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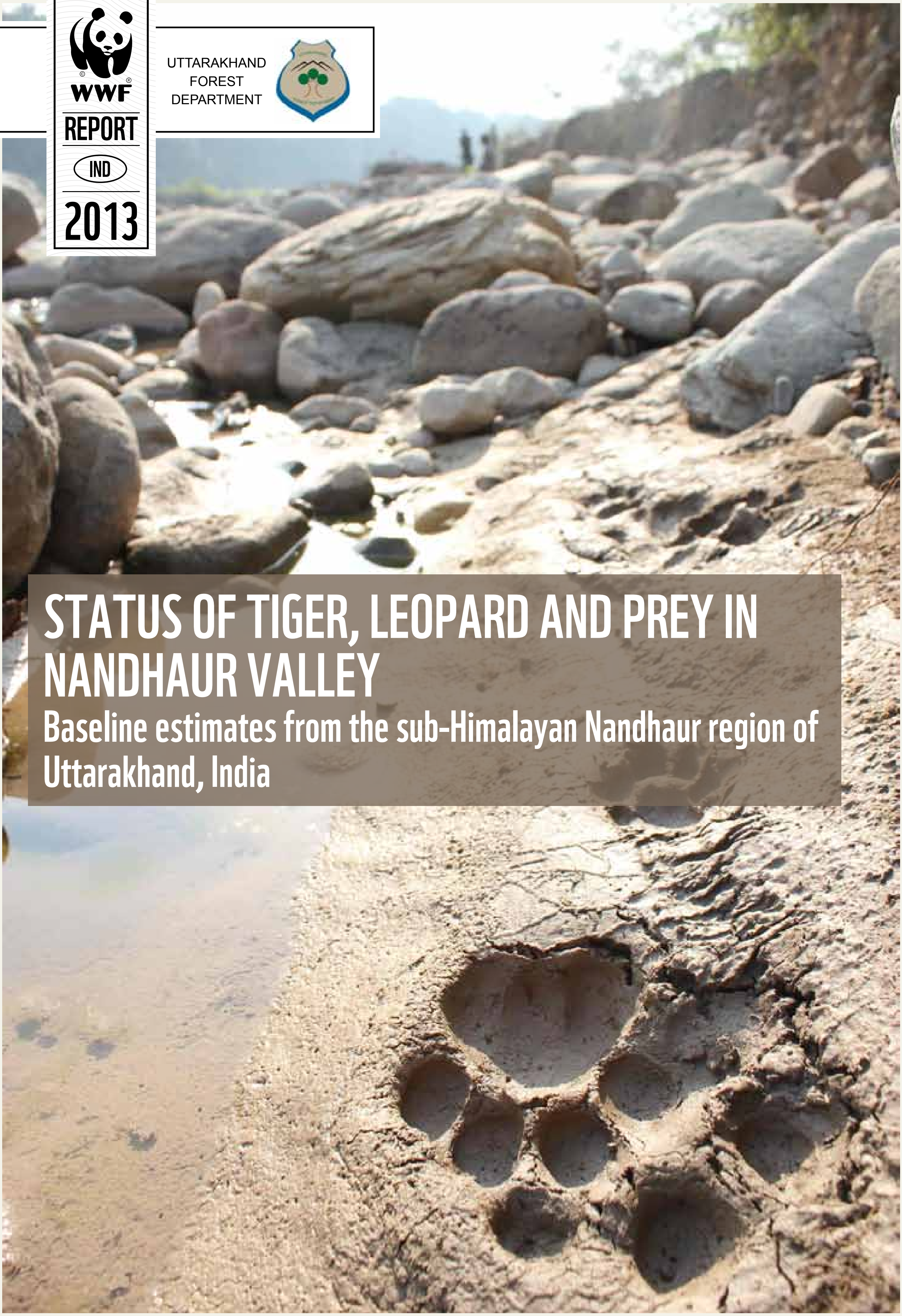

STATUS OF TIGER, LEOPARD AND PREY IN NANDHAUR VALLEY

Baseline estimates from the sub-Himalayan Nandhaur region of Uttarakhand, India

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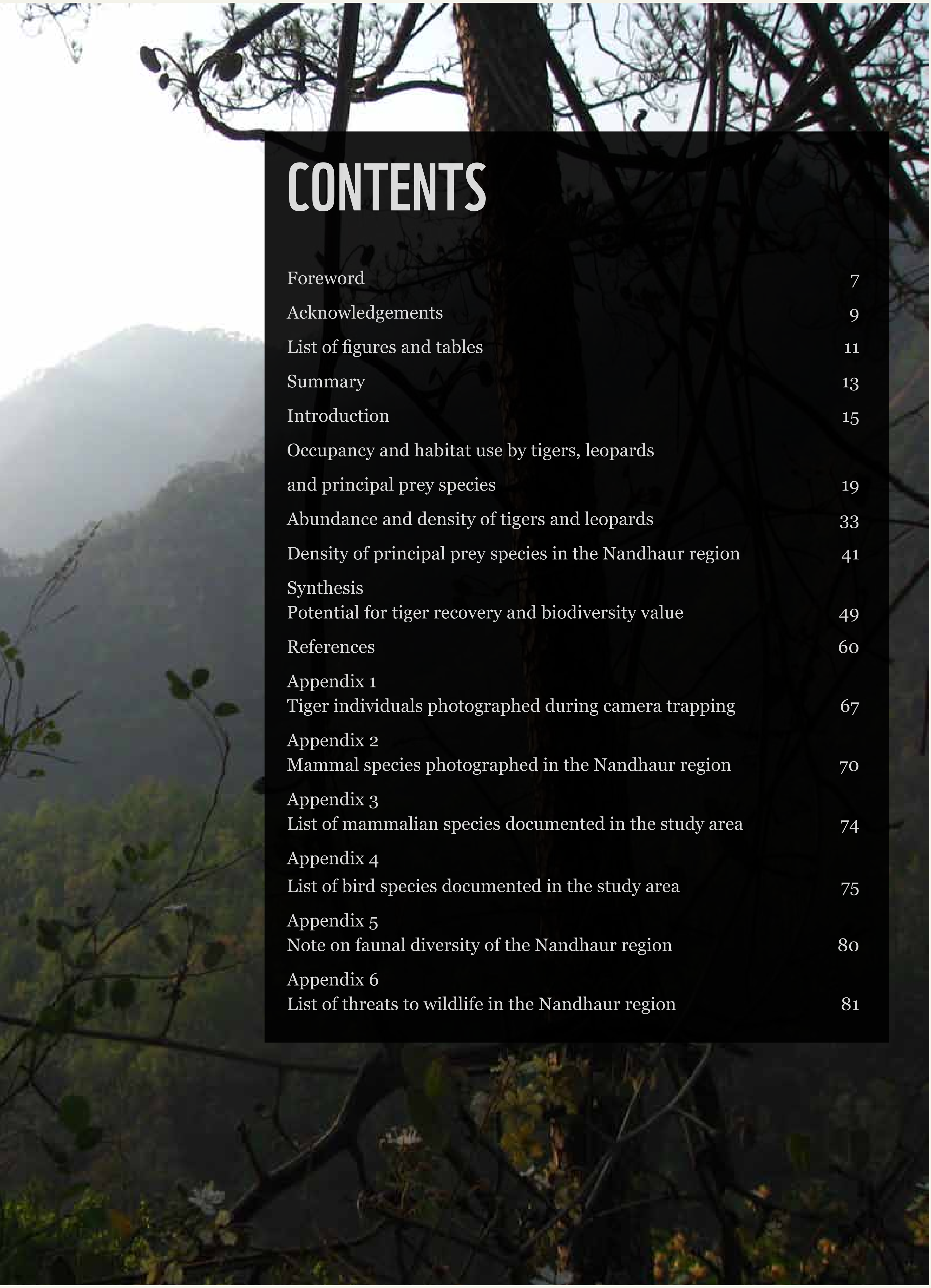

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उत्तराखण्ड शासन
डा० रघुबीर सिंह रावत, भा०व०से०
प्रमुख वन संरक्षक, उत्तराखण्ड

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FOREWORD

The status of tiger, a charismatic carnivore, is a matter of concern in all tiger range countries. India now is the last stronghold of wild tigers and provides hope for the future of this animal. Within India, lies the Terai Arc Landscape (TAL), a critical Level 1 Tiger Conservation Unit along the Himalayan foothills straddling the Indo-Nepal border and which accounts for nearly 20% of the tiger population in the country.

The Nandhaur river valley, lying at the core of this landscape, has been viewed by conservationists as a forest tract with immense potential to harbor good tiger and prey population. The region, recently due to various forms of anthropogenic pressures, indicated a decline in mammalian population. I was glad to know when WWF-India initiated a conservation program for the Nandhaur region and proposed to carry out a status survey of tigers, co-predators and its prey in the region.

The present report is an outcome of the said survey and provides insight to the varied biodiversity as well as issues, challenges and problems from the region. There is no doubt that Nandhaur region harbours breeding population of tigers, as was evident from the present study, which also augurs well for the region from conservation perspective. The high leopard density and presence of other associated wildlife including various species of birds, makes Nandhaur valley a valuable biodiversity place.

I offer my sincere thanks, and congratulate Shri Amit Verma, IFS, DFO - Haldwani and WWF-India and its team for carrying out this important survey and coming up with this valuable report. The result of this study provides a perspective not only from the standpoint of a conservation unit for tigers but also as a critical habitat patch for many faunal elements that constitute the natural heritage of the Terai Arc Landscape. I am sure this report would be utilized by key stakeholders for better wildlife management and forest protection strategy for the region.

My best wishes to WWF-India for their efforts to complement research and conservation of biodiversity in the landscape.

15.1.2013

Dr. R. B. S. Rawat, IFS
PCCF and Head of Forest Force, Government of Uttarakhand

ACKNOWLEDGEMENTS

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This study was made possible by the support we received from WWF-India, which has been spearheading conservation efforts in this landscape. Besides the financial and infrastructural support provided to us we would like to record our appreciation here for the interest and support provided by Dr. Sejal Worah, Dr. Dipankar Ghose and Joseph Vattakaven. Dr. K.D. Kandpal is thanked for taking care of administrative matters and ensuring smooth functioning in the field. S. M. Belal is thanked for organizing field logistics and assisting with camera monitoring. We thank staff at both WWF's Delhi office and at Kaladhungi who have been ever helpful.

Dr. Bivash Pandav and Dr. K. Ramesh from the Wildlife Institute of India are thanked for their encouragement in undertaking this survey and for sharing with us their vast knowledge of the landscape. We benefitted from discussions with Dr B.R. Noon on the intricacies of regression modeling and model selection and thank him for his unwavering support for our work in the Terai Arc Landscape.

Our field team was a continual source of strength and inspiration. We thank our field staff Raja, Chandan Singh, Hari Singh, Suraj, Bhuvan, Kushal and Anshu for the hard work, patience, stories and good food. Our drivers Suraj, Tara and Sunil were exceptional and negotiated bad roads with great skill.

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We thank our families and friends. Mr. and Mrs. Chanchani have been truly inspirational, their unwavering support has allowed us to go on in the face of many challenges, we thank them from the depths of our heart.

LIST OF FIGURES AND TABLES

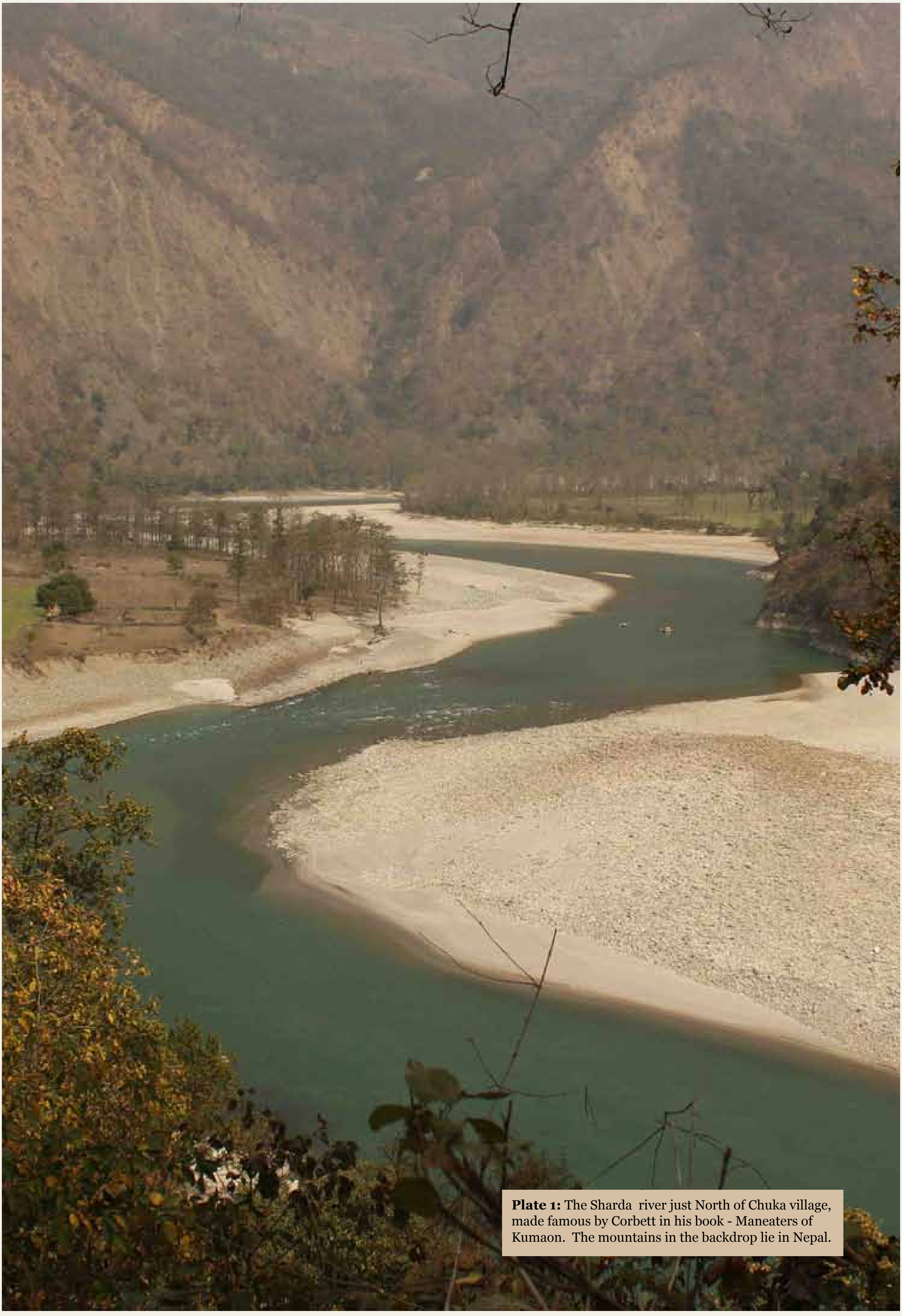

Plate 1: The Sharda river just North of Chuka village, made famous by Corbett in his book - Maneaters of Kumaon. The mountains in the backdrop lie in Nepal.

SUMMARY

- The vision to establish within the Terai-Arc Landscape (TAL) a contiguous tiger habitat is contingent upon extending conservation efforts beyond the Protected Areas. The Reserve Forests between the Gola and Sharda rivers (encompassing three Forest Divisions – Haldwani, Terai East and Champawat), henceforth, the Nandhaur region, provides a crucial link between the western and central TAL. Further, this un-fragmented forested tract of nearly 1500 km^2 presents opportunities to conserve biodiversity in the highly threatened Shivalik-Terai ecosystem.

- The primary goal of the study was to bridge gaps in information on the status of threatened large mammals in the Nandhaur region and recommend future conservation strategies. The focus of this study was the endangered tiger, its co-predators and their prey species. Data on all other mammal species was also collated.

- Using sign surveys (effort of > 280 km in 53 10km^2 cells), tiger and leopard habitat use was assessed for the Nandhaur region. Recently developed occupancy modeling methods for cluster sampling were adopted. Site occupancy for major prey species, particularly wild ungulates, was also estimated. Camera trapping was carried out in two phases. Phase-I trapping was conducted within a 2.5 km buffer on either side of the forest road running along the southern boundary of Haldwani FD. In Phase-II, the Nandhaur river valley was sampled using camera traps.

- Tiger signs were detected in ~37% and leopard signs in ~74% of the sampled 10km^2 grids. Chital and nilgai were found to be more restricted in their distribution than sambar. The inclusion of covariates in our occupancy models revealed that the occurrence of wild carnivores and some cervid species is more strongly associated with forest interiors than with disturbed forests along village peripheries. Wild prey availability and ruggedness of terrain are also useful predictors of habitat use and site occupancy for all species.

- From the overall camera trapping exercise eight individual tigers were photographed. These include two males, four females and two sub-adults (a male and a female). Three tiger mortalities were recorded in the region over the study period - these individuals did not appear in our camera trap data. During phase-I camera trapping, six individuals were captured by cameras along the region's southern boundary and an additional two females were located in the Nandhaur river valley. Leopards were captured at most camera sites, and 32 individuals were identified from left-flank data. Tiger and leopard densities were estimated to be 0.71 and 9.57 individual/ 100 km^2. A total of 32 mammal species were photographed during the study including species such as the striped hyena, Indian fox, serow, ratel (honey badger) and the large Indian civet.

- Data from>160 km of sampling along line transects (n = 24) allowed us to estimate densities for major prey species of tigers and leopards. The combined estimates for sambar, chital, barking deer, nilgai, wild pig, goral, serow and common langur using Distance methods is 23.89/km^2 (SE 4.48). The combined estimate for ungulate species (with the omission of langurs) is 7.08/km^2, (SE 1.44). This validates the contention of previous reports (Johnsingh *et al.* 2004, 2010) that the Nandhaur region is impoverished in prey abundance and that low prey densities may severely limit the growth of the regions tiger population.

- Given the occurrence of a diverse mammalian assemblage (32 species) the Nandhaur region emerges as a significant unit in the TAL for mammal diversity. Moreover its streams and rivers contain a diversity of native fauna that is fast disappearing in other sites. The region's bird diversity is also substantive. The wildlife value of this area remained largely unrecognized until recently when part of this area has been notified as a wildlife sanctuary. There is an urgent need to strengthen conservation with an emphasis on promoting and preserving biodiversity while accommodating sustainable human use of natural resources by bonafide local communities.

- This study perceives poaching of wildlife as a threat to the region's wildlife populations. Other forms of anthropogenic pressure on wildlife populations and their habitats include encroachment of forest land (particularly in Terai East Forest Division), and high human presence in forests, particularly along the Ladhya river valley and the southern boundary of the Nandhaur region. Logging, mining and fishing in some sites may cause considerable degradation of wildlife habitats. Although the Nandhaur forests are connected to other tiger-occupied sites to the east, west and south, connectivity is tenuous and the functionality of the Kilpura-Khatima and Gola River corridors is questionable. A quantitative assessment of these threats and establishment of a long term monitoring program will aid conservation efforts in the Nandhaur region.

- To facilitate the recovery of populations of tigers and other large mammals in the area, the following key measures merit attention and implementation. (i) Increased emphasis on patrolling and law enforcement to curb poaching. (ii) Active restoration efforts to prevent the further denudation of wildlife corridors. (iii) Reduction of anthropogenic pressures in key wildlife habitats, particularly in Terai East Forest Division. (iv) Scaled up monitoring of tigers and prey species on an annual basis to gain an understanding of population trends and habitat influence of species occurrence and abundance. (v) Including bonafide local communities in conservation initiatives through livelihood-support programs, livestock-depredation ex-gratia schemes, education and their participation in conservation and community based tourism initiatives. (vi) Coordination between government agencies (Forest Department, Police, Animal Husbandry and Veterinary, District Administration, Education, Health, etc.), NGOs and research organizations to implement conservation programs. (vi) Extending these efforts to proximate regions in the TAL of India and Nepal to enhance the impact of conservation programs.

INTRODUCTION

At the turn of the last century, 100,000 tigers are thought to have roamed the temperate and tropical wildernesses of Asia (Global Tiger Recovery Program 2010). Today, in the aftermath of a century of relentless hunting and deforestation, an estimated 3500 wild tigers lead a beleaguered existence within increasingly isolated habitat pockets (Walston *et al.* 2010). The precariousness of the future of tigers is best illustrated by the extinction of the Caspian and Javan sub-species in the mid 1900's, at a time when the Endangered status of the species was well recognized. The tiger's precipitous decline has however not gone unnoticed. Over three decades, concerted conservation efforts have been expended towards recovering wild tiger populations and there is increasing recognition of the role of large carnivores in the maintenance of ecosystems (Dobson *et al.* 2006). Endeavors now include innovative thinking on conservation strategies, the use of science-based monitoring techniques and engendering a world-wide consensus on curbing the trade in tiger parts (Dinerstein *et al.* 2007).

Despite these efforts, the status of this charismatic carnivore continues to decline in all 13 tiger range countries (Sanderson *et al.* 2006). India, considered to be the last stronghold of wild tigers, has seen the local extinction of the species from two Protected Areas in the last decade (Narain *et al.* 2005, Waltson *et al.* 2010). Today its ~1700 tigers survive within six landscape complexes constituting less than 11% of their historical extent (Jhala *et al.* 2011). Across these landscapes, tigers have been hemmed into small isolated habitat pockets due to deforestation and habitat degradation, impeding dispersal and other vital demographic processes. Besides these, other threats including poaching to furnish the oriental trade in tiger parts and frequent episodes of retaliatory killings arising from conflict with humans contribute significantly towards the decline of tigers within India. These problems continue to take their toll on tiger populations in the Terai Arc Landscape (TAL), a critical tiger conservation unit that lies along the Himalayan foothills straddling the Indo-Nepal border (Johnsingh *et al.* 2004).

The TAL extends over three states in India (Uttarakhand, Uttar Pradesh and Bihar) and accounts for nearly 20% of the tiger population in the country (Jhala *et al.* 2011). This region is best known for its high profile Tiger Reserves such as Corbett, Dudhwa and other important sites such as the Rajaji National Park and Pilibhit Reserve Forest. Historically the forests and alluvial grassland systems of this landscape supported

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Plate 2: The Nandhaur River flows through the central portion of the study area and is flanked by dense riverine and mixed mountain forests that provide habitats for a diversity of fauna.

a large and contiguous population of tigers, a fact testified by records of royal hunts in the region (Sunquist *et al.* 1999). However, today fragmentation resulting from deforestation and urbanization has divided the landscape into nine tenuously connected tiger habitat blocks (THB) (Johnsingh *et al.* 2004). Although tigers occur in high densities within some of these habitat blocks, the insular nature of these populations imperils their future (Wikramanayake 2004). Contemporary paradigms of tiger conservation emphasize the need to manage disjunct tiger populations within landscapes as meta-populations by establishing connectivity between them (Wikramanayake 2011). This has revived interest in conserving forested areas outside of Protected Area networks that have the potential to act as sink habitats for tigers dispersing out of high density source patches in the landscape. THB III comprising of the Reserve Forests of Haldwani, Champawat and Terai East Forest Division is one such area outside the purview of the present Protected Area network. For over a decade, this region has been viewed by conservationists as a forest tract with immense potential to harbor a resident tiger population (Johnsingh *et al.* 2004, Johnsingh and Pandav 2008).

Historical references including writings of the legendary Jim Corbett stand testimony to the faunal richness of this forested landscape bound by the Gola-Ladhya and Sharda rivers (henceforth, Nandhaur region) (Corbett, 1944, Corbett 1954). The Nandhaur river valley, lying at the core of this landscape, receives mention in several accounts for its plentiful game and fish (Corbett 1944, Corbett 1954). This hilly *bhabar* tract once supported significant populations of tigers and leopards owing to plentiful prey such as sambar *(Cervus unicolor)*, chital (*Axis axis*) goral (*Nemorhaedus goral*) and barking deer (*Muntiacus muntjak*). Besides these species the area is also reported to harbor populations of threatened species like the Asian elephant (*Elephas maximus*), the mainland serow (*Capricornis thar*), and the Asiatic black bear (*Ursus thibetanus*) (IUCN, 2011). Alongside its mammalian fauna the region hosts a rich diversity of bird species comprising of Himalayan endemics and vagrants from Nepal.

However, recent reports have indicated a declining status of large mammals in this region (Johnsingh *et al.* 2004, 2010; Johnsingh and Pandav, 2008). Surveys have reported unexpectedly low encounter rates for large mammals such as tigers, leopards and elephants (Johnsingh *et al.* 2004). Tenuous connectivity with other source populations on the Indian and Nepal side are thought to be primary reasons for this decline (Johnsingh *et al.* 2004, Rajapandian *et al.* 2010). In addition, poaching of wild animals and anthropogenic pressures on forests might have led to noticeable decimation of ungulate populations translating into low carnivore densities. For large ranging animals like tigers and elephants the current status appears to be critical. Infrastructure expansion and demands on natural resources from a rapidly urbanizing state and growing population are likely to further exacerbate this situation.

Yet the region holds enormous potential for conserving the tiger and a host of other species. Bound by the Gola-Ladhya and Sharda Rivers, the multiple use forests of Terai East, Haldwani and Champawat Forest Divisions extend unfragmented across ~ 1200 km^2. A large intact habitat (~ 400 km^2) and a 30 km stretch along the Nandhaur River, in Haldwani FD, lies free from human habitation making the Nandhaur Valley a favorable site to attempt a revival of large mammal populations (Johnsingh and Pandav, 2008).

Protecting the area and removal of existing threats and disturbances are critical to securing the future of this region as a viable habitat for tigers. PA prioritization and gauging the subsequent impacts of protection on the resident fauna are contingent upon a detailed knowledge of the existing faunal diversity of the area. A status survey for the landscape with special focus on the Nandhaur Valley is vital to management decisions and chalking out strategies for recovery and monitoring. We expect that this study will provide reliable scientific information to the Uttarakhand State Forest Department. With this goal in mind, the study had the following objectives,

Objectives

1) Estimating the proportion of available habitat occupied and used by large mammals (tigers, leopards and their principal prey species) in the Nandhaur region
2) Estimation of population size and densities of tigers and leopards.
3) Estimating densities of principal prey species.
4) Documenting the mammalian and avian diversity.

Study Area

The study area, also known as the Nandhaur region, is embedded within the Terai Arc Landscape (TAL) that extends for approximately 700 km along the base of the

Fig 1a: Location of the Nandhaur Valley

Himalayas and covers approximately 15,000 km^2 in the Indian section (Johnsingh *et al.* 2004). The TAL comprises of remnant forest patches that protect some of the most threatened ecosystems and associated fauna. Occupying a central position within the TAL, the Nandhaur region forms a disjunct Tiger Habitat Block (THBIII) with little or no connectivity with THBs to the west and east (Johnsingh *et al.* 2004). The study area is bound between the river Gola in the west and Sharda in the east. The Ladhya river valley forms the northern limit beyond which lie steep Himalayan mountain ranges dotted with numerous villages. Interspersed amid these villages are the temperate forests of Nainital and Champawat.

In the south forests give way to agricultural fields and fast urbanizing settlements. Central to this site, and from where it derives its name, is the Nandhaur river valley. The forests in the landscape are managed for multiple use and fall under three administrative Forest Divisions (FD) namely, Champawat, Haldwani and Terai East. To the west of the study area, across the Gola River, lies the Ramnagar FD and Terai Central FD. To the north-east across the Sharda river, forests of Nandhaur are contiguous with those of Nepal along the Bramhadev corridor. The south-eastern tail of the study area has a tenuous connection with Pilibhit FD.The Nandhaur landscape encompasses two physiographic zones: The Shivalik-*Bhabar* zone, characterized by hilly terrain with loose substratum made up of coarse sediments and bisected by numerous seasonal and few perennial streams. Parts of Champawat and Haldwani FD lie within this zone while Terai East lies entirely in the *terai* zone with characteristic flat topography and fine alluvial soil deposits. Main forest types are moist deciduous and sub-tropical broadleaf forests. Highly disturbed temperate forests composed of pine, oak and Rhododendron may be found in the upper reaches along the northern extent. Extensive plantations of commercially valuable species were raised during the 60's (Semwal, 2005). These have replaced much of the natural vegetation in Terai East and to a much lesser extent in the other two FD's. Haldwani FD holds more intact habitat than some Protected Areas (PAs) within the Indian TAL (Johnsingh *et al.* 2004).

Disturbance is reported to be high due to pressures from high human densities, particularly along the southern boundary of this region. Within the forest there is presence of traditional pastoralist and nomadic communities such as the *gujjars* and *bhotiyas* as well as *tharus* who practice agriculture. Hill communities also have temporary cattle camps or *khattas* within the forest and some have settled down permanently in the foothill forests. Grazing, grass collection and fuelwood collection are reported to be existing disturbances to the forest. There are numerous sites of religious and archeological significance within Nandhaur, such as the temples of Kalichaur, Suryadevi, Sumanthapla, Byandhura and Poornagiri. The Sikh temple of Reetha Sahib, situated in the Ladhya valley, attracts numerous pilgrims in the month of May who trek across the study site into the Ladhya valley. Other major pressures on wildlife habitat are from resource extraction such as boulder mining and timber removal.

OCCUPANCY AND HABITAT USE BY TIGERS, LEOPARDS AND PRINCIPAL PREY SPECIES

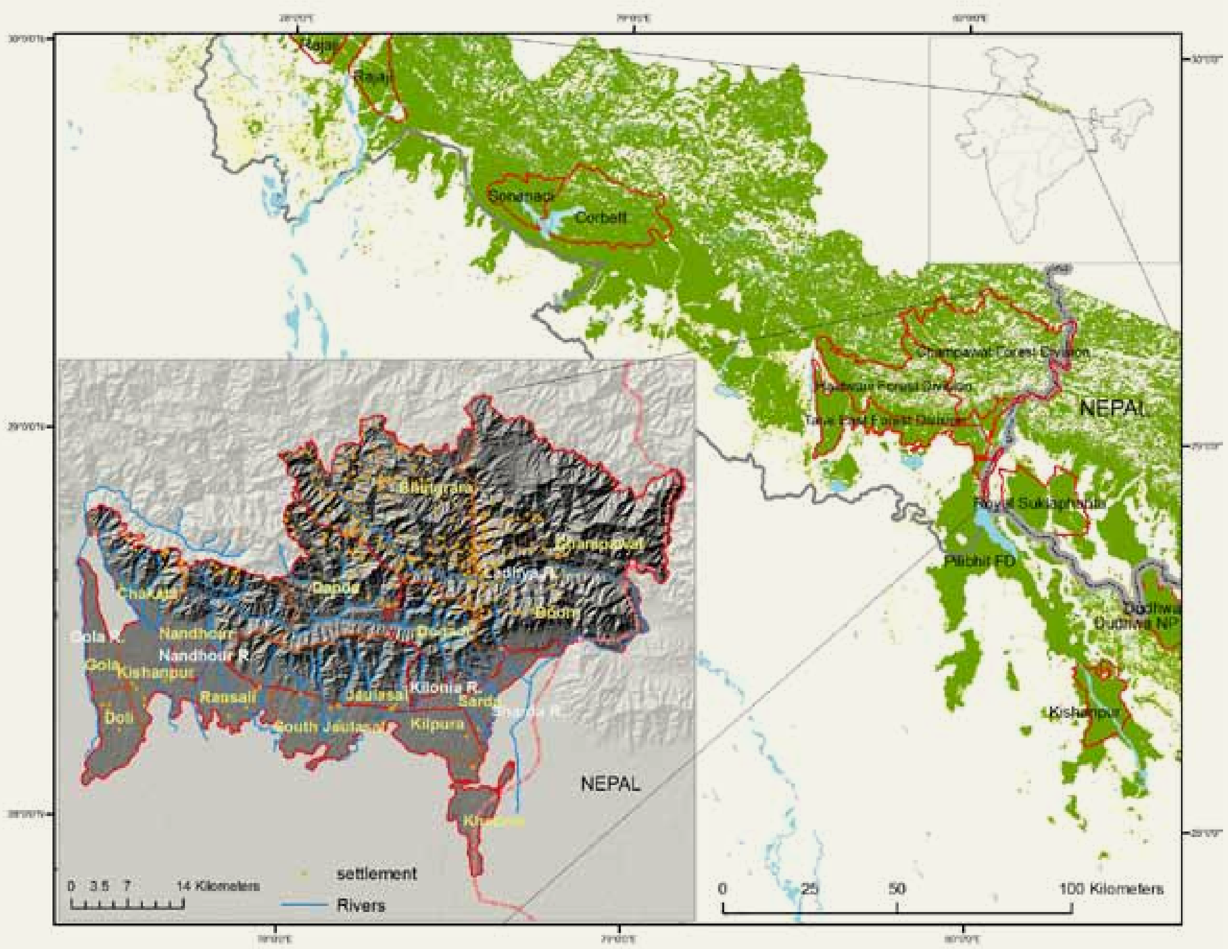

Fig 1b: Location of the Terai region in the states of Uttarakhand and Uttar Pradesh in India. Study area and prominent Protected Areas.

Introduction

The proportion of area occupied by a species is a reliable indicator of its abundance (Holt *et al.* 2002) and therefore is an important state variablte for monitoring populations of rare and threatened taxa (Mackenzie *et al.* 2005, Noon *et al.* 2012). Imperfect detection of the species of interest is an impediment to accurately estimating this variable. However, contemporary sampling and modeling techniques such as occupancy modeling allow for the estimation of this variable by explicitly accounting for detection biases. Using these techniques it is also possible to build predictive models of occupancy and habitat use by incorporating specific habitat and detection covariates. For detailed information on these techniques refer to Mackenzie *et al.* (2002, 2005) and Mackenzie and Royle (2005).

Predictive models of occupancy and habitat use are valuable tools for prioritizing conservation strategies because they allow us to assess the relative importance of habitat and disturbance specific variables in determining the distribution of species. Typically resources such as food, water and cover are the principal determinants of species occupancy and habitat use (Ngoprasert *et al.* 2012, Karanth *et al.* 2011). Coupled with this, competition for resources with conspecifics and sympatric species also strongly influences habitat occupancy and use by species (Harihar *et al.* 2011). However, in human dominated landscapes, other factors such as habitat degradation and disturbance may have a more important role in predicting habitat use. For example species may avoid areas with intense anthropogenic pressures such as areas close to forest edges (Harihar and Pandav 2012, Sunarto *et al.* 2012). Conversely, some species may be compelled to use poor quality edge habitats and degraded habitats as a result of intense competition for limiting resources with sympatric species (Harihar *et al.* 2011, Odden *et al.* 2010).

Keeping in mind the immense value of occupancy models in informing management and conservation decisions we estimated the proportion of area occupied by prey species and the fraction of the habitat used by carnivores in the study area. We also tested the relative effects of variables associated with anthropogenic disturbance and habitat type on the distribution and habitat use patterns of these species by building predictive habitat use models. Details of study design, methods and major findings are presented in the following sections.

Methods

Occupancy modeling primarily relies on detection-non detection data generated for the species of interest over several sampling subunits within the study area. Detection histories are generated either by sampling several independent spatial subunits within each sampling unit (spatial replication) or by repeatedly searching the entire sampling unit for the species of interest over 3-4 occasions (temporal replication). These detection histories are modeled to estimate detection probability ‘p’ (probability of detecting the species when it is present within a sampling unit) and bias corrected estimates of the proportion of area occupied or used by the species ‘ψ’ (MacKenzie *et al.* 2002). Further, occupancy/ habitat use and detection probability may vary across units and replicates as a function of measurable site and/or sampling characteristics (covariates). Thus, incorporating these covariates can improve the precision of *psi* and *p* estimates (Mackenzie *et al.* 2006). From a management perspective these covariates can explain observed patterns of habitat occupancy and use.

Temporal replication to generate detection histories can be impractical especially when studying species such as tigers and leopards at the scale of landscapes (Karanth *et al.* 2011) while conventional spatial replication can result in biased estimates if sampling subunits are not picked randomly and with replacement (Kendall and White 2010). Hines *et al* (2010) have developed a nuanced version of the conventional single season model that allow detection histories within cells to be generated over spatially auto correlated spatial replicates (e.g. segments along trails). This is especially valuable in surveys of species such as tigers and leopards which are known to walk long distances along trails and this method is being implemented widely across the tiger’s range (Karanth *et al.* 2011, Wibisono *et al.* 2011, Sunarto *et al.* 2012, Harihar and Pandav 2012). We employed this sampling design to estimate probabilities of occupancy and habitat use by tigers and principal prey species in the study area.

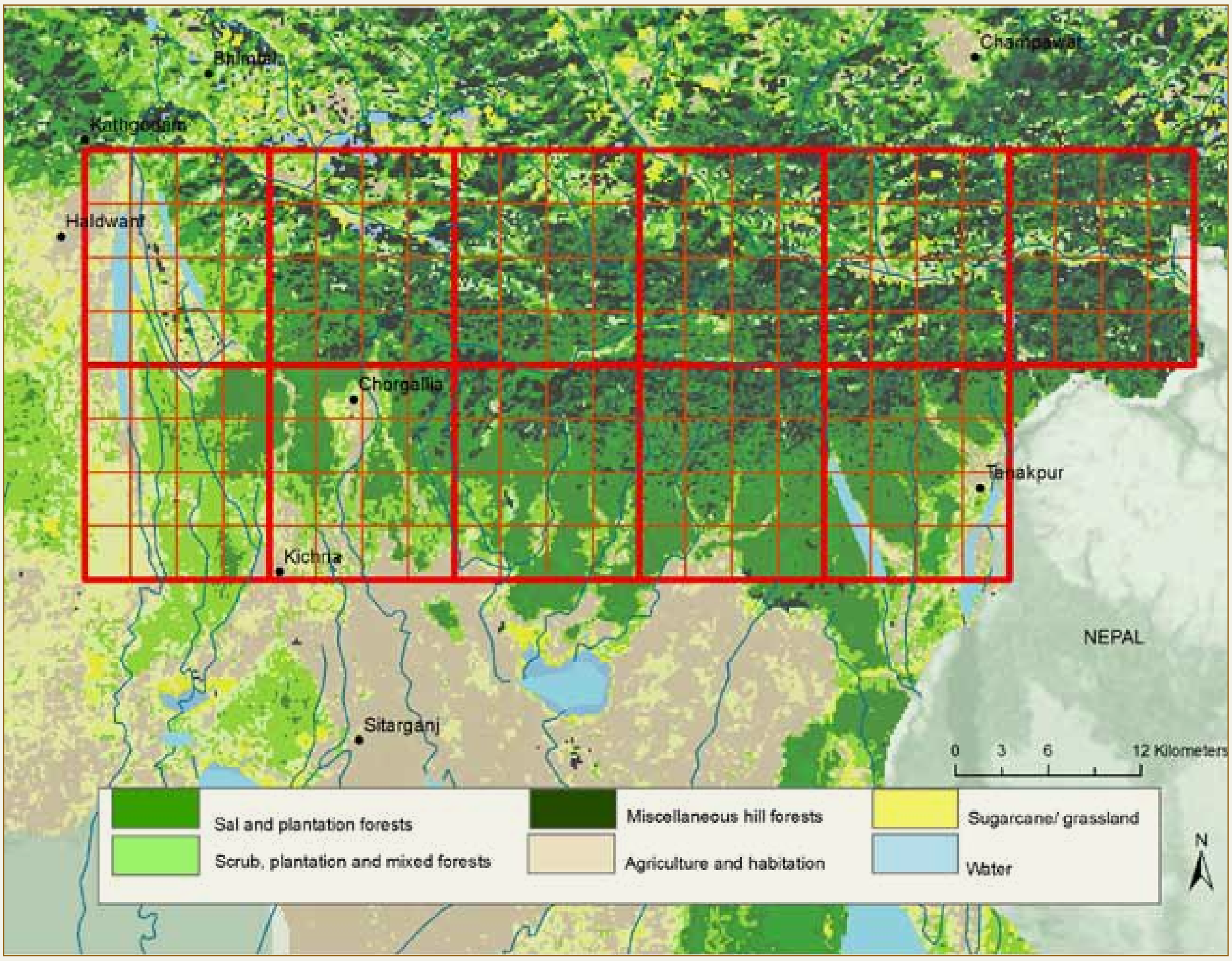

Fig 2: Map of the study area with 166 km² grids and 10 km² grids which guided sampling effort and for which we provide estimates of site occupancy and habitat use. All 166 km² grids were sampled, but our trails covered a subset of the smaller grids nested within these. Prominent vegetation types have also been included from a classified vegetation map (Johnsingh *et al.* 2004).

Survey Design

Occupancy surveys were conducted using a grid design, and we broadly followed sampling protocols of Hines *et al.* (2010) and Harihar and Pandav (2012). The entire study area was divided into eleven 166 km² grid cells, thus the area of each cell was large enough to encompass the home range of an adult male tiger. Each of these cells had nested within them sixteen, 10 km² cells which are larger than the home range of the largest prey species in the area (sambar). This design thus enables us to draw inferences about both habitat occupancy for all target species and habitat use by tigers and leopards. Cells were surveyed using forest trails/roads and sandy stream beds selected a priori to maximize detections and ensure uniform coverage of the 166km² grid cells. Surveys were carried out over five months between October 2011 and February 2012 to minimize the likelihood of changes in occupancy status of girds. Sampling effort (km of trails surveyed) within each 166 km² cell, was proportional to the extent of available tiger habitat such that for a cell with 100% habitat, the minimum survey effort was 40 km (Karanth *et al.* 2011). We allocated survey effort within grids in a manner that allowed us to sample across the range of vegetation types in the region based on the maps and descriptions of Johnsingh *et al.* (2004), and ensured that our surveys traversed a gradient of disturbance as well (both forest edges and interiors were sampled).

All sampled trails were divided into 250m spatial replicates. Within each of these sampling units signs (spoor, scat) of all the target species were counted and recorded. This resulted in presence (1)-absence (0) detection histories for all species across all sampled cells. Along each spatial sampling subunit we also collected data on covariates that were likely to influence the occupancy and detection probabilities of the target species. The covariates considered for analysis are listed in Table.1. This segment level data generated for all species was extracted for each of the 10km^2 grid with a minimum survey effort of 2.5 km.

Data Analysis

Plate 3: Steep slopes dominated by pine and associated species in the *Lowad nala* basin of Danda range in the Nandhaur region.

Analysis was carried out using software PRESENCE 4.4 (Hines 2006). We first tested for spatial dependence between sampling units by modeling the data using the conventional single season model followed by the Hines model which accounts for spatial dependency in the data. Because the Hines model performed better than the conventional model for all species, further covariate modeling was carried out using this model (Karanth *et al.* 2011). All covariates used were tested for correlation, and only uncorrelated variables (Pearson's correlation coefficient < 0.5) were incorporated in our models.
We first modeled the detection probability '*p*' by either keeping it constant or with various single and additive combinations of the detection covariates. In this step, the parameter ψ was modeled using all 5 of the site covariates. Based on the AIC rank (models with lower AIC values have higher ranks) covariates for *p* were decided. Once the covariate structure for detection probability was fixed, covariates on ψ were varied in various additive combinations to arrive at the model with the lowest AIC. The fit of the model to the data was tested using a Chi-square Goodness of Fit test. Overall estimates for ψ and *p* were obtained through model averaging (Burnham and Anderson 2002). Summed AIC weights of models in which a covariate occurred was used to determine the overall model support for each covariate in explaining probability of habitat occupancy/ use.

Flowers of *Bauhinia vahlii*, a common woody vine

Table 1: List of covariates used to model 'ψ' and 'p' and their significance

Covariates		Source	Significance/ prediction
Non-forest area	Proportion of area under village/non forest land	GIS – forest boundary files	Habitat available to a species will be inversely proportional to extent of non-forest land in the cell
Large and medium prey presence	Proportion of segments with signs of large & medium sized ungulates	Ground data	Index of prey availability. Expected to positively influence carnivore habitat use.
Livestock	Average livestock count	Ground data	Index of disturbance due to livestock grazing. Likely to negatively impact occupancy and habitat use by all species
Ruggedness	Mean standard deviation of slope	GIS – 30m ASTER DEM	High standard deviation implies rugged undulating terrain, while low deviation means uniformly flat or hilly terrain. Rugged terrain use may vary depending on species' biology and other factors
Dog presence	Proportion of segments with domestic dog presence	Ground data	Index of disturbance due to dog presence. Should negatively influence habitat use and occupancy.
Invasive weed presence	Proportion of segments with presence of weeds	Ground data	Index of habitat degradation due to presence of weeds such as lantana and eupatorium.
Trail type	Forest road/trail (0) or River bed (1)	Ground data	Species detection probability may vary with trail type.
Substrate	Index of extent of poor quality substrate within each segment	Ground data	Affects detection probability. Detection probability should be lower on segments with large stretches of poor quality substratum

Results

A total of 284.75 km. of trails/stream beds were surveyed across eleven 166 km² cells. Fifty three of the 10 km² (30%) grids had a survey effort of at least 2.5 km and are used here for the analysis. Covariate modeling resulted in 10 to 15 models per species wherein we assessed the influence of habitat and disturbance factors on species occurrence. For all species, models with covariates on ψ and p performed better than the dot models (no covariate model). Across all models, the spatial autocorrelation parameters θ (probability species present on segment given previous segment was).

The table below provides model averaged estimates for the parameters ψ and p for the two large cats and prey species. Detection probabilities were high but < 1 for all species. For all species the bias corrected estimates of proportion of area occupied was substantially higher than their respective naïve estimates indicating that signs were imperfectly detected during sampling.

Plate 4: Surveys for mammalian signs in progress along the Nandhaur River.

Table 2: Model averaged estimates of detection probability (*p*) habitat occupancy (ψ)

Species	*p*(SE)	Naïve ψ	ψ(SE)
Tiger*	0.529 (0.086)	0.377	0.457 (0.091)
Leopard*	0.744 (0.061)	0.743	0.879 (0.064)
Sambar	0.776 (0.044)	0.773	0.826 (0.094)
Chital	0.721 (0.023)	0.622	0.7 (0.031)
Nilgai	0.735 (0.023)	0.452	0.491 (0.03)

*values indicate proportion of sampled grids used by the species.

Detection Probability

*A*cross all species the covariate models performed better than the dot models in explaining segment level variation in detection probability. For all species detection probabilities were negatively influenced by the proportion of poor quality substratum within a segment. The influence of trail type on detection probabilities varied with species. Probability of detecting tiger and sambar signs were higher on segments located in stream beds or *rau*. Leopard and chital detection probabilities were higher along forest trails while trail type did not significantly influence nilgai detection probabilities. Table 3 shows the relative weights of sampling covariates *Trail Type* and *Poor Substratum* in explaining the variation in segment level detection probabilities for each species.

Plate 5: Forest road along southern boundary of Haldawni FD, one of the few maintained roads in the region. This road formed the main trapping line for camera trapping and was also surveyed for animal signs.

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Table 3: Effect of sampling covariates on detection probability P

Species	Trail Type *Rau*(1), Forest trail(0)	Poor Substratum
Tiger	+(1)	-(0.99)
Leopard	-(0.94)	-(0.04)
Sambar	**+(0.98)**	-(0.01)
Chital	-(0.98)	-(0.98)
Nilgai	+(0.04)	**-(0.99)**

(+) indicates positive correlation while (-) indicates negative correlation of sampling covariate with segment level detection probability. Values in bold indicate, statistically significant effects.

Probability of habitat use and occupancy

Habitat use by both tigers and leopards was strongly and negatively influenced by the proportion of area under village/ non-forest within each cell. For tigers, probability of habitat use is also influenced by the ruggedness within each cell. Habitat use by tigers has a significant positive correlation with ruggedness indicating that tigers are more likely to use areas with high variation in slope such as narrow river valleys. In contrast leopards were negatively affected by ruggedness indicating that they are more likely to use areas that are either flat or uniformly undulating. Presence of large and medium sized prey also positively influenced habitat use by tigers and leopards. Table 4 summarizes the relative weights of covariates in explaining variation in cell specific habitat use probabilities. Ruggedness was the most important covariate determining habitat occupancy by prey species. Ruggedness positively affected sambar occupancy indicating that sambars are more likely to occupy rugged country characterized by steep slopes and flat valleys. Chital and nilgai occupancy was affected negatively by ruggedness, which indicates that these species tend to use more uniform terrain.

Plate 6: Narrow trails like these in the mountains lead to remote villages and were used for our sign surveys and camera traps.

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Habitat occupancy for all prey species was negatively affected by proportion of village/ non forest area within the cell and by presence of domestic dogs. Table 5 summarizes the relative covariate weights for prey species.

Table 4: Effect of site covariates on carnivore habitat use

Species	Area under village	Large & medium prey presence	Ruggedness	Livestock
Tiger	- (1)	+ (0.371)	**+ (0.993)**	+(0.356)
Leopard	**- (0.809)**	**+ (0.632)**	- (0.526)	+/- (0.313)

(+) indicates positive correlation while (-) indicates negative correlation of covariate with probability of habitat use. Values in bold indicate, statistically significant effects.

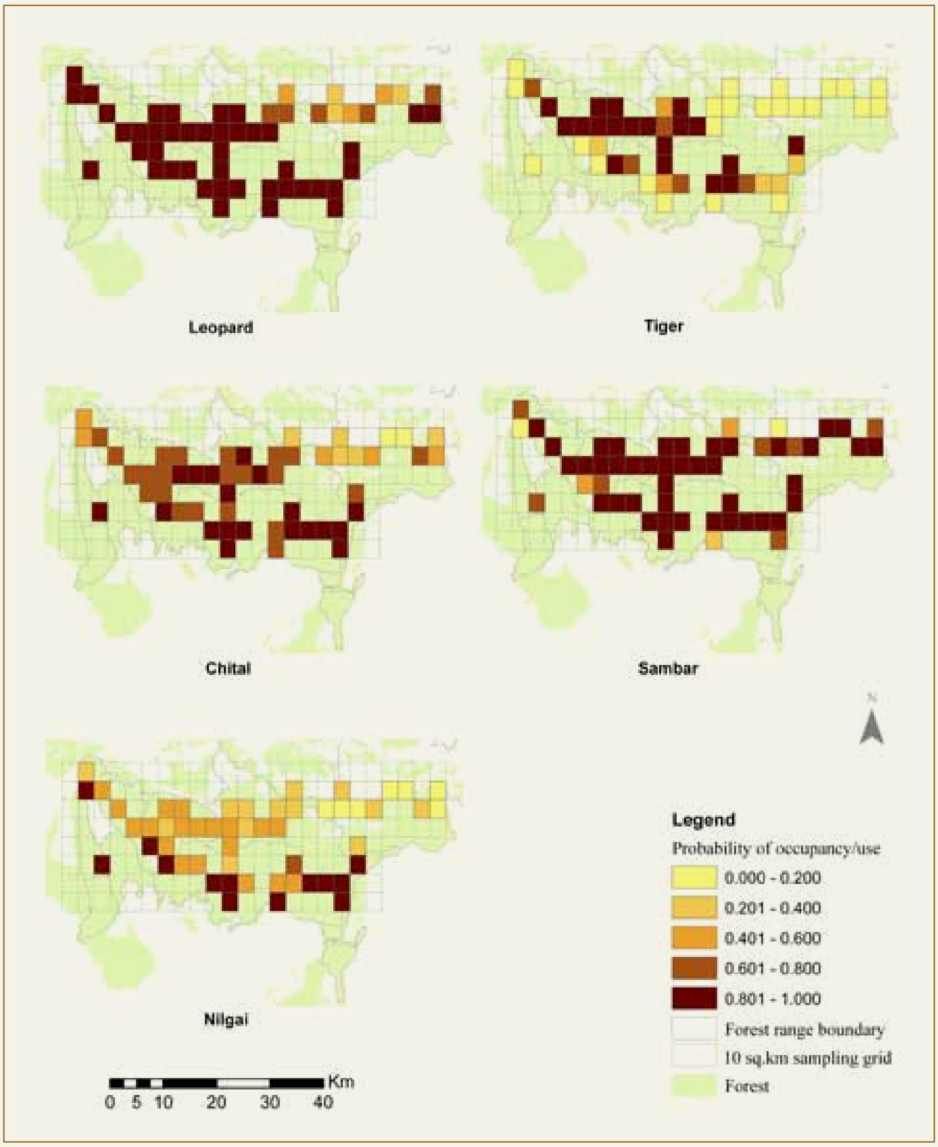
Table 5: Effects of site covariates on prey site occupancy

Species	Area under village	Ruggedness	Dog presence	Livestock	Invasive weed presence
Sambar	- (0.460)	**+ (0.795)**	**- (0.875)**	+ (0.285)	+/- (0.054)
Chital	**- (0.620)**	**- (0.406)**	- (0.210)	- (0.185)	+/- (0.188)
Nilgai	- (0.205)	**- (0.971)**	- (0.187)	+ (0.185)	+/- (0.497)

(+) indicates positive correlation while (-) indicates negative correlation of covariate with probability of occupancy. Values in bold indicate, statistically significant effects

Plate 7: Terraced fields at Aamjar village on the northern boundary of Danda Range, Haldwani FD.

Fig 3: Habitat use and occupancy probability values for different species across sampled 10km² cells.



Discussion

Tiger Habitat Use

Results from the occupancy analysis showed that for a wide ranging species, tigers used a small proportion of the sampled cells (45%) in the study area. Occupancy modeling resulted in a marginal increase in the estimate of proportion of area used by tigers over the naïve estimate indicating that tiger signs were imperfectly detected during sampling. Detection probability for tiger signs in the area was not very high (52%). This highlights the importance of accounting for detection biases while assessing the distribution status of rare and elusive species like tigers. Detection probabilities for tigers were estimated to be higher along *rau* (river beds) as compared to forest trails and were negatively influenced by poor quality substratum. Proportion of village/ non forest areas in a grid had a strong negative impact on tiger habitat use while terrain ruggedness favorably influenced habitat use by tigers. These two variables act in combination and restrict habitat use by tigers to a very narrow strip in the centre of the study area.

The extremely hilly northern reaches of the study area comprising of parts of Champawat division are dotted with villages. The low-lying southern boundary of the study area too faced high anthropogenic pressures from growing villages and settlements in Terai-East forest division (Semwal 2005). Consequently, the Nandhaur river valley presented the most suitable habitat for tigers in the study area, followed by parts of Kilpura range of Terai-East FD and Sharda range of Haldwani FD. The Ladhya valley, though topographically similar to the Nandhaur river valley, suffered from very high anthropogenic pressures and perhaps no longer a suitable habitat for tigers. Probability of habitat use was also extremely low for the cells sampled close to the corridors connecting the study area to other source populations (Surai-Khatima, Boom-Bramhadev, and Gola river corridor. These areas lying along the peripheries of the study site faced immense pressures from villages and towns such as Khatima and Haldwani. Studies on wildlife corridors in the TAL have designated the status of these corridors as critical (Johnsingh *et al.* 2004, Kanagaraj *et al.* 2011). The low probability of use of cells adjoining these corridor areas further suggests that there may be little or no functional connectivity between these patches although this needs to be verified using more focused studies.

Leopard habitat use

Leopards were estimated to use nearly 90% of the sampled cells. Leopard habitat use was negatively influenced by proportion of village/ non-forest areas in the cell and positively by the availability of large and medium sized prey. In terms of topography leopards used cells which have a uniform slope i.e. either extremely hilly or flat terrain. These habitats were typically situated along the peripheries of the study area which experience intense anthropogenic disturbance. Leopards in general are known to be more tolerant of habitat degradation than tigers (Ramakrishnan *et al.* 1999). Also because of the reduction in interference competition in suitable habitats with small tiger populations, leopard densities tend to be high (Harihar *et al.* 2011). This probably explains the high proportion of cells used by leopards in the study area.

Prey habitat occupancy

Occupancy estimates for prey species revealed that sambar have the highest occupancy in the area followed by chital and nilgai. In the study area, habitat type as determined by terrain ruggedness has a stronger influence on prey occupancy than anthropogenic disturbance factors. Models for sambar revealed that the species typically occupied areas with rugged terrain characterized by undulating hills and river valleys. Chital and nilgai occupancy was favored by terrain that showed little variation such as the flat terai regions along the southern boundary of the study area. Occupancy probabilities for sambar and chital were low close to human settlements. Presence of dog also strongly and negatively influenced habitat occupancy by sambar. Dogs frequently accompanied villagers entering the forest to extract grass and other NTFP and were also constant companions of *Bhotiya* sheep herders who camp in the study area during the winter months. Presence of dog signs was therefore, a reliable indicator of transient disturbances within the study site. Also hunting groups active in the study area frequently used dogs to run down large prey such as sambar which could further explain the strong negative effects of dog presence on sambar occupancy. Results suggest that chital and nilgai were largely confined to the southern boundary region of the study area primarily occurring in the Terai-East forest division. These areas were getting degraded at a rapid rate due to extraction pressures resulting from poor enforcement and potentially by impacts of forestry practices such as clear felling and monoculture plantations. Chital were a critical component of tiger diet and their persistence in the study area was contingent on protecting and managing these foothill habitats for wildlife. These findings also throw light on the potential for human-wildlife conflict in the area. Leopards preying upon livestock and crop raiding by nilgai are important sources of conflict across the TAL.

High use of forest edge by these species is potentially indicative of the levels of conflict in the region. The absence of reliable documentation of conflict events and the lack of compensatory schemes could be taking a toll on the tiger and leopard population of the area as a consequence of retaliatory killings by villagers.

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Plate 8: All in a day's work. Tiger and leopard pug marks detected along Kiroda nala during the occupancy surveys. A kilometer downstream from this site tiger signs are rare but elephants, bears and leopards still venture. Goral were recorded on the slopes upstream while a tiger was glimpsed disappearing amid dense bushes. All this on a single morning survey in the east-lying Sharda Range, Haldwani FD.

However, expansion of urban infrastructure poses a serious threat. Human-elephant conflict is on the rise and connectivity with Nepal maybe jeopardized. In our surveys, we also encountered many grass collectors and livestock herders from hamlets along the stream.

ABUNDANCE AND DENSITY OF TIGERS AND LEOPARDS

Method

Camera trapping in a capture-recapture framework has been widely used to estimate the abundance and density of rare and elusive large cats. This method is particular well suited for tigers and other naturally 'marked' animals such as leopards. Use of closed capture - recapture models require that three assumptions be met: 1. Population is closed to changes due to births, deaths, immigration and emigration 2. Individual identification tags are not lost during the study. This cannot occur in studies involving species with natural markings. However, poor quality photographs from which identification is not possible equate to an absence of detection. If occurring randomly this does not contribute as a source of bias. 3. Sources of variation in detection are identified and accounted for in the modeling process.

Methods of density estimation based on conventional closed capture estimators with a buffer strip estimated from the observed movement of individuals have been plagued by problems that affect the robustness of the density estimates. These methods were criticized for not explicitly dealing with (1) the movement of animals on and off the sampling grid, which is thought to result in non-closure thereby making the estimates of *N* less reliable and (2) heterogeneity in capture probability due to variable exposure of individuals to traps resulting from the juxtaposition of individual home ranges or territories and trapping array. Newly developed spatially explicit capture-recapture (SECR) analysis addresses these problems specifically by integrating information on detection histories of individuals with information on the spatial location of the individual capture events (Royle *et al.* 2009a & b). The model thus describes the distribution of the activity centers of individuals in space coupled with the encounters of individuals that result from their movement induced exposure to trapping. SECR thus represents a substantial improvement over conventional closed capture models. Significantly, these models also permit the analysis of small datasets obtained using staggered camera trapping efforts. This is especially important in rugged low density areas such as the Nandhaur landscape where rugged terrain precludes the use of large trapping blocks (see Lynam *et al.* 2007) and where tiger captures tend to be staggered in space and time.

Survey design

Given the large extent (~ 1500 km^2) of the study, constraints imposed by the mountainous terrain parts of which are fairly inaccessible, and that fact that tigers were expected to occur in low densities (Johnsingh *et al.* 2004, 2010), it was not our endeavor to sample the entire area using a conventional lattice of camera trap points distributed across the study area (Royle *et al.* 2009, Karanth *et al.* 2002, Lynam *et al.* 2007). Rather, our sampling effort for camera trap surveys was focused on the southern region of the study area - which comprises of low hills and shallow valleys and stream-beds that drain into to the plains. This belt of forest runs from Tanakpur on the Nepal border in the east to the town of Haldwani in the west and is connected to the Surai-Pilibhit forests by a narrow isthmus of woodland. As carnivore occurrence in the area was poorly known the area selected for trapping was chosen intuitively - we postulated that this belt would be among the more productive wildlife areas in the Nandhaur region. Placement of cameras in Ransali, Kishanpur and other ranges of Terai East Forest Division was sparse because these sites were very disturbed and cameras were vulnerable to theft. Local forest staff reported that these areas were seldom used by tigers. Our endeavour was to follow up this initial survey along the southern boundary with selective camera trap surveys in major river valleys and important wildlife areas in the Nandhaur mountains, based on species occupancy data.

A seasonally functional forest road runs east west along the base of the foothills traversing the entire extent of landscape. It was decided to initially set camera traps within a 5 km buffer with the road running along its centre. There were four main factors governing this decision: 1. Tigers were likely to use the plain areas adjoining the hills and the valley bottoms rather than the steep mountainsides 2. Since this was the first effort of its kind, it would be valuable to gain an understanding of the entire breadth of the landscape 3. The road would ease the task of deploying and monitoring cameras allowing us to sample a larger area in a relatively short span of time and 4. Data on tiger presence along the roads will prove useful if there are future proposals to rebuild the road for public use. Trapping was carried out in blocks following design 4 of Karanth *et al.* (2002). Major valleys within the study site were to be trapped in a second level of sampling, time permitting.

The road buffer was trapped in five blocks and an additional block was trapped within the Nandhaur river valley. Each block consisted of 17-10 camera trap sites and ran for a minimum period of 21 days or occasions (Table 6). Within each block traps were deployed at a spacing of 0.8-3 km. This ensured that within each block all tigers had a non-zero probability of exposure to camera traps. Camera sites were chosen based on presence of tiger or leopard signs. The limitations of our sampling approach are expressed in the discussion of these results.

Table 6: Details of camera trapping effort within each block

Block	Trapping Period*	No. of trap sites	Effort (no. of trap night)
1	18-Oct-11 to 07-Nov-11	11	212
2	05-Nov-11 to 26-Nov-11	17	296
3	28-Nov-11 to 19-Dec-11	10	209
4	22-Dec-11 to 14-Jan-12	12	260
5	17-Jan-12 to 08-Feb-12	10	233
6	14-Feb-12 to 08-Mar-12	14	263
Total	17-Oct-11 to 08-Mar-12	74	1473

* Minimum number of occasions that all sessions ran for is 21. A few sessions ran for more occasions and have been included in the analysis where appropriate. Not all cameras sites were operational throughout these sessions and this is reflected in the effort (number of trap nights).

Analysis

Abundance and density were estimated using the newly developed Hierarchical Bayesian Spatially-Explicit Capture-Recapture (SECR) model based on closed population sampling (Royle *et al.* 2009a). Tiger and leopard individuals were identified based on stripe and rosette patterns respectively. Two observers carried out the identification independently and the results were tallied to reduce the probability of misidentification. Spatially explicit encounter histories were developed for all unique individuals. A total of 74 trap sites were operational over six sessions with the number of occasions ranging between 21 and 24. Specifically for the SECR analysis, we excluded all areas deemed to be non-habitat existing within a 10 km buffer around the trapping grid (Fig.3). This was done by overlaying the buffered trapping zone with a fine grid of 7314 equidistant points, each representing a pixel of area 0.336 sq.km (following Royle *et al.* 2009). Each of these pixels was categorized as habitat or non-habitat resulting in 4478 (~1500 km^2) habitat pixels and 2835 non-habitat pixels. The activity centers of the individual tigers are assumed to be uniformly distributed over these habitat points. The Markov Chain Monte Carlo (MCMC) model was run using the above data for 50,000 iterations. The first 1000 iterations were discarded and posterior means were calculated for the remaining 49,000 iterations. The data augmentation value (maximum number of individuals likely to be present in the area) was set at 40 for tigers and 150 for leopards. We used a Bernoulli formulation of a hierarchical random effects GLM model to analyze the data. The analysis was carried out using SPACECAP v.1.5 (Singh *et al.*2010).

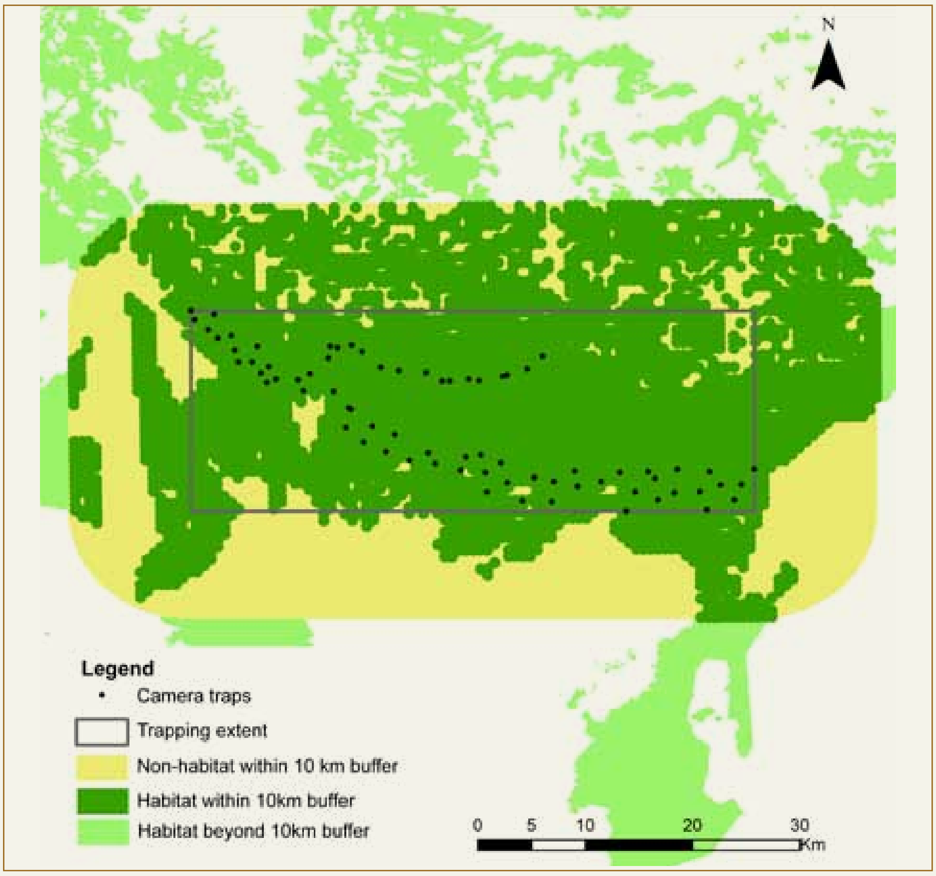


Fig 4: Trap locations and buffered area showing habitat and non-habitat. The 10km wide buffer around the trapping extents were used to make inferences about carnivore abundance and density.

Results

The trapping exercise yielded 28 captures of eight individual tigers. The captured individuals include four adult females, two adult males and two sub-adult > 12 months old (Fig. 4). Left flanks of leopards were used to identify 32 individuals with 57 captures. Density estimates using single flank data have been obtained successfully in previous studies (Harihar 2005; Harihar *et al.* 2009; Wang and Mcdonald 2009).

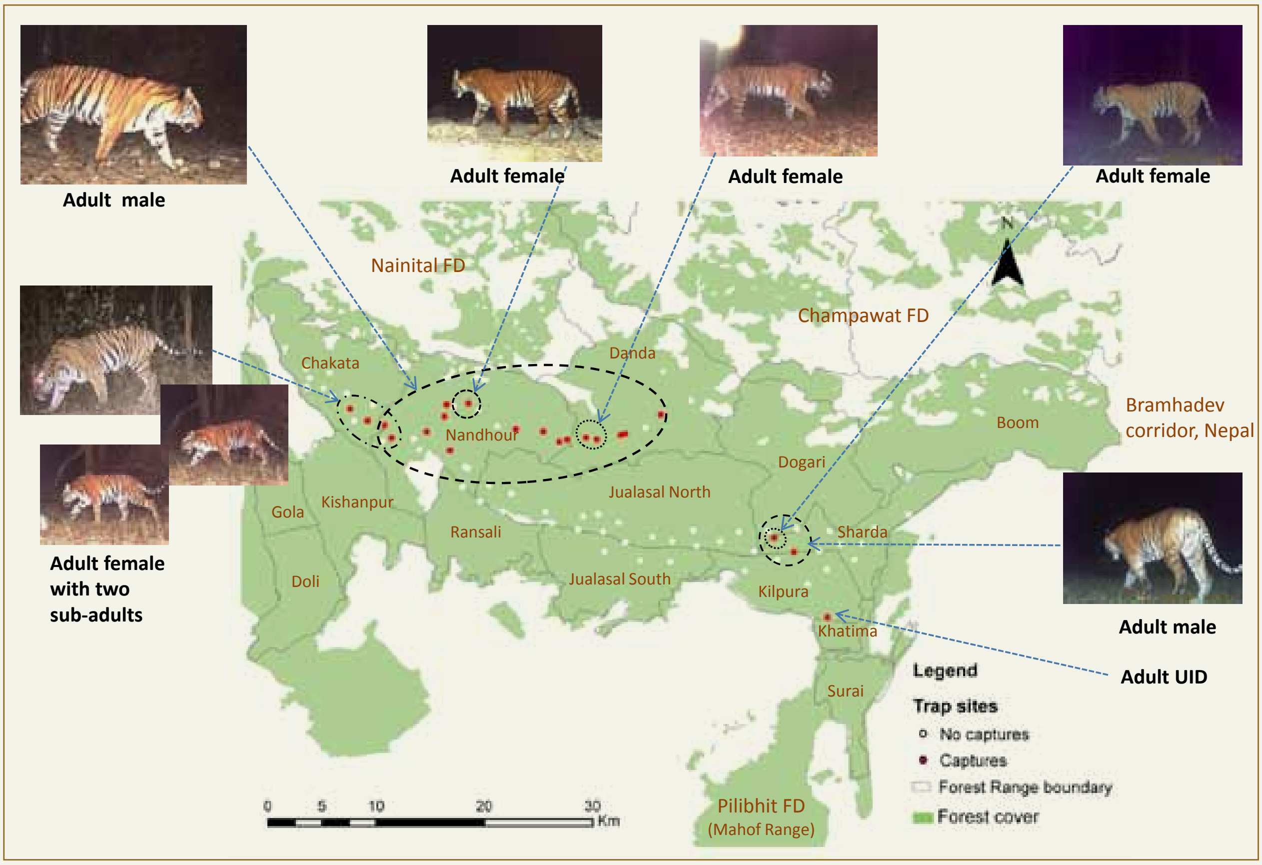


Fig 5: Tiger individuals captured in Nandhaur between October 2011 – March 2012 and location of captures

The abundance and density estimates over an area of 1523.77 km^2 were 10.75 and 0.71 for tigers (Table 7). The N super' values for tigers, generated during the MCMC simulations, did not converge possibly due to the small sample size and estimates obtained through more sophisticated modeling may vary by some degree from those reported here. These estimates are in concordance with sign survey data wherein we obtained more capture of tigers in areas where signs were frequently encountered.

Table 7: Posterior summaries of abundance (Ň) and density (Ď) for tigers and leopards

Species	Mt+1	Ň	SD	2.50% -97.50%	Ď	SD	2.50% -97.50%
Tiger	8	10.75	2.17	8 - 15	0.71	0.14	0.53 – 0.99
Leopard	32	144.23	23.61	101-182	9.57	1.57	6.70 – 12.08

Ň or Nsuper is the number of tiger activity centers in the population exposed to sampling (within region S) and Ď is the density/ 100 km^2.

Although we sampled a portion of the Nandhaur region, these spatially explicit capture-recapture estimates are for the entire Nandhaur region encompassing the following Forest Divisions: Terai East, Haldwani, Champawat (Dogari Range, Boom Range, parts of Champawat and Bhingrara) and a small part of Nainital. Tiger captures were concentrated in two sections of the trapped area. The first of these includes the Nandhaur river valley covering Danda, Nandhaur and bordering Chakata Ranges in Haldwani Forest Division. The second includes Sharda Range in Haldwani Forest Division and Kilpura Range in Terai East Forest Division. The range of some individuals may extend into Jaulasal North and South (based on sporadic signs observed in these ranges), however, there were no tiger captures in the above Forest Ranges. Relative to other sites within the *bhabar-terai* landscape, Nandhaur has low tiger densities at present (Table. 8)

Table 8: Tiger densities in sites adjoining the Nandhaur region.

Landscape	N(SE)	D(SE)	D-SECR(SE)
Corbett Tiger Reserve	109 (5.4)	17.83(1.4)	16.23 (1.63)
Ramnagar Forest Division	27 (1.5)	15.18 (2.10)	13.8 (2.74)
Rajaji National Park	7 (1.51)	3.06 (1.04)	2.25 (1.1)
Pilibhit Forest Division	12 (0.17)	4.66 (0.46)	3.78 (1.17)

All estimates are from Jhala *et al* (2011). N-estimated population size. D- density estimate based on ETA and 1/2MMDM; D-SECR- is the density estimate from a Maximum Likelihood based Spatially Explicit Capture-Recapture model (Borchers and Efford, 2008).

Leopards were estimated to be very abundant in Nandhaur with a population estimate of 144.23 and a density of 9.57 individuals/ 100 km^2 (Table 7). Leopards were captured in all six trapping blocks. Leopard densities in the Nandhaur landscape were found to be similar to densities reported from Chilla Range, Rajaji National Park (9.76/100 km^2) just after *gujjar* relocation from the park in 2004-05 (Harihar *et al.* 2011). Interestingly, leopard densities in Chilla have since reduced considerably with removal of anthropogenic disturbance and subsequent recovery of tigers (Harihar *et al.* 2011).

Discussion

The major findings from the camera trap survey were as follows: (1) the Nandhaur landscape supported a small breeding population of tigers. (2) The estimated tiger density for the Nandhaur region was considerably lower than some adjoining sites in the *bhabar – terai* tract but likely to be similar to some proximate areas in eastern Ramnagar and Terai west FD's. (3) Leopard abundance and density in the Nandhaur landscape were relatively high and resembled those from the Rajaji National Park (Harihar *et al.* 2011 - see estimates for the years 2004 and 2005). Our estimates of tiger and leopard densities from Nandhaur are likely to be an artifact of several underlying factors. Some of these are discussed below:

Prey densities. For a large sized carnivore like the tiger, available prey biomass is an important limiting factor (Karanth *et al.* 2004). Ungulate densities in Nandhaur were found to be low and this in turn may be limiting tiger densities. In contrast, leopards are able to exploit smaller sized prey such as rodents and even domestic dogs and are thus able to persist in situations with low large ungulate densities (Ramakrishnan *et al.*1999). Additionally, prey species such as Goral (*Naemorhedus goral*), occurring on steep slopes, may be more accessible to the agile leopard although Wang and Macdonald (2009) have found them to form a small part of tiger diets in Bhutan.

Poaching. Although hunting pressure on tigers is probably considerably lower today than it was in the era of sport hunting some decades ago, they remain susceptible to poachers. This is likely to have impacted the population here. The leopard population, though possibly as much at risk from being hunted, appears to be faring better - perhaps this can be attributed to their ability to exploit a more diverse prey-base and sustain themselves in marginal, peripheral habitats.

Connectivity. Several notable tiger sites (Ramnagar FD and Pilibhit FD) lie within 30 kilometers of the Nandhaur region. However, connectivity with these populations is reported to be poor (Johnsingh *et al.* 2004, Kanagaraj *et al.* 2011) and the areas that lie in between appeared to be unfavorable for tigers (Chanchani *et al.* 2011, Jhala *et al.*

Plate 9: Setting up a camera trap along the Nandhaur river in Danda Range, Haldwani FD

2011, Harihar *et al.* 2012). Poor connectivity possibly prevents effective dispersal of tigers into Nandhaur and has implications for the recovery of tiger population and their long term persistence in the Nandhaur landscape.

Not enough habitat? Although a very large area exists in the Nandhaur landscape or THBIII, the extent of habitat suitable for wildlife in Nandhaur needs further assessment. The southern section of this landscape, comprising of flat *terai* habitat, has been reduced to a narrow, highly fragmented strip. Most of the natural forests in this section have been replaced by monoculture plantations and high levels of human intrusion are high making area unsuitable for tigers. Thus, we found patches within the landscape devoid of tigers. Leopards on the other hand remained unaffected by these disturbances and they were found to occur across the trapping grid. However, as seen from the previous section of this report, probability of habitat use by leopards was also lowered in highly human modified areas as compared with interior or even edge forests.

Competition. Large carnivores are known to cause top down population regulation of other smaller guild members through competitive interactions. Therefore, the removal of large carnivores from a system results in the ecological release of other lesser carnivore species (Crooks and Soule 1999). Thus high leopard densities in Nandhaur may be a manifestation of low tiger densities.

Sampling limitations. The sampling design employed was unconventional and may influence estimates. Our estimates were derived from sampling along two narrow strips - an effort to maximize coverage of a large area in a relatively short span of time - and this may have some effects on our estimate of density and abundance. The trapping exercise lasted for a period of nearly five months. We had initially conceived of less lengthy time-periods for each of our six trapping blocks, but thought it best to extend these periods given the scarcity captures. Thus, our model did not strictly conform to the conventionally accepted criteria for *closure* (60 days) which is a key assumption in closed population models. This is a common problem in camera trap studies where target species occur in extremely low densities (Simcharoen *et al.* 2007, Wang and Macdonald 2009, Rayan and Mohamad 2009). While we have not formally tested for population closure (block design, small sample size), we expected that the use of a 10 km buffer around the extent of the trapping web would accommodate temporary emigration of individuals in our SECR models. We had no records of adult tiger mortalities over the camera trapping period. We have included capture-recapture data for two sub adult tigers although these might not constitute independent capture events - which may bias our estimates high. Our sampling design did not strictly conform with the design norms of Karanth *et al.* 2002 and our estimates may not be strictly comparable with those from systematically designed studies. We believe however, that as an exercise targeted at generating baseline information on tiger densities for a hitherto unstudied region – our design though unconventional - provided a reasonable estimate of the status of existing tiger and leopard populations in the area. These results will be of use in designing future studies, which should enhance coverage in the mountainous tracts. These results also provided the basis for designing monitoring programs, as well as for identifying conservation strategies.

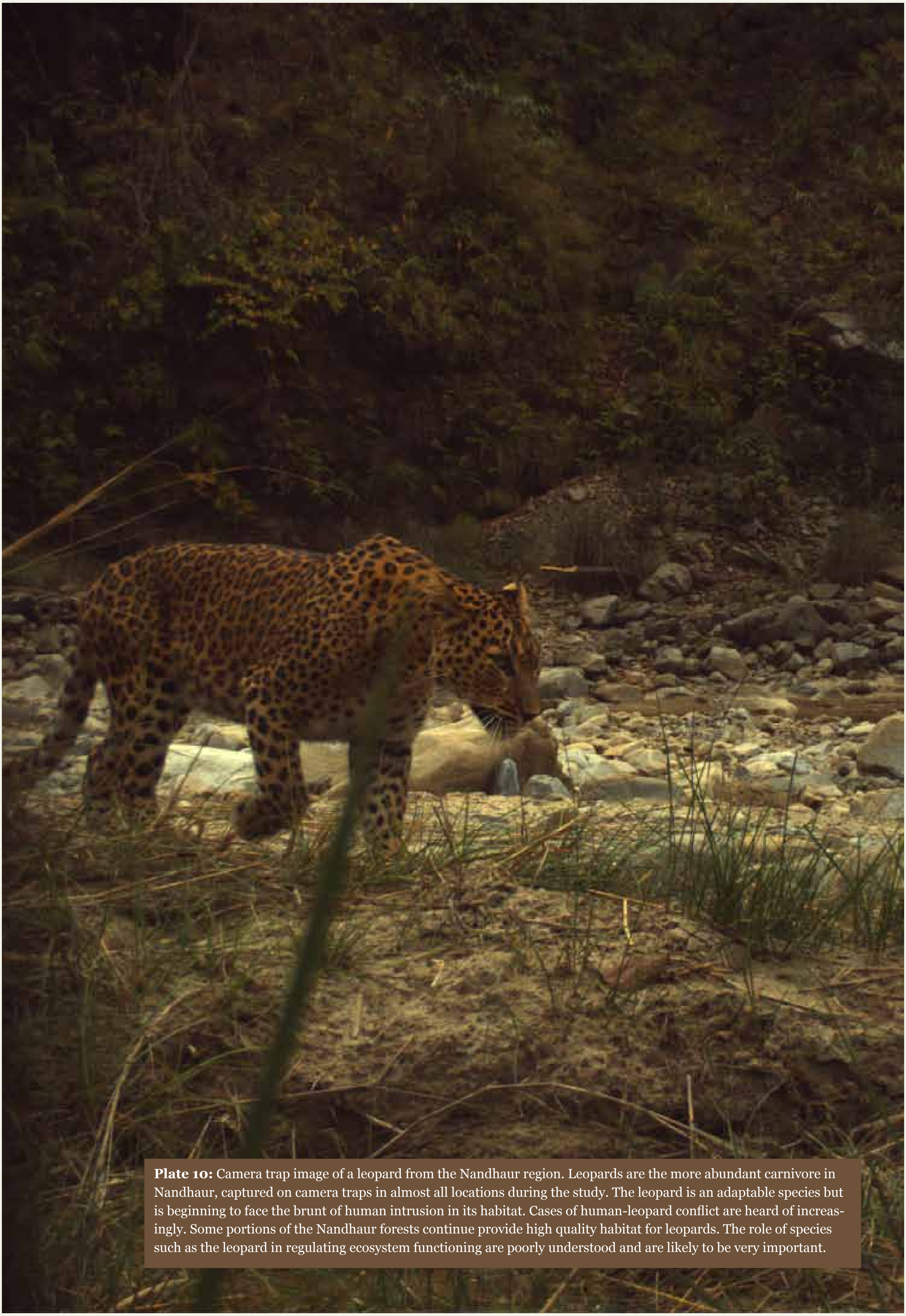


Plate 10: Camera trap image of a leopard from the Nandhaur region. Leopards are the more abundant carnivore in Nandhaur, captured on camera traps in almost all locations during the study. The leopard is an adaptable species but is beginning to face the brunt of human intrusion in its habitat. Cases of human-leopard conflict are heard of increasingly. Some portions of the Nandhaur forests continue provide high quality habitat for leopards. The role of species such as the leopard in regulating ecosystem functioning are poorly understood and are likely to be very important.

DENSITY OF PRINCIPAL PREY SPECIES IN THE NANDHAUR REGION

Introduction

Population densities of carnivores are known to be positively correlated with prey biomass (Carbone and Gittleman 2002). Not surprisingly therefore, empirical studies and deterministic models of wild tiger persistence have reiterated the importance of managing ungulate prey (Harihar *et al.* 2009, Karanth & Stith 1999, Karanth *et al.* 2004). A recent study that compared the relative contribution of poaching and prey depletion concluded that management of wild prey is crucial for the recovery of tiger populations subjected to low levels of poaching (Chapron *et al.* 2008).

The *terai-bhabar* belt harbors a diverse assemblage of ungulate species due to the heterogeneity in available habitats. However, habitat loss, fragmentation and hunting have resulted in many species such as hog deer, swamp deer and four horned antelope becoming locally extinct in many parts of the landscape. The Nandhaur valley falls primarily within the *bhabar* belt. The habitat within this region is comprised of narrow valleys bounded by steep rugged hills. Dominant vegetation communities comprise of sal (*Shorea robusta*) and associates, mixed deciduous forests along drainages and water courses, tracts of scrub forest dominated by *Dalbergia*, *Acacia* and *Zizyphus* species. In the higher reaches, there are stands of pine (*Pinus roxburghii*), banj oak (*Quercus leukotrichophora*) and associated temperate species. The understory in the entire area is shrub dominated.

These habitats are especially suited for prey species such as sambar (*Rusa unicolor*), goral (*Naemorhedus goral*) and serow (*Capricornis thar*). Species such as chital (*Axis axis*) occur in low densities in this area due to the small and patchy nature of grassland habitats which are largely restricted to river banks. Tall grasslands may have existed historically in the southern reaches of the study area (Terai East FD) supporting populations of species such as hog deer (*Hyelaphus porcinus*) and swamp deer *(Cervus duvauceli*). Other species of wild prey such as wild boar (*Sus scrofa*), nilgai (*Boselaphus tragocamelus*) and common langur (*Semnopithecus entellus*) are also found in this area. These species are known to be tolerant to anthropogenic disturbances and are frequently distributed in proximity to cultivation. The four-horned antelope (*Tetracerus quadricornis*) a small threatened ungulate restricted to forested habitats is also known to be distributed in this region (Bivash Pandav, pers.com). However, being a solitary and cryptic species there is no available data on its present status.

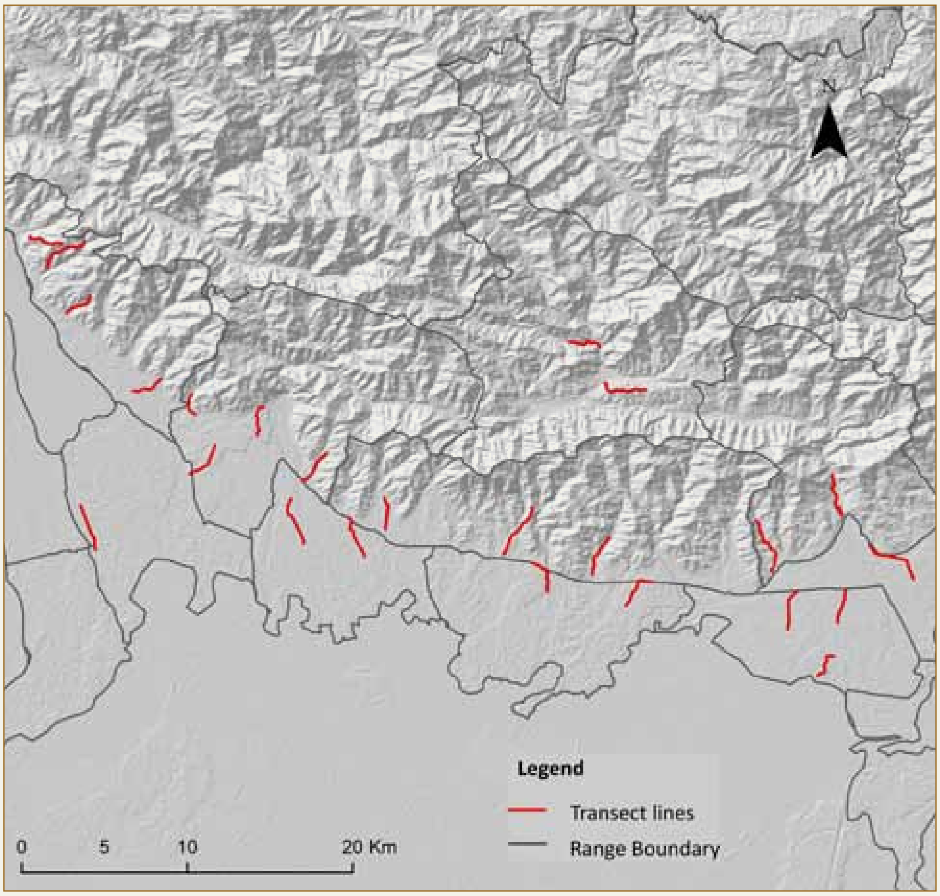
Some studies on predators and prey in India indicated that the availability of diverse prey facilitate the coexistence of sympatric carnivores (Karanth and Sunquist 1995). Predictably, the diverse assemblage of prey species in Nandhaur continues to support sympatric populations of tigers, leopards and lesser carnivores such as jackals, lesser cats etc. However, in Nandhaur, the diversity in prey species is potentially undermined by their low densities. The causes for low densities are manifold. The area has been reportedly subjected to intense hunting of wild ungulate species by inhabitants from peripheral villages as well as more organized groups that supply local meat markets (Johnsingh and Pandav 2008). It is also reported that hunters primarily target large bodied ungulate species such as sambar, wild boar and chital, which are also crucial components of tiger and leopard diets (Harihar *et al.* 2011). Coupled with hunting, habitat loss, and habitat degradation as a result of competitive pressures from cattle, fires, invasive species and land use alterations might have potentially depressed the densities and distribution of the region's wild ungulates. This study aimed to generate baseline estimates of densities and encounter rates for principal tiger and leopard prey species in a portion of the study area. The surveys have some limitations because considerably greater sampling effort was required for low density sites and because our transects were not representative of the entire region since lowlands and valleys were sampled to a greater extent. Nonetheless, these estimates derived from line transect data were indicative of the status of major ungulate prey species along the Nandhaur foothills and could be useful in assessing the impacts of improved enforcement and management in the area and in designing future studies.

Methods

Density estimation of principal prey species in the study area was carried out using conventional distance sampling methodology (Buckland *et al.* 2001). The philosophy underlying this methodology is that detection of individuals is a decreasing function of distance from the observer. This method involved observers walking along randomly laid straight transect lines looking for the species of interest. When an animal or a group of animals was detected, observations such as species identity, perpendicular distance of the animal/ cluster of animals to the transect line (measured using a range finder), number of individuals and the age-sex composition of the cluster were recorded. Data on perpendicular distances were then collated to generate a density function for detection probability at different distance classes from the transect line. This detection probability value was used to estimate the effective strip width (ESW) i.e. the distance on either side of the transect line within which all individuals were perfectly detected.

Due to the rugged nature of the terrain in the study area and paucity of time, laying straight line transects was not feasible. Therefore we randomly selected trails and fire lines with as straight an orientation as possible which served as transect lines. Although straight line transects are most suitable for collecting data on mammal densities (Buckland *et al.* 2001), the use of curvilinear features such as roads and trails is not uncommon (Varma and Sukumar 1995, Tomas *et al.* 2001, Ruette *et al.* 2003, Ogutu *et al.* 2005, Wang 2010). Trails and firelines were identified using Google Earth imagery and detailed Division maps for the area. In this study, transect sampling was restricted to the lowland forest tracts along the foothills of Haldwani Forest Division, and in the valley of the Nandhaur River. The reasons for limiting our transect surveys to this regions were twofold. Firstly, because this area matched the area where camera trapping was carried out and secondly because these areas allowed transect sampling along relatively straight trails. In many other portions of the study area, steep, crumbly and densely vegetated hills made line transect sampling a futile exercise. In order to estimate prey densities in the study area a total of 24 trails were selected randomly from a larger pools of trails that could be sampled. The lengths of these trails varied from 1.4 to 3 km. These trails were walked three times each resulting in a total survey effort of 166.35 km. To maximize detections sampling was carried out in early morning (6.30 a.m.) and late evening (5.00 p.m.) hours when animals are known to be most active.

Fig 6: Coverage of transects lines within the study site.



A histogram of the perpendicular sighting distances generated during sampling was plotted and checked for evidences of evasive movements and heaping. Following this the data was truncated to remove outliers. The perpendicular distances were then re-classed into various distance intervals to fit the key functions and adjustment terms available in the program Distance 6 (Thomas *et al.* 2009). A Chi-square goodness of fit test was used to assess the fit of the model to the data. Finally Akaike information criteria were employed to pick the best fitting model among the various competing models. The density of animal clusters (Ďs) and individuals (Ď) in the area were estimated using estimated parameters from this model.

Results

A total of 112 detections of prey species were obtained across 72 transect replicates (n=24). Table 9 summarizes the transect data in terms of total number of detections per species, average cluster size and encounter rates.

Table 9: Summaries of detections, average cluster size and encounter rates for prey species.

Species	Detections	Avg. cluster size (SD)	Encounter rate/km (SE)
Common langur	47	5.54 (5.71)	1.54(0.486)
Barking deer	24	1.125 (0.33)	0.175(0.06)
Chital	5	3.8 (2.68)	0.098(0.056)
Wild pig	8	1.62(1.40)	0.089 (0.05)
Sambar	18	2 (1.17)	0.233(0.068)
Nilgai	6	2.5 (1.51)	0.09(0.05)
Goral	3	1.33(0.57)	0.023 (0.016)
Serow	1	1	0.005(0.005)

Common langurs (*Semnopithecus entellus*) were the most common species detected on transects followed by barking deer and sambar. Serow and goral were poorly represented on the transects because these species tend to occur along steep mountain slopes which were inadequately sampled. The collected data was insufficient to permit the estimation of species-wise densities. We therefore, estimated the combined density of all prey species (all ungulates + langurs) and combined density of all ungulate prey species using the models with the least AIC weights. The half normal function with no series adjustments best fit the data in both cases and was used to estimate the parameters of interest. Total prey species density for the sampled area was estimated to be 23.89 km^{-2} (SE=4.48, χ^2=1.02, df=6, p=0.984) while the density of ungulate prey in the area was 7.08 km^{-2} (SE=1.44, χ^2=1.958, df=6, p=0.923). The final estimates of (Ďs) and (Ď), detection probability (p), average cluster size (Es) and effective strip width (ESW) for both sets of data are provided in the Table.

Table 10: Estimated prey density in Nandhaur. s and are group and individual density estimates. Es is average cluster size and ESW is effective strip width in meters. p is the detection probability.

	Ďs (SE)	Ď (SE)	p	Es (SE)	ESW (meters)
All prey (ungulates+langur)	7.05 (1.01)	23.89 (4.48)	0.51 (0.03)	3.38 (0.41)	46.09
All ungulates	3.95 (0.70)	7.08 (1.44)	0.52 (0.05)	1.79 (0.17)	47.02

Discussion

Line transect surveys totaling 166.5 km in length allowed us to obtain reasonable estimates of prey densities for the sampled areas. These results are of significance for a numbers of reasons. For one, there are few sites within the Indian *terai* for which prey species have been estimated using reliable methods. These findings suggest that the Nandhaur region supports relatively small populations of 'lowland' species such as chital whereas the region appears to sustain sizable populations of sambar and other species that are well adapted to undulating and mountainous terrain. Undoubtedly, this will have a bearing on the region's tiger population, given that tiger densities are ostensibly correlated to the occurrence and abundance of their prey (Karanth *et al.* 2004, Karanth and Stith 1999).

In the Nandhaur region, 44% of all detections on transects were of langurs, followed by barking deer (21%). The large bodied ungulates (chital, sambar, nilgai and wild pigs) constituted 33% of all observations. A number of studies on tiger food habits in peninsular India revealed that tigers selectively feed on large bodied wild ungulates. For example Sankar and Johnsingh (2002), Andheria *et al.* (2007) and Biswas and Sankar (2002) indicated from their research that chital and sambar accounted for 50 - 60% in the diet of tigers, while wild pigs appeared to be fed on to a lesser extent (6 - 10%). Langurs and barking deer were not major constituents in the diet of tigers (< 5%) in these studies. Closer to the Nandhaur region, in the Rajaji National Park, sambar alone constituted nearly 50% to the diet of tigers, with livestock (10%) chital (15%) and barking deer (3%) being less important items in the tigers diet repertoire (Harihar *et al.* 2011). Rugged terrain of the Rajaji National Park and high sambar densities are reflected in this dietary shift in tigers in this sub-Himalayan region. In the temperate montane forests of Bhutan where tigers occur in low densities and chital are largely absent, barking deer constituted 40% of tiger's diet followed by cattle (19%), sambar (15%) and wild pigs (10%) (Wang and Macdonald 2009). This indicates a shift in prey selection towards species that are most abundant locally, even though these ungulates are smaller in size and relatively unimportant in their diets in lowland habitats. Interestingly, the contribution of langurs to tiger diets was small even in montane habitats.

Reliable estimates of prey abundance, including smaller forest ungulates like barking deer and goral, are essential to determine the region's carrying capacity for tigers. While our data allowed the estimation of wild prey abundance (for eight species) or for seven ungulate species with a coefficient of variation value close to 20%, sample sizes were too small to allow species-specific estimates. This is a limitation of our study. Sample size calculations using encounter rate data (Buckland *et al.* 2001) from these surveys revealed that a phenomenal amount of effort - defined here in terms of the number of kilometers sampled - will be needed to obtain Distance sampling based species specific estimates for ungulates, with a coefficient of variation of 20%. For species that occur in clusters, most notably chital, the calculated effort is an overwhelming 4170 km. Values for barking deer, sambar and wild pigs are 518, 691 and 1556 km respectively. To estimate densities of key prey species therefore researchers have two options - to considerably scale-up survey effort in a bid to achieve acceptable levels of precision, or to use methods that link detection probabilities of animal signs with heterogeneity in their abundance to derive estimates of population size (Royle and Nichols 2003, Gopalswamy *et al.* 2012). There are tradeoffs associated with both these alternatives. In the case of line transect sampling the logistics are daunting and there are virtually no studies in tiger habitats in India with such high effort, even when the terrain is more accessible. When indirect evidences of animal presence are used to estimate abundance, a count of signs (such as number of individual hoof-prints on a trail) is mandatory. While such surveys are logistically simpler, there is much uncertainty in counts of animal tracks for forest dwelling ungulates, and often these data only allow the estimation of measures of relative abundance .

With regard to sampling design, we are aware that walking transects along human and animal trails is discouraged since it violates the assumption that transect lines should be straight and located randomly in relation to the distribution of animals within the study area. Hiby and Krishnan (2001) tested the robustness of density estimates derived from walking transects along forest trails concluded the following:

a) Trail curvature does not pose a serious problem so long as there are no sharp turns and all detections are within the radius of the curvature. This can be ensured by measuring only the shortest possible perpendicular distance of an animal detected from a curving path.

b) Estimates can be biased if animals preferentially use or avoid trails.

c) Care should be taken to ensure adequate representation of all available habitats.

We believe that our survey does not seriously violate any key assumptions and that our estimates for densities are relatively unbiased for the following reasons. First, we were able to select trails randomly (for the set of available trails) and ensure that they were distributed to uniformly cover the area of intensive sampling in this study. Second, our trails were largely straight, and curvature was typically minimal. It is therefore unlikely that we ever detected animals at distances greater than the radius of curvature. Finally, whenever animals were encountered we measured the shortest possible perpendicular distance of the animal to the trail.

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Plate 11: Sambar, one of the principal prey species for tigers occurs in low density in the study area.

Plate 12: Presence of sub-adult tigers and lactating female provides evidence of tiger breeding in Nandhaur. Just over a year old, this sub-adult and its sibling were captured several times by camera traps at the boundary of Chakata and Nandhaur Range.

SYNTHESIS

Potential for recovery of tiger population in the Nandhaur region

This study clearly establishes that THB III, which comprises primarily of hill forests between the Gola and Sharda rivers continues to support a small tiger population. Given the vastness of the area (~1500 km²) and the fact that we found evidence of two breeding females, one of which was accompanied by cubs, it appears that the population in Haldwani, Champawat and Terai East Forest Divisions is largely resident within this area. Preliminary transect surveys revealed that wild ungulate prey densities in the region were fairly low (7.04 ungulates/ km²). Our estimated densities of leopards (9/100km²) are among the highest reported from the *terai* region (see also Harihar *et al.* 2011). Although there are issues of prey abundance, habitat quality and inter-patch connectivity, anthropogenic pressure on tiger habitats and poaching have been identified as the other key variables driving population dynamics of tigers across their range (Seidensticker *et al.* 1999). A critical assessment of a recovery potential for tigers in the area requires scrutiny of these factors. Appendix 6 lists perceived threats to wildlife populations in the region. This section elaborates on some of these issues, while identifying factors that are likely to set a ceiling on the growth of the region's tiger populations. Here, we also identify key measures that may facilitate the persistence and growth of tiger populations in the Nandhaur region.

Plate 13: Grassy ridges such as this one en route to Byandhura from Senapani provide habitat for species such as sambar and goral. There are no significant grasslands in the sal dominated lower tracts of the Nandhaur region.

The influence of habitat on mammal occurrence and abundance

Topography and terrain

The most apparent feature that sets Nandhaur apart from other sites in the s*hivalik-bhabar* region (encompassing forests from the Yamuna River up to the Gola River), is that the Nandhaur region is predominantly mountainous. The topography here differs from other tiger occupied sites in the landscape in various ways. For example, both the Rajaji National Park and Ramnagar Forest Division have larger flat-land areas within them, in the form of broad valleys and plains abutting the mountains. Nandhaur, by contrast, is characterized by narrower valleys bound by hills. The hill slopes themselves are much steeper in Nandhaur (Fig 7). The Southern belt of Nandhaur (large parts of which are in the Terai East FD) comprises of a 60 km strip relatively flat or gently sloping land under forest cover. However, this strip is no wider than 1.5 - 3 km, on an average, and is perforated and fringed by busy roads, villages and cattle camps. The Rajaji National Park and Corbett Tiger Reserve have contrasting geographies. Most significantly, the prominent lowlands in these parks lie well within the forest interior (Dhikala *chaur* in Corbett and Mundhal grasslands in Rajaji). These broad, grass-dominated river valleys are nestled amidst hills, and provide high quality habitat for a variety of wild ungulates, including gregarious species, as well as for tigers. Tigers are known to hold territories in mountainous areas and temperate forests (Corbett 1944, Wang and Macdonald 2009), but appear to achieve their highest densities in areas where the terrain is mildly undulating and vegetation communities are a heterogeneous mix of woodland and grassland.

In Nandhaur, where the mountains are steeper and grassy river-valleys are largely absent, our prediction is that tigers have and can occur at lower densities than elsewhere in the *shivalik-bhabar* region. The steep terrain may impose a limit on the growth of tiger populations within the Nandhaur region. More specifically, areas defined primarily by steep terrain and lacking prominent valleys and grasslands may constitute somewhat inferior habitat. Data from our camera trap and occupancy surveys also suggest that tigers may well align their home ranges along prominent topographical features - most notably along river valleys. These offer terrain that is easily negotiable in an area that is predominantly mountainous. Drainages also attract prey - both because as they offer relatively easy travel paths in the non-monsoon period and serve as water source.

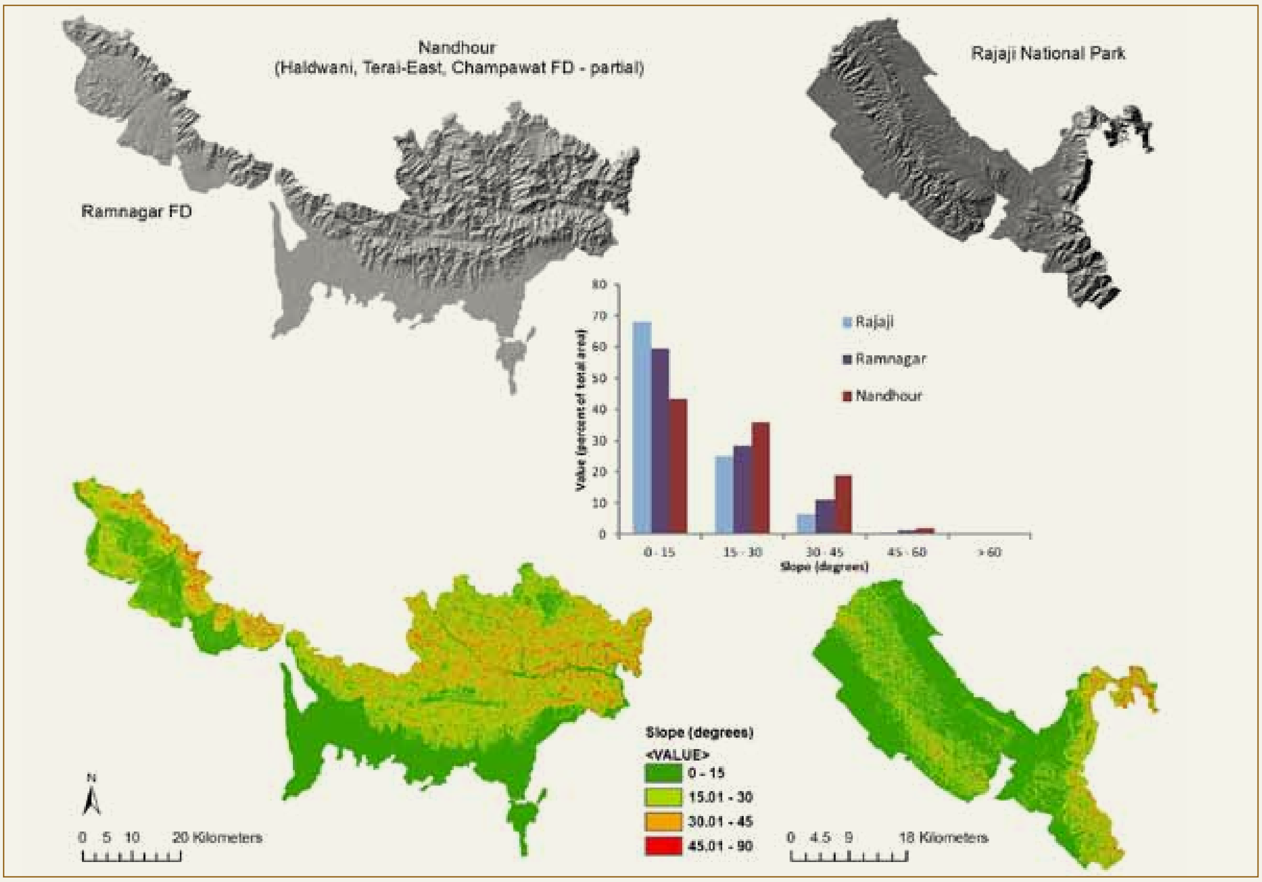

Fig 7: Comparison of the Nandhaur region, Ramnagar Forest Division and Rajaji National Park with respect to terrain (relief and slope).

Vegetation and forage availability

Most vegetation communities found elsewhere in the s*hivalik-bhabar* region of the TAL were found to be represented in the Nandhaur region. Grasslands were however conspicuous by their absence. Even in the lower reaches of rivers and streams such as the Nandhaur and Kilonia, flood and erosion-prone banks were typically characterized by dense stands of shisham (*Dalbergia sissoo)*, with little grass in the understory. While this paucity of grass was unlikely to affect browsers and mixed foragers such as sambar and barking deer, this in combination with the steepness of terrain set limits on the distribution and abundance of chital, as is evident in the habitat use models described previously. In this respect, Nandhaur deviates from other tiger habitats, most notably eastern Rajaji National Park, Corbett and Ramnagar FD, which are in general, associated with high tiger and chital densities (Harihar *et al.* 2011, Jhala *et al.* 2010). Studies that map vegetation communities and estimate the biomass of palatable species in the environment are needed to better understand habitat drivers of heterogeneity in ungulate abundance across these sites. In the absence of such information, it is reasonable to propose that the Nandhaur region is less productive for grazing ungulates than other sites in the landscape. We postulate that lower grass productivity in the Nandhaur region might limit the growth of its tiger population. This may be reflected in a decreasing tiger density gradient as one progresses from the lower Himalayan foothills in the south towards the temperate zones that lie beyond the Ladhya valley to the North.

Prey abundance and the influence of prey on tiger populations

The estimated densities for prey species in Nandhaur are very low in comparison to similar sites elsewhere in the *bhabar* tract. Based on total ungulate densities and species encounter rates it is evident that common langurs contributed significantly to the overall prey densities in the area. This is contrary to other sites, where a significant portion of the overall prey densities is contributed by large prey species such as sambar, chital and wild boar (Harihar *et al.* 2011). Table 11 provides comparative estimates of the total ungulate densities from the Corbett Tiger Reserve and the Rajaji National Park, areas which support relatively high tiger densities.

Table 11: Comparative estimates of ungulate density in Nandhaur and other sites in the Uttarakhand TAL.

Limited in extent, small tracts of tall floodplain grassland cling to river courses in the foothills.

Bamboo thickets are found in Jaulasal North and South ranges.

Mixed deciduous forests at the foothills

Grass covered ridge en route to Byandhura in Dogari Range, Champawat FD

Pure strands of pine *Pinus roxburghii* in the Nandhaur river valley

Young peak plantation in Chakta range, Haldwani FD

Sal Trees (*Shorea robusta)*

Mixed Deciduous Forest

Plate 14: Habitat and vegetation types in the Nandhaur region.

Site	Total ungulate density / km^{-2} (SE)	Reference
Nandhaur region	7.08 (1.44)	This study
Sal and Miscellaneous forests of Rajaji and Corbett	58.04 (11.39)	Jhala *et al.* 2010
Rajaji National Park, Chilla range	68.8 (N/A)	Harihar *et al.* 2009

Sambar and chital contributed significantly to the diets of tigers (Karanth and Sunquist 1995, Wegge and Storaas 2009) and prey rich habitats promote high reproductive rates in tigers (Karanth and Stith 1999). Possibly low densities of these species are probably responsible for impeding the recovery of the tiger population in the Nandhaur region. Prey recovery measures need to be emphasized in the management plan of this area in order to hasten the recovery of the region's tiger population.

Sambar was present in low densities. However, species such as chital and nilgai probably occurred in naturally low densities in the study area due to the lack of suitable habitats and the continued degradation of existing habitats due to overgrazing and unsustainable exploitation of non-timber forest produce in some areas.

Connectivity

The loss of connectivity between habitat patches can have severely deleterious impacts on large carnivore populations. These are manifest in population declines and local extinction for some species (Crooks 2002), and reduced genetic heterozygosity on account of genetic isolation (Dixon *et al.* 2007, Sharma *et al.* 2009). Although the Nandhaur region represents a large patch of tiger habitat (nearly 1500 km^2 in area), it is reported to be tenuously connected with other tiger occupied forests. Most likely, this lack of connectedness has had a bearing on Nandhaur's carnivore population, in stark contrast to the intact Rajaji - Corbett - Ramnagar forest block (THB II) (see Harihar *et al.* 2012).

In the absence of unambiguous evidence of the movement of tigers between patches based on photographic evidence, our understanding of the functionality of corridors linking the Nandhaur region, is speculative. Reconnaissance surveys in the Boom-Bramhadev corridor along the Sharda river (which marks the India - Nepal border) suggested that the Nandhaur region is well connected with the Bramhadev forests and that a few kilometers upstream from the town of Tanakpur, animals may be able to pass unimpeded by man-made obstructions. However, the northward ingression of residences and farm land from Tanakpur along the west bank of the Sharda has reportedly affected an elephant corridor. Presently, boulder mining is restricted to the Sharda riverbed downstream of the Tanakpur barrage. An expansion of this activity upstream of the barrage into other *rau* such as Kiroda and Kilonia nala will be a severe infringement on the habitat of tigers, leopards, bears, elephants and other wild mammals which frequently use these drainages. There is no reliable information available on the status of mammals in the Bramhadev forests, which are connected to the Shuklaphanta Wildlife Reserve in Nepal, but it is unlikely that the region has a large resident tiger population at present. The same cannot be said of the two other corridors, namely the Gola river corridor between Ramnagar, Nainital and Haldwani Forest Divisions. Haphazard infrastructure development and urbanization along the Gola downstream of the town of Haldwani has effectively dismembered the corridor and we suspect that it no longer serves as a route for dispersing wild mammals. The upper Gola river corridor (upstream from the town of Kathgodam) has also witnessed accelerated development in recent years on account of growing human populations in villages along the river and increased traffic volume on the Haldwani - Nainital highway. Nandhaur's connectivity with Surai Range of Terai-East FD through the Kilpura-Khatima corridor is weak, at best. An encroachment-prone 'chicken neck' in Kilpura-Khatima Ranges in combination with the large Sharda canal and multiple roads and highways make this an obstacle-laden corridor. Moreover, information from sign surveys indicated that unlike the forests of Pilibhit FD, the Surai Range forests in Terai East FD appeared to be impoverished in tigers and wild ungulates, particularly as one advances northwards from Mahof Range of Pilibhit FD (Chanchani *et al.* 2011).

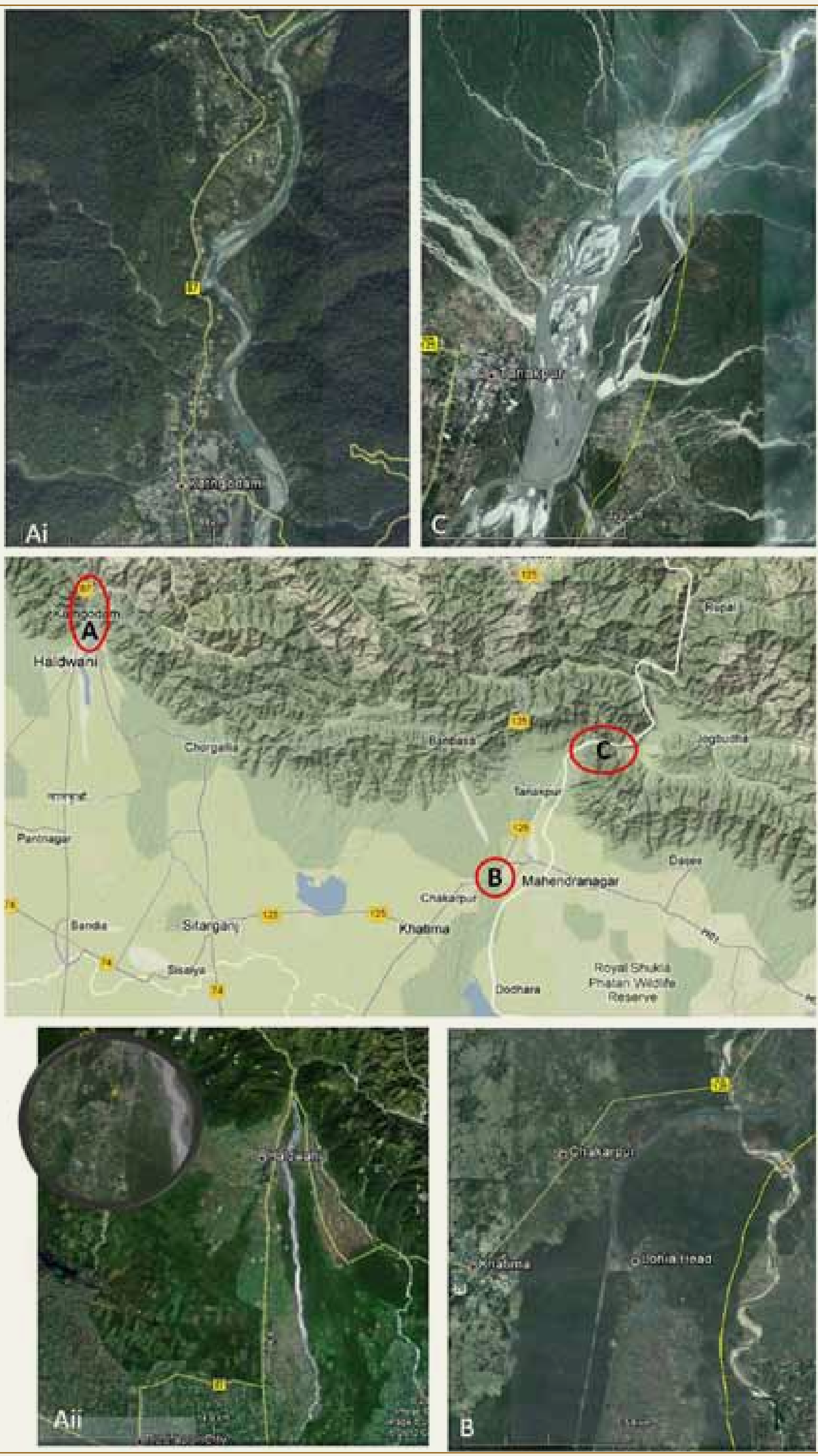

Fig 8: Satellite imagery of four major corridors in the Nandhaur region depicting forest cover and breakages in connectivity. (Image source: Google).

Ai: Upper Gola River corridor. North of the town of Kathgodam. Note development along river.

Aii: Lower Gola Corridor. The scrub forests along the Gola River are a part of Terai East FD and are severely impacted by encroachment and other forms of disturbance. On the west bank of the river are plantation and marginal forests of Terai West Forest division. The inset image (circle) illustrates the density of housing between forest patches.

B: Kilpura Khatima Corridor West from the hamlet of Chakrapur, thef orest corridor is convoluted, narrow and hemmed in by habitation. Animals using this corridor will also encounter the main Sharda canal twice (100 m wide) and will have to negotiate National Highway 125. The yellow line on the east marks the India – Nepal border.

C: Boom Bhramadev Corridor. Note how connectivity is maintained through hills on either bank of the Sharda (Mahakali). There has been a steady growth in urbanization along the river, both upstream and downstream from Tanakpur town.

Whereas there is very limited potential for management intervention to improve or alter wildlife habitats for tigers in the Nandhaur region (apart from restoring small *chaur* or restoring native forests in plantation sites), much can be done to secure corridors. Specifically, managers and conservationists can focus their efforts on monitoring animal movement across these corridors while ensuring that fragile forest linkages do not get further eroded by inappropriately-planned development and encroachment. Restoration efforts in key sections of these corridors may yield invaluable dividends for long term tiger conservation in this portion of the Terai Arc Landscape, and are likely to have positive impacts on tiger populations in India and Nepal.

Disturbance

Plate 15: Grass harvesting, dead timber extraction, and *Gujjar* settlements (from top to bottom) along with other human related activities may compromise habitat for wildlife in Nandhaur.

Results of models of animal-habitat relationships based on sign surveys are unanimous in one respect. They indicate that tigers, sambar and chital all appear to occur less along village peripheries and appear to use forest-interior habitats to a greater extent. This is consistent with the findings of Harihar and Pandav (2012) for the western portion of the TAL. Many villages in the hills bordering the Nandhaur region still lack connectivity to motor roads. The communities that live in them primarily practice subsistence agriculture and animal husbandry. They rely on forests for fuelwood, fodder, housing material, wood for tools and implements and extract other forest produce. It is reasonable to predict that human activity in forests (with the exception of wandering sheep and cattle herds) is most intense in the proximity of settlements. Wild mammals may avoid such areas to minimize contact with humans, but it is likely that these species are wary of hunters, dogs and other threats.

Disturbance in the Nandhaur region, particularly in the mountains, is relatively low-impact (presence of humans on foot) as opposed to disturbance from highways and large infrastructure projects that occur in other wilderness areas. Within Nandhaur, the forests of Haldwani Forest Division are relatively less disturbed and there are no permanent villages within this forest, though the entire Division is fringed by villages along its boundary. However, *khattas* (buffalo camps) are numerous and widespread, particularly along the southern boundary and sporadically along the course of the Nandhaur river and its tributaries. Collection of grass like *Eulaliopsis binata, Thysanolaena maxima* is a widespread activity across the area. Timber from fallen trees is also harvested across Haldwani Forest Division in the spring and summer months, and the wood is transported in trucks that ply on rudimentary roads. Wandering graziers from nearby hill villages and migratory *Bhotiya* herders graze their flocks in the forests of Nandhaur.

The Ladhiya Valley of Champawat Forest Division has numerous villages, and the landscape here comprises of fields and scrub forests interspersed with patches of forest. Although marauding tigers were reported from these villages historically (Corbett 1944, 1954), there is little current evidence of tiger presence in the mountain interiors of Champawat. The southern ranges of Terai East Forest Division comprise the flat terrain of the Nandhaur region. These are reportedly sites of significant timber operations and areas are infiltrated by humans engaged in boulder mining, tree felling (both legitimate and illegitimate). It is also perceived that encroachment of forest land and hunting by the Rai Sikh community are other factors that take a severe toll on wildlife populations here.

There is evidence from other sites in India for the recovery of wild ungulate populations following a reduction of cattle grazing pressure in their habitats (Madhusudan 2004, Harihar *et al.* 2009). Management efforts must thereby focus on regulating and reducing disturbance, while being cognizant of the livelihoods of pastoral communities that inhabit the region. Given that tigers and ungulates may use river valleys and stream courses extensively, management needs to focus on monitoring and reducing disturbance in key habitats. Given that the southern boundary of the Nandhaur region is somewhat problem-ridden and afflicted by disturbance, there is an urgent need to prioritize enforcement and conservation efforts there.

Plate 16: Day old tiger skin and the snare (below) used to trap this tigress were recovered by the Forest Department from Kilonia nala, close to the town of Tanakpur. Regular patrolling of sensitive areas can deter such incidents in future.

Poaching

Although the Nandhaur region contains over 1000 km² of forested habitat, our surveys indicated that wildlife there may currently occur at densities lower than the habitat-based carrying capacity. This is the plight of other pristine wilderness areas elsewhere in India and the tropics (Datta *et al.* 2008, Harrison 2011). While fragmentation and disturbance are likely to influence the persistence of tigers and other mammals over longer time spans, poaching might be attributed as an important factor that has led to losses in populations of tigers and herbivores in the Nandhaur region. A logical corollary for this statement is that concerted efforts towards a zero poaching regime in Nandhaur will promote the recovery of wildlife populations and could lead to a perceptible increase in tiger density over a few years.

Johnsingh *et al.* (2004, 2010) single out the Rai Sikh and Nepali populations of the region as the most active poacher communities, and we have encountered large groups of Rai Sikh men with dogs in the forest. The studies of Madhusudan (2004) and Steinmetz *et al.* (2010) indicate that if disturbance or poaching levels are reduced through management interventions, wild ungulate populations begin to increase. However, not all species respond to reduced threats at similar rates and sambar populations were found to show little recovery response over relatively short time periods in contrast to other wild ungulates. While enhancing protection to promote prey species recovery emerges as a priority for the region, it is essential that enforcement be strengthened to prevent the loss of tigers to poachers. Over the duration of our study (October 2011– May 2012), at least one tiger was known to be poached from this region while it was not possible to ascribe cause of death for two cubs. Extensive forest areas in rugged terrain with few roads have resulted in a scenario where current patrolling measures are inadequate for the region. Moreover, the region's wildlife potential has largely been unrecognized so far and there is little available infrastructure to ensure thorough patrolling. Remote forest *chowkies* are often unmanned although recent emphasis on improved infrastructure and patrolling has improved this situation. Apparently, the region's proximity to Nepal and the open international border allows poachers to act with impunity. The tiger population in the Terai Arc is threatened by poaching, and is likely also subject to incidental mortality by poisoning as a form of retaliatory killing by cattle owners.

It is perceived that poaching poses a significant risk to the region's small tiger population. Small populations of large mammals are susceptible to extinction and inbreeding depression (Pimm *et al.* 1988, Kenney *et al.* 1995, Cardillo *et al.* 2005). Clearly, sustained poaching over time can cause the tiger to become locally extinct (Check 2006). Given adequate prey, tigers are understood to be fairly resilient to low levels of poaching, (Karanth and Stith 1999). Chapron *et al.* (2008) argue compelling against this. Their models demonstrate that when tiger mortality rate exceeds 15%, prey population recovery alone may not enable tiger recovery. To conserve tigers in the Nandhaur region, it is imperative that the region be given the status of a forest area that prioritizes conservation. This, in combination with strategic patrolling and stringent law enforcement carried out by a dedicated cadre of trained personnel will serve to conserve the region's wild fauna.

Value of Nandhaur as a high biodiversity region

Data on tigers in the Nandhaur region from the current surveys are sparse and did not permit us to reliably project how many tigers are likely to persist here in the future. Such information will be gained by continued monitoring over time. Johnsingh *et al.* (2010) opined that the Gola - Sharda _ Ladhiya region has the potential to support 30 - 50 tigers. Our surveys (based on estimates of prey abundance and qualitative assessments of habitat - particularly topography) indicated that the habitat-based carrying capacity may be considerably lower than this figure.

Plate 17: The forest in kundal Village, North West from Durga Peepul. The presence of forest department staff in remote areas is integral for efficient patrolling.

Protecting populations from poaching, restoring corridor functionality and improving the prey base will help sustain this population and foster its growth. While this study identified the Nandhaur tiger population as being small, it provided compelling evidence of the region's importance for wildlife. Notable features include remarkably high leopard densities (9.57/100 km^2), a checklist of birds from *ad hoc* surveys with 206 records and evidence for the presence of 32 mammalian species, with representations of both Himalayan and peninsular groups. The Nandhaur and its tributaries are repositories of aquatic life forms including populations of the endangered Golden masheer (*Tor putitora*) and sustain communities of riparian birds. This makes Nandhaur a storehouse of valuable biodiversity. The presence of a group of forty or more elephants calls for sensitivity in managing habitats and reducing human presence in these forests.(Refer to Appendix 2-5, for further information on biodiversity in Nandhaur) We wholeheartedly support Johnsingh *et al.*'s (2010) plea to conserve wildlife habitats between the Ladhiya and Gola Rivers, and agree that the establishment of a fairly large Protected Area complex encompassing the Nandhaur, Danda, and Jaulasal (north) ranges of Haldwani FD, Boom and Dogari ranges of Champawat FD, Jaulasal (south), Kilpura ranges of Terai East FD and other proximate forest blocks will contribute significantly to global and national goals of tiger and biodiversity conservation. The Uttarakhand Forest Department has taken the right step towards that direction. Through a gazette notification, 269 sq.km of Haldwani Forest Division has been declared as the Nandhaur Wildlife Sanctuary on 14th December 2012.

Plate 18: The success of conservation programs in the Nandhaur region will ultimately depend on the well being of its people. Women from Kundal, a village on the northern boundary of Danda Range, Haldwani FD, on their way to collect grass from the Nandhaur valley (Top Left). An inhabitant of Chorgalia hauls home a headload of fuelwood (Top Right). A tharu woman with her grandson next to their mud and thatch hut at Dogari, North Jaulasal Range, Haldwani FD (Bottom Right). Proud owner of a traditional Kumaoni home in the Ladhya valley.

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APPENDIX 1

TIGER INDIVIDUALS PHOTOGRAPHED DURING CAMERA TRAPPING.

Phase I

Individual 1 (Probably Female)

Individual 2 (Male)

Individual 3 (Male)

Individual 4 (Female)

Individual 5 (Sub Adult)

Individual 6 (Sub Adult)

Phase II


Individual 7 (Female)


Individual 8 (Female)

APPENDIX 2

MAMMAL SPECIES PHOTOGRAPHED IN NANDHAUR

Leopard

Leopard cat

Jungle cat


Himalayan masked civet

Striped hyena

Indian fox

Large Indian civet

Golden jackal

Sloth bear

Asiatic black bear

Yellow throated marten

Honey badger

Mainland serow

Goral

Sambar

Nilgai

Barking deer

Chital

Elephant

Wild boar

Rhesus macaque

Common langur

Indian pangolin

Porcupine

APPENDIX 3

LIST OF MAMMALIAN SPECIES DOCUMENTED IN THE STUDY AREA

No	Common Name	Camera trap	Seen	Signs	IUCN status
1	Tiger (*Panthera tigris*)	*		*	End
2	Leopard (*Panthera pardus*)	*	*	*	NT
3	Leopard cat (*Prionailurus bengalensis*)	*		*	LC
4	Jungle cat (*Felis chaus*)	*			LC
5	Rusty spotted cat (*Pronailusurs rubiginosus*)	*			Vul
6	Striped hyena (*Hyaena hyaena*)	*			NT
7	Golden jackal (*Canis aureus*)	*	*	*	LC
8	Sloth bear (*Melursus ursinus*)	*	*	*	Vul
9	Himalayan black bear (*Ursus thibetanus*)	*			Vul
10	Small Indian civet (*Viverricula indica*)	*			LC
11	Common palm civet (P*aradoxurus hermaphroditus*)	*			LC
12	Himalayan palm civet (*Paguma larvata*)	*			LC
13	Large Indian civet (*Viverra zibetha*)	*			NT
14	Indian grey mongoose (*Herpestes edwardsii*)	*	*		LC
15	Honey badger (M*ellivora capensis*)	*	*		LC
16	Yellow throated marten (*Martes flavigula*)	*			LC
17	Asian elephant (*Elephas maximus*)	*	*	*	End
18	Sambar (*Rusa unicolor*)	*	*	*	Vul
19	Chital (*Axis axis*)	*	*	*	LC
20	Muntjac (*Muntiacus munjak*)	*	*	*	LC
21	Nilgai (*Boselaphus tragocamelus*)	*	*	*	LC
22	Goral (*Naemorhedus goral*)	*	*	*	NT
23	Serow (*Capricornis sumatraensis*)	*	*		NT
24	Wild pig (*Sus scrofa*)	*	*	*	LC
25	Indian pangolin (*Manis crassicaudata*)	*			NT
26	Rhesus macaque (*Macaca mullata*)	*	*	*	LC
27	Common langur (*Seminopithecus entellus*)	*	*	*	LC
28	Indian hare (*Lepus nigricollis*)	*	*	*	LC
29	Hispid hare (*Caprolagus hispidus*)			*	End
30	Indian crested porcupine (*Hystrix indica*)	*	*	*	LC
31	Red giant flying squirrel? (*Petaurista petaurista*)		*		LC
32	Fulvous fruit bat (*Rousettus leschenaultia*)		*		Data def

IUCN classification: End- Endangered; NT- Near threatened; Vul- Vulnerable; LC- Least Concern; Data def- data deficient

APPENDIX 4

LIST OF BIRD SPECIES DOCUMENTED IN THE STUDY AREA

No	Species	Scientific name
1	Black francolin	*Francolinus francolinus*
2	Khalij pheasant	*Lophura leucomelanos*
3	Red jungle fowl	*Gallus gallus*
4	Indian peafowl	*Parvo cristatus*
5	Ruddy shelduck	*Tadorna ferruginea*
6	Cotton pygmy goose	*Nettapus coromandelianus*
7	Tufted duck	*Aythya fuligula*
8	Common merganser	*Mergus merganser*
9	Rufous woodpecker	*Celeus brachyurus*
10	Brown-capped pygmy woodpecker	*Dendrocopos nanus*
11	Great slaty woodpecker	*Mulleripicus pulverulentus*
12	Grey-capped pygmy woodpecker	*Dendrocopos canicapillus*
13	Fulvous breasted woodpecker	*Dendrocopos macei*
14	Yellow-crowned woodpecker	*Dendrocopos mahrattensis*
15	Lesser yellownape	*Picus chlorolophus*
16	Greater yellownape	*Picus flavinucha*
17	Scaly-bellied woodpecker	*Picus squamatus*
18	Grey-headed woodpecker	*Picus canus*
19	Himalayan flameback	*Dinopium shorii*
20	Black- rumped flameback	*Dinopium benghalense*
21	Greater flameback	*Chrysocolaptes lucidus*
22	Brown-headed barbet	*Megalaima zeylanica*
23	Lineated barbet	*Megalaima lineata*
24	Blue throated barbet	*Megalaima asiatica*
25	Indian grey hornbill	*Ocyceros birostris*
26	Oriental pied hornbill	*Anthracoceros albirostris*
27	Great hornbill	*Buceros bicornis*
28	Common hoopoe	*Upupa epops*
29	Red-headed trogon	*Harpactes erythrocephallus*
30	Dollar bird	*Eurystomus orientalis*
31	Indian roller	*Coracias benghalensis*
32	Common kingfisher	*Alcedo athis*
33	White-throated kingfisher	*Halcyon smyrnensis*
34	Crested kingfisher	*Megaceryle lugubris*
35	Pied kingfisher	*Ceryle rudis*
36	Blue-bearded bee-eater	*Nyctyornis athertoni*
37	Green bee-eater	*Merops orientalis*
38	Blue-tailed bee-eater	*Merops philippinus*
39	Chestnut-headed bee-eater	*Merops leschenaulti*
40	Common hawk-cuckoo	*Hierococcyx varius*
41	Asian koel	*Eudynamys scolopacea*
42	Green billed malkoha	*Phaenicophaeus tristis*

43	Greater coucal	*Centropus sinensis*
44	Alexandrine parakeet	*Psittacula eupatria*
45	Rose-ringed parakeet	*Psittacula krameri*
46	Plum-headed parakeet	*Psittacula cyanocephala*
47	Slaty-headed parakeet	*Psittacula himalayana*
48	House swift	*Apus affinis*
49	Brown fish owl	*Ketupa zeylonensis*
50	Jungle owlet	*Glaucidium radiatum*
51	Spotted owlet	*Athene brama*
52	Large-tailed nightjar	*Caprimulgus macrurus*
53	Rock pigeon	*Columbia livia*
54	Spotted dove	*Streptopelia chinensis*
55	Emerald dove	*Chalcophaps indica*
56	Yellow-footed green pigeon	*Treron phoenicoptera*
57	White-breasted waterhen	*Amourornis phoenicurus*
58	Green sandpiper	*Tringa ochropus*
59	Eurasian thick-knee	*Burhinus oedicnemus*
60	Red-wattled lapwing	*Vanellus indicus*
61	River lapwing	*Vanellus duvaucelli*
62	Osprey	*Pandion haliaetus*
63	Black-shouldered kite	*Elanus caeruleus*
64	Black kite	*Milvus migrans*
65	Grey-headed fish eagle	*Ichthyophaga ichthyaetus*
66	Lesser fish eagle	*Ichthyophaga humilis*
67	Egyptian vulture	*Neophron percnopterus*
68	Long billed vulture	*Gyps indicus*
69	Crested serpent eagle	*Spilornis cheela*
70	Black eagle	*Ictinaetus malayensis*
71	Shikra	*Accipter badius*
72	Oriental honey-buzzard	*Pernis ptylorhyncus*
73	Rufous-bellied eagle	*Hieraaetus kienerii*
74	Changeable hawk eagle	*Spizaetus cirrhatus*
75	Common kestrel	*Falco tinnunculus*
76	Oriental hobby	*Falco severus*
77	Great crested grebe	*Podiceps cristatus*
78	Indian cormorant	*Phalacrocorax fusicollis*
79	Great cormorant	*Phalacrocorax carbo*
80	Intermediate egret	*Mesophoyx intermedia*
81	Cattle egret	*Bubulcus ibis*
82	Indian pond heron	*Ardeola grayii*
83	Little heron	*Butorides striatus*
84	Black-crowned night heron	*Nycticorax nycticorax*
85	Woolly-necked stork	*Ciconia episcopus*
86	Black stork	*Ciconia nigra*
87	Black-necked stork	*Ephippiorhynchus asiaticus*

88	Long-tailed broadbill	*Psarosomus dalhousiae*
89	Golden fronted leafbird	*Chloropsis aurifrons*
90	Orange-bellied leafbird	*Chloropsis hardwickii*
91	Brown shrike	*Lanius cristatus*
92	Bay-backed shrike	*Lanius vittatus*
93	Long-tailed shrike	*Lanius schach*
94	Red-billed blue magpie	*Urocissa erythroryhncha*
95	Common green magpie	*Cissa chinensis*
96	Rufous treepie	*Dendrocita vagabunda*
97	Grey treepie	*Dendrocitta formosae*
98	House crow	*Corvus splendens*
99	Large-billed crow	*Corvus macrorhynochos*
100	Eurasian golden oriole	*Oriolus oriolus*
101	Black-hooded oriole	*Oriolus xanthornus*
102	Maroon oriole	*Oriolus trailii*
103	Large cuckooshrike	*Coracina macei*
104	Scarlet minivet	*Pericrocotus flammeus*
105	Long-tailed minivet	*Pericrocotus ethologus*
106	Small minivet	*Pericrocotus cinnamomeus*
107	Bar-winged flycatcher shrike	*Hemipus picatus*
108	White-throated fantail	*Rhipidura albicollis*
109	Yellow-bellied fantail	*Rhipidura hypoxantha*
110	Black drongo	*Dicrurus macrocercus*
111	Ashy drongo	*Dicrurus leucophaeus*
112	White-bellied drongo	*Dicrurus caerulescens*
113	Bronzed drongo	*Dicrucus aeneus*
114	Crow-billed drongo	*Dicrurus annectans*
115	Lesser racket-tailed drongo	*Dicrurus remifer*
116	Spangled drongo	*Dicrurus hottentottus*
117	Greater racket-tailed drongo	*Dicrurus paradiseus*
118	Black-naped monarch	*Hypothymis azurea*
119	Asian paradise-fly-catcher	*Terpsiphone paradisi*
120	Common iora	*Aegithina tiphia*
121	Brown dipper	*Cinclus pallasii*
122	Chestnut-bellied rock thrush	*Monticola rufiventris*
123	Blue-capped rock thrush	*Monticola cynclorhynchus*
124	Blue whistling thrush	*Myophonus caeruleus*
125	Orange-headed thrush	*Zoothera cyanotus*
126	Grey-winged blackbird	*Turdus boulboul*
127	Asian brown flycatcher	*Muscicapa dauurica*
128	Rusty-tailed flycatcher	*Muscicapa ruficauda*
129	Rufous-gorgeted flycatcher	*Ficedula strophiata*
130	Red-throated flycatcher	*Ficedula parva*
131	Little pied flycatcher	*Ficedula westermanii*
132	Verditer flycatcher	*Eumyias sordida*

133	Ultramarine flycatcher	*Ficedula superciliaris*
134	Small niltava	*Niltava macgrogoriae*
135	Rufous bellied niltava	*Niltava sundara*
136	Blue throated flycatcher	*Cyornis rubeculoides*
137	Grey-headed canary flycatcher	*Culicicapa ceylonensis*
138	White-tailed rubythroat	*Luscinia pectoralis*
139	Oriental magpie robin	*Copsychus solaris*
140	Indian robin	*Saxicoloides fulicata*
141	White-rumped shama	*Copsychus malabaricus*
142	Black redstart	*Phoenicurus ochruros*
143	Blue-fronted redstart	*Phoenicurus frontalis*
144	White-capped water redstart	*Chaimarrornis leucocephalus*
145	Plumbeous water redstart	*Rhyacornis fuliginosus*
146	Black-backed forktail	*Enicurus immaculatus*
147	Spotted forktail	*Enicurus maculatus*
148	Slaty-backed forktail	*Enicurus scistaceus*
149	Common stonechat	*Saxicola torquata*
150	Pied bushchat	*Saxicola caprata*
151	Grey bushchat	*Saxicola ferrea*
152	Spot-winged starling	*Saroglossa spiloptera*
153	Brahminy starling	*Sturnus pagodarum*
154	Chestnut-tailed starling	*Sturnus malabaricus*
155	Asian pied starling	*Sturnus contra*
156	Common myna	*Acridotheres tristis*
157	Bank myna	*Acridotheres ginginianus*
158	Jungle myna	*Acridotheres fuscus*
159	Chestnut-bellied nuthatch	*Sitta castanes*
160	Velvet-fronted nuthatch	*Sitta frontalis*
161	Bar-tailed treecreeper	*Certhia himalayana*
162	Great tit	*Parus major*
163	Black-lored tit	*Parus xanthogenys*
164	Black-throated tit	*Aegithalos leucogenys*
165	Eurasian crag martin	*Hirundo rupestris*
166	Barn swallow	*Hirundo tahitica*
167	Red-rumped swallow	*Hirundo daurica*
168	Black-crested bulbul	*Picnonotus melanicterus*
169	Red-whiskered bulbul	*Picnonotus jocosus*
170	Red-vented bulbul	*Picnonotus cafer*
171	Himalayan bulbul	*Picnonotus leucogenys*
172	Ashy bulbul	*Hemixos flavala*
173	Black bulbul	*Hypsipetes leucocephalus*
174	Grey-breasted prinia	*Prinia hodgsonii*
175	Ashy prinia	*Prinia socialis*
176	Oriental white-eye	*Zoosterops palpebrosus*
177	Grey-sided bush warbler	*Cettia brunifrons*

178	Common tailorbird	*Orthotomus sutorius*
179	Lemon-rumped warbler	*Phylloscopus chloronotus*
180	Greenish warbler	*Phylloscopus trochiloides*
181	Large-billed leaf-warbler	*Phylloscopus magnirostris*
182	Western crowned leaf-warbler	*Phylloscopus occipitalis*
183	Grey-hooded warbler	*Seicercus xanthoschistos*
184	White-throated laughingthrush	*Garrulax albogularis*
185	White-crested laughingthrush	*Garrulax leucolophus*
186	Puff-throated babbler	*Pellorneum ruficeps*
187	Rusty-cheeked scimitar babbler	*Pomatorhinus erythrogenys*
188	White-browed scimitar babbler	*Pomatorhunis schisticeps*
189	Black-chinned babbler	*Stachyris pyrrhops*
190	Jungle babbler	*Turdoides striatus*
191	Common babbler	*Turdoides caudatus*
192	White-browed shrike babbler	*Pteruthius flaviscapis*
193	Blue-winged minla	*Minla cyanouroptera*
194	Nepal fulvetta	*Alcippe nipalensis*
195	Whiskered yuhina	*Yuhina flavicollis*
196	Rufous sibia	*Heterophasia capistrata*
197	Plain flowerpecker	*Dicaeum concolor*
198	Purple sunbird	*Nectarinia asiatica*
199	Black-thraoted sunbird	*Aethopyga saturata*
200	Crimson sunbird	*Aethopyga siparaja*
201	Fire-tailed sunbird	*Aethopyga ignicauda*
202	House sparrow passer	*Passer domesticus*
203	White-browed wagtail	*Motacila maderaspatensis*
204	Grey wagtail	*Motacila cinerea*
205	Baya weaver	*Ploceus philippinus*
206	Scaly-breasted munia	Lonchura punctulata

APPENDIX 5

FAUNAL DIVERSITY OF THE NANDHAUR REGION

The Nandhaur valley landscape is an amalgamation of different physiographic zones such as the terai and bhabar. Lying along the Kumaon foothills the region is also close to the highly diverse Nepal Himalayas. Due to the topographic variations and the consequent diversity in forest types the region supports a rich assemblage of mammalian and bird species. During the survey a total of 32 species of mammals were recorded (Appendix 2). In total the list comprises of 3 endangered species, 6 Near threatened species and 4 vulnerable species. This list includes sixteen species of greater and lesser carnivores and nine species of ungulates. Many of the rare and more elusive species were recorded during camera trap surveys for tigers while the existence of the other was confirmed either through direct sightings, signs or from reliable sources. Species such as the striped hyena and large Indian civet occur in very low densities in the bhabar and are seldom seen because of their nocturnal habits (Jhala *et al.* 2011). Other elusive and rare mammals in the list include the endangered hispid hare which is increasingly losing its riverine grassland habitat across the TAL. Many of the other species such as serow and rusty spotted cat are also increasingly becoming rare in the TAL due to fragmentation and habitat loss. The TAL has already experienced the local extinction of species such as wild dogs (*Cuon alpinus*) and four horned antelopes (*Tetracerus quadricornis*) from many sites.

We also recorded and maintained lists of bird species in the area (Appendix 3). In all a total of 206 bird species were recorded from opportunistic sightings and birding trips between October 2011- and March 2012. The bird list includes rare habitat specialist species such as the red headed trogon (*Harpactes erythrocephallus*) and long tailed broadbill (*Psarosomus dalhousiae*). Besides these, the region also hosts Himalayan endemics such as the blue winged minla (*Minla cyanouroptera)*, spot-winged starling and Nepal fulvetta (*Alcippe nipalensis)*. The perennial nandhaur river and the fishes it harbors support high densities of crested kingfishers and fishing eagles. The river was also home to a flock of common mergansers (*Mergus merganser)* overwintering in the area.

The presence of such a diversity of mammalian and bird species many of which are habitat specialists is indicative of the fact that the landscape still holds pristine habitat patches. The density of many of these species however is worryingly low. For example, the camera trapping exercise covered much of the study area and extended over nearly 5 months and yet yielded only one capture of a striped Hyena and a large Indian civet. The trapping exercise was carried out along the southern boundary road between Haldwani FD and Terai-East FD and along the Nandhaur river. Much of the mammalian species listed in Appendix 2 were recorded along these two stretches. There is therefore substantial evidence to suggest that these two areas harbor besides tigers a high faunal diversity. The conservation of these patches which face existing (logging operations, fishing, dynamiting etc. along the Nandoaur River) and potential (proposal to metal the Haldwani-Tanakpur forest road) threats is of critical importance.

Finally, the roster of faunal species of the area reemphasizes the need to view this landscape not only from the standpoint of a conservation unit for tigers but also as a critical habitat patch for the many faunal elements that constitute the natural heritage of the Terai Arc Landscape.

APPENDIX 6

LIST OF THREATS TO WILDLIFE IN THE NANDHAUR REGION

Threats are classified as 'existing' - operational for certain or 'potential' - likely to be operating and needs further assessment.

Threat	Description	Threat status	Remarks
Poaching	Large cat poaching by organized groups for body parts trade; Prey species by locals for meat	Existing	The field team encountered a tiger poaching incident in the eastern part of the study site. Being close to the Nepal border the study site is known to be a poaching hub. Poachers were encountered once in Terai East FD. Poachers were also captured in camera traps a few times.
Livestock grazing	Prey population depression through competition	Potential	Livestock grazing was documented in most parts of the study site. It's potential as a threat in the landscape needs assessment.
NTFP collection	Habitat degradation lowering wildlife populations	Potential	Grass and fodder collection is prevalent close to forest edges. The threshold of coexistence is unknown.
Forestry operations (Dead wood logging, Road construction)	Habitat degradation; Poaching by laborers camped in the forest	Potential	There is removal of dead logs from the study area and a temporary motorable road is constructed along the Nandhaur river and other areas for the purpose each year. Again the threat from such activities needs to be evaluated.
Boulder mining	Habitat degradation; Poaching by laborers camped along river bed	Potential	Boulder mining takes place for 8-9 months, 6 days a week, each year in some of the major rivers in the study landscape. Mining involves huge number of labor, who camp by the rivers. Effects of mining on the riparian vegetation, in stream flows etc. are unknown. Discovery of the threatened Hispid hare pellets in the Nandhaur river raises concerns related to mining activities in this river.
Nomadic and other pastoralists	Retaliatory poisoning of carnivores for livestock depredation; Poaching of prey	Existing/ Potential	From January through March, *bhotiyas* along with holdings of nearly 400 sheep and goat descend from higher elevations. The field survey team encountered dogs kept by the *bhotiyas* bringing down a Sambar. It is possible that the pastoralist use their dogs to hunt ungulates.
Pilgrim traffic	Disturbance	Potential	The landscape is dotted with sites of religious significance to the local people. Pilgrim traffic needs monitoring so as to reduce disturbance to the habitat.

7.04 Ungulates/ km²

A low ungulate density estimated through line transect survey point to the need for reviving tiger prey base as a major conservation measure.

32 Mammal Species

This survey recorded presence of a rich mammalian assemblage that include elusive small carnivores like honey badgers and large Indian civet.

300 km Sign Survey

Extensive sign surveys reveal distribution pattern of tiger and other large mammals in the landscape.

1473 Trap Nights

Camera trapping a portion of the landscape yielded captures of 8 tigers and an estimate of upto 15 individuals in Nandhaur. For leopards, 32 individual leopards were captured with an estimate of upto 182 individuals in Nandhaur.

206 Bird Species

The region bustles with birdlife including rare species.
The Nandhaur river supports wintering flock of common merganser, kingfishers and fishing eagles while numerous streams in the landscape receive forktail and redstart seasonally.

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