggest following recommendation on the basis of current study.

- Prey monitoring work should be continued for the effective conservation and management intervention and it should be done after burning and sprouting young grasses inside the reserve.
- People should be motivated for the use of alternative sources of energy like biogas plant, solar energy, bio briquette instead of collection fire wood from the jungle.
- Grassland management, water hole management, fire line construction and maintenance boundary wall or fencing line preparation should be done more effectively.
- Grazing should be controlled immediately inside the reserve and local people should be aware for keeping qualitative Cattle.

.

7. REFERENCES

Anderson, D. R., Laake J. L., Crain, B. R. and Burnham, K. P. 1979. Guidelines for the transect sampling of biological populations. Journal of Wildlife Management **43**: 70-78.

Bagale, R. P. 2005. A Study on Tiger- Prey Relationship in Royal Chitwan National Park, Nepal. A report submitted to Terai Arc Landscape Program, Protected Areas and Buffer zone (TAL-PA- BZ) Royal Bardiya National Park Thakurdwara, Bardiya, Nepal.

Bagchi, S., Goyal, S. P. and Sankar, K. 2003. Prey abundance and prey selection by Tigers (*Panthera tigris*) in a semi-arid, dry deciduous forest in western India. Journal of Zoology **260**: 285-290.

Balson, W. 1976. General Report on the Royal Shuklaphanta Wildlife Reserve, Project NEP 72/002, HMG/UNDP/FAO, Kathmandu.

Baral, H. S., and Inskipp, C. 2009. The Birds of Sukla Phanta Wildlife Reserve, Nepal. Our Nature (2009) **7**: 56-81.

Barrette, C. 1977. The social behavior of captive Muntjacs, *Muntiacus reevesi* (Ogilby 1839). Zeitschrift für Tierpsychologie **43**: 188-213.

Barrette, C. 2004. Ungulate of India, ENVIS. Bulletin (Wildlife and Protected), Wildlife Institute of India **7**: 17-28.

Berwick, S. 1974. The Gir Forest: an endangered ecosystem. American Scientist **64**: 28-440.

Bhat, S. D. 1993. Habitat use by Chital (Cervus axis) in Dholkhanda, Rajaji National Park, U. P. M. Sc. Thesis. Saurashtra University, Gujarat.

Bhatta, A. D. 1998. Factors effecting the population of Swamp deer *Cervus duvauceli duvauceli* at Royal Shuklaphanta Wildlife Reserve. M. Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Bhuju, U. R., Shakya, P. R., Basnet, T. B., Shrestha, S. 2007. Nepal Biodiversity Resource Book. Protected Areas, Ramsar Sites, and World Heritage Sites. International Centre for Integrated Mountain Development, Ministry of Environment, Science and Technology, in cooperation with United Nations Environment Programme, Regional Office for Asia and the Pacific. Kathmandu, Nepal.

Biswas, S. and. Sankar, K. 2002. Prey abundance and food habit of Tigers (*Panthera tigris tigris*) in Pench National Park, Madhya Pradesh, India. Journal of Zoology **256**: 411-420.

Buckland, S. T., Anderson, D. R., Burnham, K. P. and Laake, J. L. 1993. *Distance Sampling: Estimating Abundance of Biological Populations*. Chapman and Hall, London. United Kingdom.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L. and Thomas, L. 2001. Introduction to Distance Sampling. Oxford University Press. London. United Kingdom.

Buckland, S. T., Elston, D. A. and Beaney, S. J. 1996. Predicting distributional change, with application to bird distributions in north east Scotland Global Ecology and Biogeograph Letters **5**: 66–84.

Burnham, K. P., Anderson, D. J and Laake, J. L. 1980. Estimation of density from line transects sampling of biological populations. Wildlife Monographs **72**: 1-202.

Cahill, S., Llimona, F. and Gracia, J. 2003. Spacing and nocturnal activities of wild boar *Sus scrofa* in a Mediterranean Metropolitan Park. Wildl. Biol. **9** (1): 3-13.

Carbone, C. and Gittleman, J. L. 2002. A common rule for the scaling of carnivore density. Science **295**: 2273-2276.

Chalise, L. 2011. Prey abundance and trend of Tiger population in Shuklaphanta Wildlife Reserve. B. Sc. Thesis. Kathmandu Forestry College, Institute of Forestry, Tribhuvan University, Kathmandu, Nepal.

Chaudhary, R. 2005. Study on population status and distribution pattern of Bengal Florican *Haubaropsis bengalensis* in Royal Shuklaphanta Wildlife Reserve, Kanchanpur, Nepal. B. Sc. Thesis. Hetauda Forestry Campus, Institute of Forestry, Tribhuvan University, Kathmandu, Nepal.

Chauhan, N. P. S. 2004. Ungulate of India, ENVIS Bulletin (Wildlife and Protected), Wildlife Institute of India **7**: 203-218.

Chundawat, R. S., Habib, B., Karanth, U., Kawanishi, K., Ahmad Khan, J., Lynam, T., Miquelle, D., Nyhus, P., Sunarto, S., Tilson, R. and Sonam, W. 2011. *Panthera tigris*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011. 2. www.iucnredlist.org. Downloaded on 07 May 2012**.**

Clutton-Brock, T. H. and Harvey. P. H. 1977. Primate ecology and social organization. Journal of Zoology **183**: 1-39.

Dhungel, S. K. and Ogara, B. W. 1991. Ecology of the Hog Deer in Royal Chitwan National Park, Nepal. A publication of Wild life Society. Wildlife monograph **119**: 3-40.

Dinerstein, E. 1980. An ecological survey of the Royal Karnali-Bardia Wildlife Reserve, Nepal. Part III: Ungulate populations. Biological Conservation **18**: 5-37.

DNPWC/PCP. 2004. Department of national park and Wildlife Conservation/ Participatory Conservation Programme, Resource Profile, Royal Shuklaphanta Wildlife Reserve and Buffer Zone.

DNPWC. 2009. Annual report (2065/66-2008/09). Department of National Parks and Wildlife Conservation, Ministry of Forests and Soil conservation, Government of Nepal, Kathmandu.

DNPWC. 2010. Annual report (2066/67-2009/10). Department of National Parks and Wildlife Conservation, Ministry of Forests and Soil conservation, Government of Nepal, Kathmandu.

DNPWC. 2011. Annual report. 2067/68. Suklaphnta Wildlife Reserve. Gov. of Nepal, Ministry of forest and soil convention, Department of National park and Wildlife conservation.

DNPWC. 2013. Press released. Third global Tiger conservation day 2070 Sharaban 14 (29 July 2013).

Eberhardt, L. L. 1978. Transect methods for population studies. Journal of Wildlife Management **42**: 131.

Edgaonkar, A. 2008. Ecology of the Leopard (*Panthera pardus*) in Bori Wildlife Sanctuary and Satpura National Park, India. Ph. D. Thesis, the University of Florida, USA.

Eisenberg, J. F. and Lockhart, M. 1972. An ecological reconnaissance of Wilpattu National Park. Smithsonian Contributions to Knowledge **101**: 1-118.

Eisenberg, J. F. and Seidensticker, J. 1976. Ungluates in Southern Asia: A Consideration of Biomass Estimates for Selected Habitats. Biological Conservation **10**: 293-305.

Gautam, D. N. 2005. Abundance and distribution and habitat preferences of wild ungulate in Karnali flood plain of Royal Bardiya National Park. M. Sc. Thesis. School of Environmental Management and Sustainable Development (SchEMS), Kathmandu, Nepal.

Gopal, R., Quereshi, Q., Quereshi, M., Bhardwaj, M., Jagadish Singh, R. K. and Yadvendradev, V. J. 2010. Evaluating the status of the endangered Tiger *Panthera tigris tigris* and its prey in Panna Tiger Reserve, Madhya Pradesh, India**.** Oryx **44**: 383-389.

Harihar, A., Pandav, B. and Goyal, S. P. 2009. Responses of Tiger (*Panthera tigris*) and their prey to removal of anthropogenic influences in Rajaji National Park, India. European Journal of Wildlife Research **55**: 97–105.

Jathanna, D., Karanth, K. U. and Johnsingh, A. J. T. 2003. Estimation of large herbivore densities in the tropical forests of southern India using distance sampling. Journal of Zoology **261**: 285-290.

Johnsingh, A. J. T. 1983. Large mammalian prey- predators in Bandipur. Journal of the Bombay Natural History Society **80**: 1-57.

Johnsingh, A. J. T., Ramesh, K., Qureshi, Q., David, A., Goyal, S. P., Rawt, G. S., Rajapandian, K. and Prasad, S. 2004. Conservation Status of Tiger and associated species in the Terai Arc Landscape, India. Wildlife Institute of India.

Karanth, K. U. 1999. Counting the Tiger's prey, reliably. In Riding the Tiger: 104–105. Seidensticker, J., Christie, S. & Jackson, P. (Eds). London: Cambridge University Press.

Karanth, K. U. and Nichols, J. D. 1998. Estimation of Tiger densities in India using photographic captures and recaptures. Ecology **79**: 2852-2862.

Karanth, K. U. and Nichols, J. D. 2002. Monitoring Tigers and their prey: a manual for researchers, managers, and conservationists in Tropical Asia. Center for Wildlife Studies, Bangalore, India.

Karanth, K. U., Nichols, J. D., Kumar, N. S., Link, W. A. and Hines, J. E. 2004. Tiger and their prey: predicting carnivore densities from prey abundance. Proceedings of the Natural Academy of Sciences of United States of America. **101** (14): 4854–4858.

Karanth, K. U., Nichols, J. D., Seidensticker, J., Dinerstein, E., Smith, J. L. D., Mc Dougal, C., Johnsingh, A. J. T., Chundawat, R. S., and Thapar, V. 2003. Science deficiency in conservation practice: the monitoring of Tiger populations in India. Animal Conservation **6**: 141-146.

Karanth, K. U. and Stith, B. M. 1999. Prey depletion as a critical determinant of Tiger densities. In Seidensticker, J., Christie, S. and Jackson, P. (eds.). Riding the Tiger: Tiger conservation in human dominated landscapes. Cambridge University Press, Cambridge, UK. pp. 100-113.

Karanth, K. U. and Sunquist, M. E. 1992. Population structure, density and biomass of large herbivores in the tropical forests of Nagarahole, India. Journal of Tropical Ecology **8**: 21-35.

Karanth, K. U. and Sunquist, M. E. 1995. Prey selection by Tiger, Leopard and dhole in tropical forests. Journal of Animal Ecology **64**: 439-450.

Karki, A. 2009. Relative abundance and distribution of Tiger prey base in Bardiya, Katarniyaghat corridor forest, Bardiya, Nepal. B. Sc. Thesis. Kathmandu Forestry College (KAFCOL). Institute of Forestry, Tribhuvan University.

Karki, J. B. 2011. Occupancy and abundance of Tigers and their prey in the Terai Arc Landscape, Nepal. Ph. D. Thesis. Forest Research Institute University, Deharadun, Uttarakhanda, India.

Khadka, C. 2011. Abundance and distribution of Tiger and it's prey in Karnali flood plain of Bardiya National Park, Terai Arc Landscape. B. Sc. Thesis. Kathmandu Forestry College, Institute of Forestry, Pokhara, Tribhuvan University, Kathmandu, Nepal.

Khadka, G. 2007. Status and Conservation Issues of Swamp Deer *Cervus duvauceli duvauceli* in Nepal. B. Sc. Thesis. Tribhuvan University, Kathmandu, Nepal.

Khan, J. A., Chellam, R., Rodgers, W. A. and Johnsingh, A. J. T. 1996. Ungulate densities and biomass in the tropical dry deciduous forests of Gir, Gujrat, India. Journal of Tropical Ecology **12** (1): 149-162.

Khan, M. M. H. 2012. Population and prey of the Bengal Tiger *Panthera tigris tigris* (Linnaeus, 1758) (Carnivora: Felidae) and their prey in the Sundarbans, Bangladesh. Journal of Threatened Taxa **4** (2): 2370–2380.

Khatri, T.B. 1993. Status and Food habits of Nilgai (*Bocelaphus tragocamelus*) in Royal Bardia National Park. M. Sc. Thesis. Agricultural University of Norway.

Kortlandt, A. 1984. Vegetation research and the 'bull dozer' herbivores of tropical Africa. 205-226 in A.C. Chadwick and S. L. Sutton (eds). Tropical rainforest: the Leeds symposium. Leeds Philosophical and Library Society, Leeds.

Laake, J. L., Buckland, S. T., Anderson, D. R. and Burnham, K. P. 1994. DISTANCE user's guide, Version 2.1. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, Colorado.

Maharjan, K. 2006. Monitoring status and abundance of Swamp deer *Cervus duvauceli duvauceli* in grassland of Shuklaphnta Wildlife Reserve. B. Sc. Thesis. Department of Environmental Science and Engineering, School of Science, Kathmandu University, Nepal.

Malla, S. 2009. Estimating the Status and Impact of Hunting on Tiger Prey in Bardia National Park, Nepal. M. Sc. Thesis, Saurasthra University, India.

Manandhar, S. 2006. A study on relative abundance and distribution of ungulate by pellet count method in Shuklaphanta Wildlife Reserve, Nepal. B. Sc. Thesis. Department of Environmental Science and Engineering, School of Science, Kathmandu University, Nepal.

Massei, G., Bacon, P., Genov, P. V. 1998. Fallow deer and wild boar pellet group disappearance in a Mediterranean area. J. Wildl. Manage **62**: 1086–1094.

Mathati, M. 1999. Habitat occupancy across anthropogenic disturbances by sympatric ungulate species in Panna Tiger reserve. M. Sc. Thesis, Saurashtra University, Gujarat, India.

Mathur, V. B. 1991. The ecological interaction between habitat composition, habitat quality and abundance of some wild ungulate in India. D. Phil. Thesis University of Oxford, UK.

Mishra, H. R. 1982. The ecology and behaviour of chital (*Axis axis*) in the Royal Chitwan National Park, Nepal. Ph. D. Thesis. University of Edinburgh, UK.

Naess, K. J. and Anderson, H. J. (1993). Assessing Census technique for wild ungulate in Royal Bardiya National Park, Nepal. A thesis submitted to the Agriculture University of Norwey in partial fulfillment of the requirement for the degree of Master of Science in management and conservation of Natural Resources.

Newton, P. N. 1987. The Social Organization of Forest Hanuman Langurs *(Presbytis entellus).* International Journal of Primatology **8**: 199-232.

Odden, M., Wegge, P. and Storaas, T. 2005. Hog deer *Axis porcinus* need threatened tall grass floodplains: a study of habitat selection in lowland Nepal. Animal Conservation **8**: 1-6.

Paliwal, A. 2009. Geospatial modeling of ungulate habitat relationship in Tadoba- Andhari Tiger Reserve in Maharastra. Ph. D. Thesis, Saurasthra University, India.

Pokhrel, C. P. 1996. Habitat preference and food habits of Barasingha *Cervus duvauceli duvauceli* in Royal Bardiya National Park, Nepal. M. Sc. Thesis. Tribhuvan University, Kathmandu, Nepal.

Pokhrel, S. 2005. Distribution and abundance of wild ungulate in Royal Shuklaphanta Wildlife Reserve. M. Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu.

Prater, S. H. 1971. The Book of Indian Animals. Bombay Nat. Hist. Soc., Bombay, India. 2nd. ed. 324 p.

Ramesh, T. 2010. Prey selection and food habits of large carnivores: Tiger *Panthera tigris*, Leopard *Panthera pardus*, Dhole *Cuon alpinus* in Madhumalai Tiger Reserve, Tamilnadu. Ph. D. Thesis. Saurasthra University, Rajkot, Gujrat, India.

Reza, A. H. M., Foerez, M. M. and Islam, M. A. 2002. Prey species density of Bengal Tiger in the Sundarbans. J. Asiat. Soc. Bangladesh, Science **28** (1): 35-42.

Roberge, J. M. and Angelstam, P. 2004. Usefulness of the Umbrella Species Concept as a Conservation Tool. Conservation Biology **18** (1): 76-85.

Sankar, K. 1994. The ecology of three large sympatric herbivores (Chital, Sambar, Nilgai) with special reference for reserve management in Sariska Tiger Reserve, Rajasthan. Ph. D. Thesis. University of Rajasthan, Jaipur, India.

Sankar, K, A. and J. T. Johnsingh. 2002. Food habits of Tiger (*Panthera tigris*) and Leopard (*Panthera pardus*) in Sariska Tiger Reserve, Rajasthan, India, as shown by scat analysis. Mammalia **66:** 285-289.

Schaaf, C. D. 1978. Population Size and Structure and Habitat Relation of the Swamp Deer (*Cervus duvauceli duvauceli*) in Shuklaphanta Wildlife Reserve, Nepal. Ph. D. Thesis. Michigan State University, USA. 111p.

Schaller, G. B. 1967. The deer and the Tiger. University of Chicago Press. Chicago, Illinois. USA.

Seidensticker, J. 1976. Ungulate populations in Chitwan Valley, Nepal. Biological Conservation **10:** 183- 210.

Seidensticker, J., Christie, S. and Jackson, P. 1999. Preface. Pages xv–xix in Seidensticker, J., Christie, S., Jackson, P. eds. riding the Tiger: Tiger Conservation in Human-dominated Landscapes. Cambridge (United Kingdom): Cambridge University Press.

Sharma, S. 2006. Population status and distribution of Lesser Adjutant *Leptotilos javanicus* in far western lowland, Nepal. Tiger paper **33** (4): 9-11.

Shrestha, M. K. 2004. Relative ungulate abundance in fragmented landscape: Implication for Tiger conservation. Ph. D. Thesis. Faculty of Graduate School, University of Minnesota.

Shrestha, S. 2008. Study on relative abundance and distribution of Tiger prey base species (Ungulate) by pellet count in Shuklaphanta Wildlife Reserve, Nepal. B. Sc. Thesis. Department of Environmental Science and Engineering, School of Science, Kathmandu University, Nepal.

Singh, P. B. 2005. Population status and habitat utilization of Swamp Francolin (*Francolinus gularis*) in RSWR, Nepal. A report submitted to Oriental Bird Club, U. K. Feb. 2005.

Steneck, R. S. 2005. An ecological context for the role of large carnivores in conserving biodiversity. In Ray, J. C., Redford, K. H., Steneck, R. S., Berger J. (eds.). Island Press, Washington, D. C. Large carnivores and the conservation of biodiversity. pp. 9-32.

Subedi, N. 2002. Feasibility study on translocation of Swamp deer (*Cervus duvauceli duvauceli*) from Royal Shuklaphanta Wildlife Reserve to Royal Chitwan National Park. A report submitted to TAL- DNPWC, Thakurdwara, Bardiaya.

Sunquist, M. E. 1981. The social organization of Tigers in Royal Chitawan National Park, Nepal. Smithsonian Contributions Zoology **336**: 1-98.

Sunquist, M. E., Karanthand, K. U., Sunquist, F. 1999. Ecology, behaviour and resilience of the Tiger and its conservation needs. In Seidensticker, J., Christie, S. and Jackson, P. (eds.), Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes, pp. 5–18. Cambridge University Press, Cambridge, UK.

Sunquist, M. E. and Sunquist, F. 2002. Wild Cats of the World. The University of Chicago Press, Chicago, USA.

Sunquist, M. E. and Sunquist, F. C. 1989. Ecological constraints on predation by large felids. In: Gittleman JL (Ed) Carnivore behavior, ecology, and evolution. Cornell University Press, Ithaca, NY, p 283–301.

Tamang, K. M. 1982. The status of the Tiger (*Panthera tigris tigris*) and its impact on principle prey populations in the Royal Chitwan National Park, Nepal. Ph. D. Thesis. Michigan State University, USA.

Thanet, D. R. 2010. Ecological study of Tiger (*Panthera tigris*) in Chitwan National Park, Nepal. B. Sc. Thesis. Institute of Forestry, Pokhara, Tribhuvan University.

Thapa, K. and Lohani, S. 2007. Tiger went up the hill: A case study from Parsa Wildlife Reserve in the Terai Arc Landscape, Nepal. Submitted to National Parks and Wildlife Conservation and University of Missouri, Tiger for Tiger Program.

Thapa, P. S. 2008. An assement of increasing factors of poaching and illegal wildlife trade: A case study from Shuklaphanta Wildlife Reserve. B. Sc. Thesis. Institute of Forestry, Pokhara, Tribhuvan University.

Thapa, T. B. 2011. Habitat suitability evaluation for Leopard (*Panthera pardus*) using remote sensing and GIS in and around Chitwan National Park, Nepal. Ph. D. Thesis. Saurasthra University, Rajkot, Gujrat, India.

Thomas, L., Laake, J. L., Strindberg, S., Marques, F. F. C., Buckland, S. T., Borchers, D. L., Anderson, D. R., Burnham, K. P., Hedley, S. L., Pollard, J. H., Bishop, J. R. B. and Marques, T. A. 2006. Distance 6. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, United Kingdom. http://www.ruwpa.st-and.ac.uk/distance.

Thomas, L., Laake, J. L., Rexstad, E., Strindberg, S., Marques, F. F. C., Buckland, S. T. Borchers, D. L., Anderson, D. R., Burnham, K. P., Burt, M. L., Hedley, S. L., Pollard, J. H., Bishop, J. R. B. and Marques, T. A. 2009. Distance 6.0. Release 2. Research Unit for Wildlif Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance.

Timmins, R. J., Steinmetz, R., Baral, H. S., Kumar, N. S., Duckworth, J. W., Islam, Md. A., Giman, B., Hedges, S., Lynam, A. J., Fellowes, J., Chan, B. P. L. and Evans. 2008. *Rusa unicolor*. In: IUCN 2008. IUCN Red List of Threatened Species. Downloaded on 12 December 2010**.**

UNEP-WCMC (Comps.) 2011. Checklist of CITES species (CD-ROM). CITES Secretariat, Geneva, Switzerland, and UNEP-WCMC, Cambridge, United Kingdom.

Varman, K. S. and Sukumar, R. 1995. The line transects method for estimating densities of large mammals in a tropical deciduous forest: an evaluation of modes and field experiments. Journal of Biosciences **20**: 273-287.

Wang, S. W. 2010. Estimating population densities and biomass of ungulate in the temperate ecosystem of Bhutan. Oryx **44:** 376- 382.

Weaver, D. J. 1991. A survey of Bengal Floricans at Royal Shuklaphanta Wildlife Reserve and Royal Bardiya National Park, western Nepal. A report submitted to Oriental Bird Club, CLO the Ledge, Sandy, UK.

Wegge, P., Odden, M., Pokharel, C. P. and Storaas, T. 2009. Predator–prey relationships and responses of ungulate and their predators to the establishment of protected areas: a case study of Tigers, Leopards and their prey in Bardia National Park, Nepal. Biological Conservation **142**: 189–202.

Wegge, P., Shrestha, A. K., Moe, S. R., 2006. Dry season diets of sympatric ungulate in lowland Nepal: competition and facilitation in alluvial tall grasslands. Ecological Research **21**: 698–706.

Wegge, P and Storaas, T. 2009. Sampling Tiger ungulate prey by the distance method: lessons learned in Bardia National Park, Nepal. Animal Conservation **12**: 78–84.

Yadav, R. P., Thaguna, S. S. and Sah, J. P. 2000. Grassland in Royal Shuklaphanta Wildlife Reserve: Status, Importance and Management In: Protected Areas of Nepal. Vol. 2 Technical and status papers on grasslands of Terai protected Areas: 128-137.

Yadav, H. K. 2006. Density, Biomass and Distribution of Tiger's Prey Species in Shuklaphanta Wildlife Reserve, Western Lowland, Nepal. M. Sc. Thesis. Department of Environmental Science and Engineering, School of Science, Kathmandu University, Nepal.

Annex - 1: Field data sheet

Date: ……
Transect ID: ……..
Bearing:……
Time start: ……
Time end:…....
GPS Start 44R: ……
UTM: ……
Habitat type:……
GPS end 44R: ……
UTM: ……
Location start:…..
Weather: ……
Transect length:……
Location end…….

S.N	Species	Age/sex Number					Sighting Angle	Sighting Distamce	Location		GPS reading		Animal Activity	Habitat Type
		AM	AF	SAM	SAF	Y/J			Start	End	N	S		

Annex - 2: Location of line transects in SWR, Nepal.

Transect	Transect	GPS Start		GPS End			Starting	Ending
I.D	Length (km)	44R	UTM	44R	UTM	Habitat	Elev (m)	Elev (m)
B1T1	1.86	419083	3202370	417222	3202418	SF	204	200
B1T2	3.76	421219	3201292	417458	3201398	SF	193	197
B1T3	3.5	420933	3200293	417430	3200386	SF	200	191
B1T4	5.5	422459	3199257	416976	3199401	SF	200	198
B1T5	6.8	423399	3198217	416588	3298412	SF	180	190
B3T6	7.03	423612	3197223	416577	3197406	SG	199	190
B3T7	7.02	423943	3196184	416807	3196387	SG	181	198
B3T8	6.55	417273	3195285	423824	3195235	SF	183	197
B3T9	6.68	423864	3194238	417193	3194286	SF	187	189
B3T10	5.76	418187	3193239	423949	3193239	SF	192	186
B3T11	4.83	423467	3192241	418631	3192368	SF	179	181
B3T12	5.99	419260	3191233	423377	3191248	SF	171	181
B4T13	6.79	416672	3190289	423458	3190251	SF	170	180
B4T14	2.2	418654	3189312	416453	3189312	RF	163	172
B4T15	4.41	416127	3188322	420540	3188278	TG	167	166
B4T16	5.41	421525	3187313	416407	3188278	TG	166	177
B4T17	4.32	421567	3186305	417240	3186303	TG	168	178
B4T18	4.47	418116	3185289	422583	3185045	TG	160	168
B2T5	2.06	414531	3198471	416588	3198412	RF	182	189
B2T6	2.09	416588	3198412	416577	3197406	RF	183	190
B2T7	2.24	416807	3196387	414565	3196448	SF	185	170
B2T8	2.77	414503	3195347	417273	3195285	SF	170	185
B6T14	1.9	427560	3189211	429418	3189158	SF	177	166
B6T15	1.8	429034	3188187	427259	3188216	SF	184	164
B6T16	2.11	426520	3187218	428610	3187167	SF	167	144
B6T17	1.4	428253	3186176	426850	3186196	SF	168	158

SF- Sal forest, SG short grass land, RF riverine forest, TG- tall grass land

Annex - 3: Rainfall, temperature and relative humidity of Kanchanpur district (Mahendranagar station)

Month	Temp	2000	2001	2002	2003	2004	2005	2006	2007	2009	2010	Total	Average
Jan	Max	19.6	20	22.2	15.6	15.6	26.6	22.7	20.7	23.5	18.2	204.9	20.49
	Min	7.7	6.7	6.1	7.7	7.6	8	6.8	5.2	9	8.3	73.1	7.31
Feb	Max	22.4	25.6	25.1	23.6	24.8	23.8	26.3	23.5	27.7	25.2	248	24.8
	Min	7.7	7.6	9	9.6	9.7	10.1	11.7	9.4	10	10	94.8	9.48
March	Max	29.4	30.4	32.2	33	30.3	30.3	31.7	28.3	32.1	32.5	308.6	30.86
	Min	11.3	11.4	14.4	13.3	13.4	13.5	12.3	12.6	12.5	15.2	129.9	12.99
April	Max	35.9	36.1	35.2	36.3	35.7	35.9	36	35.1	37.2	38.6	362	36.2
	Min	17.2	17.4	18.6	18	19.2	16.9	18	17.3	16.4	20.6	179.6	17.96
May	Max	35.3	35.9	36.1	37.5	36.9	37.6	35.6	35	36.6	38.2	364.7	36.47
	Min	24	23.2	24.5	21.8	22.8	21.4	22.8	20.9	21.8	22.9	226.1	22.61
June	Max	32.7	33.9	35.9	35.5	34.2	39.9	36.1	37.7	38.1	37.7	361.7	36.17
	Min	24.7	24.3	25.5	24.7	24.6	24.1	25.9	25.8	23.9	24.8	248.3	24.83
July	Max	32.9	34	34.4	31.9	33.9	33.5	33.4	32.6	34.6	33.3	335	33.5
	Min	25.8	25.4	26.5	25.6	25	25.1	25.7	25.8	25.8	25.3	256	25.6
Aug	Max	32.1	34	32.8	-	34.6	34.1	33.5	32.5	33.3	33.5	300.4	33.38
	Min	25.1	25.4	25.3	-	25.7	24.5	25.8	25.5	25.1	25.1	227.5	25.27
Sept	Max	32.2	34.6	30.8	32.8	32.5	33.6	32.7	32.9	33.1	32.6	327.8	32.78

	Min	23.3	23.3	22.8	21.2	24.2	24	24	24.9	24.1	24	235.8	23.58
Oct	Max	31.2	33.3	31.2	31.3	30	30.6	31.6	-	31.1	32.1	282.4	31.37
	Min	18.4	20	18.5	18.5	17.6	19.6	19.5	-	18.1	19.6	169.8	18.86
Nov	Max	27.8	26.1	27.6	27.5	26.6	27.2	26.9	-	27.3	27	244	27.1
	Min	13.9	10.6	12.4	12.4	11.6	14.5	12.8	-	13.3	14.9	116.4	12.93
Dec	Max	23.9	22.9	22.3	22.4	22.9	23.8	23.1	-	23.5	23	207.8	23.08
	Min	7.7	8.4	9.3	9.3	8.9	6.9	8.8	-	8.4	7.5	75.2	8.35

Rainfall in Kanchanpur district:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	24.4	32.8	2.5	15	132.1	443.9	510.3	413	203.5	0	0	0
2001	12.6	32.8	9	0	113.3	524.1	300.4	312.3	32.3	26.7	0	0
2002	68.4	32.8	0	27.3	35.3	229.9	265.8	754	253.5	13.3	3.5	5.5
2003	51.3	32.8	3.7	18.4	31.5	259.6	577.2	491	644.2	0	3.5	8.8
2004	47.5	32.8	0	0	79.1	297.5	368.1	239.1	317.1	35.6	0	0
2005	52.3	32.8	36.8	0	43.5	54.3	602	376.2	426.9	8.1	0	5.5
2006	0	32.8	33.1	27.8	94	220.6	625.9	244.9	48.3	10.8	0	3.2
2007	0	32.8	54.8	16.3	48.1	416.5	642.8	302	209.2	8.6	0	1.9
2008	5.9	32.8	0	3.9	53.6	513.3	498.8	336.8	426.8	77.4	0	0
2009	0	32.8	20.9	9.3	38	105.9	235.6	719.9	261	589.5	9.1	3.1
2010	1.9	32.8	0	0	22	149.9	514.2	634.7	431.9	0.3	1.7	0.9
2011	27.7	32.8	0.3	11.2	217.2	217.2	290.9	838.3	215.4	0	0	20
Total	292	393.6	161.1	129.2	907.7	3432.7	5432	5662.2	3470.1	770.3	17.8	48.9
Average	24.33	32.8	13.42	10.76	75.41	286.05	452.66	471.85	289.17	64.19	1.48	4.07

(Source:DHM/GOVN).

Data of Relative Humidity in Kanchanpur district of at 8:45am.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	95.9	88	73.6	57.3	72	85	85.7	90.8	85.9	84.1	90.7	96.2
2001	95.6	92.2	70.9	46.8	64.6	82.1	85.2	87.5	85.4	85.6	98.2	96.4
2002	97.7	93	71.6	56.1	60.9	72.8	84.1	89.1	87.1	83.9	87	95.1
2003	96.3	91	78.9	55.1	50.2	77.7	86.2	-	93.7	84	88.4	95.5
2004	95.3	96.5	83.2	67.4	71.2	81.2	90.1	86.4	88.1	81.8	82.7	90.4
2005	89.4	89.3	78.7	60	55.9	63.1	86.3	87.6	86.9	81.3	86.7	91.6
2006	95.7	94.6	90.8	58	79	83.5	91.6	86.3	87.3	88.5	91.7	93.1
2007	95	95	87.4	87.6	76.7	83.6	87.4	88.3	87.5	-	-	-
2009	95.5	94.9	83.9	59.7	63.3	69.7	89.2	91.8	94.3	89.7	91.4	95
2010	96.5	93.8	89.8	92.5	94.6	90.8	92.9	94.6	96	95.5	94.5	95.9
Total	952.9	928.3	808.8	640.5	688.4	789.5	878.7	802.4	892.2	774.4	811.3	849.2
Average	95.29	92.83	80.88	64.05	68.84	78.95	87.87	89.15	89.22	86.04	90.14	94.35

(Source: DHM/GOVN).

Annex - 4: Photo references of prey species in SWR, Nepal.

Herd of Chital

Langur in forest

Nilgai (Source: SCP-NTNC, 2012)

Rhesus with her young

Wild Pig (Source: SCP-NTNC, 2012)

Herd of Swamp Deer

Annex - 5: Fecal matter of wildlife taken from the field work in SWR, Nepal.

Feces of Wild Pig

Pellets of Swamp Deer

Scat of Tiger

Pellets of Chital

Pellets of Nilgai

Pellets of Barking Deer

Annex - 6: Photos of the field visit in SWR, Nepal.

Transect walk on foot

Encounter with killed Wild Pig

Sighting of wildlife

Rescue of Chital

Pugmark of Tiger

Transect walk through Elephant