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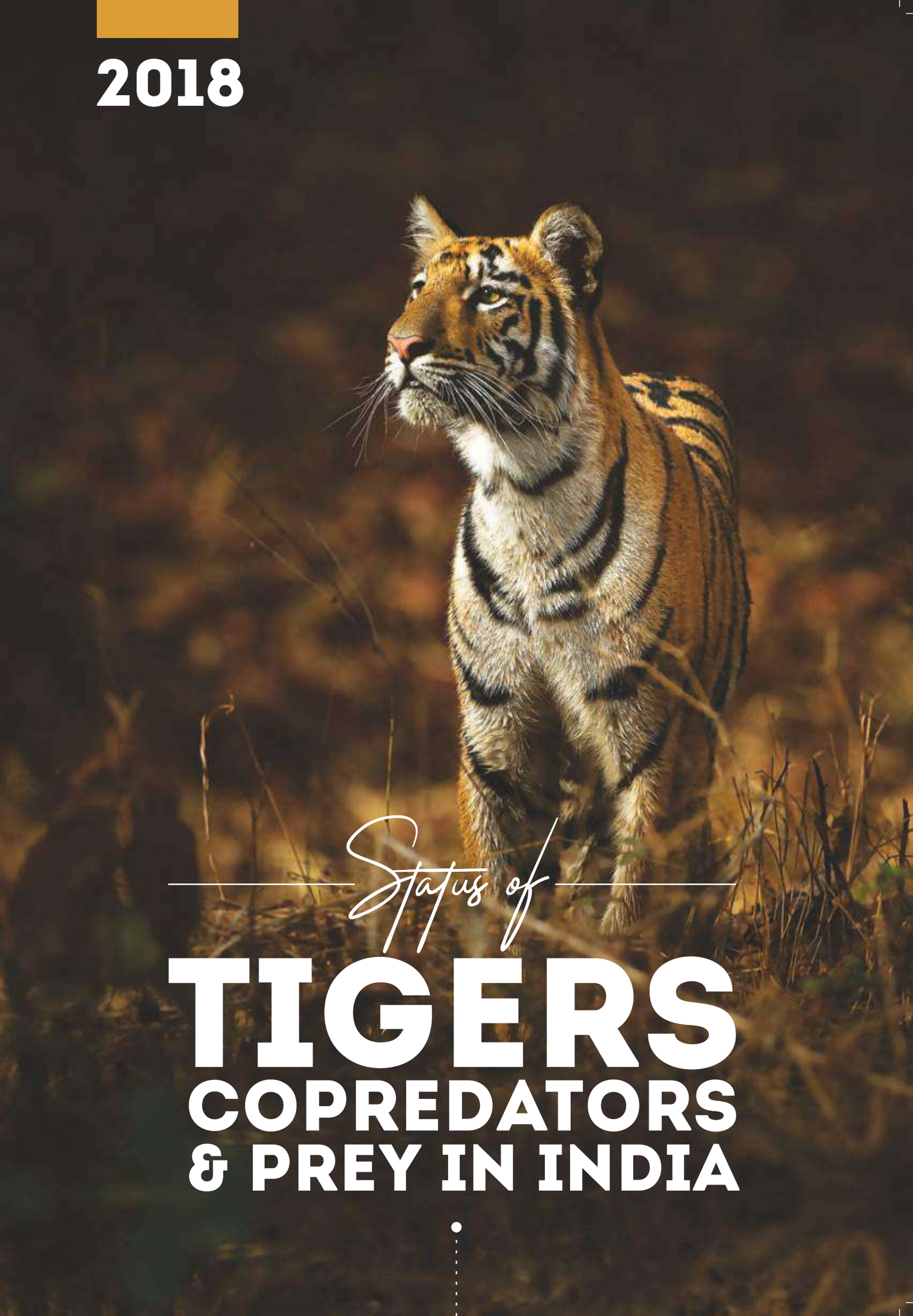

Status of

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मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन
सूचना एवं प्रसारण और
भारी उद्योग एवं लोक उद्यम
भारत सरकार

सत्यमेव जयते

MINISTER
Environment, Forest & Climate Change
INFORMATION & BROADCASTING AND
HEAVY INDSTRIES & PUBLIC ENTERPRISES
GOVERNMENT OF INDIA

प्रकाश जावड़ेकर
PRAKASH JAVADEKAR

Every four years, India takes stock of its tiger population. This exercise is of massive scale in terms of area covered and personnel involved. It uses cutting edge science and best technology to evaluate tiger habitat across 20 tiger bearing States of India. The status of tiger, co-predators and embodies the holistic approach to conservation in our country. The fourth cycle of the all India Tiger Estimation has been successfully completed and has shown significant numbers rise in tiger estimates. India has lived up to its global commitments in ensuring the protection and continued increase of its tiger population, which is currently around 3000 individuals (excluding cubs.) The tiger signifies the health of the forest, their ecosystem function and services. Thus, despite all the odd, the population pressures, pressing demand for the development and livelihoods, we have achieved this balance between modernization and conservation.

I compliment the entire team of the National Tiger Conservation Authority, Wildlife Institute of India, State Forest Departments and other stakeholders for this commendable achievement.

PRAKASH JAVADEKAR
Date: 22.04.2020

।। प्लास्टिक नहीं, कपड़ा सही ।।

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Government of India

सत्यमेव जयते

केन्द्रीय राज्य मंत्री
पर्यावरण, वन एवं जलवायु
परिवर्तन मंत्रालय
भारत सरकार

बाबुल सुप्रियो
Babul Supriyo

Tiger is our national and culture heritage and is therefore revered by many National as its National Animal. The success of India in conserving and doubling its wild tiger population in a span of about 12 years (much before the targeted year of 2022 as per St. Petersburg Declaration) is commendable especially when the tiger is highly threatened globally due to the high illegal demand of its body parts.

The Fourth Cycle of all India Tiger Estimation has been successfully completed and has shown an increase in the tiger numbers. Most tiger range countries who were in a better economic position have failed to protect the tiger, the success in India is largely attributable to the people, culture and religious tolerance and reverence to all life forms that co-habit this planet with us. I specifically applaud the effort of entire team of National Tiger Conservation Authority, Wildlife Institute of India and State forest department for this success.

The recovery of tiger populations signifies recovering ecosystems and their life support systems that are so important for mankind in India and on the planet.

BABUL SUPRIYO

Shivang Mehta

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01

INTRODUCTION

Tigers, the top predators in an ecosystem, are vital in regulating and perpetuating ecological processes (Terborgh 1991, Sunquist et al. 1999). Ensuring the conservation of this top carnivore guarantees the well-being of forested ecosystems, the biodiversity they represent as well as water and climate security. However, the rise in organized poaching driven by an international demand for tiger parts and products, depletion of tiger prey and habitat loss have led to largely disconnected fragmented populations. Extant tiger populations are confined to less than 7% of their historical range in patchily distributed habitats across a range of 12 regional tiger conservation landscapes (TCLs) in southern, northern, and south-eastern Asia (Dinerstein et al. 2007). Of these, six global priority TCLs for long-term tiger conservation significance are present in the Indian subcontinent alone. Home to more than 80% of the global population of 3,159 adult free-ranging tigers (Goodrich et al. 2015) and harboring >60% of the global genetic variation in the species (Mondol et al. 2009), India plays a crucial role in accomplishing the objectives of the Global Tiger Recovery Plan that was ratified at the meeting of world leaders held at St. Petersburg (Russia) in 2010.

In India, tigers inhabit a wide variety of habitats ranging from the high mountains, mangrove swamps, tall grasslands, to dry and moist deciduous forests, as well as evergreen and shola forest systems. By virtue of this, tiger is not only a conservation icon but also acts as an umbrella species for majority of eco-regions in the Indian subcontinent. On the other hand, tigers need large undisturbed forested landscapes with ample prey to raise young and to maintain long-term genetic and demographic viability (Seidensticker et al. 1993, Karanth and Sunquist 1995). In a country with an increasing demand for land by an ever-growing population, conserving such a large carnivore demands innovative approaches to land use planning that maintains connectivity between tiger source populations in a metapopulation framework. The Project Tiger, that was initiated in 1973 aimed to harness the functional role of the tiger and its charisma to garner resources and public support for conserving representative ecosystems. Under the stewardship of Project Tiger, the initial number of nine tiger reserves (~18,278 km^2) has now expanded to 50 tiger reserves (~72,749 km^2) covering about 2.21% of India's geographical area. Nevertheless, many Tiger Reserves and Protected Areas in India are analogous to small islands in a vast sea of ecologically unsustainable land uses of varying degrees. Many tiger populations are confined within small Protected Areas and some have habitat corridors that permit tiger movement between them (Qureshi et al. 2014, Yumnam et al. 2014). However, most of the corridor habitats in India are not protected areas, and are degrading due to unsustainable human use and developmental projects.

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For designing, implementing, and evaluating the success of any conservation program for an endangered species, it is vital to monitor the status, distribution, and trends in the populations of the target species. Scientific objectives aim to understand the dynamics of the monitored system, while management objectives seek to use such information for making informed decisions. In the recent past, scientists, governments and NGOs had increasingly recognized that monitoring should be a central and operational part of all conservation activities, because if one cannot measure and assess the impact of our actions on biodiversity conservation, one can never adapt practices or improve their effectiveness (Nichols et al. 2017). Hence, monitoring is a process, not a result, a means to an end rather than an end in itself. Monitoring tiger populations is thus synonymous with understanding the pulse of the forested ecosystems of the country, both spatially and temporally. Monitoring programs need to be holistic, addressing an array of parameters related to the survival of the species by using the blend of the best available science and technology while being practical to implement at large spatial scales. Any monitoring program is a compromise between what is required by science and what is logistically and cost effectively possible (Hutto and Young 2002).

Lions and tigers were traditionally tracked by professional *shikaris* from their pugmarks for *shikar*. After the first lion census, based on pugmark count, by Wynter-Blyth and Dharmakumarsinh (1950), Saroj Raj Choudhury, a forest officer from Odisha modified the approach for counting tigers (Choudhury 1970). Subsequently, several forest officials advocated and improvised on the pugmark method for tiger census (Panwar 1980, Sawarkar 1987, Singh 1999, Rishi 2010). Karanth et al. (2003) brought out several deficiencies of the pugmark census in light of modern science dealing with animal abundance estimation (Williams et al. 2002). But it was only after the Sariska debacle in 2004-05 (and subsequently in Panna in 2007-08), where despite total local extinction of tigers due to poaching, official records showed presence of substantial tigers based on the pugmark census. This disaster and its extensive media coverage prompted the Prime Minister of India to appoint the Tiger Task Force (TTF) with a mandate to develop a strategy for tiger conservation in India. Besides recommending the creation of the National Tiger Conservation Authority (NTCA), and amendment of the Wildlife (Protection) Act 1972, the TTF also suggested a country wide monitoring of tigers and their ecosystems based on modern scientific protocols developed by the Wildlife Institute of India in collaboration with Project Tiger Directorate and Madhya Pradesh Forest Department (Jhala et al. 2005). NTCA in collaboration with the State Forest Departments, Conservation NGO's and coordinated by the Wildlife Institute of India (WII), has conducted a National assessment for the "Status of Tigers, Co-predators, Prey and their Habitat" every four years since then. The first status assessment of 2006 was peer reviewed by international carnivore experts and the IUCN. The methodology (*vide* Methodology Chapter of the current report for more detail) used for these assessments was standardized after a pilot survey conducted in about 20,000 km^2 area of Satpura-Maikal landscape of Central India.

The parameters used to assess the Indian tiger population status are abundance, i.e., the number of individuals in a population occupying the same space at the same time, and density i.e. abundance scaled by area and spatial distribution. The first countrywide assessment was done in 2006 and it estimated India's tiger population to be 1,411 (SE range 1,165 to 1,675). Before this scientifically objective assessment, the official tiger number in India was estimated at 3,500 tigers. The 2006 assessment was spatially explicit and determined the extent and size of individual tiger populations and the status of habitat connectivity between these populations for the first time at a national scale (Jhala et al. 2008). During the 2006 exercise the Sundarban landscape was not assessed, as at that time, the protocol for sampling this hostile and unique tiger habitat had not been developed. The second and third assessments were carried out in 2010 and 2014 which estimated India's tiger population to have increased to 1,706 (1,520 to 1,909) and 2,226 (1,945 to 2,491) respectively (Jhala et al. 2011, 2015). These 2010 and 2014 assessments included the Sundarban tigers which accounted for 70 (64-90) and 76 (62-96) tigers.

The information generated by the earlier three cycles of tiger status evaluation exercises resulted in major changes in policy and management of tiger populations and provided scientific data to fully implement provisions of the Wildlife (Protection) Act 1972, as amended in 2006, in letter and spirit. The major outcomes that were direct or indirect consequence of information generated by the monitoring exercises were 1) tiger landscape conservation plans, 2) designation and notification of inviolate critical core and buffer areas of tiger reserves, 3) identification and declaration of new tiger reserves, 4) recognition of tiger landscapes and the importance of the corridors and their physical delineation at the highest levels of governance (Yumnam et al. 2014), 5) integrating tiger conservation with developmental activities using the power of reliable information in a Geographic Information System database, 6) planning reintroduction and supplementation strategies for tigers and 7) to prioritize conservation investments to target unique vulnerable gene pools (Kolipakam et al. 2019). All these provide an opportunity to incorporate conservation objectives supported with sound science based data, on equal footing with economic, sociological, and other values in policy and decision making for the benefit of the society.

The fourth cycle of the assessment was undertaken in 2018 and 2019 using the best available science, technology and analytical tools. The unique feature of this cycle of assessment, in keeping up with "Digital India", is the development and use of innovative technological tools in collection and processing of data to reduce human errors. In this cycle, recording of primary field data digitally, through mobile phone application M-STrIPES (Monitoring system for tigers - intensive protection and ecological status), that uses GPS to geotag photo-evidences and survey information, made this exercise more accurate. Further, it involved the development of innovative technology like automated segregation of camera trap photographs to species using artificial intelligence and neural network models (software CaTRAT- Camera Trap data Repository and Analysis Tool). Program ExtractCompare (Hiby et al. 2009) that fingerprints tigers from their stripe patterns was used to count the number of individual tigers.

Like the previous cycles, this time also the country was divided in five tiger occupied landscape complexes having unique geographical features and tiger populations:

1. Shivalik and the Gangetic Plains landscape extends across the states of Uttarakhand, Uttar Pradesh and Bihar.

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2. Central Indian and Eastern Ghats landscape extends across the states of Rajasthan, Madhya Pradesh, Chhattisgarh, Jharkhand, Maharashtra, Telangana, Andhra Pradesh, and Odisha.

© A. Kumar

3. Western Ghats landscape extends across the states of Karnataka, Tamil Nadu, Goa, and Kerala.

© C. Sinha

© D. R. Laha

4. North Eastern Hills and Brahmaputra Flood Plains landscape extends across parts of Northern West Bengal, Assam, Arunachal Pradesh, Mizoram, Nagaland.

© I. Paul

5. Sundarban landscape comprises of the mangrove forests of southern part of West Bengal and extends into Bangladesh.

This report assesses the status of tigers in terms of spatial occupancy and density of individual populations across India. In addition to the summary report released by the Hon'ble Prime Minister of India on the "Status of Tigers in India" in July 2019, this detailed report compares information obtained from the earlier three surveys (2006, 2010, and 2014) with data obtained from the 2018-19 survey to estimate population trends at country and landscape scales, patch colonization and extinction rates along with information on likely factors responsible for changes in tiger status at the fine spatial resolution of 100 km^2. The report evaluates the status of habitat corridors connecting major tiger populations and highlights vulnerable areas that require conservation attention for each landscape. The report provides information on major carnivores and ungulates regarding their distribution and relative abundance. Chapters on individual sites that were assessed by camera traps and some that were assessed by line transects, report the details of tiger densities and prey densities. We provide photographs of all individual tigers that were recorded across India (2018-19) as an appendix to the report. We hope that all of this information will be useful to wildlife biologists, wildlife managers and policy makers to assist in better conserving our natural heritage.

02

METHODOLOGY

This chapter introduces the general approach for assessing the status of tigers, copredators and prey across India. It subsequently explains the details of field sampling, data processing and data analysis. The state parameters of interest were 1) spatial distribution of species, 2) spatial relative abundance, 3) abundance and, 4) spatially explicit density. It is well known that enumeration of the total population of any free-ranging wildlife, even within a small protected area, is almost impossible (Williams et al. 2002). Given the vastness of the tiger bearing forests, as well as the elusive nature of most wildlife species, it was important to conduct the assessment with an appropriate statistical design that accounts for non-detection of target species. Since 2006, the entire country has been delineated into 100 km^2 grids that were fixed for all the subsequent National survey cycles (2010, 2014 and current 2018). Inferences of species occupancy, relative abundance, and density are made on this same spatial scale (same 100 km^2 grids) for all the four assessments allowing for temporal comparisons on the same sampling frame. Data were collected in a design that allowed analysis using modern statistical approaches that explicitly account for non-detections, like Occupancy Analysis (MacKenzie et al. 2018), Capture-Mark-Recapture (CMR) (Otis et al. 1978), Distance Sampling (Buckland et al. 2001) and Spatially Explicit Capture Recapture (SECR) (Borchers and Efford 2008).

The ultimate objective for any status assessment and monitoring exercise is that the findings of the study are used for conservation management and policy formulation. For this to happen, it is important that the agencies responsible for management of wildlife resources are directly involved in the entire process of the assessment so that the results are *owned* by them and required changes in management and policy are subsequently implemented. Therefore, primary data collection for a) occupancy, b) habitat assessment, c) human impacts and d) prey assessment were done by the frontline staff of the forest departments of the 20 tiger states. Since the field methodology being used for the status assessment has essentially been the same since 2006 (Appendix 1), the competency of the wildlife managers in conducting these exercises has increased significantly over the years. Now camera traps are regularly used by the management staff of all tiger reserves each year to estimate the minimum number of tigers (Phase IV Protocol). Some wildlife managers have been trained and have acquired skills for designing, implementing, and analyzing CMR and distance sampling based studies. Thus, many of the sites across India were camera trapped and line transects sampled by wildlife managers of these areas for the 2018-19 assessment (Appendix 2). The protocols for field data collection are simple and can be taught to the front-line field staff in 1-2 day training workshops (Appendix 3). The protocols were written up as a field guide in nine regional languages (Jhala et al. 2017) and provided to each frontline staff (beat guard) in all of the 20 tiger bearing states of India.

PHASE I
DETERMINING OCCUPANCY AND RELATIVE ABUNDANCE

Field Method

The forest administration system across most of India is based on division of States into Forest Divisions, Divisions into Ranges and Ranges into Beats in a spatially hierarchical manner. The boundaries of Beats are based on natural features that are easily identifiable in the field. Besides, each forest beat is allocated to a beat guard who usually has intimate knowledge of his beat. The average size of a forest beat in India is about 16 km^2. We used this spatial administrative system to systematically distribute sampling units at a very fine spatial scale across all forested areas within each landscape.

State forest departments sampled all current and potential tiger habitats using Phase I protocols across 20 tiger bearing states of India (Fig 2.1) with each beat as a sampling unit. Data were either recorded manually on forms or digitally using M-STrIPES (Monitoring System for Tigers: Intensive Protection and Ecological Status) ecological mobile application (Fig 2.2). The protocol for Phase I (Jhala et al. 2017) consisted of five forms with simple procedures for :

a) **Carnivore sign encounters**
[Form 1: multiple (3-5 spatial, each~5 km long, search paths) occupancy surveys in a beat recorded as a GPS track log]

b) **Tiger prey abundance**
[Form 2: Distance sampling on 1-2 line transect(s) of~2 km length in each beat]

c) **Vegetation**
[Form 3A and 3C: Canopy cover, tree, shrub and herb composition, weed infestation on 30m, 10m, and 1m diameter plots every 400m on each transect in each beat]

d) **Human disturbance**
[Form 3B: Multiple plots (every 400m) of 30m diameter on line transects to record signs of human impacts] and,

e) **Dung counts**
[Form 4: count of all dung/fecal pellets identified to species in multiple 2x20m plots on transects every 400m in each beat]

Regional training workshops for training of trainers for implementing these protocols were conducted in Pench Tiger Reserve (TR) Maharashtra, and Kanha TR for the Central Indian Landscape, Mudumalai TR for the Western Ghats landscape, Valmiki TR for the Shivalik-Terai landscape, Sundarban TR for the Sundarban landscape and Kaziranga TR for the North Eastern Hills and Brahmaputra Flood Plains landscape by the NTCA-WII Tiger Cell. Trained officers subsequently imparted training to the frontline staff in their respective states through several workshops.

All forest beats (in Tiger Reserves, Protected Areas, Reserve Forests, Protected Forests, Revenue Forests in all Wildlife and Territorial divisions) were sampled for the above-mentioned Phase I protocols. Occupancy sign surveys were done with three to five spatially different searches of~5 km each. The spatial configuration of each survey walk and each sign of carnivore or megaherbivore seen was recorded by either the M-STrIPES android app or a hand held GPS. One or two line transects of 2-4 km length within each beat were sampled early morning with two to three replicate walks (temporal replicates). Species seen, group size, number of young, radial distance to the observed animal(s), bearing of the animal(s) and transect bearing were recorded with a laser range finder and a see through compass.

With two persons (a Forest Guard and his assistant) sampling a beat, the entire exercise of laying transects and data collection for the above mentioned five aspects (Phase I data) were collected within a period of eight to ten days for each beat.

Figure 2.1

Search paths for occupancy survey of carnivores and megaherbivores across the forests of tiger occupied states. The red color represents the search paths where tiger signs were recorded while blue color represents surveys where tiger signs were not recorded. The distribution of tiger sign detected areas provides a range map of tiger distribution in India for 2018-19.

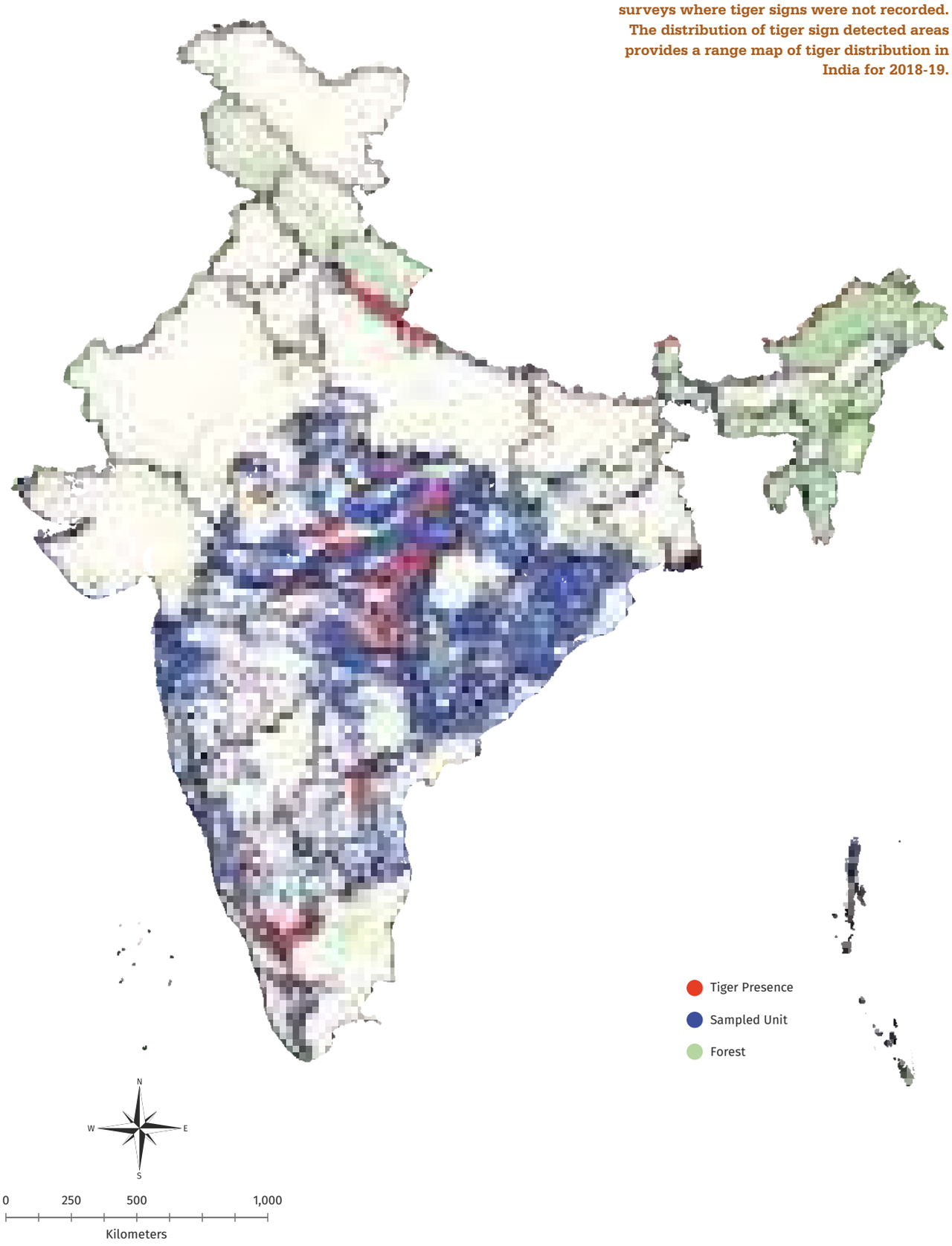
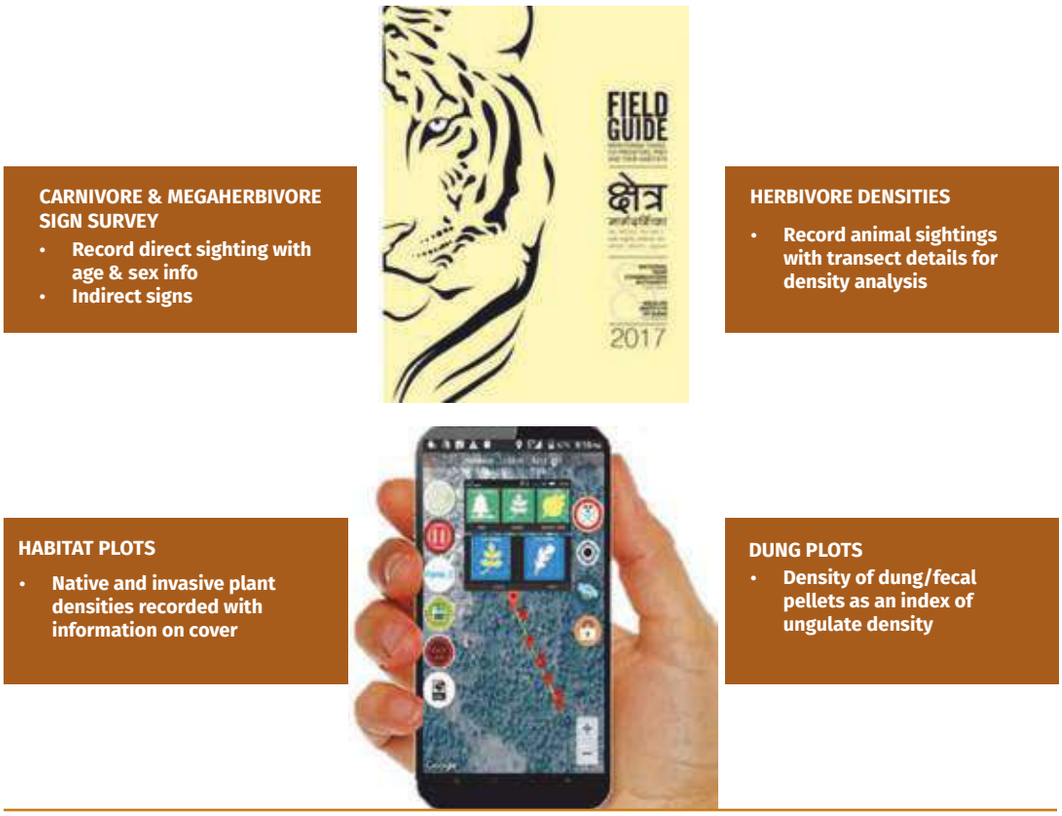


Figure 2.2

Use of M-STrIPES ecological application in android mobile for collecting data on occupancy of tigers and other carnivores, prey density, habitat characteristics and human disturbance parameters.



In Arunachal Pradesh, Mizoram, Nagaland and parts of Assam standard phase I sampling could not be carried out due to logistic constraints (inhospitable terrain, lack of manpower, transportation and lack of forest road network) and absence of demarcated administrative units at the beat level. We targeted priority tiger habitats based on past surveys and published literature, in these areas for tiger population estimation by combining information from polygon search method, scat based DNA profiling and opportunistic camera trapping. We superimposed a 5x5 km grid (within the fixed 100 km^2) and within each grid (25 km^2 grid as a sampling unit in place of a beat) a minimum of five sign surveys were conducted on animal trails where each search path was of 3-5 km in length. On the survey trail, signs of carnivores and all herbivores were intensively searched and recorded using the polygon search android application (M-STrIPES ecological - polygon search app). Information on species, sign type, approximate age of sign, time and location details were recorded. At every 500 m of the survey trail, a habitat plot of 30 m diameter was sampled to record signs of human impacts (tree felling, lopping, grass and bamboo cutting, livestock and people seen, and number of human trails) and the cover of invasive plants, grass, shrubs, and canopy. At the same location, a rectangular plot of 2x20 m was sampled to enumerate the scat/pellet/dung of herbivorous species (Jhala et al. 2017).

Data analysis

Processing of Phase I data

Shapefiles of all administrative boundaries of Divisions, Ranges and Beats were customized for 615 Forest Divisions of the country so that the data could be collected using M-STrIPES mobile android app and could directly be imported and analyzed in M-STrIPES desktop software. Phase I data was received from 491 Forest Divisions of India and these were processed using M-STrIPES desktop software. Data entry errors, if any, were communicated back to the respective Forest Divisions for rectification. Data for each spatial and temporal replicate was recorded at the beat scale (occupancy surveys, line transects, and plots) were transferred to the standard 100 km^2 grid for analysis and subsequent inference.

In case of carnivore sign survey data (Form 1), the M-STrIPES desktop software was used to prepare input files for modelling occupancy. In case of herbivore density (Form 2), the M-STrIPES software generated

outputs ready to use data, for analysis in program DISTANCE. Tiger sign encounter rates, prey encounter (direct sighting) rates, prey dung density, human disturbance indices (signs of livestock, human trails, wood cutting, lopping, grass removal) were computed as average encounter rates for 10x10 km grids based on effort (km of survey) invested in each 100 km^2 grid. Since these inference grids have been fixed since 2006 and subsequent inferences of 2010, 2014 and the current assessment 2018 were done on the same scale and sampling units consistently across India, data were conducive for multi-season occupancy analysis to determine patch occupancy, colonization and extinction rates (MacKenzie et al. 2018).

PHASE II
REMOTELY SENSED SPATIAL AND ATTRIBUTE COVARIATES

Remotely sensed data that depict landscape characteristics and anthropogenic impacts and could potentially affect tiger (wildlife) occupancy and density were obtained from various sources (Table 2.1). These data consisted of:

a) Landscape characteristics such as forest area, vegetation cover (Normalized Difference Vegetation Index, NDVI), forest patch size, forest core areas (forest patch area buffered inward by a 2 km buffer), elevation, distance from protected areas and drainage density;

b) Variables that index anthropogenic impacts such as forest degradation, distance to and area of night lights, distance to and density of major roads and human footprint index.

Table 2.1

Details of spatial and attribute data used for assessing patterns of tiger distribution and density.

Spatial Data	Time period	Satellite/Sensor	Resolution	Source	Reference
Water bodies	March 1984 to October 2015	Landsat 4,5,7	30 m	Joint Research Centre's Global Surface Water Dataset (JRC)	Pekel et al. 2016
Normalized Difference Vegetation Index (NDVI)	April and October 2018	Moderate Resolution Imaging Spectroradio meter (MODIS)	250 m	National Aeronautics and Space Administration (NASA)	Didan et al. 2015
Night lights	2016	Visible Infrared Imaging Radiometer Suite (VIIRS)	15 arc sec~600 m	National Oceanic and Atmospheric Administration (NOAA)	Elvidge et al. 2017
Forest cover map	2016	Linear Imaging Self Scanning Sensor (LISS-III, IV)	23 m	Forest Survey of India	FSI 2017
Protected Area & Tiger Reserves				Wildlife Database cell, Wildlife Institute of India and Project Tiger Directorate	
Digital elevation model	2000	Shuttle Radar Topography Mission (SRTM)	30 m	National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA)	Rodriguez et al. 2005 & Farr et al. 2007
Road network				Survey of India	
Human foot print	2009		1 km	Last of the Wild Project, Version 3 (LWP-3)	Venter et al. 2018
Forest Loss	2001-2017	LANDSAT 4,5,7 & 8	30 m	Global Forest Watch	Hansen et al. 2013

Occupancy modeling

The extent of habitat occupied by a species is often used as a one of the state parameter for evaluating its status. Detection of a species or its signs is inferred as an area being occupied, while non-detection could either result from absence of the species from the area or failure to detect the species in an occupied area. Occupancy modelling uses multiple surveys to compute detection probabilities and correct for imperfect detection to infer occupied area. We used a likelihood-based approach to estimate detection probability and occupancy (MacKenzie et al. 2006).

The entire tiger range of India has been gridded into 10 × 10 km grids that have been fixed since 2006 and have been sampled with multiple spatial surveys to detect carnivore and megaherbivore presence using the same sampling approach (Jhala et al. 2005) in 2006, 2010, 2014 and 2018. This data from replicate sign surveys were analysed using *multi-season* (here a season represents a four yearly cycle of national tiger estimation) occupancy models (MacKenzie et al. 2018) to estimate patch occupancy for each sampled year (ψ_t), patch colonization (γ_t) and patch extinction (ε_t) rates between cycles.

We hypothesised that tiger occupancy and colonization would be positively correlated with prey availability, legal protection status, amount of habitat and its quality in a grid, while anthropogenic impacts surrogated by night lights, road density, human impacts and livestock indices recorded during ground surveys (Phase I) would be negatively correlated with occupancy and colonization and positively correlated with patch extinction. Remotely sensed and attribute covariates along with their sources, used for multi-season occupancy models, are given in Table 2.1. These covariates were transformed for linearity and standardised (Z-scores). Occupancy models using Maximum Likelihood were fitted to the data in PRESENCE Ver. 12.35 (https://www.mbr-pwrc.usgs.gov/software/presence.html) and package 'unmarked' in R for multi-season site occupancy of tigers (Fiske and Chandler 2011; R Development Core Team 2010). Models were evaluated using Akaike Information Criteria (AIC) and parameter estimates from alternative models that differed by < 5 AICs were averaged based on model weights to account for model uncertainty (Akaike 2011). Besides site occupancy, colonisation and extinction rates, seasonal persistence (φ_t), rate of change in occupancy (λ_t) and turnover (probability of changing occupancy status between seasons) (τ'_t) as defined by MacKenzie et al. (2018) were estimated along with covariates to provide ecological insights into these important ecological processes and characteristics of sites to guide policy and management.

PHASE III
ABUNDANCE ESTIMATION OF TIGERS, LEOPARDS AND UNGULATES

Camera trap based spatially explicit capture-mark-recapture

Spatial data on individual tiger and leopard photo-captures was used in combination with spatial data on prey, habitat, and anthropogenic factors as covariates in a likelihood based spatially explicit capture-mark-recapture (SECR) covariate framework (Efford 2015) to arrive at tiger population estimates for each tiger landscape.

This method entails estimating spatial covariates effecting relative abundance of tigers, co-predators, and ungulates, human impact indices, and habitat characteristics across all potential tiger habitat in India, at a fine spatial resolution of a forest beat which is on average about 16 km^2 (Phase I). Subsequently, several replicates of >400km^2 area covering the entire density range of tigers, within each landscape, were sampled using camera traps at a high spatial density of one double camera location in 2 km^2 (Phase III). The concept is similar to that of double sampling (Cochran 1977) wherein indices or raw counts of abundance obtained from the entire sample space are calibrated against absolute density obtained from limited samples. The difference between double sampling and SECR approach is that double sampling uses ratio or regression to calibrate a univariate index, while tiger population estimation uses spatial information on capture-mark-recapture (that accounts for detection correction) in a likelihood framework with spatial covariates of prey abundance, human disturbance, tiger and leopard sign intensity, and habitat characteristics. This approach estimates tiger and leopard density directly within camera trapped areas, calibrates the covariates with this density from camera trapped areas, and subsequently estimates density based on covariate values within areas having tigers but where camera traps were not deployed (Fig 2.3).

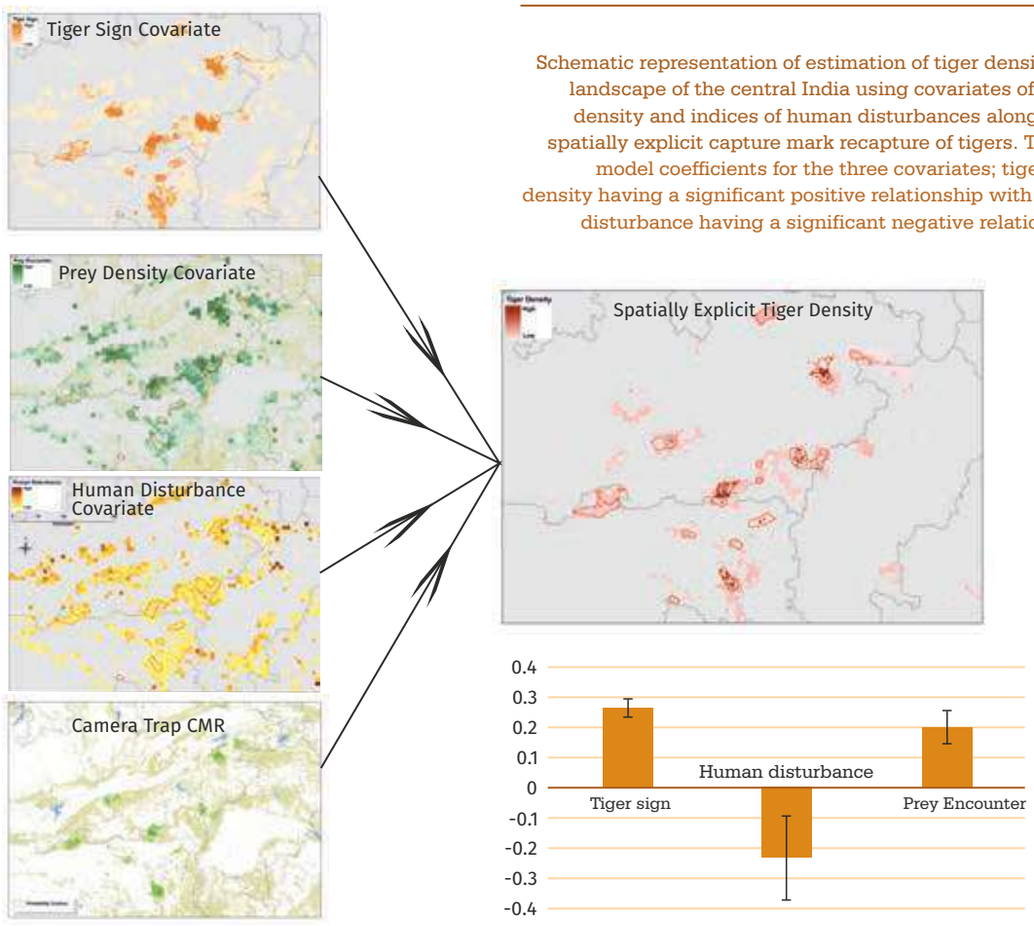


Figure 2.3

Schematic representation of estimation of tiger density across Satpura-Maikal landscape of the central India using covariates of tiger sign intensity, prey density and indices of human disturbances along with camera trap based spatially explicit capture mark recapture of tigers. The chart inset shows the model coefficients for the three covariates; tiger sign intensity and prey density having a significant positive relationship with tiger density and human disturbance having a significant negative relationship with tiger density.

Since tigers (and leopards) occur across varied habitats and a large geographical expanse of India, we divided tiger bearing habitats into five major landscapes as mentioned earlier into 1) Shivalik-Gangetic plains, 2) Central India and Eastern Ghats, 3) Western Ghats, 4) North Eastern Hills and Brahmaputra Flood Plains, and 5) the Sundarban. Each landscape was analyzed separately since covariates were likely to differ in their relationship with tiger abundance between landscapes. In addition, landscapes formed logical and biological units wherein tiger (and leopard) populations can share common individuals, a common genepool and can potentially disperse between populations. However, tiger movement between landscapes was likely to be a rare event in modern times.

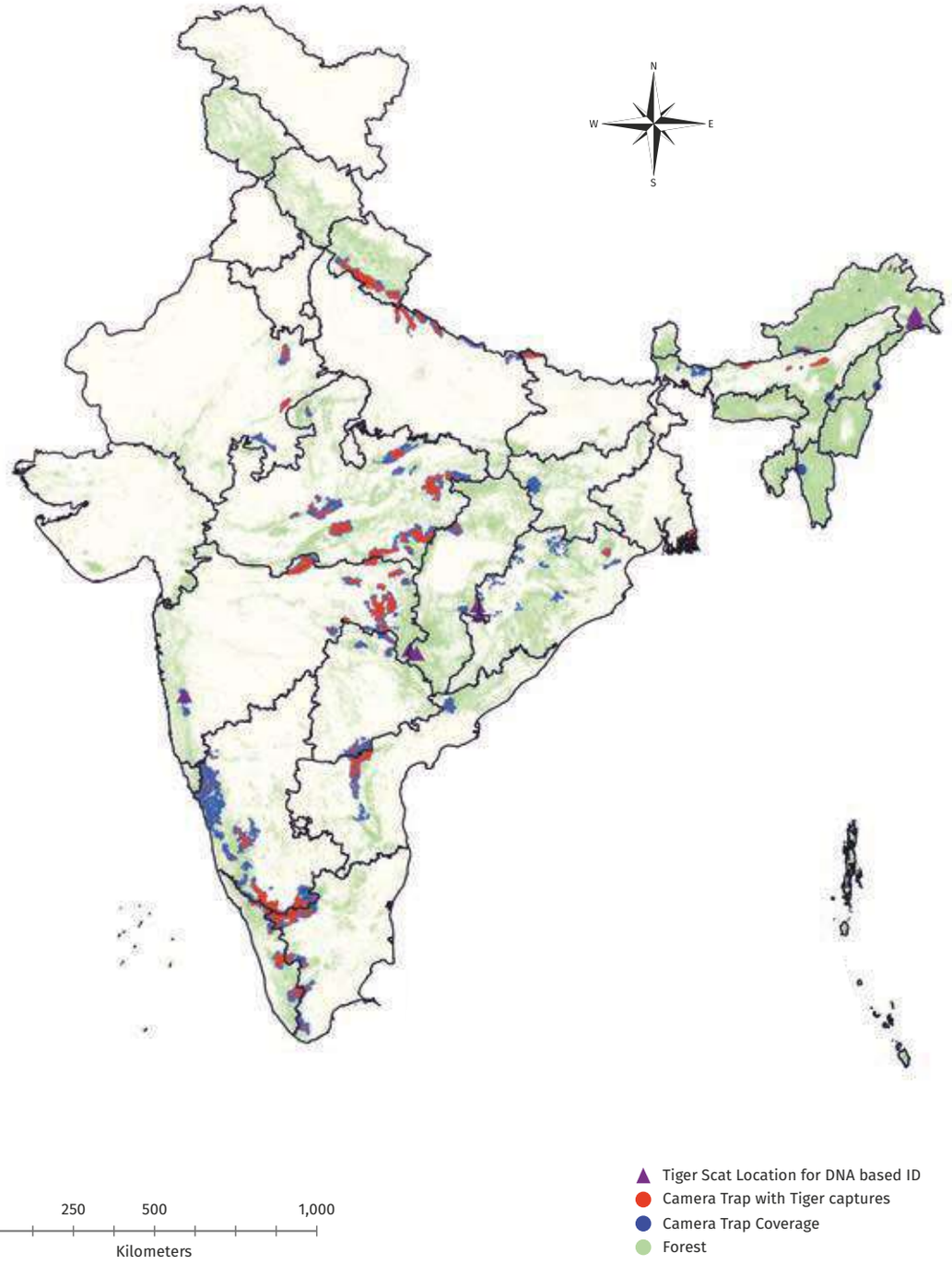
Field Method

With availability and affordability of digital camera traps, these have become a mainstream tool for monitoring elusive wildlife. Tigers and leopards with their unique individualistic stripes and rosettes permit individual identification and subsequent estimation of their abundance using capture-mark-recapture framework. Spatially explicit capture-recapture models (SECR) consider the spatial context of capture and recapture of individuals alongside their temporal capture history to estimate density. SECR ties the detection process to the actual space usage of an animal hence giving rise to robust population parameter estimates (Borchers and Efford 2008).

Sampling areas were systematically sampled by deploying a set of double camera traps within a 2 km^2 grid. The camera set was deployed at sites having the highest chance of photo-capturing tigers and leopards. These locations were determined by extensive search through sign surveys to find the ideal locations along animal trails, dirt tracks and dry stream beds. Each of these 2 km^2 grids were set within the 100 km^2 country wide grid. This enabled our inferences to be comparable on the same spatial scale between all National assessments since 2006. Sampling was carried out in a minimum block of 200 km^2. Adjacent camera stations were separated by a minimum distance of 1 km. Cameras were usually operated between 25 to 35 days at each site with an effort of over 1,200 trap-nights per ~100 km^2. Camera traps were placed at 26,838 locations spread across 141 sites (Fig. 2.4).

Figure 2.4

Camera trap locations, cameras with tiger captures (red) and tiger positive scat locations (purple) across tiger bearing forests of India in 2018-19



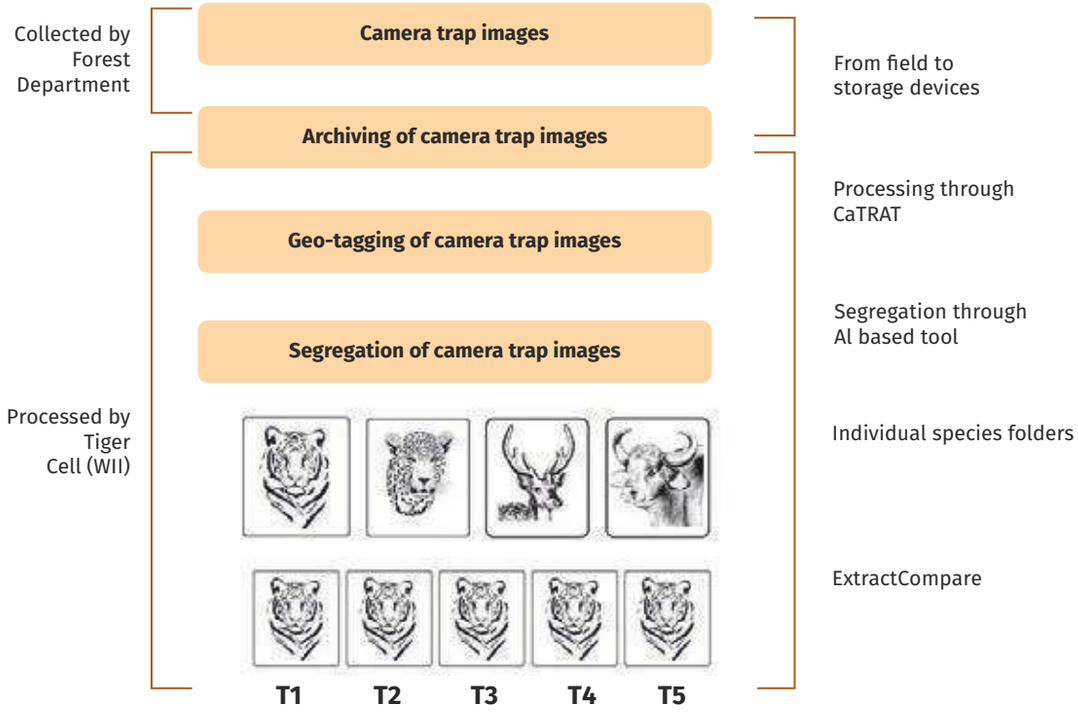
Data analysis

Processing of Phase III data

An artificial intelligence (AI) based image processing tool, to automatically geotag and segregate the camera trap images into species (Fig. 2.5), was developed in collaboration with Indraprastha Institute of Information Technology, New Delhi. This image processing software known as CaTRAT (Camera Trap Data Repository and Analysis Tool) (Cheema et al. 2018) (Fig. 2.6) was used for geotagging, coding and segregating the images to individual species folders. The geo-tagged images were scrutinized for potential software misclassification. Segregated photos of tigers and leopards were further processed for identification of individual tigers and leopards.

Figure 2.5

Workflow of species identification from camera trap images using artificial intelligence based tool, CaTRAT.



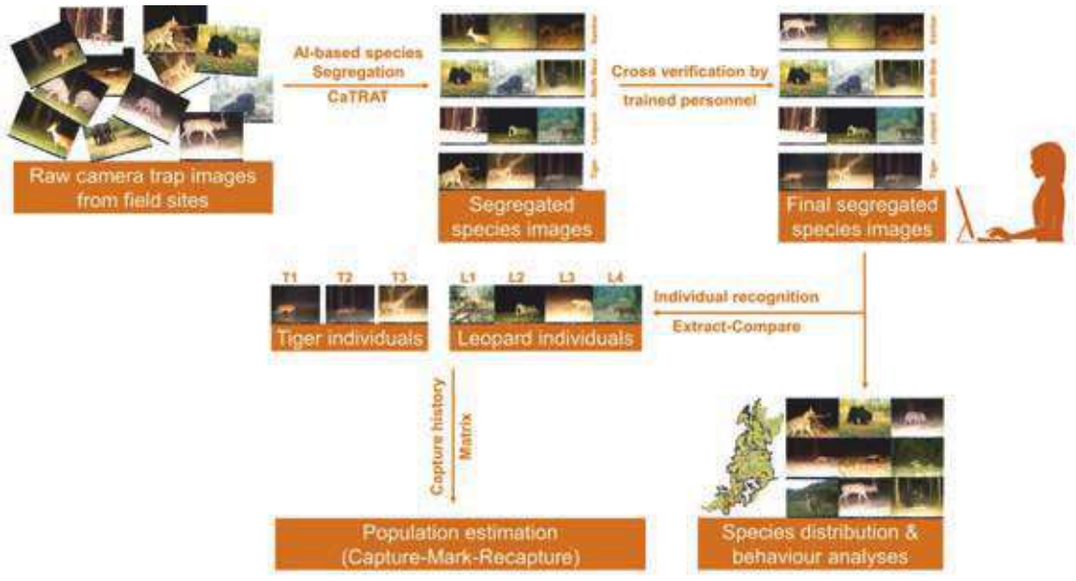


Figure 2.6

Graphic depiction of CaTRAT that uses Artificial Intelligence to segregate camera trap images to species. The segregated images are checked for errors, tagged with camera trap coordinates, time and date stamp in their metadata and stored for further analysis.

Individual identification of tigers and leopards

Individual identification was carried out using a pattern recognition program ExtractCompare (Hiby et al. 2009) for tigers and Hot Spotter (Crall et al. 2013) for leopards. Tiger cubs smaller than the mid-shoulder height of mothers (Fig. 2.7) were not considered for population estimation since this cohort has high mortality and low capture probability by camera traps. This criteria of classifying young tigers have been consistently used for population estimation since 2006. In ExtractCompare, a three-dimensional surface model of a tiger is superimposed on a tiger photo to account for pitch and roll related to body posture and angle of photograph before extracting the stripe pattern (Fig 2.8). Using an automated process, ExtractCompare searches through the database of images, to calculate similarity scores between digitized tiger coat patterns to score close matches. Biologists then choose from amongst these matches if images represent the same tiger or not. Unique tigers photo-captured at each site were identified first using this method. Subsequently, tiger photographs of adjoining sites and within each landscape were compared using the National tiger database, so as to estimate number of same tigers shared between sites, if any, and understand tiger dispersal. In case of single flank or partial photos of tigers, the long-term database was a great help in determining the identity of the individual tiger and only a few photographs had to be discarded due to poor quality.

Figure 2.7

Tiger cubs aged a) 2-3 months, b) 4-5 months, c) 5-8 months and d) juvenile (~1-1.5 yr) in relation to their mothers. Cubs at and above mid-shoulder height of mothers (d) were considered for tiger population estimation since 2006

Figure 2.8

Process of individual identification of tigers using ExtractCompare software.

a

Placing seeds on prominent body parts (mid shoulder, tail, hip)

b

3-D model fitting which takes into account the angle at which the photo is taken

c

Pattern extracted

d

Visual comparison to match tiger images after the computer program has provided a few options from several thousand images

Once individual tigers were identified, two matrices for each site were prepared - a) camera trap matrix with camera trap IDs, their coordinates, deployment and operation history, b) capture matrix with session ID, animal ID, occasion ID (when the individual animal was photo-captured), trap ID (where the animal was photo-captured) and gender of the animal if possible (Table 2.2); c) a habitat mask that included all potential tiger habitats within a two sigma (s) km (explained below) buffer of the outermost camera traps was made alongside. The SECR model could then potentially estimate the activity centers of photo-captured tigers/leopards within this habitat mask (model space).

Table 2.2

Camera trap and capture matrices prepared from individually identified tigers for each site.

Session	Tiger_ID	Occasion	Trap	Sex	
Anamalai-18	ANM_1	4	ANM-5	F	Capture matrix
Anamalai-18	ANM_1	25	ANM-48	F	
Anamalai-18	ANM_2	5	ANM-24	M	
Anamalai-18	ANM_2	8	ANM-34	M	
Anamalai-18	ANM_PARA_1	5	ANM-3	M	
Anamalai-18	ANM_PARA_1	6	ANM-8	M	

Trap ID	Long	Lat	Day_1	Day_2	Day_3	
ANM_c001a	22.785978	91.53280	1	1	0	Camera trap matrix
ANM_c001b	22.785978	91.53280	1	1	1	
ANM_c002a	22.7855673	91.545110	1	1	1	
ANM_c002b	22.7855673	91.545110	0	0	1	
ANM_c003a	22.7110078	91.4528011	0	0	1	
ANM_c003b	22.7110078	91.4528011	0	0	1	

Abundance estimation through Spatially Explicit Capture Recapture

Maximum likelihood based spatially explicit capture recapture (SECR) was used to estimate tiger abundance/density from the camera trap data. In SECR, we assume that individual tigers have home ranges and the 'activity centres' of these home ranges are distributed in a spatial Poisson point process and are independent and identically distributed. Detection probability at the activity center is 'g_0' and this detection probability declines as we move away from the activity center which is modeled as spatial scale of detection 'σ' using Gaussian, hazard, etc. functions (Fig. 2.9) akin to Distance sampling (Buckland et al. 2001). However, these activity centres are in reality unobserved and hence considered latent variables. By marginalizing over the entire available space, we then need to estimate only g_0 and σ to assess the density (Borchers and Efford 2008).

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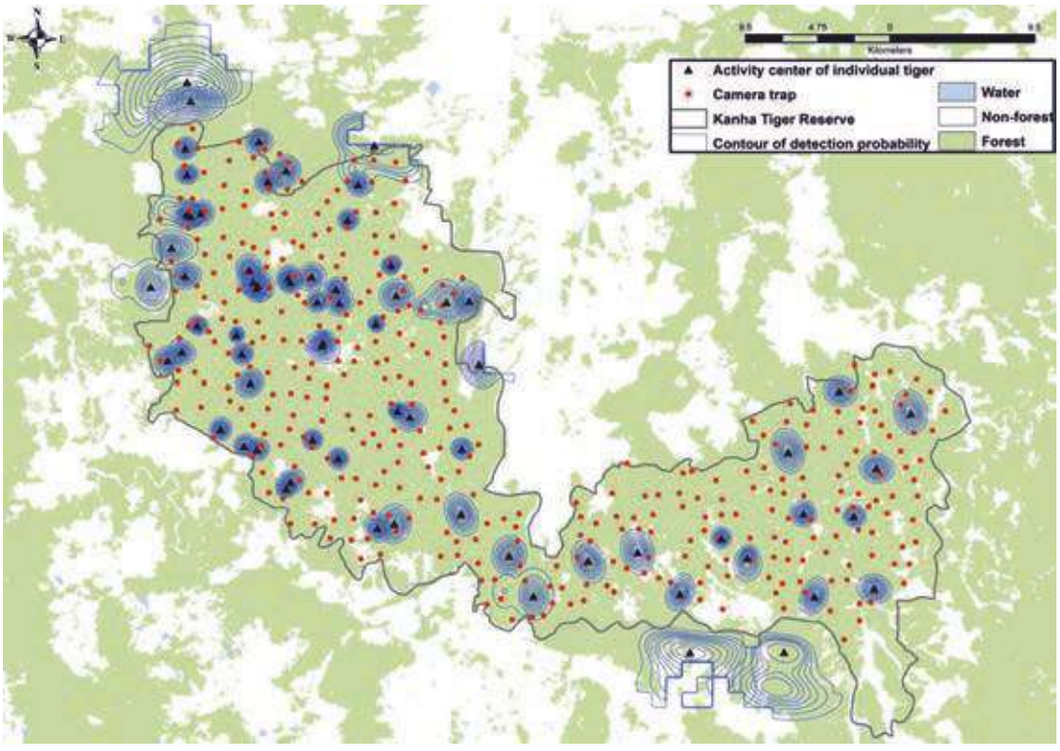


Figure 2.9

Camera trap locations, activity centers of photo captured tigers modelled with a declining detection function (s) with increasing distance from activity center. Summation of the spatial capture probabilities across the area combined with detection probability of non-captured individuals provides a flat density surface for the region.

Since the gender of most photo-captured tigers could be ascertained and male and female tigers are known to have different ranging patterns (Smith et al. 1987, Smith 1993), we modeled g_0 and σ as variable with tiger gender in a mixture model framework. This allowed us to estimate detection corrected sex ratio of tigers in the population. Tiger density is largely influenced by prey availability, habitat characteristics, and human impacts. A priori, we expected tiger density to increase with increase in forest area, prey availability, and level of protection while decrease with increase in anthropogenic pressures as depicted by night lights, road density, human footprint and human impact indices recorded during Phase I. We modeled tiger and leopard density as a function of these covariates. A number of models having various combination of the variables obtained from Phase I and Phase II were used within SECR as covariates to model tiger density for each landscape using package secr (Efford 2015) in program R (R Development Core Team 2010). The best covariate model was then selected on the basis of AIC (Akaike 2011) for that landscape. In areas where tigers were detected but the area was not camera trapped, their numbers were then estimated by predicting tiger density from covariates (prey, habitat and human disturbances) using the best model or model averaged parameters.

PHASE III
FOR AREAS WHERE CAMERA TRAPPING WAS NOT FEASIBLE

Systematic camera trapping was not possible in areas with militancy, with lack of personnel and inaccessible terrain. Therefore, we resorted to the following methods for estimating minimum tiger numbers for such areas.

Laboratory Methods

DNA profiling

Carnivore scat were collected from these areas and DNA extracted from them using the guanidinium thiocyanate method (Boom et al. 1990). Following extraction, DNA samples were first screened for species identification using a tiger specific cytochrome-b marker (Bhagavatula and Singh 2006). Tiger positive samples were confirmed after samples were run along with a positive and negative control. A panel of 11 polymorphic microsatellites was used to identify individuals (Yumnam et al. 2014, Kolipakam et al. 2019). Minimum number of individual tigers were then estimated for an area.

Analytical Methods

Maximum Entropy Models

For the North East Hill areas especially in Arunachal Pradesh, we used tiger presence locations (tiger scats confirmed by DNA profile), and tiger images from camera trap data as presence points along with environmental and ecological covariates to model suitable tiger habitat (at a pixel size of 1 km^2), using the Maximum Entropy models (MaxEnt) (Phillips et. al 2006). The prediction of suitable habitats by MaxEnt models can be influenced by spatially biased locations (e.g. clustered presence). In order to avoid autocorrelation within the input data, it was filtered so as to select only one presence point from a pixel. We took random subsets of the presence locations using k-fold partitioning design (k=5 and training= 80% of presence data of tigers) to build the model and validate the output by unused presence locations (testing 20%). The environmental predictors were: elevation, enhanced vegetation index, and distance from human settlements. We used linear, quadratic, hinge and product features to generate the MaxEnt model with 100 bootstrap replicates.

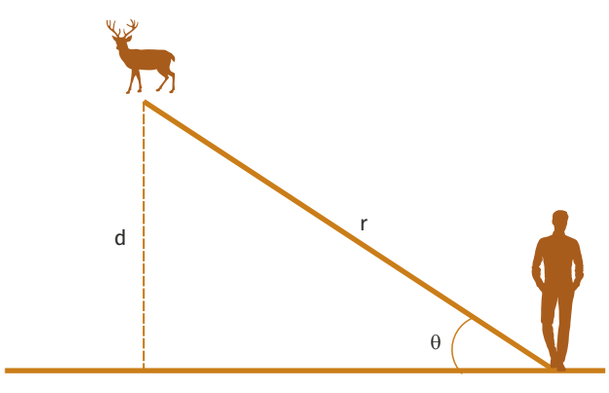
MaxEnt produces habitat suitability for every pixel varying from 0 to 1. We averaged the results of all the k-partitioned model runs, to get average habitat suitability for each pixel. All pixels of the predicted raster that had greater than the threshold True Skill Statistics (TSS) value (Liu et al. 2013) was considered as having high probability of tiger presence. 'Area Under the receiving operating characteristic Curve' (AUC) of MaxEnt model was considered as an additional criterion to assess the ability of MaxEnt model (Hosmer and Lemeshow 1989) to predict tiger presence. This provided us the extent of suitable tiger habitat in the sampled area. We subsequently modelled potential tiger density by extending the minimal camera trap-based capture-recapture density across the suitable habitat in the larger sampling area. As tiger signs and photographs were not recorded in Intanki (Nagaland) and Dampa (Mizoram), we did not model tiger density for these areas.

Distance Sampling

During phase I sampling, the state forest departments and WII researchers conducted line transect walks (and khal [river and tidal channels] surveys for Sundarban) for ungulates, fowls, and primates. For each sighting on the transect record was kept on species, group size, sighting distance, animal bearing and walk bearing, major habitat type, terrain type, geographic coordinates of animal(s) detected. This data was either recorded on forms or digitally on the M-STrIPES ecological mobile application for line transects (Form 2).

Figure 2.10

Line transects being sampled on foot for estimating prey density. a) The observer records radial distance [r] and bearing of the animal [θ] from which the perpendicular distance [d] of the animal is computed. b) Animal detections plotted against distance from transects are a declining function. This function allows the estimation of the Effective Strip Width within which all sightings are considered to have occurred and allows detection corrected density estimates.



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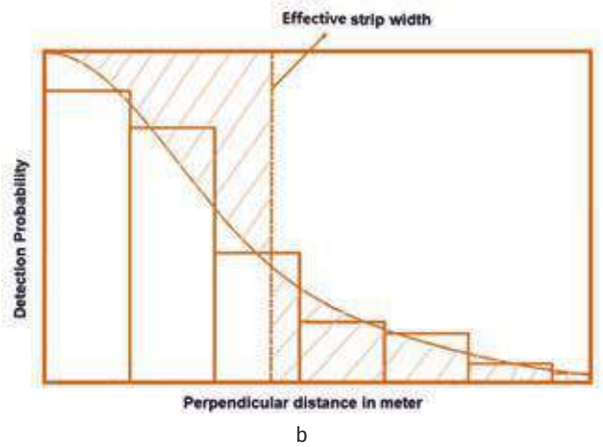

b

Data analysis

Ungulate abundance estimates were analysed using conventional distance sampling approach (Buckland et al. 2001) in program Distance (Version 7.0; Thomas et al. 2010) for each tiger reserve. Shape criteria were examined for heaping and any outliers were right truncated where necessary. Three key functions (uniform, half-normal and hazard rate with cosine and polynomial series adjustment) were considered for the analysis. Model selection was done using AIC, while Kolmogorov-Smirnov and Chi-square test statistics were used to assess the goodness of fit of each model to the observed data (Buckland et al. 2004).

PHASE III
SPECIES DISTRIBUTION AND RELATIVE ABUNDANCE IN TIGER RESERVES

Apart from providing tiger and prey density information, for 49 tiger reserves we used program CaTRAT to use the camera trap data for evaluating species distribution and relative abundance from camera trap data. Abundance indices are used to characterize spatial distribution and abundance of species with the assumption that these indices scale monotonically with actual abundance (Güthlin et al. 2014). The program calculates the number of trap-days for each camera trap from the time it was deployed until the time it was retrieved. For every photocapture, species in the photo, date and location of photocapture was recorded. In the program we defined independent events as consecutive photographs of the same species (or individual when identification was possible) taken more than 30 minutes apart at the same camera trap. The number of independent photo-captures of a species was used to calculate two relative abundance indices (RAI) for terrestrial mammals as follows:

RAI_1 is defined as the number of independent photo-captures of species in 100 trap nights (Carbone et al. 2001, O'Brien et al. 2003). We computed the RAI_1 as: $RAI_1 = 100 \times (A/N)$, where A is independent photo captures and N is trap nights.

RAI_2 is the number of trap nights required to get a single independent photo-capture of the species.

$RAI_2 = N/A_1$ (Jenks et. al 2011).

The desktop of M-STrIPES with the CaTRAT module computes these indices. This data and its analysis provides, for the first time, the inventory and spatial status of major mammalian species for all tiger reserves and will serve as a baseline for future monitoring.

Appendix 1 show cases be relationship between RAI and Tiger density, authenticating RAI's validity to monitor trends in abundance.

Peer Participation: The NTCA invited three international experts in carnivore ecology and shared with them the advancements done for the 2018-19 tiger status assessment. These experts visited field sites, experienced data collection procedures and protocols, used M-STrIPES mobile application. At the Wildlife Institute of India, they discussed the analytical procedures with WII's Principal Investigators and Tiger Cell visualized the Phase I data in GIS and, camera trap photo repositories. At the field sites and NTCA they interacted with Tiger Reserve managers and administrators to understand issues related to tiger status assessment, management, and conservation. Their perceptions are appended as annexure (Appendix 4) to this report.

Dr. Joseph Bump, University of Minnesota observing collection of carnivore scat for DNA analysis

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03

RESULTS OF TIGER STATUS AT A GLANCE

The fourth cycle of National tiger status assessment of 2018-19 covered **381,400 km^2** of forested habitats in **20** states of India. A foot survey of **522,996 km** was done for carnivore signs and prey abundance estimation. In these forests, **317,958** habitat plots were sampled for vegetation, human impacts and prey dung. Camera traps were deployed at 26,838 locations. These cameras resulted in **34,858,623** photographs of which **76,651** were of tigers and **51,777** were of leopards. The total effective area sampled by camera traps was about **121,337 km^2**. The total effort invested in the survey was over **620,795** man-days. We believe that this is the world's largest effort invested in any wildlife survey till date, on all of the above counts.

A total of **2,461** individual tigers (>~1 year of age) were photo-captured. The overall tiger population in India was estimated at **2,967** (SE range 2,603 to 3,346) (Table 3.1, Fig. 3.3). Out of this, **83%** were actually camera trapped individual tigers and **87%** were accounted for by camera trap-based capture-mark-recapture and remaining **13%** were estimated through SECR covariate based models (Fig. 3.1). Tigers were observed to be increasing at a rate of **6%** per annum in India when consistently sampled areas were compared from 2006 to 2018 (Fig. 3.2).

Table 3.1

Estimated tiger numbers in States and Landscapes of India. Numbers in parenthesis are one standard error limits of the mean.

State	Tiger Population			
	2006	2010	2014	2018
Shivalik Hills and Gangetic Plains Landscape				
Bihar	10 (7-13)	8	28(25-31)	31 (26 - 37)
Uttarakhand	178 (161-195)	227 (199-256)	340 (299-381)	442 (393 - 491)
Uttar Pradesh	109 (91-127)	118 (113-124)	117 (103-131)	173 (148 - 198)
Shivalik-Gangetic	297 (259-335)	353(320-388)	485 (427-543)	646 (567 - 726)
Central Indian Landscape and Eastern Ghats				
Andhra Pradesh	95 (84-107)	72 (65-79)	68 (58-78)	48 (40 - 56)#
Telangana	-	-	-	26 (23 - 30)#
Chhattisgarh	26 (23-28}	26 (24-27)	46 (39-53)*	19 (18 - 21)
Jharkhand		10 (6-14)	3*	5
Madhya Pradesh	300 (236-364)	257 (213-301)	308 (264-352)*	526 (441 - 621)
Maharashtra	103 (76-131)	168 (155-183)	190 (163-217)*	312 (270 - 354)
Odisha	45 (37-53)	32 (20-44)	28 (24-32)*	28 (26 - 30)
Rajasthan	32 (30-35)	36 (35-37)	45 (39-51)	69 (62 - 76)
Central India & Eastern Ghats	601 (486-718)	601 (518-685)	688 (596-780)	1,033 (885- 1,193)
Western Ghats Landscape				
Goa	-	-	5*	3
Karnataka	290 (241-339)	300 (280-320)	406 (360-452)	524 (475 - 573)
Kerala	46 (39-53)	71 (67-75)	136 (119-150)	190 (166 - 215)
Tamil Nadu	76 (56-95)	163 (153-173)	229 (201-253)	264 (227 - 302)
Western Ghats	402 (336-487)	534 (500-568)	776 (685-861)	981 (871 - 1,093)
North East Hills and Brahmaputra Plains Landscape				
Arunachal Pradesh	14 (12-18)		28*	29*
Assam	70 (60-80)	143 (113-173)	167 (150-184)	190 (165 - 215)
Mizoram	6 (4-8)	5	3*	0
Nagaland	-	-	-	0
Northern West Bengal	10 (8-12)	-	3*	0
North East Hills, and Brahmaputra	100 (84-118)	148 (118-178)	201 (174-212)	219 (194 - 244)
Sundarban		70 (62-96)	76 (62-96)	88 (86-90)
TOTAL	**1,411 (1,165-1,657)**	**1,706 (1,507-1,896)**	**2,226 (1,945-2,491)**	**2,967 (2,603-3,346)**

*: Scat DNA based estimates were also used

#: For comparison with previous estimates of Andhra Pradesh, combine Andhra Pradesh and Telangana population estimate of current year

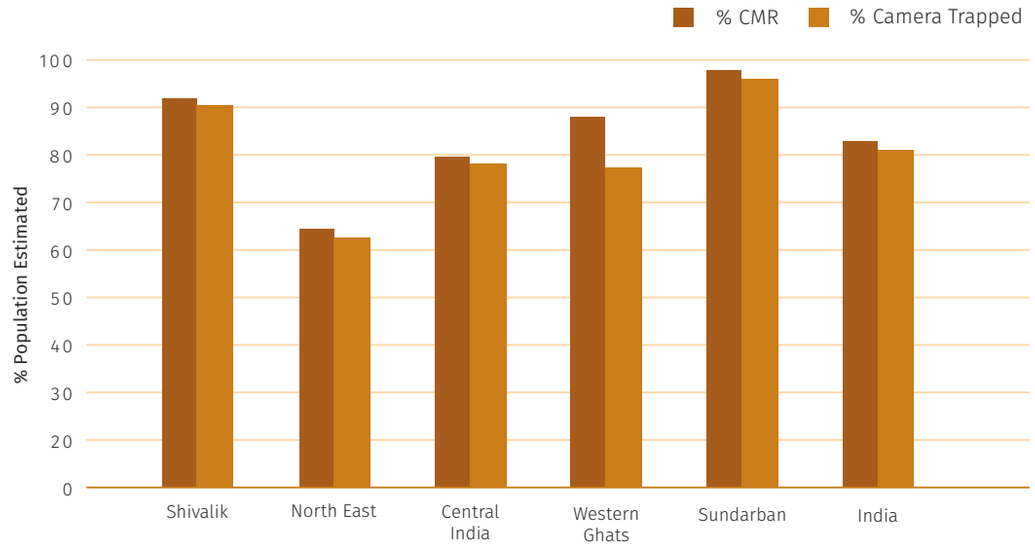


Figure 3.1

Proportion of the total tiger population camera trapped and estimated by capture-mark recapture (CMR)

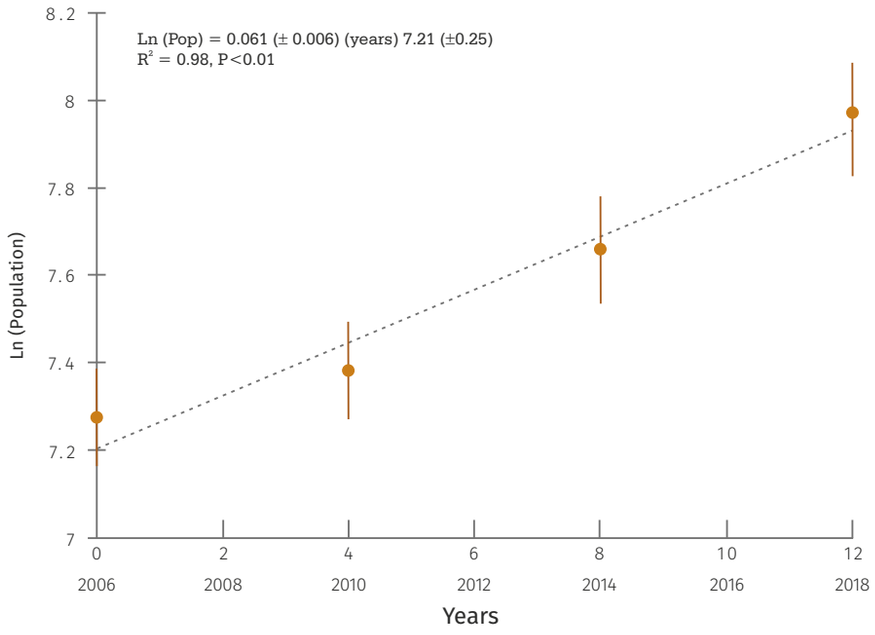


Figure 3.2

Growth rate of tigers in India estimated by regressing natural log transformed population against years. The slope of the regression gives the instantaneous growth rate (r = 0.06). Growth rate was computed only from areas that were sampled consistently from 2006 to 2018.

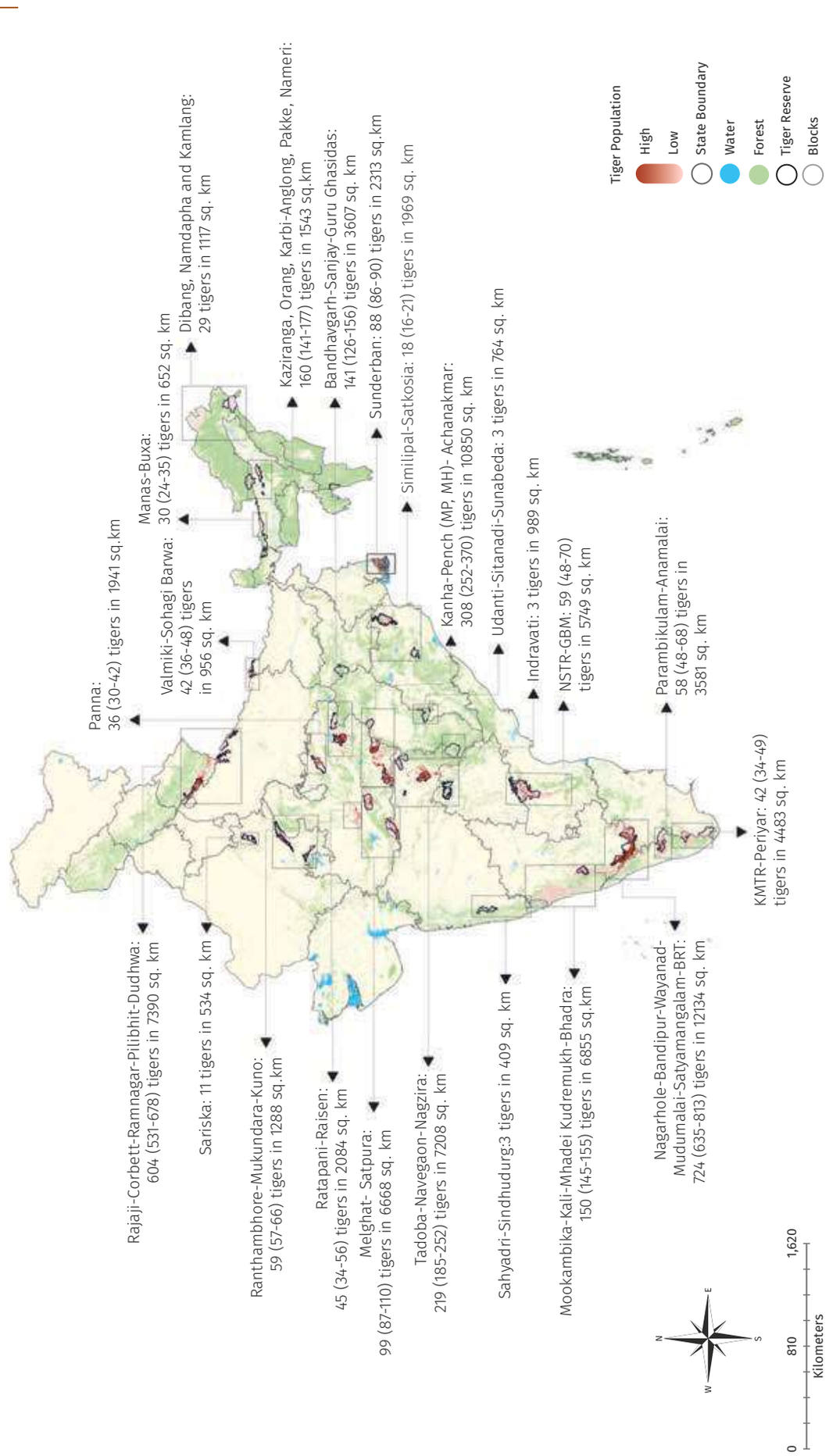


Figure 3.3

Tiger density, extent and population blocks in India.

Tiger occupancy was found to be stable at 88,985 km^2 at the country scale since 2014 (88,558 km^2). Though there were losses and gains at individual landscapes and state scales. The occupancy reported in this report is based on latest forest cover by Forest Survey of India (2017) and therefore cannot be compared with earlier occupied areas which were computed from earlier forest cover data. To make the comparison on the same scale we have recomputed tiger occupied forests for the 2014 cycle on the forest cover of 2017 (Table 3.2). Reduction in occupied areas was due to a) not finding evidence of tiger presence in sampled forests (20% actual loss), and b) not sampling forests that had tiger presence in 2014 (8 %). New areas that were colonized by tigers in 2018 constituted 25,709 (28%) km^2. This analysis suggests that loss and gain of tiger occupancy was mostly from habitat pockets that support low density populations. Such habitats with low density tigers, though contributing minimally to overall tiger numbers, are crucial links for gene flow and maintaining connectivity between source populations. The loss and gain of tiger occupancy in these marginal areas is a dynamic process and depends on several factors like proximity of a tiger source population, anthropogenic pressures operating in the landscape, associated change in habitat conditions and protection regime. Tiger occupancy has increased in the state of Madhya Pradesh, and Andhra Pradesh. Loss in North East is due to poor sampling. Madhya Pradesh has also registered a substantial increase in their tiger population and along with Karnataka ranks highest in tiger numbers. The poor and continued decline in tiger status in the states of Chhattisgarh, Jharkhand and Odisha is a matter of concern. The largest contiguous tiger population in the world of about 724 tigers was found in the Western Ghats (Nagarhole-Bandipur-Wayanad-Mudumalai-Satyamangalam-BRT block) while the second largest population of about 604 tigers was found across Uttrakhand and western Uttar Pradesh (Rajaji-Corbett-Ramnagar-Pilibhit-Dudhwa block) (Fig. 3.3). There were now eight tiger populations in India and trans-boundary Sundarban that numbered over 100 individuals and served as major source populations in the landscapes (Fig. 3.3).

Landscape	Tiger occupancy 2014	Tiger occupancy 2018	Difference	Gain 2018	Tiger present in 2014 but not sampled in 2018	Actual loss
Shivalik	8,815	8,346	-469	688	279	904
Central India	40,185	47,717	7,532	18,089	276	10,216
Western Ghats	27,824	27,297	-527	5,778	769	5,524
North East	9,901	3,312	-6,589	675	6,040	1,237
Sundarban	1,834	2,313	479	479	0	0
India	88,558	88,985	427	25,709	7,364	17,881

Table 3.2
Tiger occupied forests (km^2) for 2018 and 2014 for each landscape. Forest Survey of India (2017) forest cover is used for computation of forest occupancy.

Since full coverage by field surveys using standardized protocols (Jhala et al. 2017) were done only in the Shivalik-Gangetic Plains Landscape, Central Indian and Eastern Ghats Landscape, and the Western Ghats landscape, we limit the following analysis to 9,402 grids of 100 km^2 that were sampled within these three landscapes. Sundarban though sampled entirely with field survey and camera traps was not included in this analysis as the field protocols differed substantially.

We classified these 9,402 grids into six categories based on tiger density estimated in them (Table 3.3). Majority of the grids did not have tigers (83%), and about 2% had high density of tigers. Of the 1,673 grids with tiger presence, 1,397 (85.3%) were camera trapped. Thus, covariate model-based inference was used to infer tiger density and numbers for only the remaining 14.7% of the area occupied by tigers. Grids with high tiger density were all camera trapped (Table 3.3), and population estimates for these were obtained from SECR.

Table 3.3
The number of grids (100 km^2) sampled in different tiger density range, and percent of these grids camera trapped.

Tiger Density Category	Tigers per 100 km^2	Number of Grids	Percent of Total Grids	Camera Trapped Grids (%)
0	0	7,767	82.6	382 (5)
1	>0 to 1	870	9.3	706 (81)
2	>1-3	331	3.5	270 (82)
3	>3-5	276	2.9	263 (95)
4	>5-10	117	1.2	117 (100)
5	>10	41	0.4	41 (100)

To understand various factors that correlate and possibly determine tiger density we conducted exploratory data analysis as well as formal hypothesis tests with a priori expectations as follows:

1) Tiger density would increase with increase in primary prey (chital, sambar and gaur).
2) Tiger density would increase with increase in tiger habitat and its quality.
3) Tiger density should decline with increasing human impacts and decrease in protection regime.

Box and whisker plots were examined for indices of tiger sign, tiger prey, habitat and human impacts for various tiger density categories (Table 3.3). Since data were non-normal, nonparametric ANOVA (Kruskal-Wallis) followed by multiple comparisons were done to test the hypothesis that covariates differed for different tiger density categories (Zar 1999). For this analysis we used only those grids where tiger density was estimated from camera trap based SECR and not from covariate models (Table 3.3).

Tiger density was significantly and strongly related with prey abundance indices. Tiger densities increased as chital, sambar and gaur encounter rates as well as their dung density increased (Fig. 3.4 - 3.6). Tiger density was also significantly and strongly related with total tiger prey encounters and dung densities. Amongst habitat indices the amount of forest in a grid (Fig. 3.7), especially forest away from edge effects (core forest area) (Fig. 3.8) was significantly and positively related with tiger density. Security in the form of Protected areas harbored higher tiger densities (Fig. 3.9). Human impact indices in the form of night light area (Fig. 3.10), distance to night lights (Fig. 3.11), livestock presence (Fig. 3.12), signs of wood cutting (Fig. 3.13), signs of lopping (Fig. 3.14), human and livestock trails (Fig. 3.15), were negatively and strongly related with tiger density. Encounter rate of tiger sign, (pugmark, scat, rake-marks, and scrape marks) were strongly and significantly related to tiger density (Fig. 3.16).

Chital encounters and pellet densities were significantly higher (Kruskal-Wallis One-Way ANOVA, χ^2= 891 chital ER, χ^2 = 1073 chital pellet, P<0.001) for grids with higher tiger densities for all tiger density categories (Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.4).

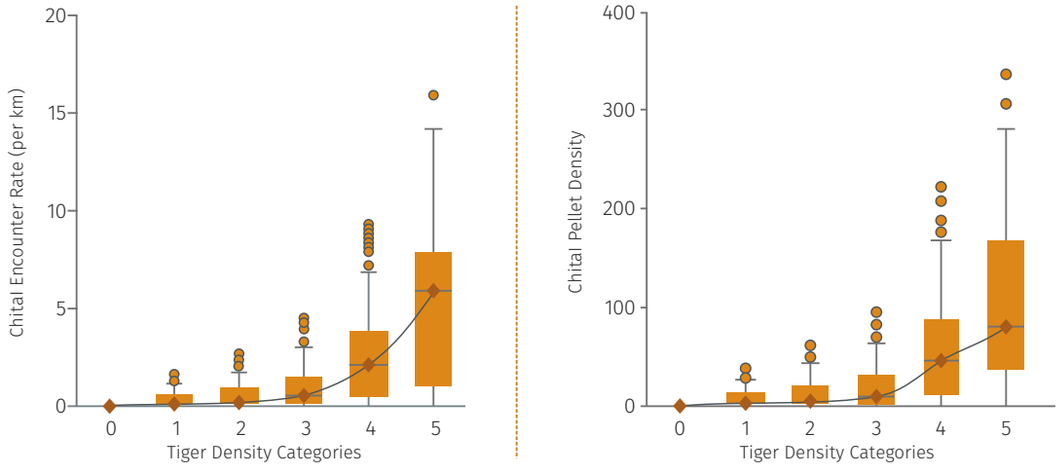


Figure 3.4
Encounter rates of chital and chital pellet density in different tiger density classes.

Sambar encounters and pellet density were significantly higher (Kruskal-Wallis One-Way ANOA, χ^2= 939 encounter rate, χ^2=1218 pellet density, P<0.001) for grids with higher tiger densities for all density categories except sambar ER for tiger density category 3 and 4 which were similar (Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.5).

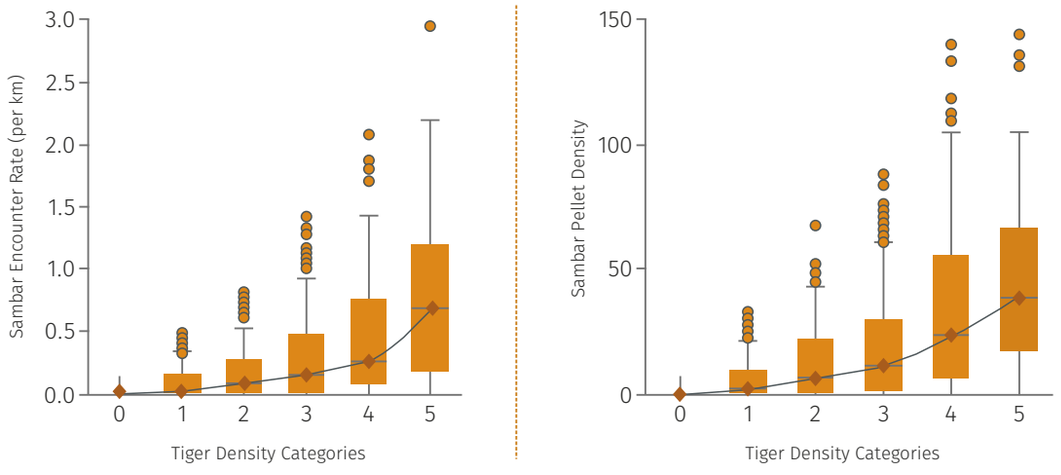


Figure 3.5
Encounter rates of sambar and sambar pellet density in different tiger density classes.

Gaur encounters and dung were significantly higher (Kruskal-Wallis One-Way ANOVA, χ^2= 431 Gaur ER, χ^2= 333 Gaur dung P<0.001). Gaur encounter rate for tiger absence grids was lower than all tiger present grids. But gaur did not differ in their encounter rates and dung within low density tiger grids (1 and 2) and high density grids (3, 4 and 5), while low tiger density grids (1 and 2) differed significantly from high density tiger grids (3, 4 and 5; Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.6)

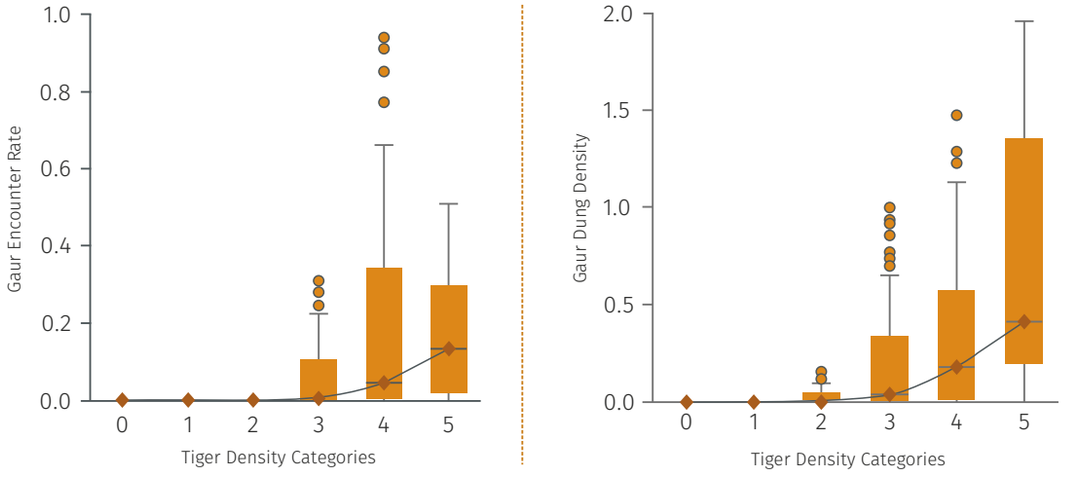
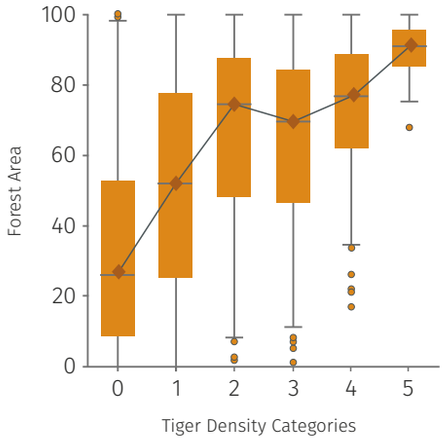


Figure 3.6
Encounter rates of gaur and gaur dung density in different tiger density classes.

Amount of forest area in 100 km^2 grids was significantly higher (Kruskal-Wallis One-Way ANOVA, χ^2= 887; P<0.001) for grids with higher tiger densities while tiger density category grids 2, 3 and 4 did not differ between themselves in the amount of forested habitat (Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.7).

Figure 3.7

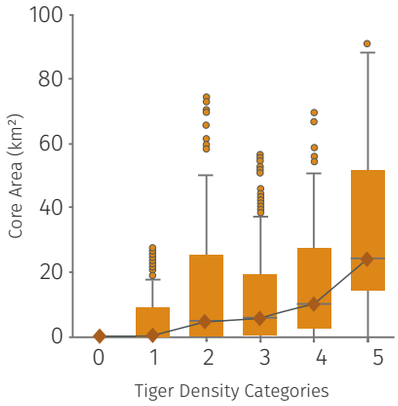
Forest area in a cell (100 km^2) for different tiger density classes.



The amount of core forest area was significantly higher (Kruskal-Wallis One-Way ANOVA, χ^2= 782; P<0.001) for grids with higher tiger densities for all tiger density categories except 2, 3 and 4 which had similar core area habitat (Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.8). Tiger density differed with distance from Protected Area (Kruskal-Wallis One-Way ANOVA, χ^2= 1497; P<0.001). Increasing distance from PAs resulted into significant decline in tiger density for all density categories except category 1 and 2 which were at similar distances from Protected Areas (Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.9).

Figure 3.8

Core forest area (2 km inward buffered) in a cell for different tiger density classes. The error bars are 90% Confidence intervals on the mean.



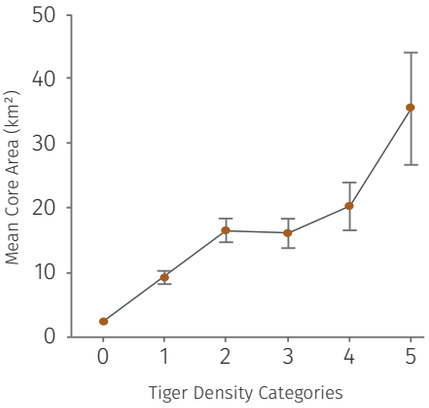
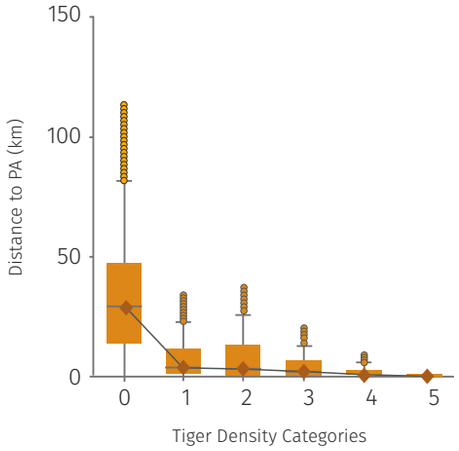
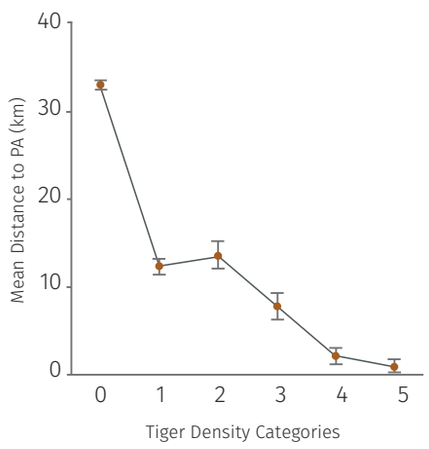


Figure 3.9

Distance from protected area with different tiger density classes. The error bars are 90% Confidence intervals on the mean.





Amount of nightlight significantly differed between tiger density categories (Kruskal-Wallis One-Way ANOVA, χ^2= 219; P<0.001). Tiger absence grids had higher night light area compared to tiger presence grids, low tiger density grids (1, 2 and 3 density categories) had similar night light area which were higher than high tiger density grids (4 and 5 density category; Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.10).

Different tiger density grids differed in their distance to night lights (Kruskal-Wallis One-Way ANOVA, χ^2=323; P<0.001). Tiger absence grids were significantly closer to night lights, while tiger density categories 2, 3 and 4 did not differ between themselves in terms of their distance to night lights but tiger density category 5 was significantly further from night lights compared to all other grids (Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.11). Cattle encounters and livestock dung density differed in grids with different tiger density (Kruskal-Wallis One-Way ANOVA, χ^2= 42 cattle dung, χ^2= 33 cattle ER P<0.001 cattle dung, P=0.003 cattle ER). Tiger absence grids (0 category) and tiger occurrence grids (density category 1) differed amongst themselves in amount of cattle encounters and dung, while tiger absence grids had higher cattle dung than other tiger density categories (2, 3, 4 and 5) which did not differ between themselves in cattle encounters or their dung density; Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.12).

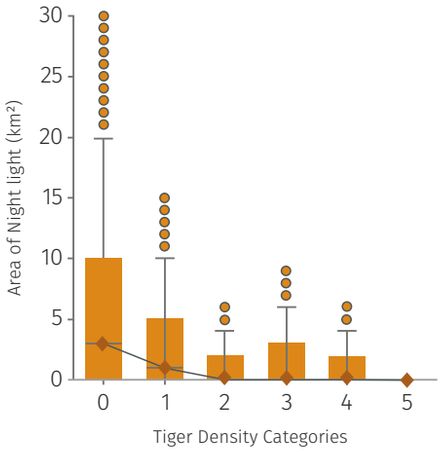


Figure 3.10
Night light area within a cell for different tiger density classes.

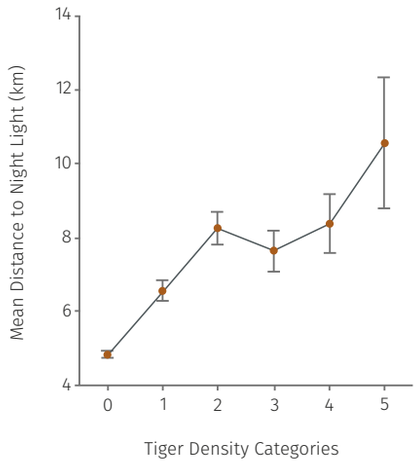
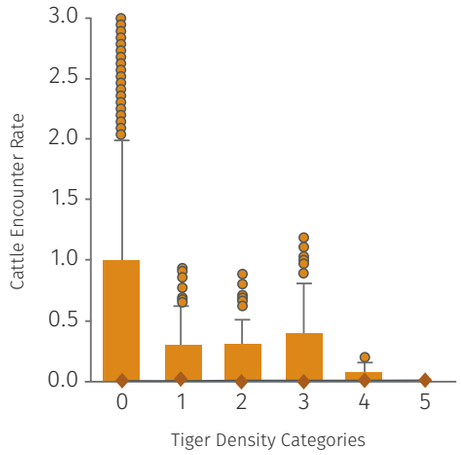


Figure 3.11
Distance to nightlights for different tiger density classes. The error bars are 90% Confidence intervals on the mean.



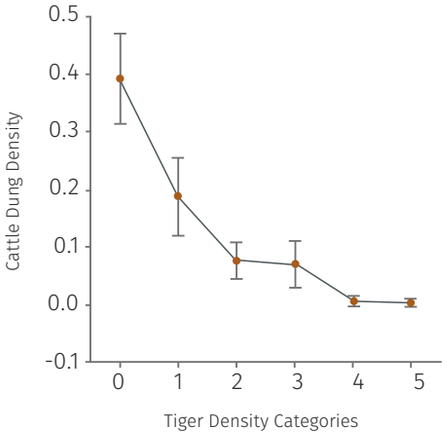
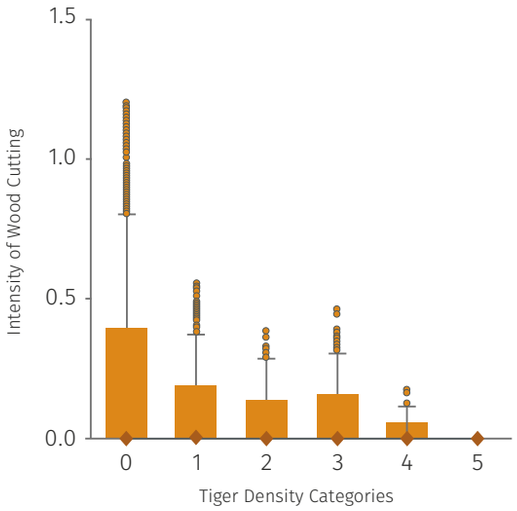


Figure 3.12
Cattle encounters and cattle dung density for different tiger density classes.

Figure 3.13
Human disturbance (intensity of wood cutting) for different tiger density classes.



Intensity of wood cutting were significantly different (Kruskal-Wallis One-Way ANOVA, χ^2= 73; P<0.001) between grids with different tiger densities. Tiger absence grids had higher wood cutting compared to all tiger presence grids, low density tiger grids had similar signs of wood cutting (density categories 1 and 2) which were higher than wood cutting signs for high density grids (category 3, 4 and 5). High tiger density grids (category 3, 4 and 5) did not significantly differ between themselves in the number of wood-cutting signs recorded (Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.13).

Intensity of lopping significantly differed for different tiger density grids (Kruskal-Wallis One-Way ANOVA, χ^2= 108; P<0.001). Tiger absence grids had higher lopping signs compared to all tiger presence grids; low density tiger grids had similar signs of lopping (density categories 1 and 2) which were higher than lopping signs for high density grids (category 3, 4 and 5). High tiger density grids (category 3, 4 and 5) did not significantly differ between themselves in the number of lopping signs recorded (Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.14). Intensity of human-livestock trails were significantly different for different tiger density grids (Kruskal-Wallis One-Way ANOVA, χ^2= 195; P<0.001). Tiger absence grids had higher human-livestock trails compared to all tiger presence grids; low density tiger grids had similar number of trails (density categories 1 and 2) which were higher than trails for high density grids (category 3, 4 and 5). High tiger density grids (category 3, 4 and 5) did not significantly differ between themselves in the number of trails recorded (Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.15).

Figure 3.14
Intensity of lopping fodder trees (human disturbance) for different tiger density classes.

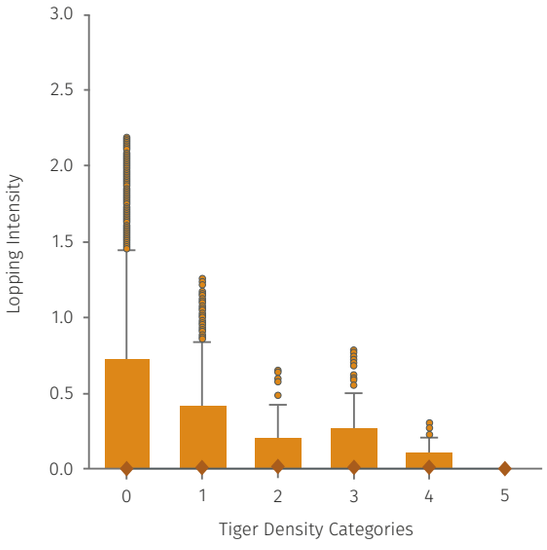
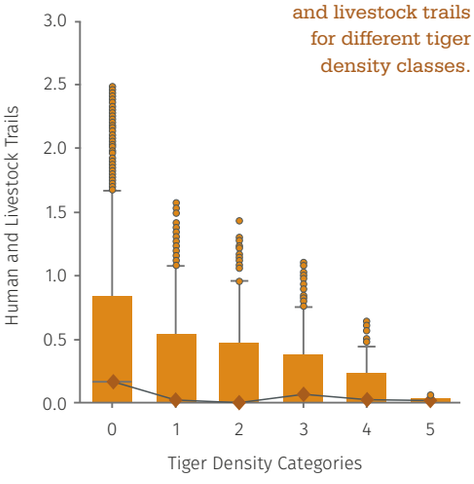


Figure 3.15
Intensity of human and livestock trails for different tiger density classes.



Tiger signs were significantly different for density categories (Kruskal-Wallis One-Way ANOVA, χ^2= 1841; P<0.001). Tiger signs significantly increased with increase in density categories, except for high density category 4 and 5 which did not differ significantly between themselves at the country scale (Tukey-Kramer Multiple-Comparison Test, P<0.05; Fig. 3.16). Analysis at landscape scale (as done with covariate models) would reduce variance due to climate (rainfall), and vegetation in sign deposition, decay, and detection to improve this relation with tiger density (Jhala et al. 2011).

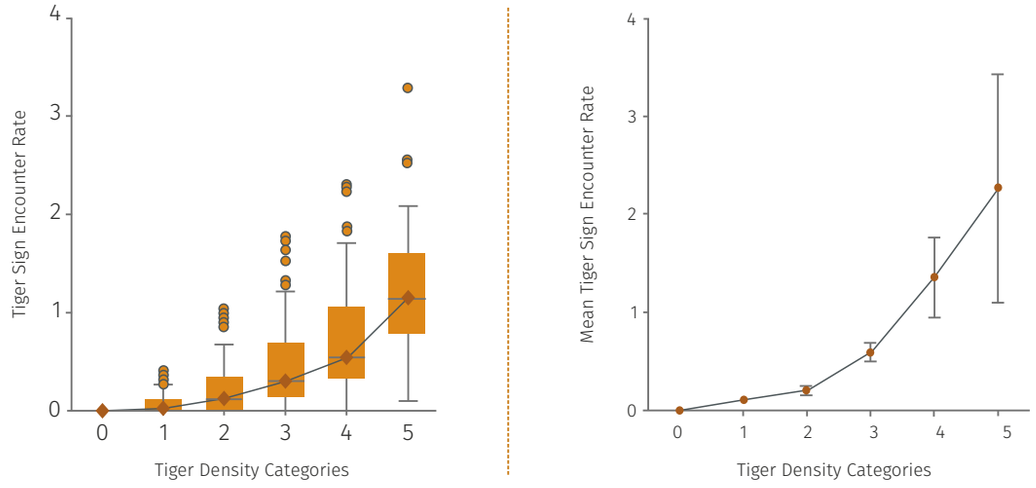


Figure 3.16
Tiger sign (pugmark, scat, rake-marks and scrape marks) encounter rate for different tiger density classes. The error bars are 90% Confidence intervals on the mean.

Since the current analysis (2018) of tiger abundance was done in a spatially explicit framework, it was possible to provide abundance estimates for individual tiger reserves along with the number of tigers using each tiger reserve (Table 3.4). There is always an issue of defining a number within an area that has contiguous habitat that can potentially be used by tigers outside of tiger reserves (Tiger Reserves not having hard boundaries but embedded within larger forested areas). In such cases tigers that are photo-captured within a reserve could potentially have their activity centers way beyond the boundaries of a tiger reserve, but visit and use the TR and thus get photo-captured. In such cases, often when extensive and intensive camera trapping is done, the minimum number of tiger's photo-captured can exceed the population estimate from within the administrative boundaries of a TR. To avoid this confusion, we report estimates of tigers that have their activity centers located within and in very close proximity of the TR administrative boundary (tiger population within the TR). We also report the estimated tiger population that could potentially utilize the tiger reserve and be exposed to the camera traps. This latter population can be compared with the annual Phase IV estimates (of minimum number of tigers photo-captured without correcting for detection), while the former (tigers within tiger reserves are to be compared with estimates of tiger population obtained and reported in 2014 (Jhala et al. 2015). Corbett Tiger Reserve had the largest population at about 231 tigers; Bandhavgarh, Bandipur, Nagarhole, Mudumalai and Kaziranga each had over a hundred tigers, while Dudhwa, Kanha, Tadoba, Sathyamangalam and Sundarban had over 80 tigers each. These tiger reserves are important source populations for their landscapes. The remaining tiger reserves have smaller tiger populations and need to be managed in a metapopulation framework for their long-term survival. In these tiger reserves connecting habitat corridors need to become an integral part for their management strategy. No tiger was recorded in Palamau Tiger Reserve during the 2018 assessment. However, one tiger was photo captured and evidence of tiger signs were recorded from the Tiger Reserve subsequently in between January and August 2019. Tigers were not recorded from Buxa (West Bengal) and Dampa (Mizoram) Tiger Reserves which had poor tiger status in the earlier assessments as well. The poor tiger status in Indravati, Udanti-Sitanadi and Achanakmar was related to law and order situation in these areas.

Some reserves like Similipal, Amrabad, Nagarjunsagar Sri Sailam, Palamau, Sanjay-Dubri, Manas, Buxa, Dampa, Anshi Dandeli, Pakke, Nameri and Kawal are below their potential and require resources and targeted management. In areas where tigers have not been recorded or the population has declined, restoration needs to proceed by improving protection, augmentation of prey, and reintroduction of tigers from an appropriate source (Kolipakam et al. 2019). For reintroduction of tigers into Palamau, prey augmentation needs to be coupled with restoration of law and order. For tiger reintroduction or supplementation in Palamau and Similipal, tigers need to be sourced from the closest source in the same genetic cluster. Buxa and Dampa can be repopulated through reintroductions from Kaziranga, after prey restoration in Buxa and strengthening protection in Dampa which has a good prey base. Currently tiger population within Tiger Reserves is 1,923 (65% of the total tiger population of India).

Table 3.4
Population estimates of tigers in tiger reserves for the year 2018-19.

	State	Tiger Reserves	Tigers utilizing the Tiger Reserve		Tigers within the Tiger Reserve	
			Tiger Number	SE	Tiger Number	SE
Shivalik Hills and Gangetic Plains						
1.	Bihar	Valmiki	33	1	32	0.06
2.	Uttar Pradesh	Dudhwa	107	16	82	3.4
3.	Uttar Pradesh	Pilibhit	65	3	57	0.3
4.	Uttarakhand	Corbett	266	6	231	0.3
5.	Uttarakhand	Rajaji	52	5	38	1
Central India and Eastern Ghats						
6.	Andhra Pradesh	Nagarjunasagar Srisailam	43	2	38	0.03
7.	Chhattisgarh	Achankamar	-	-	5	-
8.	Chhattisgarh	Indravati*	3	-	3	-
9.	Chhattisgarh	Udanti Sitanadi	-	-	1	-
10.	Jharkhand	Palamau	-	-	0	-
11.	Madhya Pradesh	Bandhavgarh	124	5	104	0.43
12.	Madhya Pradesh	Kanha	108	5	88	0.45
13.	Madhya Pradesh	Panna	31	3	25	0.5
14.	Madhya Pradesh	Pench	87	10	61	4
15.	Madhya Pradesh	Satpuda	47	2	40	0.02
16.	Madhya Pradesh	Sanjay Dubri	6	-	5	-
17.	Maharashtra	Bor	-	-	6	-
18.	Maharashtra	Melghat	49	2	46	0.04
19.	Maharashtra	Navegaon Nagzira	6	1	6	0.003
20.	Maharashtra	Pench	82	8	53	2.5
21.	Maharashtra	Sahyadri*	-	-	3	-
22.	Maharashtra	Tadoba	106	6	83	1.15
23.	Odisha	Satkosia	-	-	1	-
24.	Odisha	Simlipal	12	1	8	0.04
25.	Rajasthan	Mukundra	-	-	1	-
26.	Rajasthan	Ranthambore	55	1	53	0.17
27.	Rajasthan	Sariska	-	-	11	-
28.	Telangana	Amrabad	9	2	7	0.25
29.	Telangana	Kawal	-	-	1	-
Western Ghats						
30.	Karnataka	Bandipur	173	12	126	2
31.	Karnataka	Bhadra	38	4	30	0.32
32.	Karnataka	Biligiri Rangaswamy Temple	86	8	52	0.25
33.	Karnataka	Anshi Dandeli (Kali)	11	-	4	-
34.	Karnataka	Nagarhole	164	7	127	0.43
35.	Kerala	Parambikulam	33	3	26	0.2

State		Tiger Reserves	Tigers utilizing the Tiger Reserve		Tigers within the Tiger Reserve	
			Tiger Number	SE	Tiger Number	SE
36.	Kerala	Periyar	33	6	26	0.46
37.	Tamil Nadu	Anamalai	25	3	20	0.23
38.	Tamil Nadu	KMTR	8	1	7	0.01
39.	Tamil Nadu	Mudumalai	162	10	103	0.38
40.	Tamil Nadu	Sathyamangalam	126	6	83	2
NE Hills and Brahmaputra Plains						
41.	Arunachal Pradesh	Kamlang#	-	-	4	1
42.	Arunachal Pradesh	Namdapha#	-	-	11	1
43.	Arunachal Pradesh	Pakke	-	-	3	-
44.	Assam	Kaziranga	135	7	104	10
45.	Assam	Manas	31	2	31	2
46.	Assam	Nameri	-	-	3	-
47.	Assam	Orang	21	3	21	2.8
48.	Mizoram	Dampa	-	-	0	-
49.	West Bengal	Buxa	-	-	0	-
Sundarban						
50.	West Bengal	Sundarban	106	4	88	2

#: MaxEnt model result; *: scat DNA result

** Same three tigers in Nameri and Paake. In some tiger reserves that abut each other (Bandipur, Madumalai, and Satyamangalam; Pench – Madhya Pradesh and Pench - Maharashtra) individual tigers could be double counted. These double counts are accounted for in estimating the tiger population at the landscape and State scale. In order to minimize double count of tigers the estimate of "Tigers within Tiger Reserves" is to be used.

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04

SHIVALIK HILLS AND GANGETIC PLAINS LANDSCAPE

Background

The Shivalik Hills and Gangetic Plains landscape in India spans across the states of Himachal Pradesh, Uttarakhand, Uttar Pradesh, Bihar, West Bengal and Assam and is comprised of three parallel geological zones, *viz*. the Shivaliks, the bhabar tract and the terai plains. For convenience of assessment of tigers, herein, this landscape is limited to the eastern extent of Bihar. The lower altitude hills of West Bengal and Assam are included in the Brahmaputra plains and North-eastern hills.

The Shivaliks, present in both India and Nepal (known as the Churia hills) are young fold mountains with an elevation ranging between 1,000-1,500 meters, forming an intermediate zone between the Indus-Gangetic-Brahmaputra-Irrawaddy plains and the Himalayas (Wadia 1973, Mani 1974). They are characterised by loose boulders, ephemeral streams and are prone to erosion. This eroded material gets deposited along the relatively less steep slopes and gives rise to the bouldery bhabar tract. Most of the streams of the Shivaliks, enter underground in the bhabar region and re-emerge further south in the terai zone (Mani 1974). This terai zone is composed of the flood plains of rivers Ganga and Brahmaputra. Terai region is characterised by a high water table, annual flooding, and shifting floodplains and consequently dominated by tall grass species (Mathur 2000).

Western portion of this landscape is characterised by a large number of seasonal streams called *raus* and perennial streams called sots. Both, *raus* and sots flow into the terai and act as water sources throughout the year. The eastern portion of this landscape on the other hand, is composed of primarily the terai grasslands that thrive on the alluvial silts and clay deposits brought down by the meandering rivers from the Himalayas. This region is characterised by large swampy areas that attract migratory water fowl and support conditions conducive to survival of rare species like the swamp deer, hog deer and the rhinoceros.

Location

River Yamuna (30°30' N to 77°30' E) marks the western limit of the Shivalik Hills and Gangetic Plains landscape while Valmiki Tiger Reserve (27°15' N to 84°45' E) bounds it on the east. This landscape stretches across 900 kilometres from east to west with an average width of 50-60 kilometres. The total area occupied by this zone is approximately 42,700 km^2 of which 15,000 km^2 is forested (Johnsingh et al. 2004) and includes five important Tiger Reserves (TRs), *viz*. Rajaji, Corbett, Pilibhit, Dudhwa and Valmiki. Several other protected areas (PA) lie within this zone under the administration of 20 Forest Divisions (FDs). As mentioned above, the western portion of this landscape (between rivers Yamuna and Sharda) lies in the bhabar tracts and has about 36% forest cover (Johnsingh et al. 2004). Rajaji and Corbett TRs are situated in this region. The eastern portion (area to the east of river Sharda) is characterised by intensive agriculture and low forest cover (17%) (Johnsingh et al. 2004). The PAs within this zone namely, Pilibhit, Dudhwa and Valmiki TRs are embedded in a matrix of human use and sugarcane fields.

Ecological background

The wet, marshy conditions of the terai support tall grasslands which provide shelter to myriad species of ungulates and their predators. Thus, this region historically has been known for the high density of 'game' and attracted hunters during the short winter when possibilities of contracting malaria were low (Seidensticker et al. 2010). Areas around present day Corbett TR (also the first protected area in the country) often find mention in Jim Corbett's accounts of wildlife and people of India while F.W. Champion's experiments with the self-triggered camera in 1950s in this region were probably amongst the first experiments in documenting wildlife of an area using such devices. After the discovery of dichloro-diphenyl-trichloroethane (DDT) in the 1950s and the subsequent control of malaria in the region, most of this area underwent a massive change due to an altered land use policy, settlement of refugees at the time of India's independence, expansion of area under agriculture during the Green Revolution, reclamation of swamps and other anthropogenic factors (Mathur 2000).

Conservation significance

The terai region is a part of one of the 200 globally important eco-regions for its intact large mammal assemblages (Olson and Dinerstein 1998). Johnsingh et al. (2004) identified nine Tiger Habitat Blocks (THBs) in this region as disjunct forest blocks with varying tiger populations. These THBs formed a continuum of forests with tigers and their prey until recent times till anthropogenic disturbances and reclamation of land for agriculture disrupted the forest continuity, leaving them connected by means of 13 essential narrow corridors (Johnsingh et al. 2004). However, this area still holds the key to long-term tiger conservation by hosting two of the important level I tiger conservation units, namely, Rajaji-Corbett and Chitwan-Parsa-Valmiki (former two being in Nepal) along with some level II tiger conservation units (Wikramanayake et al. 1998). Studies indicate that this landscape complex has 20,800 km^2 of tiger habitat in the Indian side even today (Qureshi et al. 2006). However, in present day context, the distribution of tigers in this zone is patchy with high variations in the frequency of occurrence (Johnsingh 2006) even though this zone contains the single largest contiguous terai patch comprising of Pilibhit, Suklaphanta, Kishanpur, Dudhwa, Bardia and Katerniaghat forests. Most of the terai forests in India are connected with the terai regions of Nepal. Since key parts of this complex are in Nepal and Bhutan, thus trans-boundary cooperation is a must (Qureshi et al. 2006) for effective tiger conservation.

Vegetation

The Shivaliks have floral elements of both peninsular India and temperate regions of western Himalayas. The bhabar tracts are dominated by moist deciduous forests with sal (*Shorea robusta*) being the predominant species. On the other hand, the terai plains comprise of woodland-grassland-wetland forests dominated by graminoid species of *Saccharum narenga, Sclerostachya, Imperata* and *Typha sp.* (Mathur 2000). The region also has some species which are closely related to those found in the eastern Himalayas or the Western Ghats like *Schefflera venulosa, Diospyros embryopteris, Phoebe lanceolota, Wallichia densiflora and Bischoffia javanica*. Two endemic species found in this region are *Eremostachys superba and Catamixis baccharoides*.

Fauna

This landscape hosts five species of cervids, namely, chital (*Axis axis*), sambar (*Rusa unicolor*), muntjac (*Muntiacus vaginalis*), hog deer (*Axis porcinus*) and the swamp deer (*Rucervus duvaucelii*); three species of antelope, nilgai (*Boselaphus tragocamelus*), blackbuck (*Antilope cervicapra*) and four-horned antelope (*Tetracerus quadricornis*); other ungulates like the Asian elephant (*Elephas maximus*), one horned rhinoceros (*Rhinoceros unicornis*), Gaur (*Bos gaurus*), wild pig (*Sus scrofa*) and other rare species like the hispid hare (*Caprolagus hispidus*). Amongst large carnivores, leopard (*Panthera pardus*), tiger (*Panthera tigris),* wild dog (*Cuon alpinus*), hyena (*Hyaena hyaena*), the Asiatic black bear (*Ursus thibetanus*) and sloth bear (*Melursus ursinus*) are found in this zone. Goral (*Naemorhedus goral*) and serow (*Capricornis thar*) are also found on the slopes of the Shivaliks. The avifaunal diversity of this region is also high with Sharma et al. (unpublished data) reporting 549 species of birds from Corbett and Pandey et al. (1994) reporting 312 species of birds from Rajaji National Park alone. The Himalayan quail (*Ophrysia superciliosa*) represents a genus endemic to this region but has not been sighted with certainty since 1876. The endangered Bengal florican occurs in habitat patches across this landscape. A small section of the Western Himalaya Endemic Bird Area (EBA) falls within this zone.

Conservation importance

This landscape is renowned for its productivity, high concentration of ungulates and therefore, ability to sustain some of the highest density of tigers in the world (Dinerstein, 1980, Sunquist, 1981, Smith, 1993). Kolipakam et al. (2019) identified two separate populations of tigers in this landscape *viz.*, Valmiki and Rajaji-Corbett-Dudhwa. Given, its continuity with Nepal, importance has been given to connecting large tracts of this landscape with the aim of securing a single meta-population of tigers between Nepal and Indian terai (Wikramanayake et al. 2004; Dinerstein et al. 2007). Apart from the tigers, the landscape harbours subspecies of the endangered Swamp deer and the only surviving population of gaur and wild dog (in Valmiki Tiger Reserve) present in the Indian Terai. Amongst the rare and endangered birds, the two that stand-out are the Bengal florican (*Houbaropsis bengalensis*) and the swamp francolin (*Francolinus gularis*). Hence, the forest tracts of this landscape need to be conserved to continue to harbour this endangered fauna.

Tiger Occupancy

Out of the 323 grid cells, tiger signs were detected in 100 cells in 2006, 137 cells in 2010, 146 cells in 2014 and 160 cells in 2018. When these grids were categorised as occupied (1111), colonized (0111, 0011, 0001), extinct (1000, 1100, 1110), absent (0000) and transitional (all other combinations) and compared with site covariates, we observed the hypothesized relation between the occupancy parameters and site covariates (Fig. 4.1). This strengthened the relevance of using the considered site covariates for modelling the occupancy parameters of tigers.

Different occupancy models were derived by various combinations of site covariates shown in the Table 4.1. The beta estimates of the best model are provided in the Table 4.2. The detection probability consistently increased from 2006 to 2018, and was significantly related to the encounter rate of tiger signs in the grid. The initial occupancy of tigers in this landscape was 47%, and was significantly related to high prey encounter rate (Fig. 4.3). The initial occupancy of year 2006 revealed that tigers were present only in and around Tiger Reserves (Rajaji, Corbett, Pilibhit, Dudhwa and Valmiki) (Fig. 4.2). Colonization rate in 2010 was largest with a 14% increase and subsequently marginally decreased in 2014 and 2018, as most of the habitats were already occupied. The probability of colonization significantly increased with increased prey encounter rate and proximity of a grid to a protected area occupied by tigers in the previous years (Fig. 4.3). Hence, higher colonization was observed in the forested areas around Corbett and Dudhwa, and non-tiger reserve areas like Lansdowne, Amangarh, Terai East, Terai West, Nandhaur Wildlife Sanctuary, were colonized by tigers (Fig. 4.2). The colonization probability of areas around Valmiki Tiger Reserve consistently increased, which can be attributed to prey restoration within the park and increase in the tiger population in the adjoining Chitwan National Park of Nepal that acts as a source population for tigers in this landscape. Improved tiger status in Valmiki has in turn facilitated the colonization of Sohagibarwa Wildlife Sanctuary. These dynamics between higher colonization rate and lower extinction probabilities resulted in increased occupancy across this landscape from 2014 to 2018 (Fig. 4.4).

The extinction probability in this region, though minimal has been increasing since 2010, with edge grids being more vulnerable. The probability of extinction was explained by the increase in night time light areas, indexing the expansion of human settlements (Fig. 4.3). As a consequence, grids surrounding the townships of Dehradun, Haridwar, Kalagarh, Singahi and Bhiraura, as well as along the Gulariya-Nepalgunj highway (in Nepal) had higher extinction probability. The landscape west to the river Ganga (Western Rajaji, Shivalik division, Dehradun forest division and Mussoorie) had higher extinction probability, which could be attributed to the isolation of this area from the nearest source population (Eastern Rajaji) due to the densely populated city of Haridwar and Rishikesh along with development of impassable linear infrastructure joining these townships and the city of Dehradun, thus disrupting wildlife corridors.

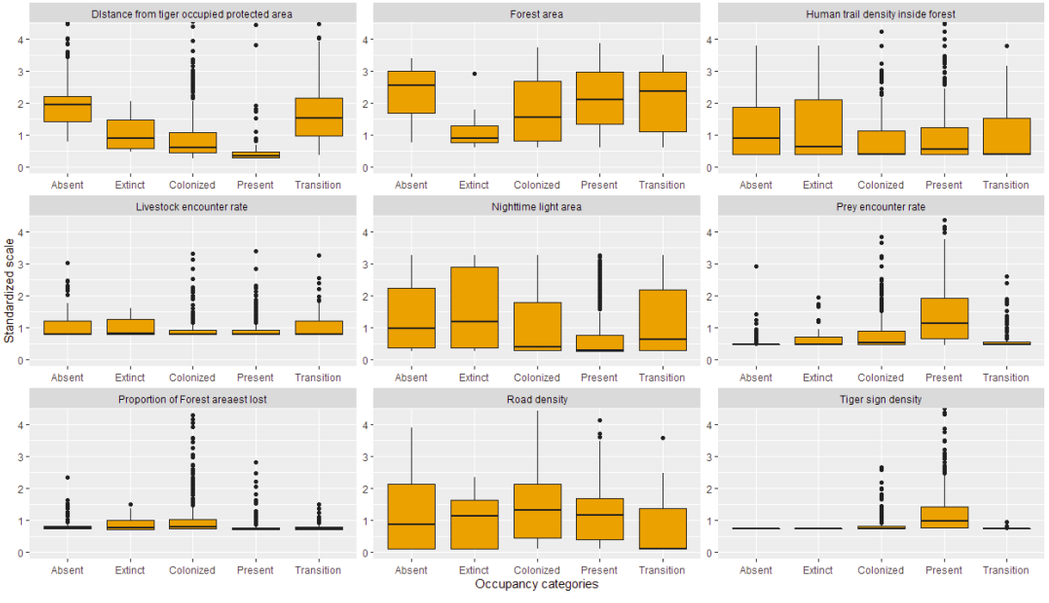


Figure 4.1

Characteristics of habitat, human disturbance, and prey covariates within grids with different tiger presence status (consistently absent, consistently present, colonized, extinct and transitional tiger occupancy) between 2006-2018 in the Shivalik and Gangetic Plains landscape.

Table 4.1

Model selection statistics for tiger occupancy (Ψ), colonization (γ), extinction (ε) and detection (p) modelled using various combinations of covariates representing prey, habitat, human impacts and tiger sign intensity in the Shivalik and Gangetic Plains landscape (2006-18). The most parsimonious model was the one with least AIC and was considered to best explain these occupancy parameters. (prey: encounter rate of prey, dpa: distance from protected areas that were occupied by tigers in the previous cycle (t-1), for: forest area, na: nighttime light area, pso: encounter rate of tiger signs, lvsn: encounter rate of livestock, trail: density of human trails in the forest, road: density of tar road in the grid, 1: one intercept, year: yearly intercept).

Model	AIC	Delta AIC	No.Par.	-2*log likelihood
Ψ (prey),γ(year,dpa,prey,fora),ε(year,na),p(year,pso)	9756.06	0	26	9704.06
Ψ (prey),γ(dpa,prey,fora),ε(na),p(year,pso)	9767.27	11.21	22	9723.27
Ψ (.),ε(.),γ(.),p(year,pso)	9801.71	45.65	15	9771.71
Ψ (.),ε(1),γ(1),p(year,pso)	9801.71	45.65	15	9771.71
Ψ (prey),γ(dpa,lvsn,for),ε(na),p(pso)	9987.14	231.08	19	9949.14
Ψ (prey),γ(dpa,for),ε(na),p(pso)	9988.12	232.06	16	9956.12
Ψ (prey),γ(dpa,prey,for),ε(na),p(pso)	9988.5	232.44	19	9950.5
Ψ (prey),γ(1,dpa),ε(1,na),p(1,pso)	9989.92	233.86	15	9959.92
Ψ (prey),γ(1,dpa,prey),ε(1,na,road),p(1,pso)	9990.8	234.74	19	9952.8
Ψ (prey),γ(dpa,trail,for),ε(na),p(pso)	9992.17	236.11	19	9954.17
Ψ (na),γ(dpa,for),ε(na),p(pso)	9994.35	238.29	16	9962.35
Ψ (prey),γ(dpa,prey,for),ε(lvsn),p(pso)	10002.58	246.52	19	9964.58
Ψ (prey),γ(dpa,for),ε(lvsn),p(pso)	10002.91	246.85	16	9970.91
Ψ (prey),γ(dpa,for),ε(trail),p(pso)	10006.34	250.28	16	9974.34
Ψ (year,for),γ(year,dpa),ε(year,na),p(1,pso)	10014.82	258.76	15	9984.82
Ψ (road),γ(1,dpa),ε(1,na),p(1,pso)	10014.93	258.87	15	9984.93
Ψ (.),ε(.),γ(.),p(.)	10351.76	595.7	11	10329.76
Ψ (na),γ(dpa,for),ε(na),p(.)	10459.73	703.67	12	10435.73
Ψ (na),γ(dpa),ε(na),p(.)	10460.49	704.43	11	10438.49

Parameter	Beta Estimate	Standard error
Ψ 1.intercept	-0.748	0.131
Ψ 1.prey	0.638	0.136
γ 1.intercept	0.099	0.226
γ 2.intercept	-0.975	0.343
γ 3.intercept	-0.931	0.307
γ1.dpa_y6	-0.865	0.331
γ 2.dpa_y10	-0.361	0.433
γ3.dpa_y14	-0.971	0.424
γ1.prey_y10	-0.169	0.235
γ2.prey_y14	0.678	0.392
γ3.prey_y18	0.436	0.303
γ.for	0.227	0.147
ε1.intercept	-2.777	0.579

Parameter	Beta Estimate	Standard error
ε 2.intercept	-1.597	0.343
ε3.intercept	-1.343	0.227
ε1.na_y10	0.825	0.552
ε2.na_y14	0.968	0.380
ε3.na_y18	0.011	0.218
p1.intercept	-0.526	0.055
p2.intercept	0.582	0.067
p3.intercept	0.403	0.061
p4.intercept	-0.017	0.044
p1.pso_y6	0.205	0.038
p2.pso_y10	0.546	0.062
p3.pso_y14	0.905	0.063
p4.pso_y18	0.553	0.042

Table 4.2

Parameter estimates from the best model explaining tiger occupancy (Ψ), colonization (γ), extinction (ε) and detection (p) in the Shivalik and Gangetic Plains landscape (2006-18). The suffix y6, y10, y14 and y18 represents covariates for the sampling years of 2006, 2010, 2014 and 2018.

Figure 4.2

Spatial occupancy, colonization and extinction probabilities of tigers in the Shivalik and Gangetic Plains landscape between 2006 to 2018.

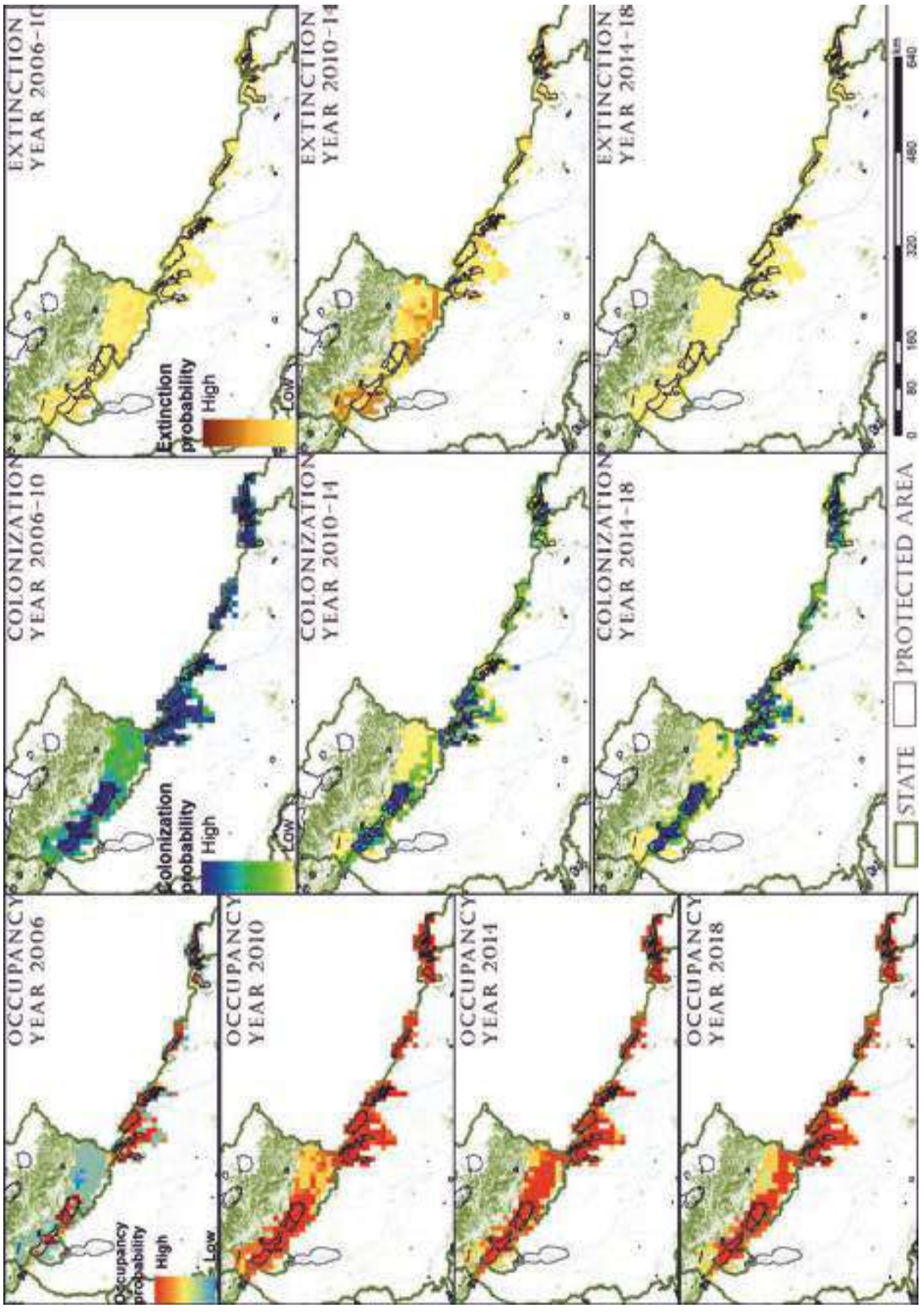


Figure 4.3

Relation of tiger occupancy parameters and site covariates in the Shivalik and Gangetic Plains landscape. (A) relation in the probability of colonization and distance from protected areas (km) occupied by tigers in the previous season, (B) relation in the probability of extinction and night time light areas (km^2), (C) relation in the probability of tiger occupancy and encounter rate of prey species per km.

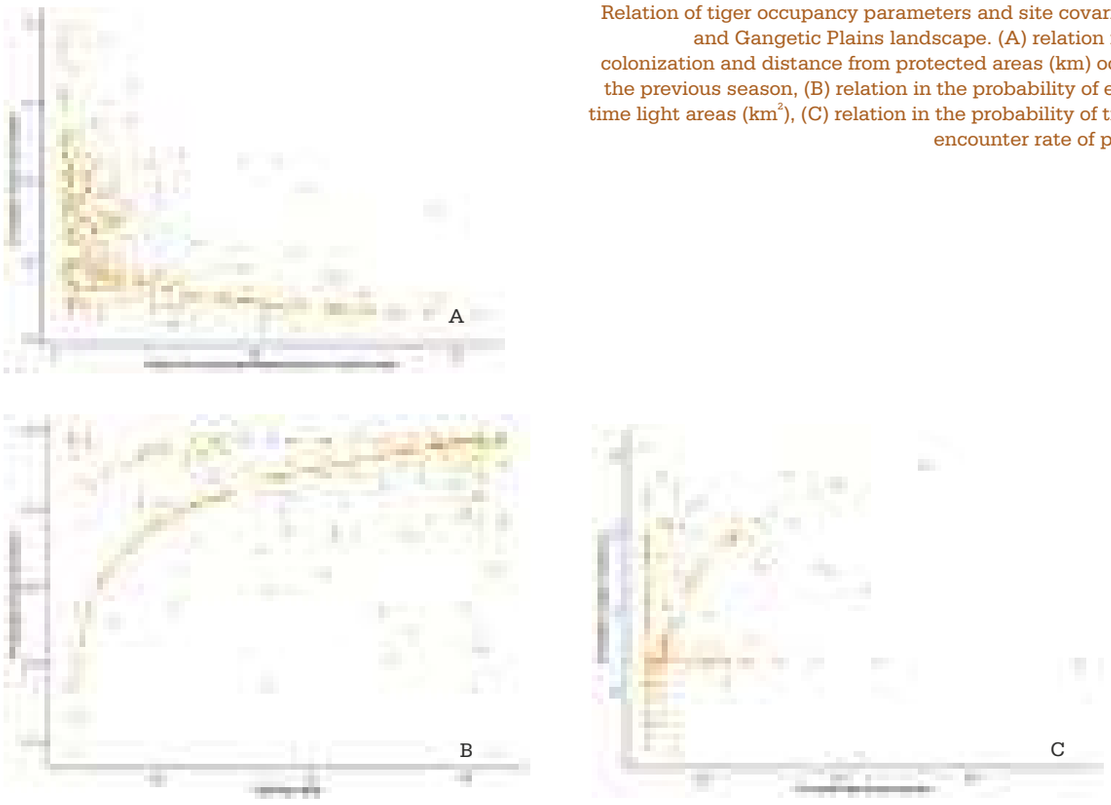
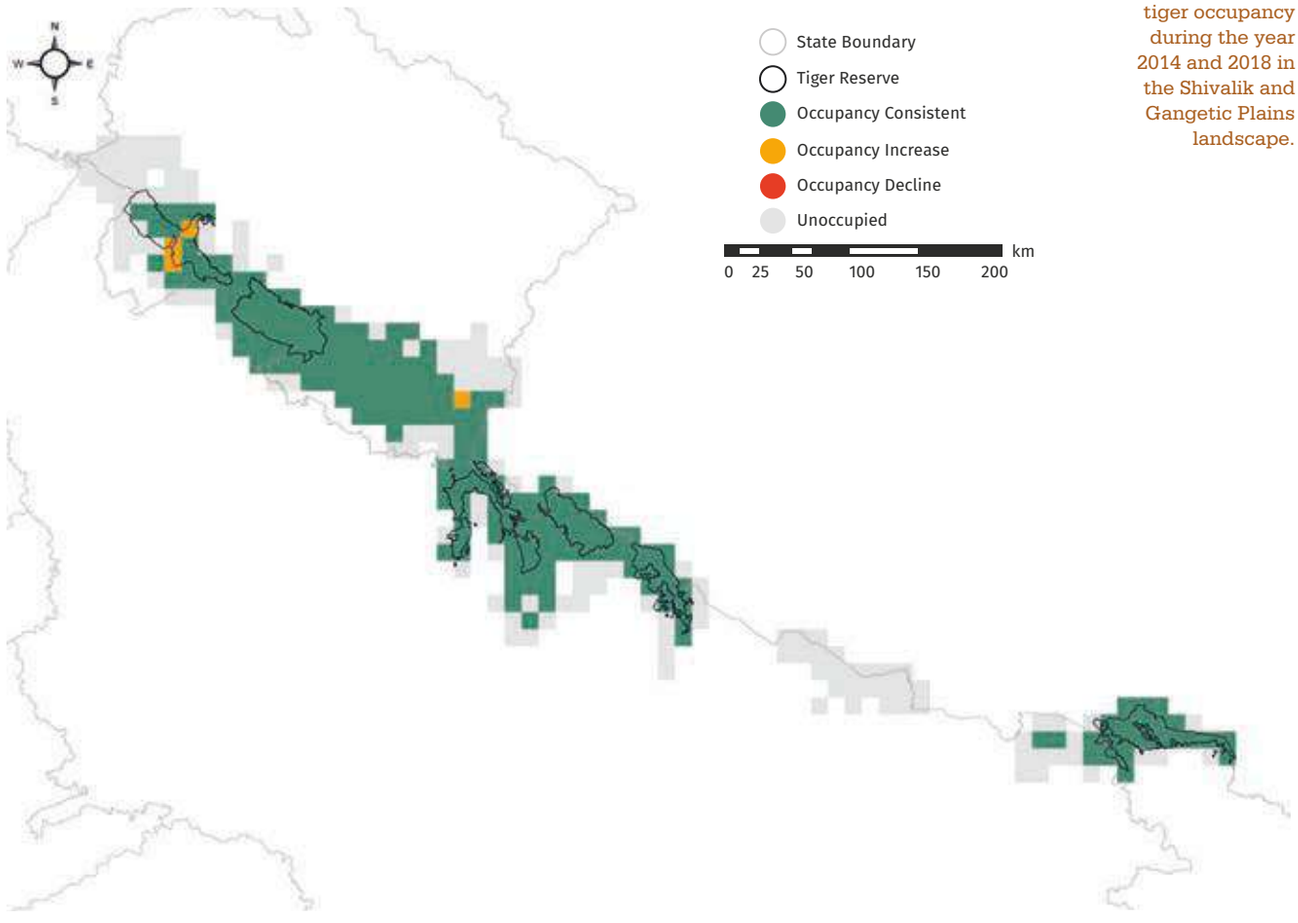


Figure 4.4

Rate of change of tiger occupancy during the year 2014 and 2018 in the Shivalik and Gangetic Plains landscape.



Tiger population extents and abundance across the Shivalik-Gangetic Plains Landscape

Mark-recapture population and density estimates of tigers based on camera-trapping were obtained for Rajaji TR, Lansdowne Forest Division, Bijnore Forest Division, Corbett TR, Ramnagar Forest Division, Terai East, Terai West, Terai Central, Nanital Forest Division, Champawat Forest Division, Haldwani Forest Division, Pilibhit TR, Katerniaghat Wildlife Sanctuary, Kishanpur Wildlife Sanctuary, Dudhwa National Park, Suhelwa Wildlife Sanctuary, Sohagibarwa Wildlife Sanctuary and Valmiki TR. Tiger densities in the Shivalik-Gangetic Plains ranged between 1.4 to 15 tigers per 100 km^2 (see site specific chapters). After joining contiguous grids with tiger presence, two tiger populations were identified within the Shivalik-Gangetic Plains (Fig 4.5). These include:

a) The western most population of tigers in Rajaji TR along with Lansdowne FD, Corbett TR, Bijnore FD, Terai West FD, Ramnagar FD, Haldwani FD, Terai Central and East FDs and Pilibhit TR and Dudhwa TR having tiger occupancy in about 7,390 km^2 of forested habitat with an estimated population size of between 531-678 individuals. This contiguous population harbours one of the major source of tigers for Western TAL (Corbett TR) and along with tigers of Bardia NP (77) and Shuklaphanta NP (15) in Nepal (DWNP and DFSC 2018) constitutes the second largest tiger population in the world.

b) The Valmiki-Sohagibarwa continuum spans across parts of India and Nepal (Chitwan National Park 89-102 tiger; DWNP and DFSC 2018) with 956 km^2 tiger occupancy on the Indian side with 36-48 individuals.

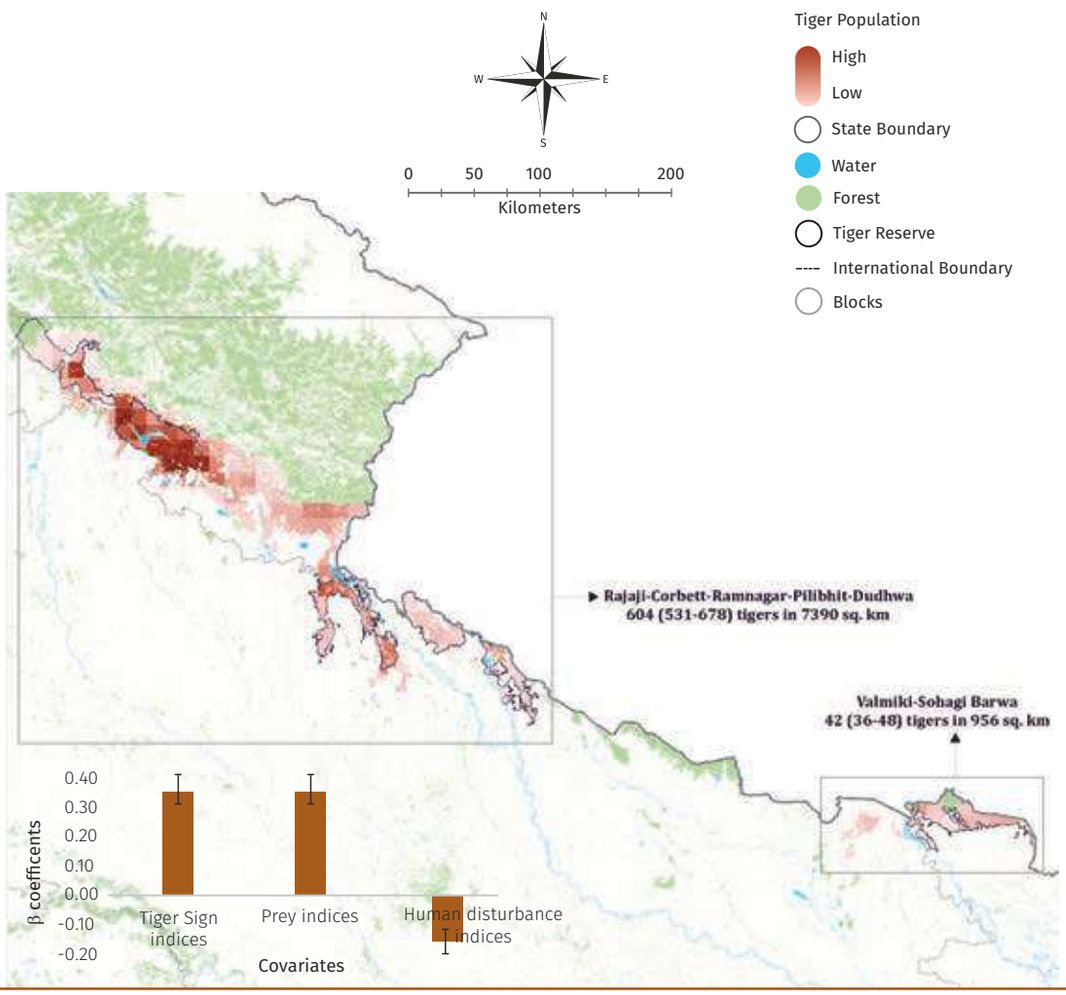


Figure 4.5

Spatially explicit tiger density modelled from camera traps-based capture-mark-recapture and covariates of tiger sign, prey, and human disturbance index. The graph inset shows the covariate coefficients.

Critical corridors, habitat connectivity and conservation

The western-most tiger distribution in this landscape ends in western Rajaji where two tigresses continue to be isolated since 2008. With tiger supplimentation planned for western Rajaji it is important to ensure that this tiger reserve becomes a source to repopulate the Shivalik forest division of Uttar Pradesh and Kalesar wildlife sanctuary (WLS) of Haryana as forest connectivity is currently contiguous along the Shivalik hills from Western Rajaji to Kalesar WLS and into Himachal Pradesh (Fig 4.6). However, if tiger occupancy is to be encouraged in this empty landscape of about 700 km^2, restorative inputs are required to curtail poaching of prey, illegal timber extraction and livestock grazing. The village of Kalesar in Haryana, Bahral in Himachal Pradesh and Rehna in Uttar Pradesh are all expanding along the banks of the Yamuna with agriculture and urban sprawl threatening to choke the narrow corridor for wildlife (and potentially tigers). This connectivity is also important for the movement of elephants to Kalesar WLS.

The connectivity between eastern and western Rajaji (Chilla-Motichur corridor) has further deteriorated over the years despite sensitization and awareness. Mitigation measures have been proposed for the past 20 years. Implementation of these mitigations partially commenced with the construction of the flyover on the National Highway 58. However, this project has not been completed for the past several years and lies in a state of abandonment. In the meanwhile, urban sprawl extending from Rishikesh and Haridwar has almost joined the two cities as is evidenced from night light expansion between 2014 and 2018 (**Fig. 4.6 a and b**). Absence of tiger dispersal into western Rajaji since 2006 from the eastern part is due to loss of this corridor connectivity despite improvement in tiger abundance in eastern Rajaji. Curtailment of human disturbance along the Song river, river islands in the Ganga, and making underpasses for wildlife as mitigation for the Highway 58 and railway tracts are essential for the continued wildlife values of western Rajaji (tiger habitat of 257 km^2 with a good prey base). The supplementation of tigers into western Rajaji is a quick but short term solution. For long-term persistence in this area, connectivity with eastern Rajaji is vital.

Eastern Rajaji is connected to Corbett TR by the Lansdowne corridor and by the Haridwar and Bijnore Forest Divisions and this connectivity is crucial for the recovery and long-term viability of tiger populations in the western Terai landscape (Bisht et al. 2019). Both these corridors are impacted by the growing township of Kotdwar and the increase in traffic on National Highway 119 that connects Najibabad to Kotdwar. The integrity of the Landsdowne corridor is further threatened by the proposed Kandi road that will connect Kotdwar to Ramnagar through parts of Corbett TR (WII 2018) as discussions are still ongoing in various sectors on the alignment and mitigation measures for the same. Another proposed road from Laldhang to Kotdwar passing through Rajaji as an all season motorable public road would cut across the Haridwar-Bijnor corridor, further fragmenting this habitat (Sultan 2017). Rajaji TR is also connected to Jhilmil Jeel Conservation Reserve through the forests of Chidiyapur range but is traversed by State Highway 34 and the Eastern Ganga canal. Both these infrastructures require appropriate mitigation (WII 2016).

Wildlife habitat is contiguous across Lansdowne, Sonanadi WLS, and Corbett National Park. Subsequently, connectivity towards the east of Corbett TR is restricted by the township of Ramnagar and the linear development along National Highway 121 of resorts, township and private farms along the banks of the Kosi river. Only two corridors remain that connect Corbett forests with Ramnagar Forest Division. These are along the Garjia to Sunderkhal settlement on the northern side and Bijrani range of Corbett in the southern part. These linkages need to be fostered with restorative inputs wherein infrastructural development is mitigated with appropriate measures and encroachment strictly controlled. Resorts and private land owners need to be sensitized to remove fences that are impermeable to wildlife at critical points to permit passage through their property.

From Ramnagar Forest Division forest connectivity is continuous till the township of Haldwani. Forest connectivity of Haldwani division to the Shuklaphanta NP of Nepal terai is maintained by the Gola corridor forests along with Nandhaur WLS and Champawat division. However, this corridor is severely impacted by urban sprawl of Haldwani township, boulder mining and various human activities along with National Highway 87 and railway line to Kathgodam. This corridor connectivity is almost lost, and tigers possibly use the forests of lower Himalayas to move eastward (as evidenced from camera trap data of tigers from Rajaji and Corbett being photo-captured east of Haldwani township). Restoring the connectivity in the foothills and less hilly tracts of the Gola corridor is crucial for elephant movement that is currently almost curtailed and leads to conflict in the region. The Haldwani division is also connected to the Lagabhagga tall grassland forest mosaic by the Sharda river.

On the southern side the forests of Kilpura-Khatima corridor join with Pilibhit TR and Nepal (Churia hills and Bhramagiri forests). The intervening matrix of grasslands, sugarcane fields along the flood plains of the Sharda river connect Dudhwa TR with Pilibhit and Lagabhagga-Shuklaphanta NP. Wildlife including tigers freely move across this habitat matrix and come into frequent conflict with humans due to loss of natural habitat. The river Mohana is an important link between Dudhwa and Katarniaghat. The Khata corridor along river Girwa connects Bardia NP (Nepal) with Katarniaghat and is frequently used by rhinos, elephants and tigers, while the river system allows gharial and Gangetic dolphin to move between India and Nepal. There is no habitat connectivity between Katarniaghat and Suhalwa WLS on the Indian side, but the forests of Bardia NP and Banke NP along the Churia hill forests of Nepal form a connecting corridor to Suhelwa WLS. Forests of Nepal along the Himalaya foot hills (Mahabharat Range) and the Churia hills connect Chitwan NP and Valmiki TR to the western Terai Arc Landscape. However, there seems to be little tiger movement between the Dudhwa-Pilibhit-Bardia complex and the Chitwan-Valmiki complex due to the large geographic distance and no remaining tiger presence in the intervening forests. This is also reflected in the genetic analysis where tigers from Valmiki (Kolipakam et al. 2019) and Chitwan stand out as a unique cluster in the Terai Arc Landscape. Major roads are planned along the border of India and Nepal, these will traverse crucial International corridors that are vital linkages for trans-boundary movement of wildlife including tigers and elephants between the Protected areas of India and Nepal. For some populations this movement is crucial to maintain genetic and demographic viability through metapopulation dynamics. Alignment of these roads should avoid traversing Protected Areas and corridors and ensure appropriate and adequate animal passage ways through mitigation where alternate alignment is not possible. National and international efforts and coordination are required to maintain permeability of these vital border corridors.

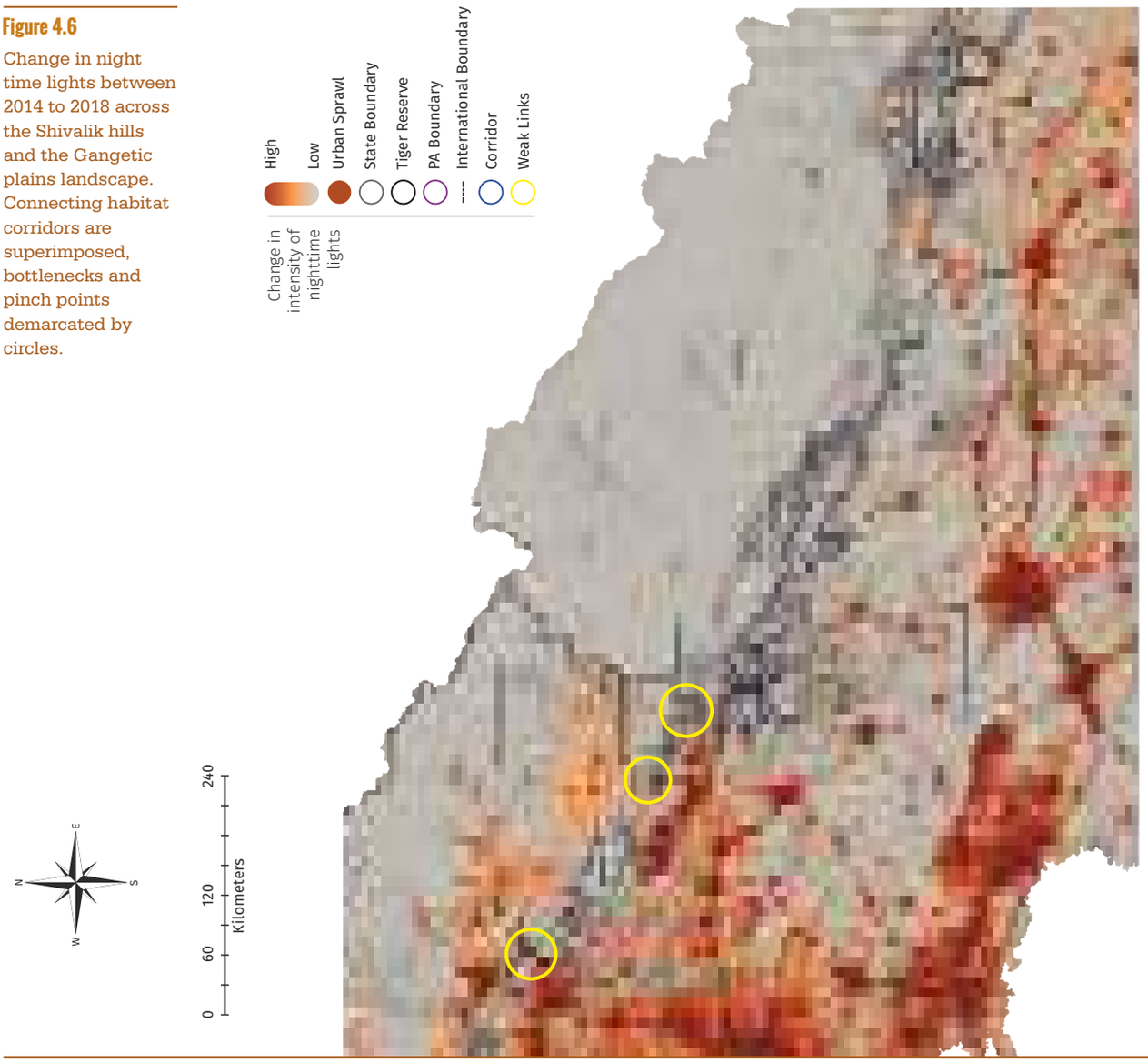


Figure 4.6

Change in night time lights between 2014 to 2018 across the Shivalik hills and the Gangetic plains landscape. Connecting habitat corridors are superimposed, bottlenecks and pinch points demarcated by circles.

Spatial Occupancy of Co-predators in Shivalik Gangetic Plains Landscape, 2018-19

Leopard

(*Panthera pardus*)

[Wildlife (Protection) Act 1972

Schedule I

IUCN Red List: Vulnerable

The population of leopards is contiguous across much of Uttarakhand, Uttar Pradesh and habitats in Nepal. Leopards extend their range from the Terai habitats into the higher reaches of the Himalayas. The recorded occupancy of leopards within forested areas of the Shivalik-Gangetic Plains landscape was 10,119 km^2. High tiger density areas like Corbett and Dudhwa TRs though occupied by leopards, had relatively low leopard sign intensity (Fig. 4.7).

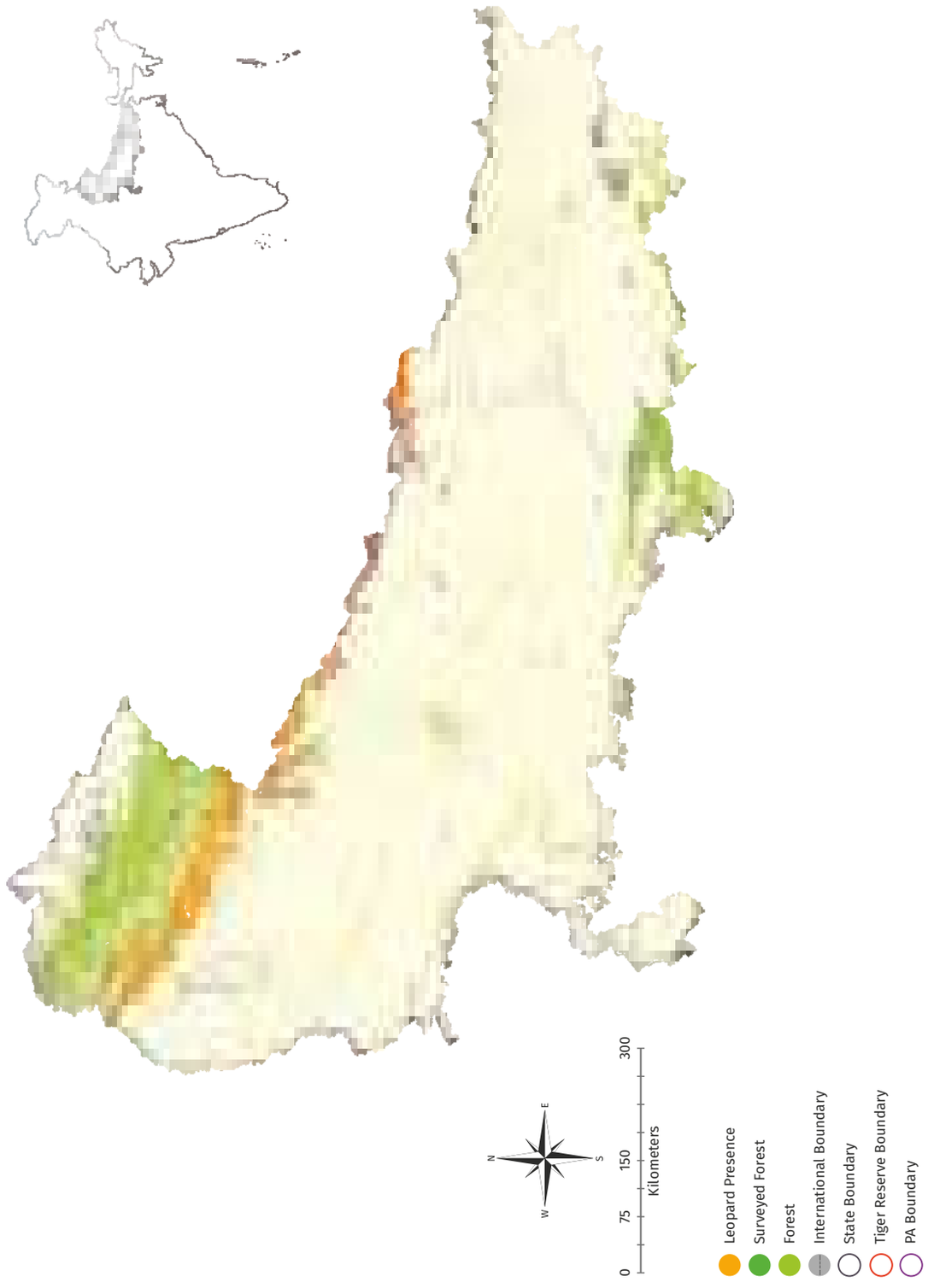


Figure 4.7
Leopard distribution in Shivalik Gangetic Plains landscape, 2018-19

Bear

(Melursus ursinus and Ursus thibetanus)

Melursus ursinus

[Wildlife (Protection) Act 1972 Schedule I

IUCN Red List: Vulnerable]

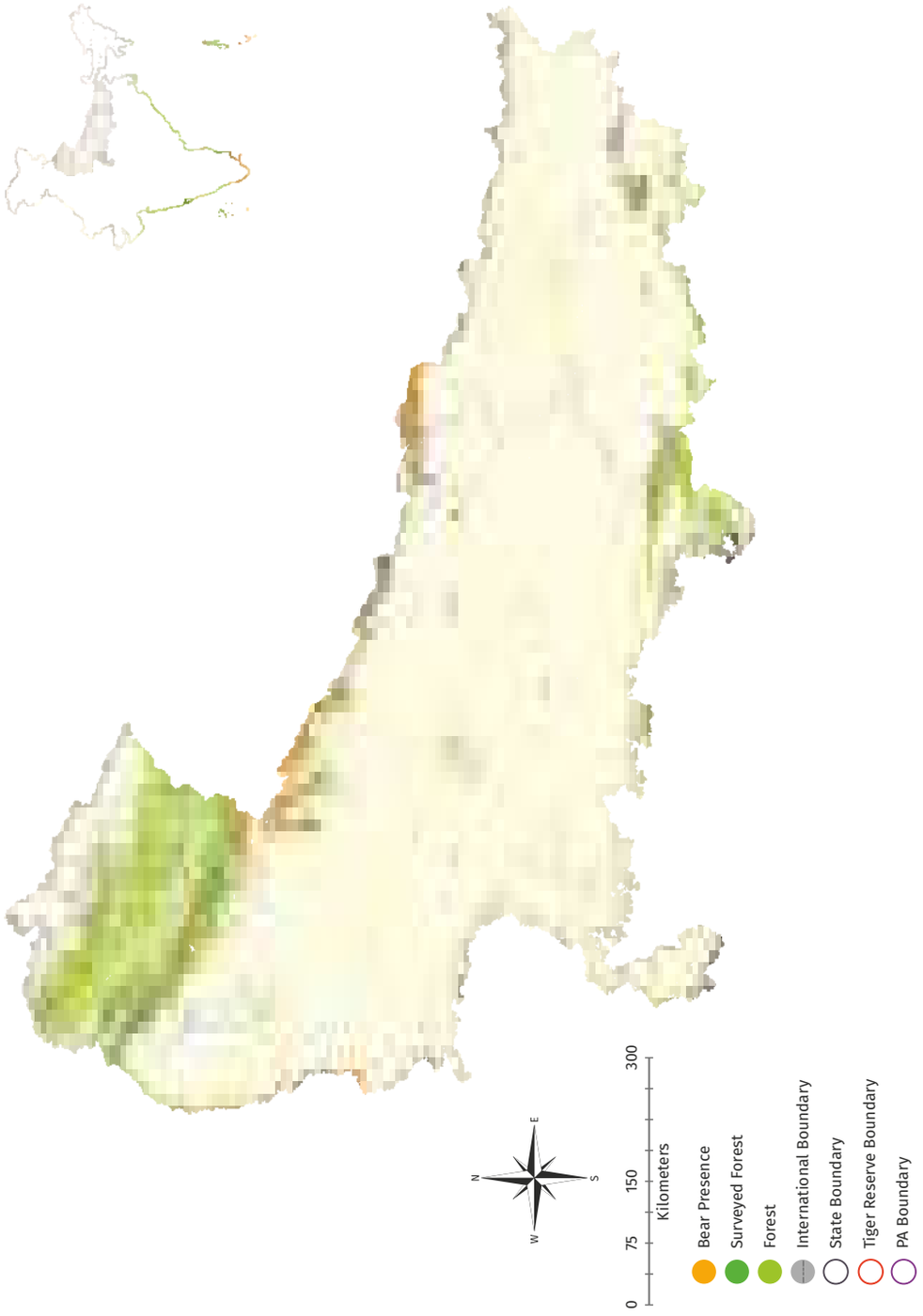
Ursus thibetanus

[Wildlife (Protection) Act 1972 Schedule II

IUCN Red List: Vulnerable]

This landscape has two bear species the sloth bear as well as the Asian black bear that comes to the foothills and Terai habitats in winters. Distinguishing Asian black bear signs from those of the sloth bear requires genetic analysis of faecal DNA We therefore did not attempt to segregate the distribution of black and sloth bear from their signs. However, a clear pattern is visible from the distribution map. The presence grids in the higher elevation were likely exclusively black bear, while occupied grids within the Shivaliks, bhabhar, and the terai were mostly sloth bear with occasional black bear occurrence in the Shivaliks (especially in winter). The total forested area occupied by bears in this landscape was 3,227 km^2 (Fig. 4.8).

Figure 4.8
Bear distribution in Shivalik Gangetic Plains landscape, 2018-19



Striped hyena

(Hyaena hyaena)

[Wildlife (Protection) Act 1972

Schedule III

IUCN Red List: Near Threatened]

Striped hyena distribution was limited to parts of Rajaji in Uttarakhand (Fig. 4.9). Along with pugmarks we recorded camera trap photographs of hyena photographs from Corbett TR. Since hyena distribution and abundance coincides with that of livestock, they are more common on peripheries of PAs rather than within the core areas. Hyena presence was recorded in Dudhwa and Sohagibarwa in 2010 (Jhala et al. 2011) but not in 2018-19. Presence was also recorded on the periphery of Valmiki TR. However, hyena seems to be more abundant in Suhlewa WLS and in the forests of south-eastern UP rather than in the Shivalik-Bhabhar tracts of this landscape. The total recorded occupancy within forested areas of this landscape was 1,054 km^2 (Fig. 4.9). Conservation of striped hyena in this landscape requires attention.

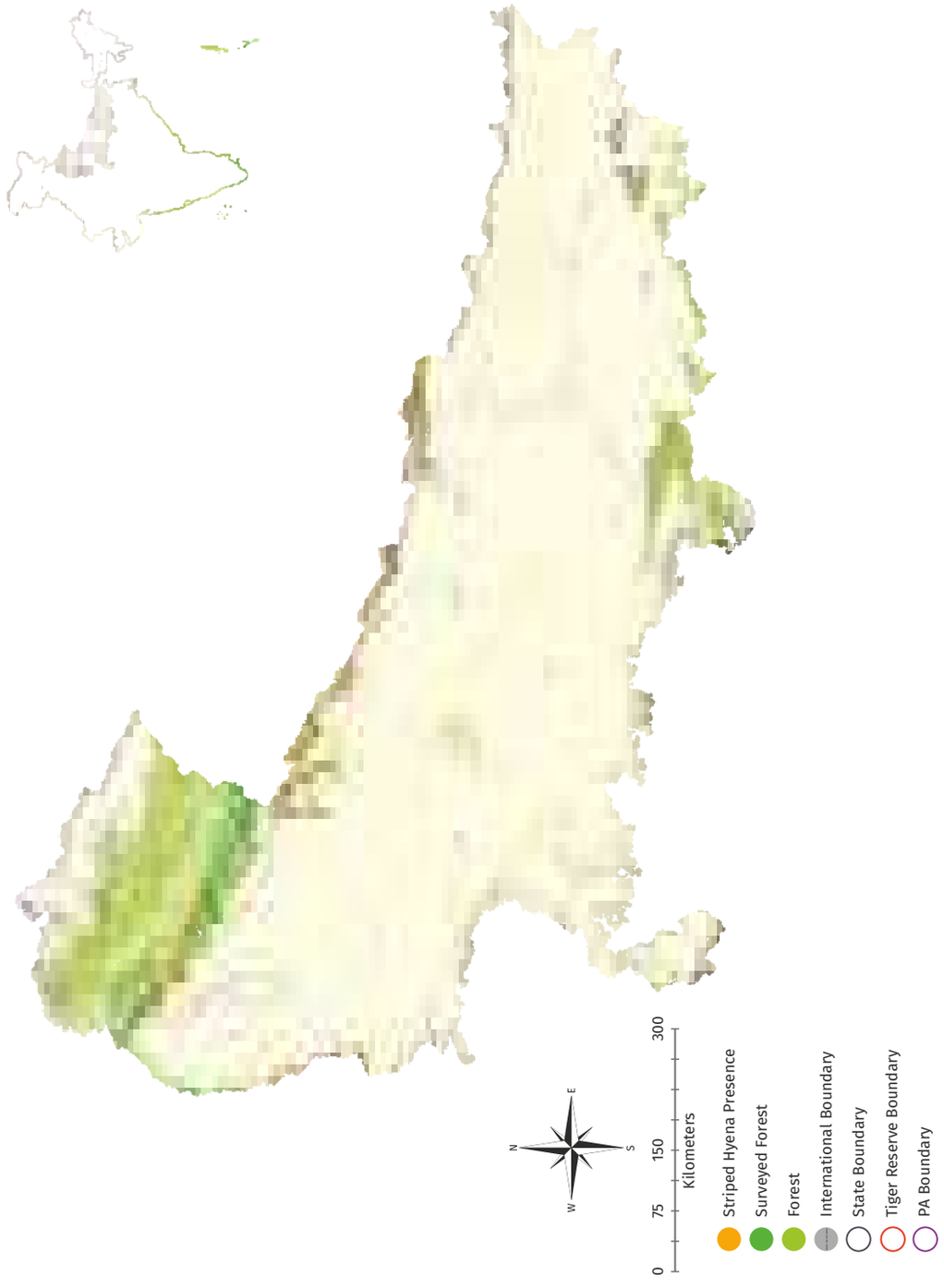


Figure 4.9

Hyena distribution in Shivalik Gangetic Plains landscape, 2018-19

Wild dog

(Cuon alpinus)

[Wildlife (Protection) Act 1972

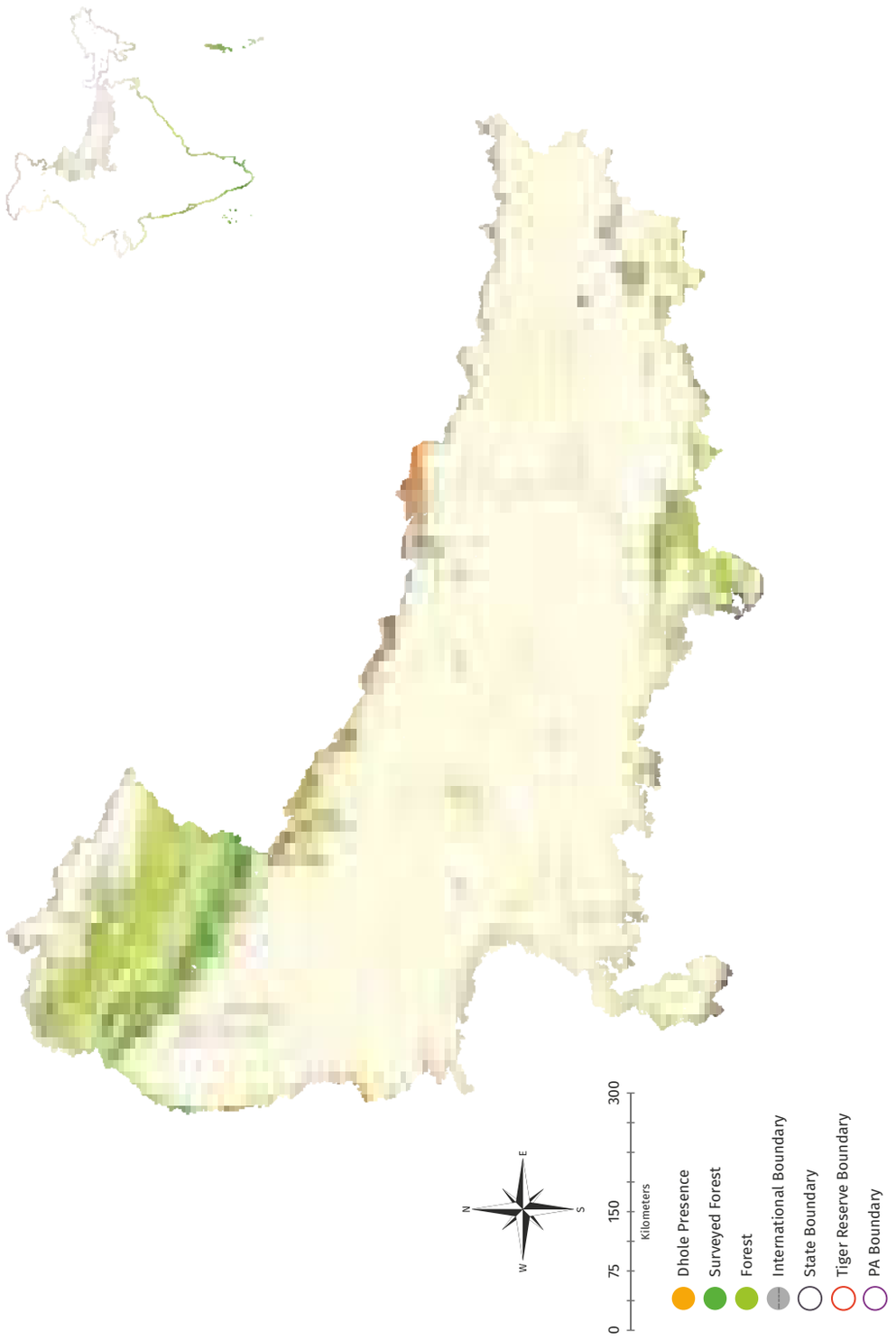
Schedule II

IUCN Red List: Endangered]

Dhole was recorded only from Valmiki TR and Mirzapur forests of south-eastern UP in 2010 and the distribution in 2018 was limited to Suhelwa WLS in UP [378 km^2 of forest area] and Valmiki TR in Bihar [667 km^2 of forest area] (Fig. 4.10). Dhole were found to occur across this landscape in the past (Champion 1927) but were likely exterminated from western Terai due to bounty driven persecution (Fox 1984). It would be pertinent to attempt reintroduction of this important large carnivore in parts of its historic range for its role as a selective predator and restoration of historical biodiversity extirpated by recent intentional actions of humans (Jhala 2019).

Figure 4.10

Dhole distribution in Shivalik Gangetic Plains landscape, 2018-19



Golden Jackal

(Canis aureus)

[Wildlife (Protection) Act 1972

Schedule II

IUCN Red List: Least concern]

Golden jackal was found to be distributed throughout the landscape with an occupancy of 1,428 km^2. Jackals occupy forested areas and occur in rural areas and agricultural fields in this landscape (Fig. 4.11).

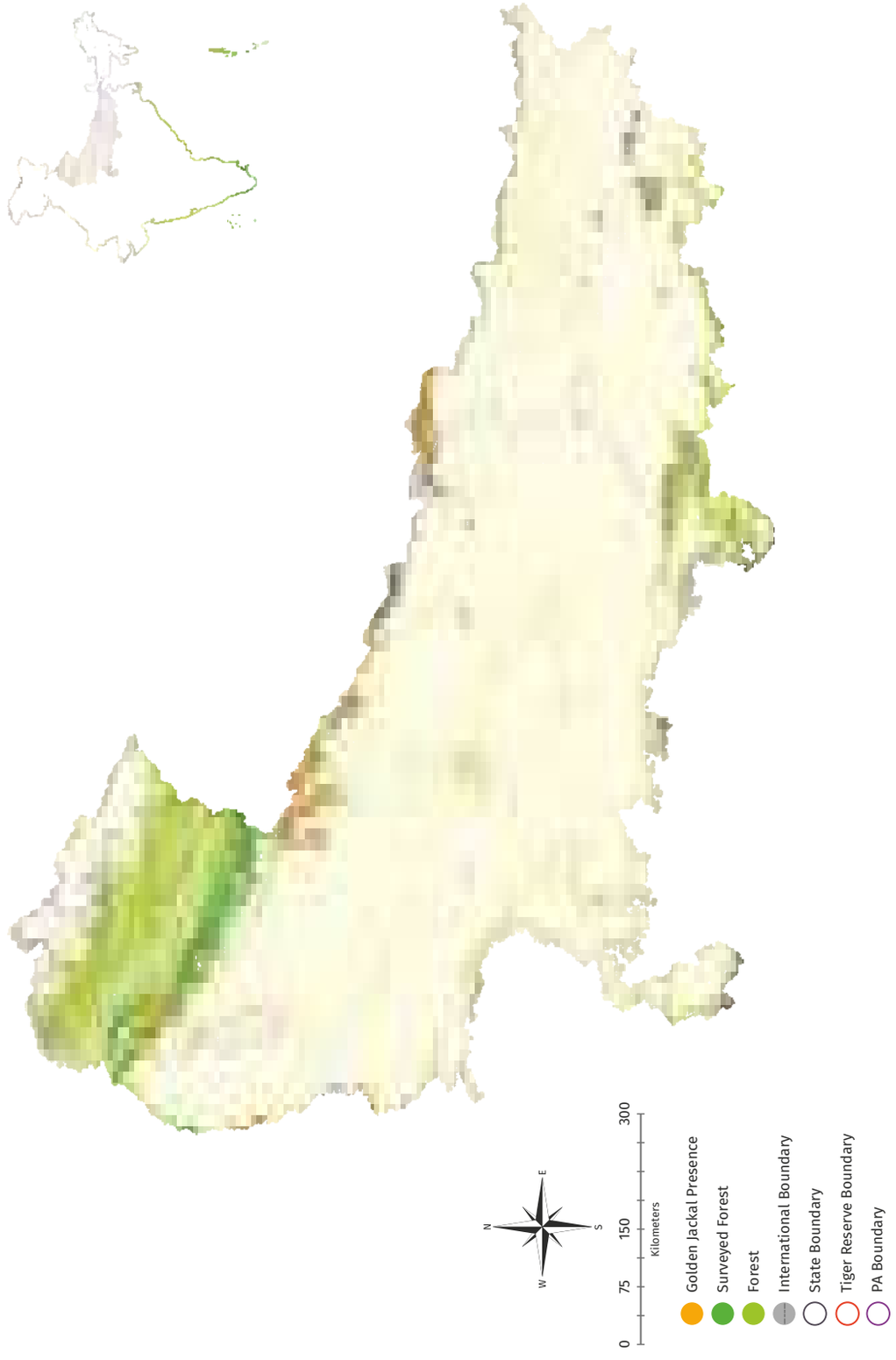


Figure 4.11
Golden jackal distribution in Shivalik Gangetic Plains landscape, 2018-19

Occupancy of Major Prey Species In Shivalik and Gangetic Plains Landscape, 2018-19

Sambar

(Rusa unicolor)

[Wildlife (Protection) Act 1972

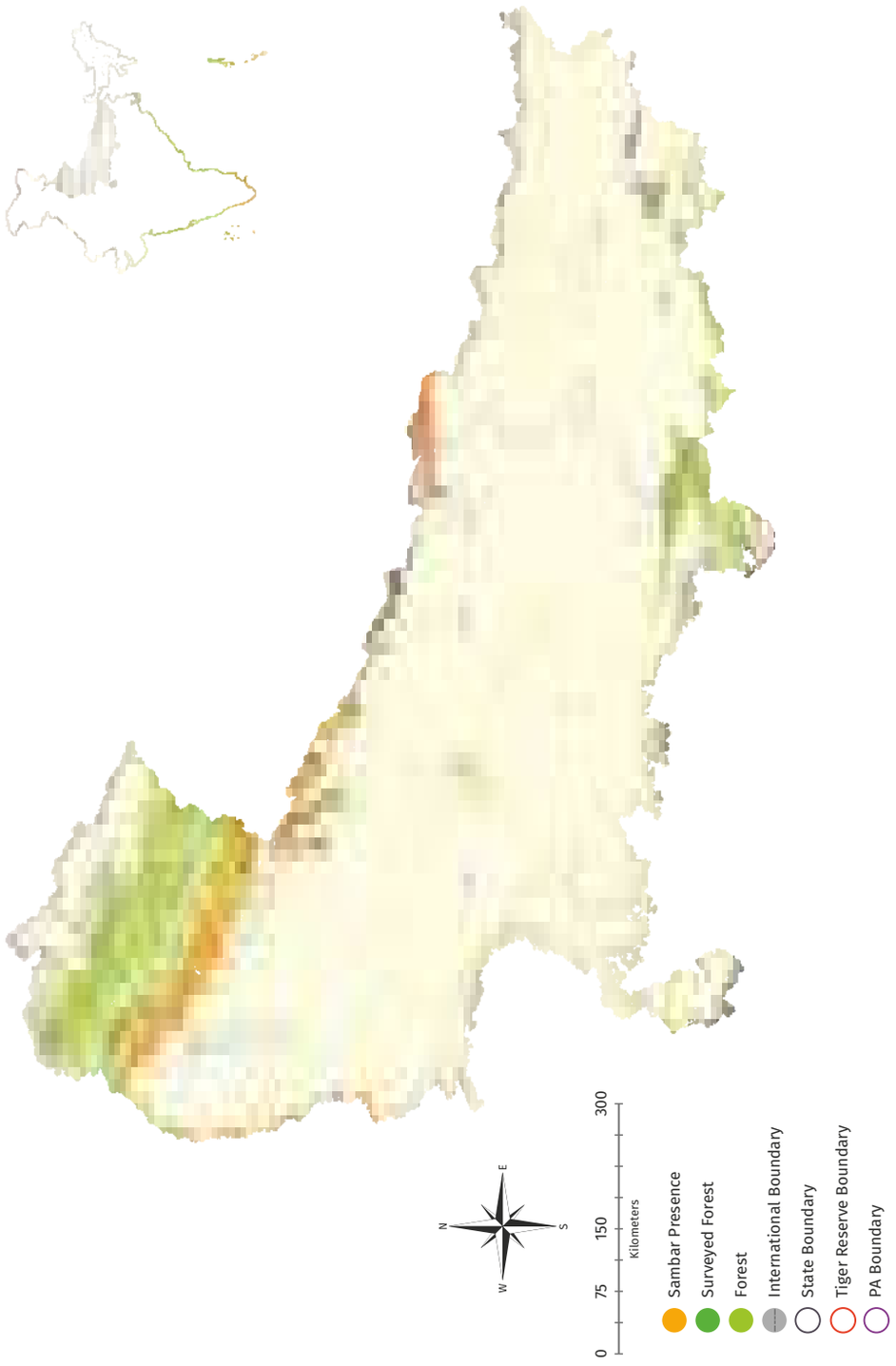
Schedule III

IUCN Red List: Vulnerable]

Sambar was the most wide spread cervid across the Shivalik-Gangetic Plains landscape and constitutes the an important prey for tigers. Sambar were estimated to occupy 8,127 km^2 of forest area (Fig. 4.12). This is probably an under-estimate of sambar occupancy in this region as much of the Alpine areas where sambar are known to occur were not sampled. Tiger presence has been recorded in the higher reaches of the Himalayas (Champawat, Nainital) in Uttarakhand. Sambar is the only large ungulate that occurs at these altitudes and is thus an important determinant of tiger occupancy in the higher elevations.

Figure 4.12

Sambar distribution in Shivalik and Gangetic Plains landscape, 2018-19



Chital

(Axis axis)

[Wildlife (Protection) Act 1972

Schedule III

IUCN Red List: Least Concern]

Chital distribution was recorded in the Shivalik hills, occupying and area of 8,941 km^2 of forested habitat along the Shivaliks and within the terai (Fig. 4.13). They were recorded within all the PAs. Chital was also recorded in a patchy distribution from southern UP forests of Sonbhadra and Mirzapur.

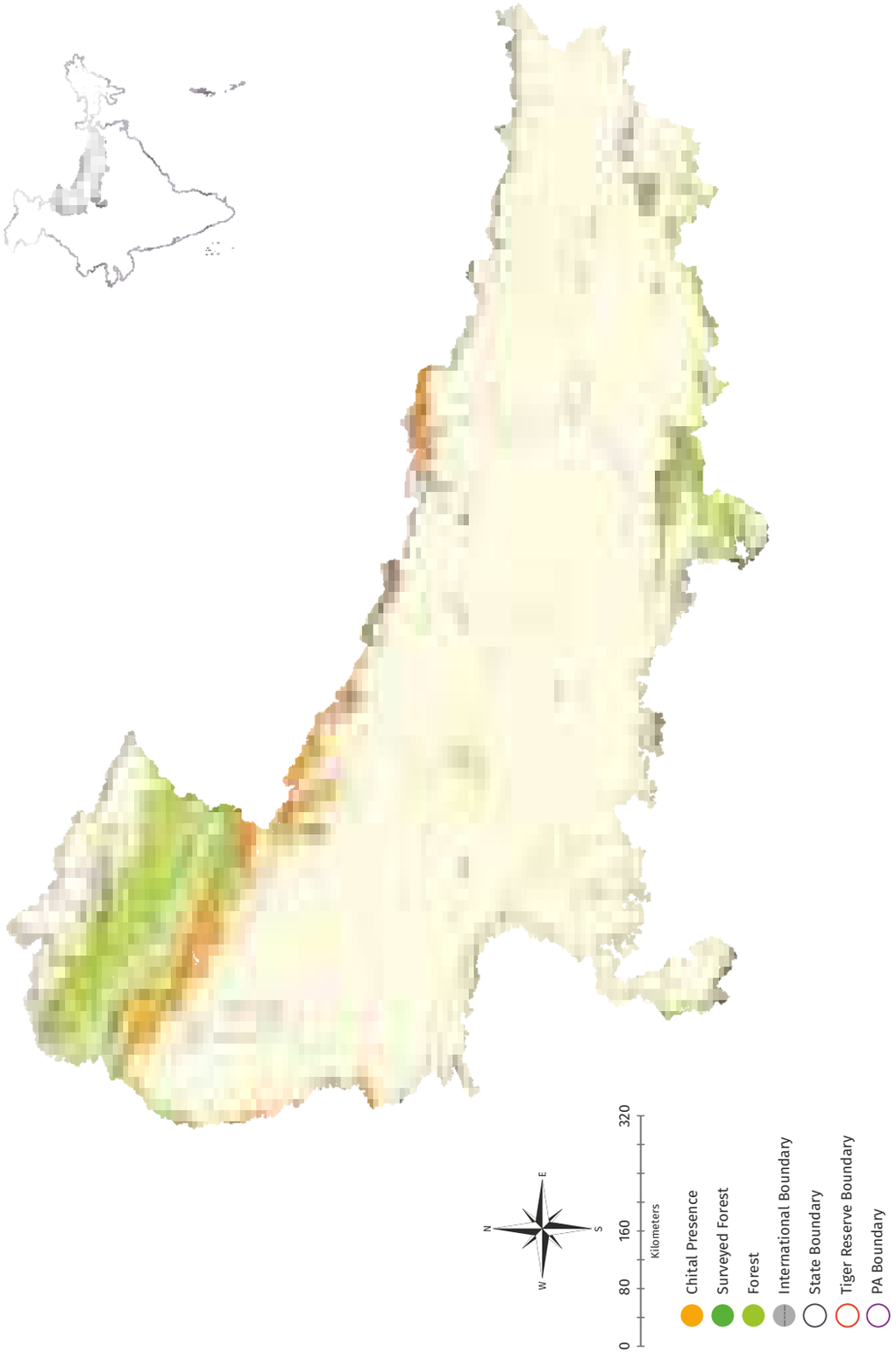


Figure 4.13
Chital distribution in Shivalik Gangetic Plains landscape, 2018-19

Hog deer

(Axis porcinus)

[Wildlife (Protection) Act 1972

Schedule III

IUCN Red List: Endangered]

Hog deer distribution was primarily restricted to the flood plain habitats within PAs (occupancy of 2,596 km^2 of forested areas) (Fig. 4.14). Corbett TR and Terai West FD harbour a good population of hog deer. Major hog deer habitats are now under agriculture. Within PAs the dynamics of the flood plain system has been disrupted by vegetation succession and by ill-informed practices of grassland management like harrowing and burning. The species is on the decline and serious intervention is required to conserve them through proper management their remaining habitat and control of poaching of the species on the periphery of PA's.

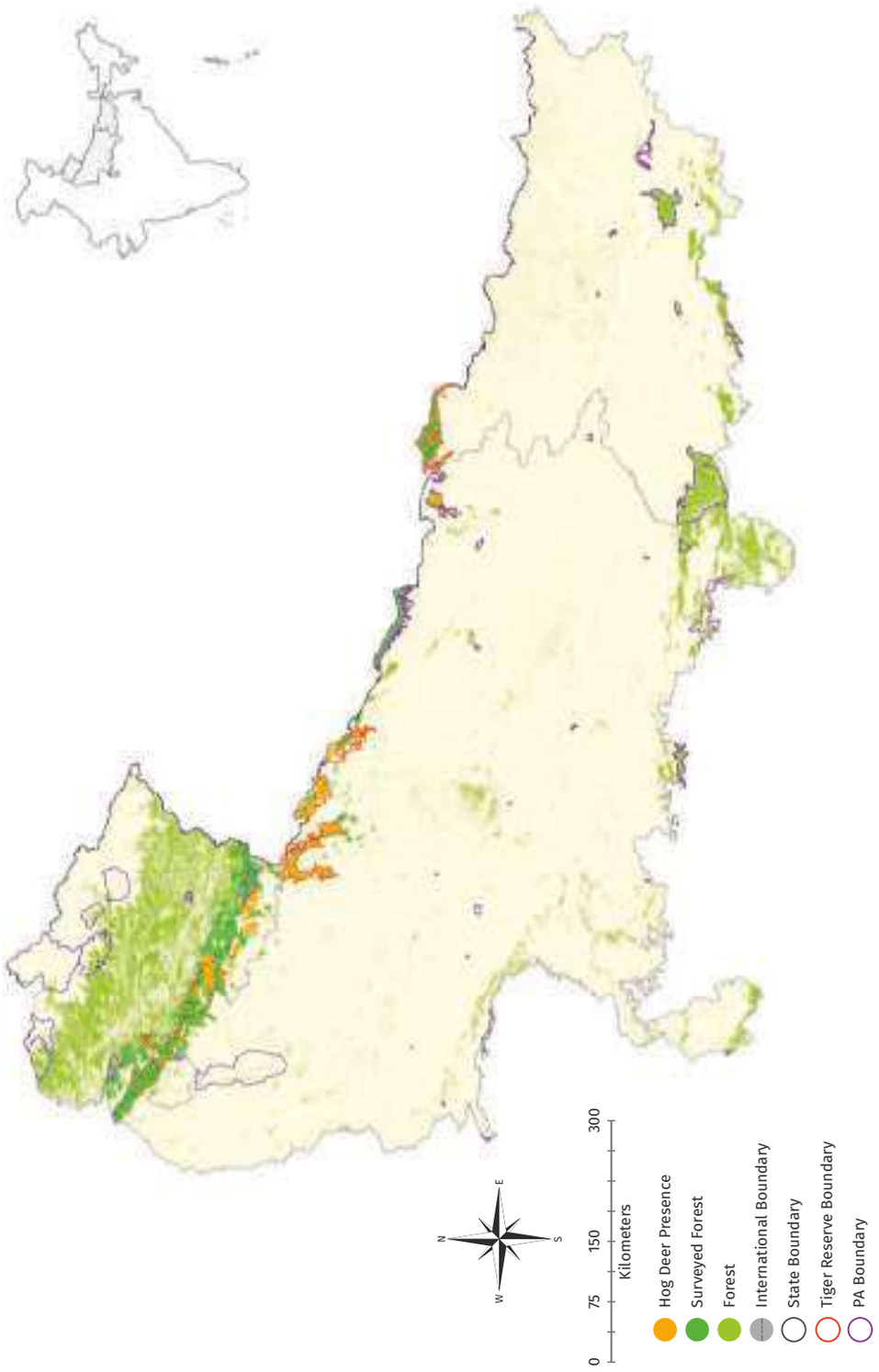


Figure 4.14

Hog deer distribution in Shivalik Gangetic Plains landscape, 2018-19

Elephant

(Elephas maximus)

[Wildlife (Protection) Act 1972

Schedule I

IUCN Red List: Endangered]

Elephant occurrence was observed within the Shivalik-Terai belt west of Katerniaghat within an area of 5,201 km^2 (Fig. 4.15). Contiguous occupancy was recorded from the Shivalik FD of Western Uttar Pradesh up to Ramnagar FD in Uttarakhand. Though the forests are contiguous from Ramnagar FD to Pilibhit and Kishanpur and into Dudhwa via Nepal, elephant occurrence was not reported suggestive of very low density and/or only occasional passage across this landscape. The restoration of the Gola corridor connectivity is important for genetic and demographic connectivity of elephants between eastern and western parts of this landscape. Though Chitwan National Park in Nepal has elephants, their occurrence was not reported from Valmiki.

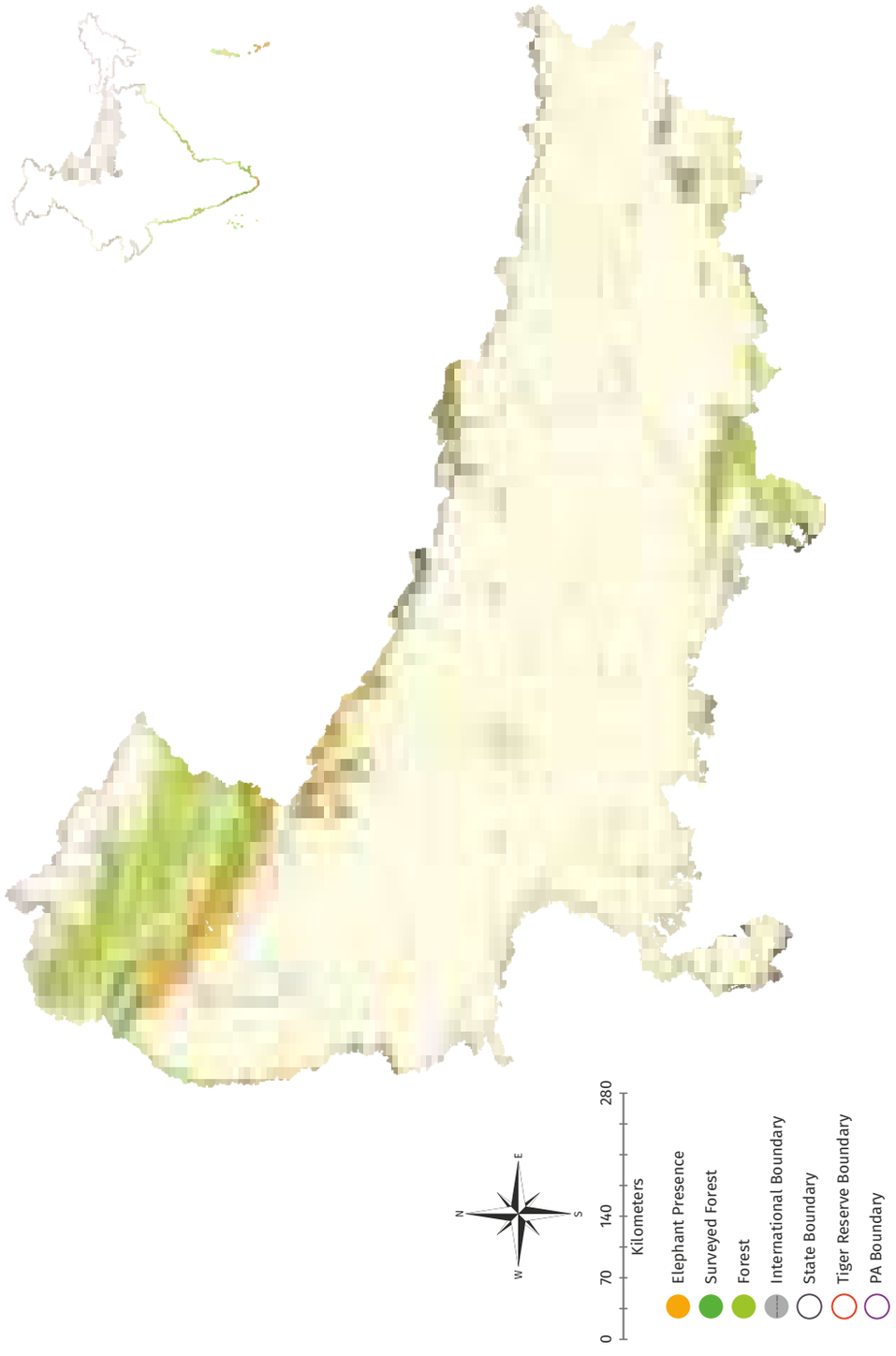


Figure 4.15
Elephant distribution in Shivalik Gangetic Plains landscape, 2018-19

Barasingha

(Rucervus duvaucelii)

[Wildlife (Protection) Act 1972

Schedule I

IUCN Red List: Vulnerable]

Barasingha habitats are threatened with the same factors as mentioned for hog deer. Their occurrence was limited to habitat pockets of the flood plains of Ganga, Sharda and their tributaries (876 km^2) (Fig. 4.16). Though these populations were genetically connected through occasional movements via river systems until recently, this gene flow is currently highly restricted due to growing townships and infrastructure development along riverine tracts. It is known that barasingha occur within Hastinapur WLS in Uttar Pradesh. However, the WLS was not sampled during this exercise.

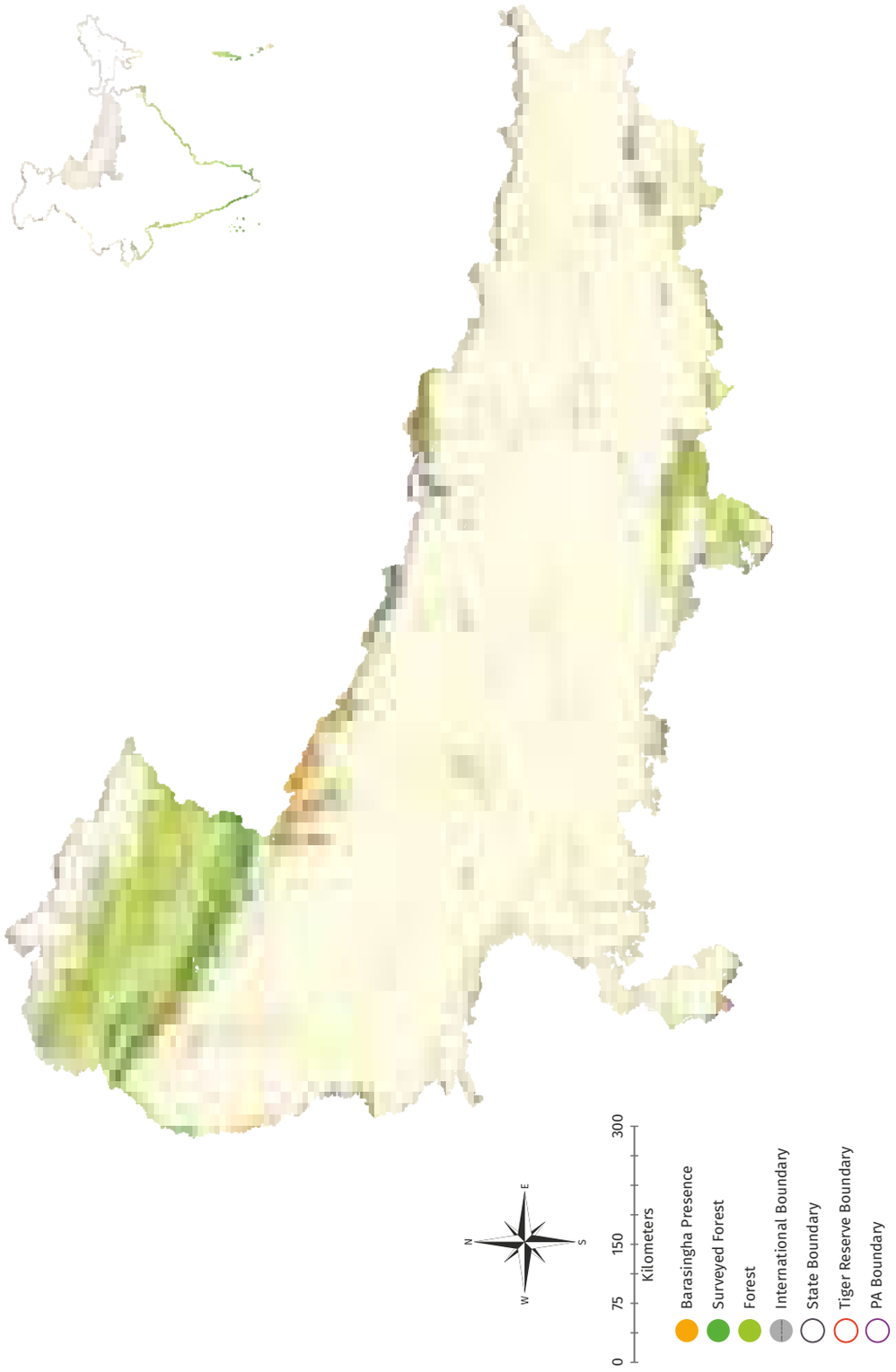


Figure 4.16
Barasingha distribution in Shivalik Gangetic Plains landscape, 2018-19

Gaur

(Bos gaurus)

[Wildlife (Protection) Act 1972

Schedule I

IUCN Red List: Vulnerable]

Gaur was reported only from Valmiki Tiger Reserve (497 km^2) in this landscape (Fig. 4.17). This species needs focus conservation attention and consideration of reintroductions in historic range after a careful study.

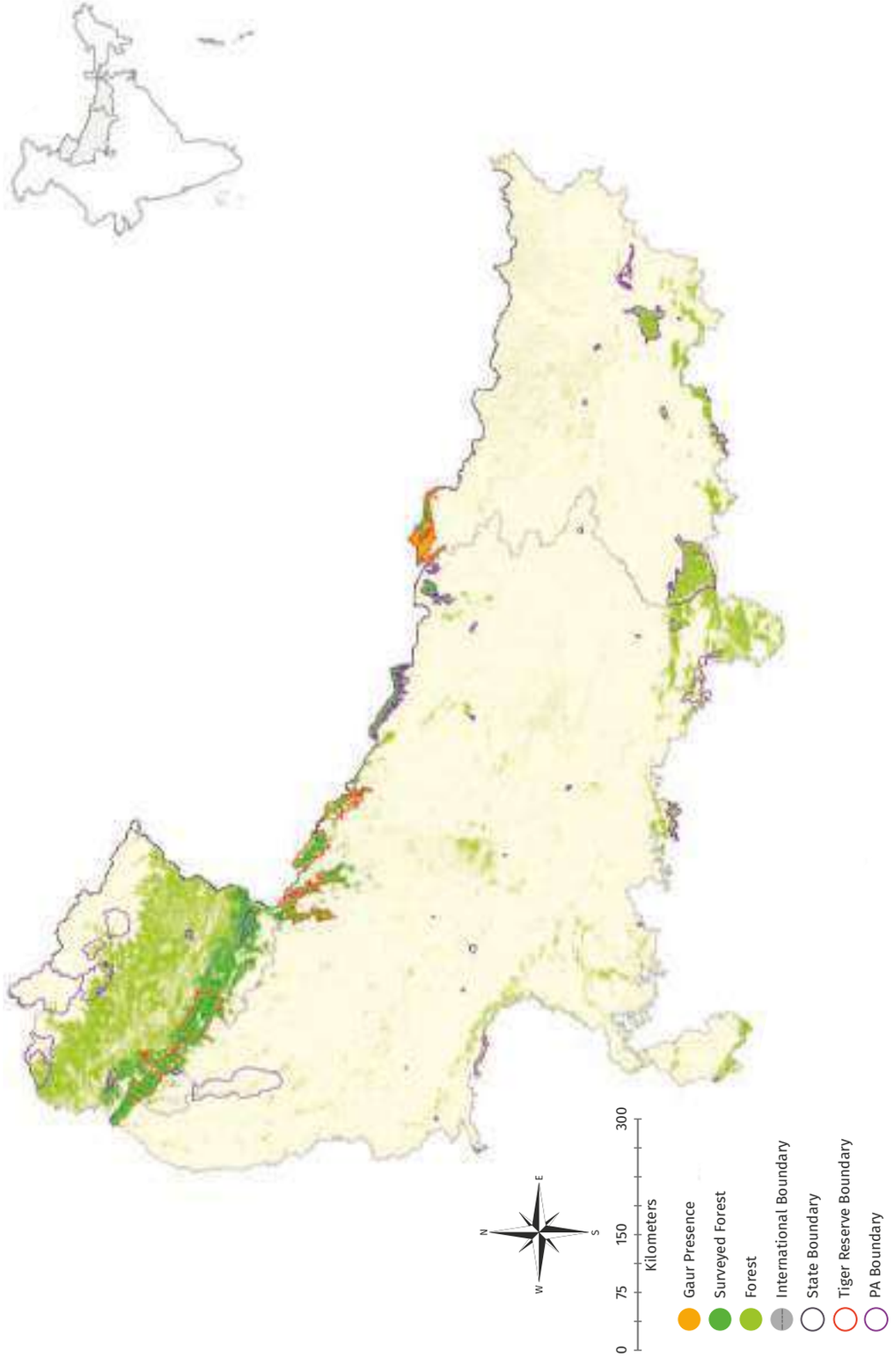


Figure 4.17
Gaur distribution in Shivalik Gangetic Plains landscape, 2018-19

Greater one horned rhinoceros

(Rhinoceros unicornis)

[Wildlife (Protection) Act 1972

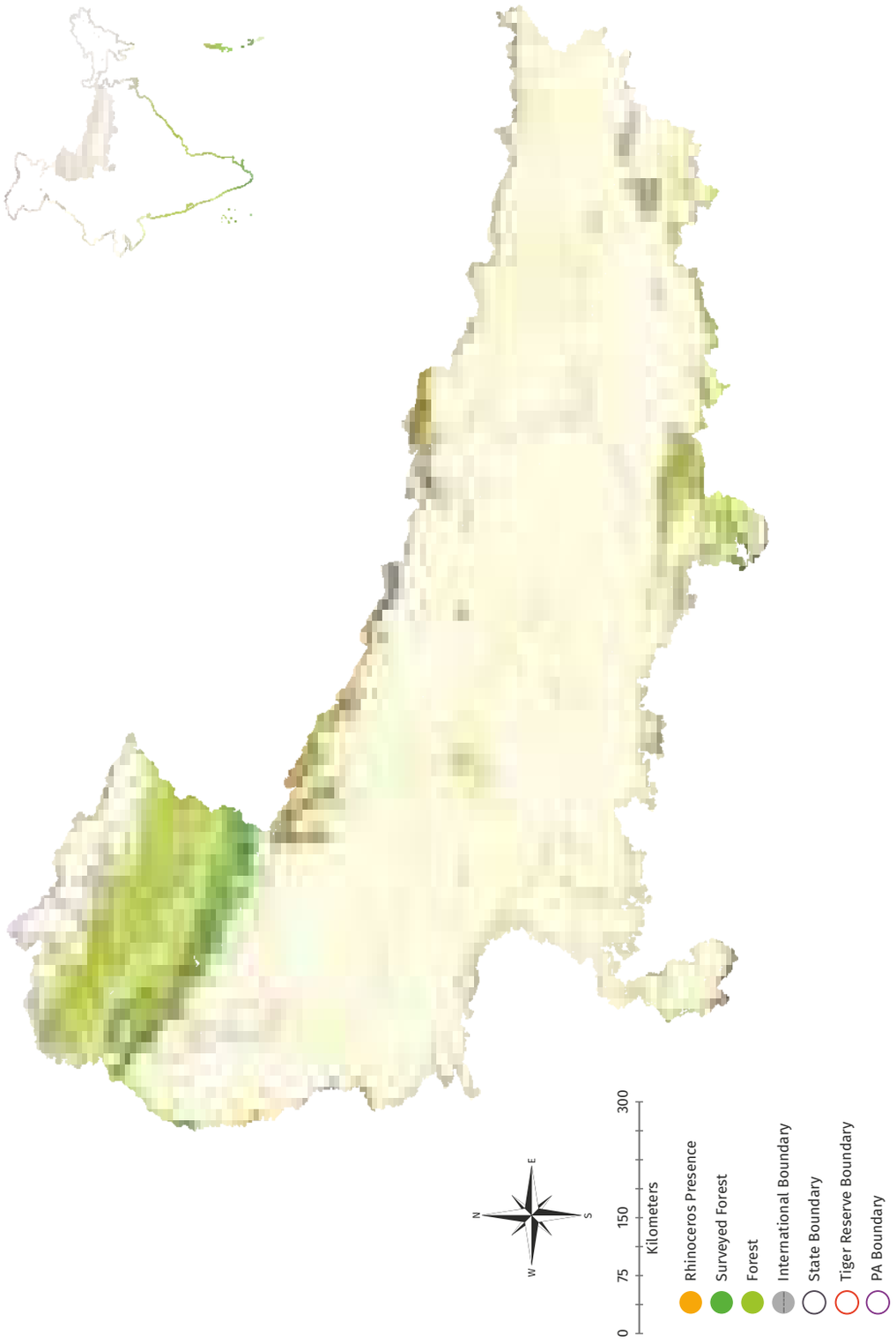
Schedule I

IUCN Red List: Vulnerable]

Rhinoceros was reported in the sign survey data from Dudhwa National Park in Uttar Pradesh where a reintroduced population has been established but in need of supplementation. Western part of Valmiki Tiger Reserve in Bihar reported rhino presence where rhinos occasionally come in from Chitwan (Fig. 4.18). Valmiki is considering reintroducing of rhinos, but considerable investment in terms of protection regime and realignment of railway tract is required for establishing a rhino population here (Jhala et al. 2020).

Figure 4.18

Greater one horned rhinoceros distribution in Shivalik Gangetic Plains landscape, 2018-19



Barking Deer

(Muntiacus vaginalis)

[Wildlife (Protection) Act 1972

Schedule III

IUCN Red List: Least concern]

It is one of the most widely distributed deer species in India. In the Shivalik Gangetic plains landscape, barking deer was recorded to have a continuous distribution throughout the Shivalik hills and Himalayan foothills. The total occupancy recorded was 7,925 km^2 forested landscape (Fig. 4.19). Barking deer do occur at higher elevations as well but these areas were not sampled in this exercise.

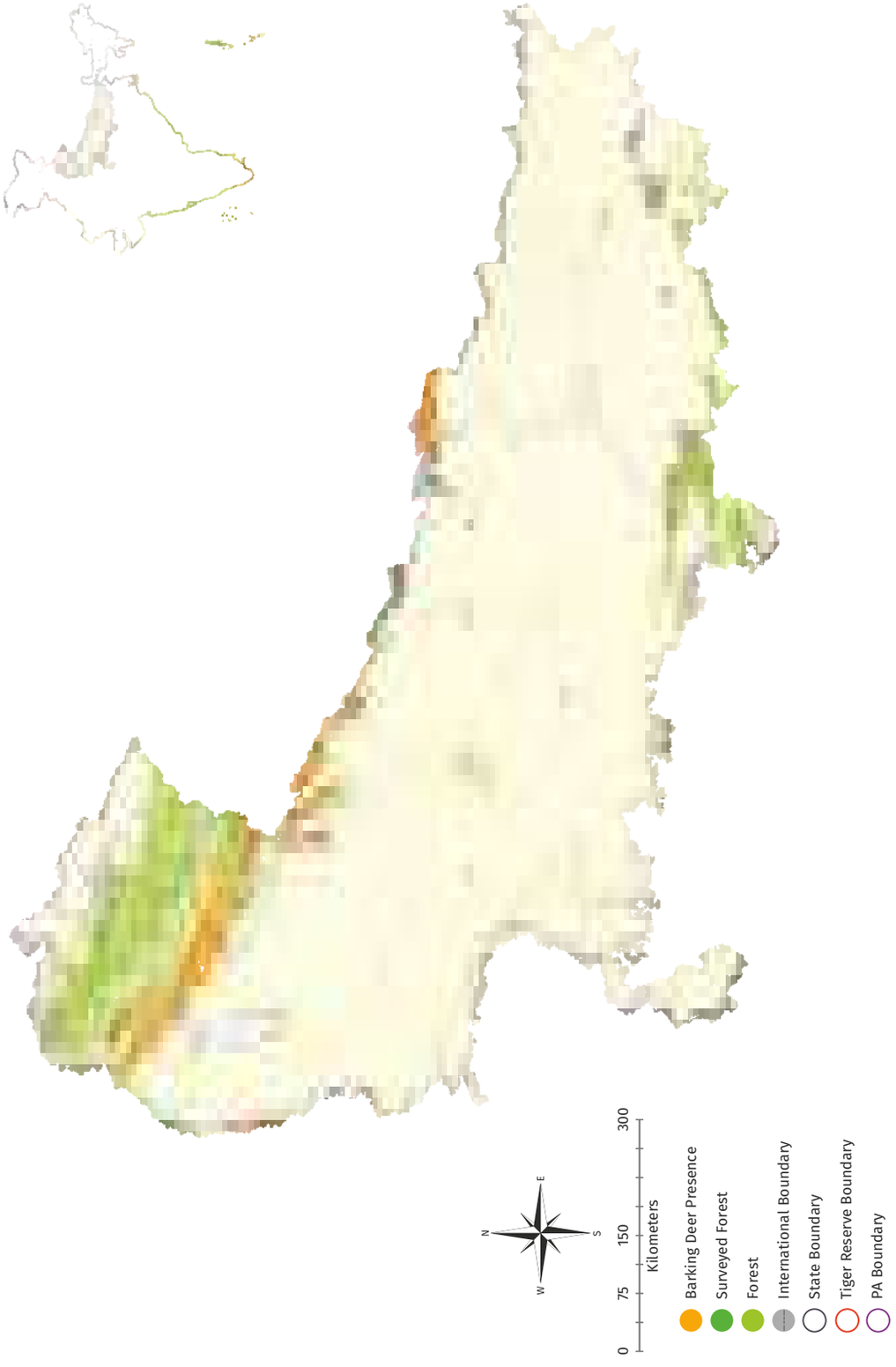


Figure 4.19

Barking deer distribution in Shivalik Gangetic Plains landscape, 2018-19

Nilgai

(Boselaphus tragocamelus)

[Wildlife (Protection) Act 1972

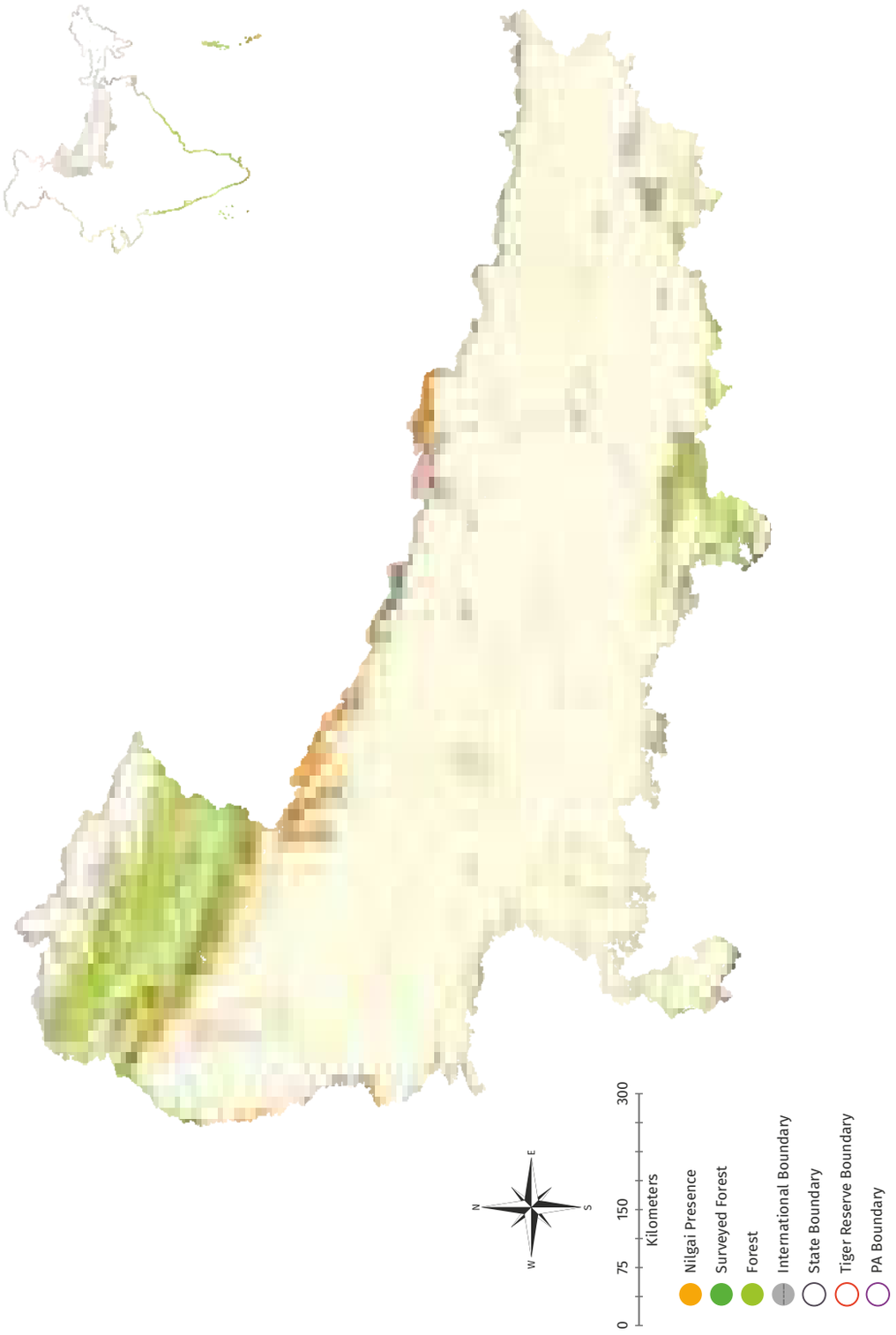
Schedule III

IUCN Red List: Least concern]

Nilgai was recorded throughout the plain areas of the landscape. Its occupancy was recorded to be 6,722 km^2 (Fig. 4.20). Nilgai was found mostly in the fringes of the forested areas and in agricultural areas of the landscape.

Figure 4.20

Nilgai distribution in Shivalik Gangetic Plains landscape, 2018-19



Wild pig

(Sus scrofa)

[Wildlife (Protection) Act 1972

Schedule III

IUCN Red List: Least concern]

Wild pig was found throughout the Shivalik and Gangetic hill landscape, and unlike nilgai its distribution was not limited by the Shivalik hills (Fig. 4.21). Wild pigs occupied an area of 9,262 km^2 in this landscape. Along with nilgai, they are of major concern for human wildlife conflict due to crop raiding in this landscape.

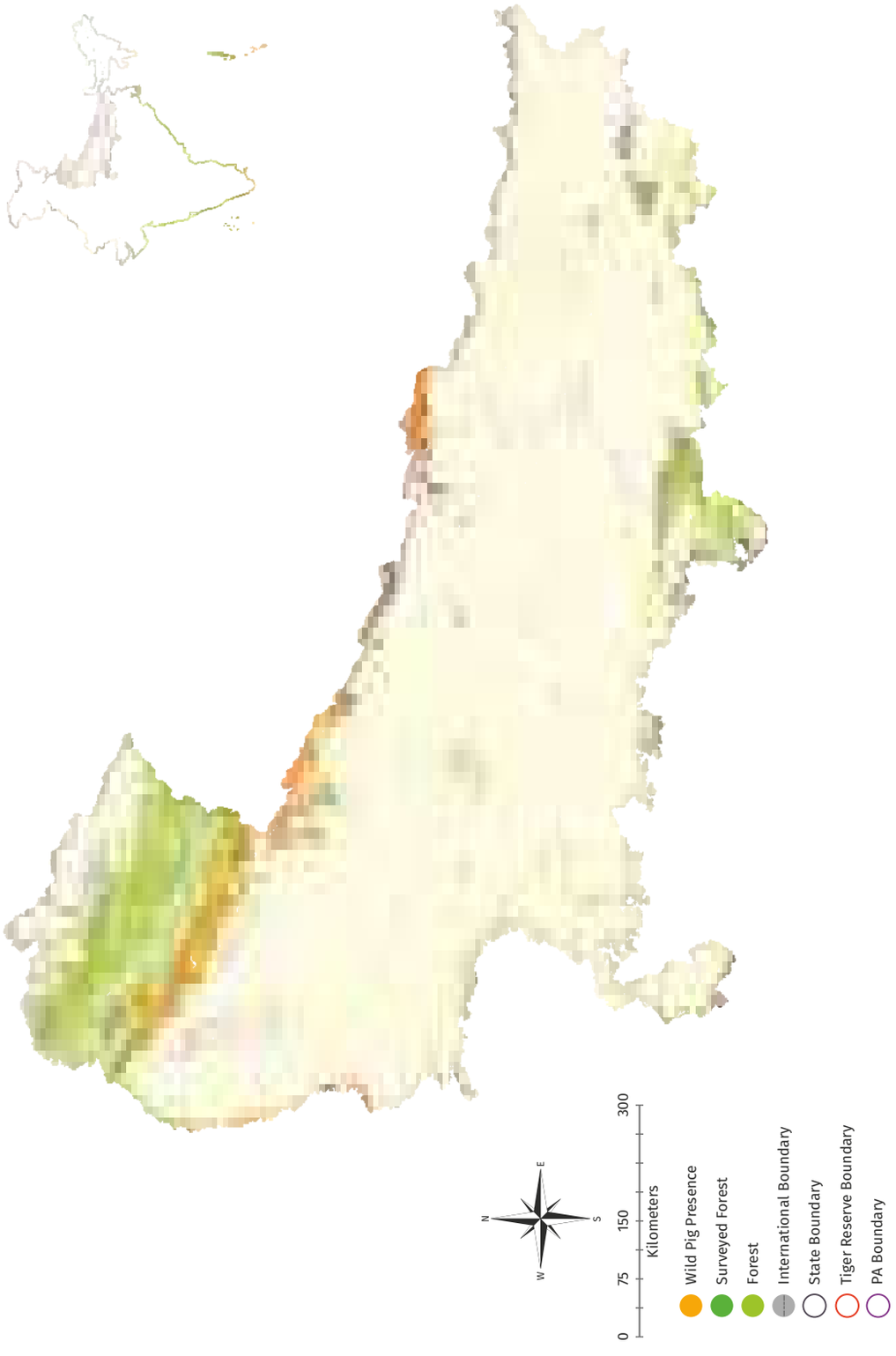


Figure 4.21
Wild pig distribution in Shivalik Gangetic Plains landscape, 2018-19

05

CENTRAL INDIA AND EASTERN GHATS LANDSCAPE

The Central India and Eastern Ghats landscape comprises of the semi-arid zone of Rajasthan, central Indian plateau (Maharashtra, Madhya Pradesh, Chhattisgarh, Jharkhand and Odisha) and includes parts of the Eastern Ghats (Telangana, Andhra Pradesh and Odisha). Parts of the northern Western Ghats (Sahyadri) in Maharashtra are included here for convenience so as not to split the state into two landscapes. Parts of Eastern Ghats of Tamil Nadu and Karnataka are not included here, for the same reason; they are discussed in the Western Ghats landscape chapter.

The Central India landscape is surrounded by Aravalli hills in the north-west, Satpura hills in the south, Chota Nagpur plateau in the north-east and Eastern Ghats of Odisha in the south-east. These hills range between 200 to 1300m in elevation. Aravalli is the oldest mountain range in India, and stretches over 700 km from Gujarat to Delhi in southwest-northeast direction (Mani 1974) with an extensive belt in Rajasthan. The northern Sahyadri acts as a connecting zone between Western Ghats and the central highlands, through the Saputara hills in Dang district of southern Gujarat. The hills of Vindhya and the Satpura divide the peninsular region of India from the Indo-Gangetic plains. The Chota Nagpur plateau situated in Jharkhand, Chhattisgarh and Northern Odisha, comprises of the Hazaribagh, Ranchi and Koderma plateaus in a step like formation. The Eastern Ghats are located parallel to the east coast of India from Mahanadi valley to further south of Krishna valley with rivers Godavari and Krishna cutting across the hills. The major ranges of Eastern Ghats are Nallamala, Erramala, Palakonda, Velikonda, Seshachalam, Papikondalu, Maliya, Madugula Konda and Garhjat.

Many of the areas in this landscape are forested since the mosaic of hills and plateaus with patches of shallow infertile soils do not permit extensive cultivation. The forests of Eastern Ghats had historic continuity with the Central India forests along the Chota Nagpur plateau which is now almost lost.

Ecological background

This landscape constitutes a vast network of protected areas (PAs) which includes almost half (23 out of 50) of the total notified tiger reserves in India and several other PAs with extensive tiger occupancy. Eastern Rajasthan and part of north western Madhya Pradesh of this landscape lie in semi-arid zone. This region is a transition zone between the peninsular forests and Thar desert, receiving low rainfall compared to the peninsular forests. The peninsular region of this landscape (which consists of Madhya Pradesh, Maharashtra, Chhattisgarh, Odisha, Telangana and Andhra Pradesh) is the largest landmass of India. Diverse habitats from moist to dry deciduous forests, valley to hilly terrains within this region support high biodiversity. Most of this landscape was under the control of many small to large princely states during the pre-colonial era and subsequently came under the direct administration of British rule. An approximation of tiger abundance of these areas can be drawn by just looking at the shooting records of erstwhile rulers and British hunters. The last cheetah (*Acinonyx jubatus*) of India was shot in the eastern part of Chhattisgarh in Koriya district in 1951. The Asiatic lion (*Panthera leo persica*) was once distributed throughout the Narmada valley and the Ganga catchment of the Central Indian landscape. Populations of barasingha (*Rucerveus duvaucelii*) and wild water buffalo (*Bubalaus arnee*) that were once wide spread are now surviving here as relict populations.

Conservation significance

This landscape has some of the prime tiger habitats of India and is home to the largest scheduled tribe population dependent on forestland. This region's importance in tiger conservation is further emphasized by the presence of four level I Tiger Conservation Units (TCUs), five level II, 24 level III and 3 priority survey sites (Wikramnayke et al. 2004). However, with the current population status most of these would all qualify as level I TCUs. The tiger population in central India is genetically most diverse with a unique lineage in Similipal Tiger Reserve (Kolipakam et al. 2019). This area is home to five biosphere reserves Similipal, Pachmarhi, Achanakmar-Amarkantak, Panna, and Seshachalam. This region is home to the Indian wild buffalo and hard ground barasingha, subspecies endemic to this landscape and facing extinction risk due to habitat loss and human disturbances. However, despite the high biodiversity value and conservation significance, the forests of this region are under immense pressure from mining (having the largest mining concentration), linear infrastructures, livestock grazing, NTFP collection and insurgency. Tiger populations though overall increasing in the landscape have declined in status in the tiger reserves of Palamau, Kawal, Satkosia and Udanti-Sitanadi and are under threat of local extinction.

Vegetation

Champion and Seth (1968) classified, most of this landscape as tropical dry deciduous forests, with small sections of tropical moist deciduous forest in the eastern region and tropical thorn forest in western parts along the junction of Madhya Pradesh, Uttar Pradesh and Rajasthan. The river Narmada is believed to be the natural boundary between the teak (*Tectona grandis*) forests of the southern peninsula and the sal (*Shorea robusta*) forests of northern plains (Forsyth 1919). These two zones overlap in the Chhattisgarh Raipur circle.

The Chambal ravines stretched over eastern parts of Rajasthan and northern part of Madhya Pradesh, have thorn forests with the predominant species being *Acacia spp.*, *Anogeissus pendula, Carissa spinarum, Ziziphus spp., Wrightia tinctoria, Euphorbia nivlia, Lagerstroemia parviflora and Prosopis juliflora*. The tropical hill forests of Madhya Pradesh restricted primarily to the Pachmari and Bailadilla hills, comprise chiefly of *Syzigium cumini, Rhus ellipticus, Murraya paniculata, Dillenia pentagyna* and *Sterculia villosa* along with climbers such as *Gnetumula, Acacia torta, Clematis triloba*. Tree ferns like *Cyathea gigantean* and *C. latebrosa* are common in the gorges of Pachmarhi. In the moist peninsular sal forests of eastern Madhya Pradesh, Chhattisgarh and parts of Odhisa, the predominant species include *Syzygium cumini, Dendrocalamus strictus, Shorea robusta, Bauhinia spp., Albizia chinensis, Emblica officinalis, Terminalia spp., Adina cordifolia, Mitragyna parviflora, Lagerstroemia spp., Anogeissus latifolia* and *Gmelina arborea*. In parts of Palamau, along smaller streams, *Aegle* forests occur with *Phoenix sylvestris* . These forests may occasionally be associated with *Butea, Carissa opaca, Capparis spp.* and *Salvadora spp.*. In this region and on hillsides in Madhya Pradesh and Maharashtra, with about 90 cm rainfall, *Dendrocalamus* brakes are common. Dry deciduous forests comprising of *Tectona grandis* and its associates like *Anogeissus latifolia* and *Terminalia spp., Diospyros tomentosa, Hardwickia binata* and others like *Pterocarpus marsupium, Dalbergia latifolia, Cassia fistula, Butea monosperma, Adina cordifolia, Mitragyna parviflora, Bridelia retusa, Aegle marmelos, Lagerstroemia parviflora, Wrightiat*

inctoria, Bauhinia spp., *Dendrocalamus strictus, Woodfordia fruticosa* and *Helictoris isora* are found in parts of Eastern Maharashtra along the border of Madhya Pradesh. *Hardwickia* forests are scattered in patches in drier parts of Satpura in Madhya Pradesh and Maharashtra and in the Eastern Ghats of Andhra Pradesh. In such regions, 70% of the forest comprises of *Hardwickia binata* with other species such as *Boswellia serrata, Lannea coromandelica, Anogeissus latifolia, Albizzia lebbeck, Lagerstroemia parviflora, Diospyros tomentosa, Tectona gradis, Acacia catechu* and *Dendrocalamus strictus*. The forests of Eastern Ghats are of primarily southern tropical dry mixed deciduous. *Tectona grandis* is the major tree species along with *Anogeissus latifolia, Terminalia alata, Diospyros melanoxylon, Lannea coromandelica, Xylia xylocarpa* and *Gardenia spp*. Moist deciduous forests are restricted to areas with high soil moisture and rainfall.

Fauna

This region shares similarities in mammalian diversity from the biodiversity hotspot regions of Himalayas, Indo-Malayan and Western Ghats. This landscape has five species of Canidae, viz., jackal (*Canis aureus*), wolf (*Canis lupus*), fox (*Vulpes bengalensis*), desert fox (*Vulpes vulpes*) and wild dog (*Cuon alpinus*); eight species of Felidae, viz., leopard (*Panthera pardus*), tiger (*Panthera tigris*), jungle cat (*Felis chaus*),desert cat (*Felis sylvestris*), caracal (*Caracal caracal*), rusty spotted cat (*Prionailurus rubiginosus*), leopard cat (*Prionailurus bengalensis*) and fishing cat (*Prionailurus viverrinus*); six species of Bovidae, viz., balckbuck (*Antilope cervicapra*), gaur (*Bos gaurus*), nilgai (*Boselaphus tragocamelus*), wild buffalo (*Bubalus arnee*), chinkara (*Gazella benetti*) and chowsingha (*Tetracerus quadricornis*) along with several other species of ungulates mainly chital (*Axis axis*), hard ground barasingha (*Rucervus duvacelli branderi*),sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*), wild pig (*Sus scrofa*) and Asiatic elephant (*Elephas maximus*).

Much of the information on the faunal assemblage of this region come from the large number of prehistoric cave paintings found in Sidhi, Rewa, Satna, Bhimbetka, Panna, Mirzapur and parts of Satpura, first discovered by J. Cockburn in early 19th century (Mukherjee 1984). Based on these paintings, the existence of rhinoceros in Vindhya, and elephant and wild buffalo in Panna can be inferred (Mukherjee 1984). Until the 17th century, lion was common in the Narmada valley while the distribution of elephant spanned across much of this landscape. However, while the former is now extinct from the region, small populations of elephant still exist within the eastern parts of this landscape. A small population of wild buffalo (*Bubalus arnee*) still exists in the Bastar region of this landscape. Hard ground swamp deer once distributed throughout from Satpura to Indravati Tiger Reserve has now become confined to a small extant population in Kanha Tiger Reserve. At least 300 species of birds are known from this landscape with some like the forest owlet (*Athene blewitti*) being rediscovered from north-west Maharashtra in 1997 (King and Rasmussen 1998). While there is restricted information available on the herpetofauna of this region, at least 104 species with 89 species of reptiles and 19 species of amphibians are known from Madhya Pradesh and Chhattisgarh alone (Chandra and Gajbe 2005). According to species inventories, 174 species of butterflies were recorded from Madhya Pradesh and Chhattisgarh (Chandra et al. 2007) while 89 from Nagarjunasagar Srisailam Tiger Reserve (Rao et al. 2004) in recent times.

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Tiger Occupancy

Out of 4929 grid cells surveyed, tiger signs were detected in 526 cells in 2006, 537 cells in 2010, 292 cells in 2014 and 780 cells in 2018. This yielded a naïve occupancy of 33,505 km^2 in 2006; 33,522 km^2 in 2010; 34,940 km^2 in 2014 and 46,764 km^2 in 2018.

When these grids were categorised as occupied (1111), colonized (0111, 0011, 0001), extinct (1000, 1100, 1110), absent (0000) and transitional (all other combinations) and compared with site covariates, we observed the hypothesized relation between the occupancy parameters and site covariates in (Figure 5.2). This relationship lends credence to the usage of these site covariates for modeling occupancy parameters for tigers in this landscape.

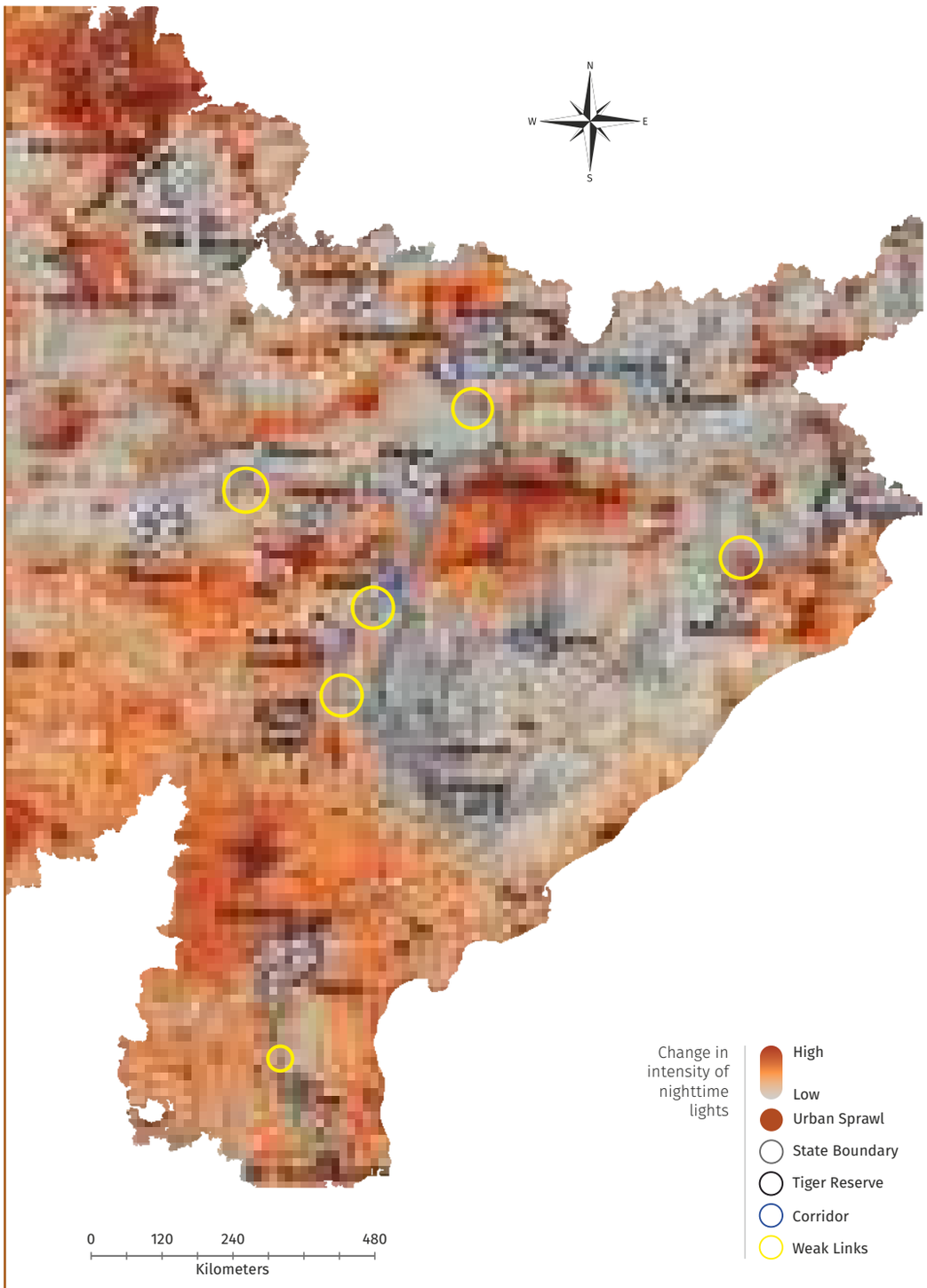

Figure 5.1

Change in night time lights between 2014 to 2018 across the Central Indian and Eastern Ghats landscape. Connecting habitat corridors are superimposed, bottlenecks and pinch points demarcated by circles.

Figure 5.2

The relationship between site covariates and occupancy status of tigers in the Central Indian and Eastern Ghats landscape. The occupancy categories were: Absent (0000), Extinct (1000, 1100, 1110), Colonized (0111, 0011, 0001), Present (1111) and Transitional (all other combinations).

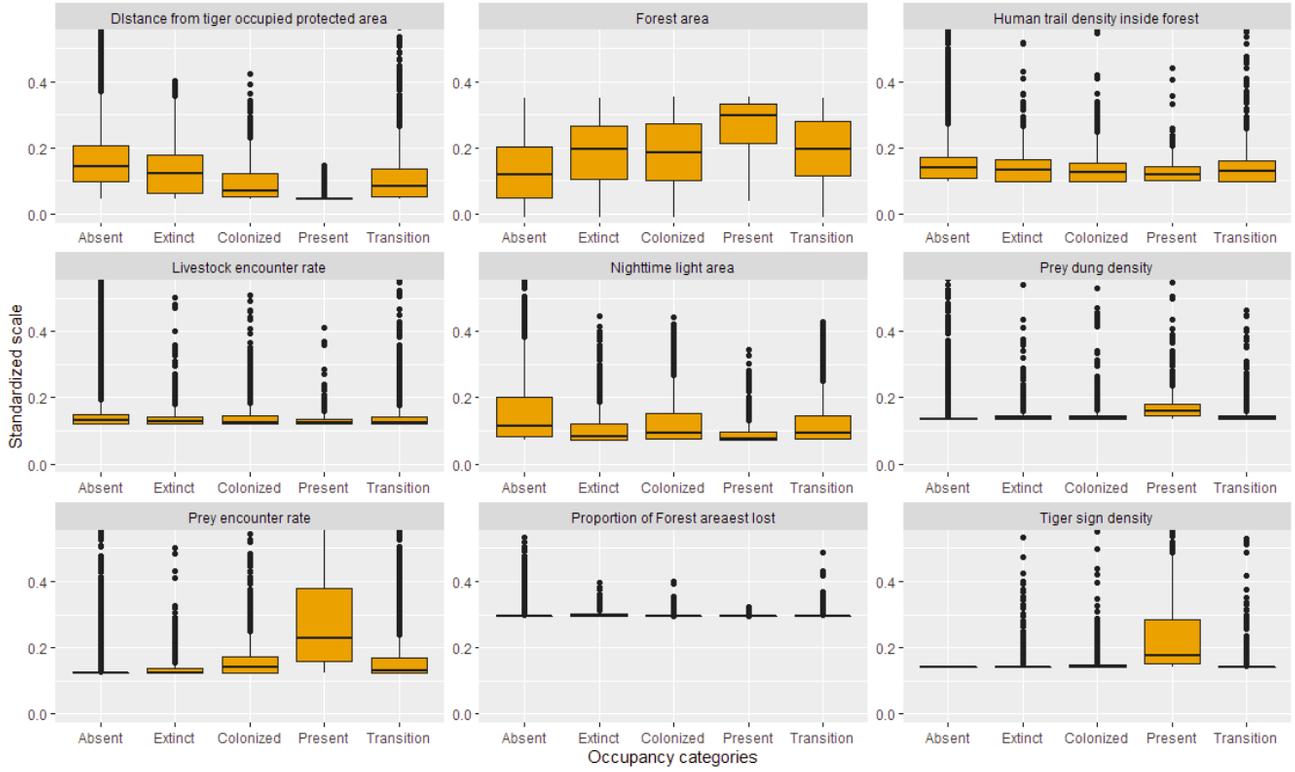

Table 5.1

Different models explaining the parameters of tiger occupancy (Ψ), colonization (γ), extinction (ε) and detection (p) in the Central Indian and Eastern Ghats landscape. The most parsimonious model was the one with least AIC and was considered to best explain these occupancy parameters. (prey: encounter rate of prey, dpa: distance from protected areas that were occupied by tigers in the previous cycle (t-1), for: forest area, for loss: proportion of forest area lost in the duration of four years, prey-change: rate of change in the prey encounter rate within a grid, na: nighttime light area, pso: encounter rate of tiger signs, lvsn: encounter rate of livestock, trail: density of human trails in the forest, road: density of tar road in the grid, year: different for years)

Model	AIC	Delta AIC	No. Par	-2*log likelihood
Ψ(for, prey6), γ(year, dpa, prey_change), ε(year, na, forloss), p(year, pso)	54038.89	0	27	53984.89
Ψ (for, prey 6), γ (year, dpa, prey_change), ε(year, na, forloss), p(year, pso)	54079.4452	40.5536	25	54029.45
Ψ (for, prey6), γ(year, dpa, prey_change), ε(year, na),p(year, pso)	54093.37	54.48	24	54045.37
Ψ (for, prey6), γ(year, dpa, prey_change), ε(year, forloss), p(year, pso)	54118.62	79.73	22	54074.62
Ψ(.),γ(.), ε(.),p(.)	61564.33	7525.44	4	61556.33
Ψ(.), γ(year), ε(year), p(year)	62038.67	7999.78	11	62016.67
Ψ(.), γ(year), ε(year), p(.)	62186.24	8147.35	8	62170.24

Table 5.2

Best model explaining the effect of covariates (Beta Estimate) on tiger occupancy (Ψ), colonization (γ), extinction (ε) and detection (p) in the Central Indian and Eastern Ghats landscape. The suffix y6, y10, y14 and y18 represents the covariate of the sampling year 2006, 2010, 2014 and 2018.

Covariate	Beta Estimate	Std error
Ψ 1.intercept	-1.86	0.06
Ψ 1.forest area	0.70	0.05
Ψ 1.prey	0.51	0.07
γ 1.intercept	-2.72	0.22
γ 2.intercept	-3.46	0.19
γ 3.intercept	-2.84	0.11
γ 1.dpa_y6	-1.08	0.37
γ 2.dpa_y10	-1.45	0.29
γ 3.dpa_y14	-1.46	0.16
γ 1.prey_increase	0.79	0.12
ε 1.intercept	-0.17	0.18
ε 2.intercept	-0.28	0.14
ε 3.intercept	-1.07	0.13
ε 1.na_y10	0.36	0.21
ε 2.na_y14	0.25	0.13
ε 3.na_y18	0.37	0.14
ε 1.forest loss_10	12.82	2.71
ε 2.forest loss_14	5.51	2.47
ε 3.forest loss_18	1.37	0.48
p1.intercept	-1.74	0.04
p2.intercept	-1.28	0.03
p3.intercept	-1.44	0.03
p4.intercept	-1.30	0.02
p1.pso_y6	0.46	0.02
p2.pso_y10	0.88	0.04
p3.pso_y14	0.51	0.02
p4.pso_y18	0.59	0.02

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Different occupancy models for correcting detection and incorporating the dynamic parameters modelled by covariates are shown in the Table 5.1. The best model differed from the next competing model by an AIC difference of ~40. Hence, the parameters of the best model were considered to explain multi-season occupancy of tigers in this landscape. The beta estimates of the best model are provided in the Table 5.2.

Detection probability of tiger signs increased from 2006 to 2010 and changed insignificantly after that. It was significantly related to the encounter rate of tiger signs within a grid. The initial occupancy of tigers in this landscape was 16%, and was significantly related to larger forested areas with high prey encounter rate (Fig. 5.3).

The initial tiger occupancy for the year 2006 was high in most tiger reserves excluding few that had lower occupancy (Sahyadri, Sanjay-Dubri, Bor, Indrawati, Palamu, Panna, and Mukundara) (Fig. 5.3). However, tiger occupancy was also observed outside tiger reserves, in and around Kuno Wildlife Sanctuary, Ranipur Wildlife Sanctuary, Raisen Forest Division, Satpura-Melghat corridor, Kanha-Pench corridor, Chandrapur and Gadchiroli districts of Maharashtra, forests in and around Pranahita Wildlife Sanctuary and Papikonda National Park, Eastern Ghats hills at the junction of Andhra Pradesh and Odisha, hilly forests between Kotagarh Wildlife Sanctuary and Satkosia Tiger Reserve, and the southern Eastern Ghats around Sri Penusila Narasimha Wildlife Sanctuary. The subsequent modeled occupancy of tigers in this landscape is provided in Figure 5.3, and was observed to vary insignificantly across the sampling duration. However, the average tiger occupancy was observed to decline (insignificantly) in the year 2014.

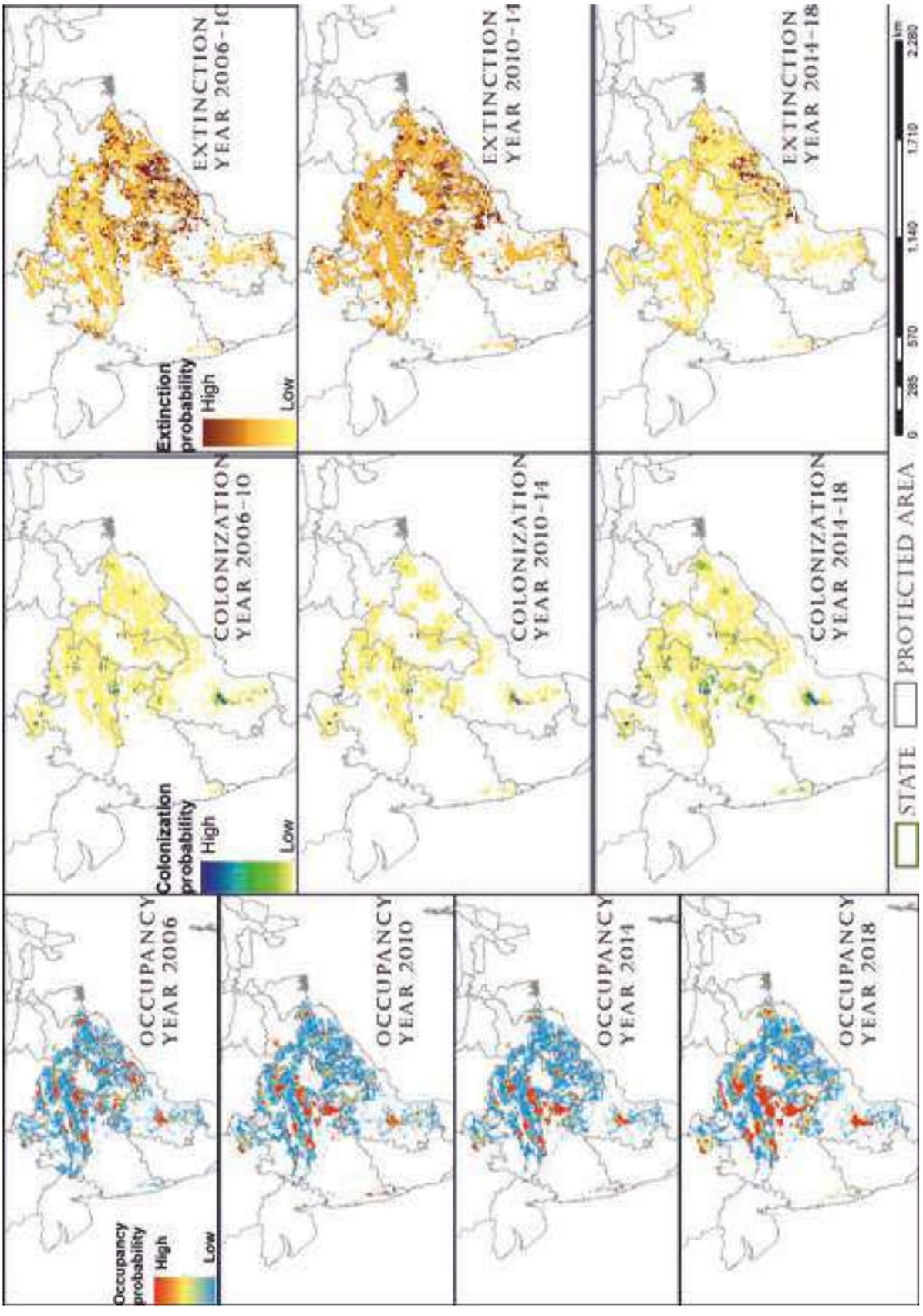
Colonization probability increased from 2006 to 2010, declined from 2010 to 2014 and increased again in 2018 (Fig. 5.3). Colonization probability was higher in those grids that were in proximity to protected areas occupied by tigers in the previous years, and had consistent growth in prey encounter rate across the years (Fig. 5.3). Hence, higher colonization was observed in the forested areas around many tiger reserves (Ranthambhore, Bandhavgarh, Sanjay Dubri, Kanha, Pench, Satpuda, Melghat, Navegaon Nagzira, Bor and Tadoba) (Fig. 5.3). The larger colonized areas also coincided with tiger corridors identified in this landscape. Many other forest divisions that were in proximity to tiger reserves or tiger corridors, were hence seen to be consistently colonized by tigers (e.g. Balaghat, Raisen, Ranipur, Sarni, Yawal, Chandrapur, Brahmapuri, Umred Karhandla, Central Chanda, Nagpur and Gondia) (Fig. 5.3). This colonization increased the tiger occupancy from 2014 to 2018 as depicted in Fig 5.5.

Patch extinction in this landscape was highest from 2006 to 2010 and decreased thereafter, with areas in the eastern part of the Eastern Ghats being relatively more vulnerable (Fig. 5.3). The probability of extinction was significantly explained by increasing night time light areas, indexing the increase in urbanization and human settlements and loss in the available forest area (Fig. 5.4). As a result of expansion in human settlements and forest loss a significant number of areas witnessed local tiger extinction. These areas were around Raigarh, Korba, Kanker, Pakhanjore in Chhattisgarh; Satna, Katni, Singrauli, Obaidullaganj and Mandla in Madhya Pradesh; Sundarnagar range, Gadchiroli, Dhanora, Chandgad and Radhanagari Wildlife Sanctuary in Maharashtra; Sobhanadripuram, Devarapalli and Kaundinya Wildlife Sanctuary in Andhra Pradesh; Ramagundam in Telangana; Kotagarh Wildlife Sanctuary, Karlapat Wildlife Sanctuary, Kendujhar-Saranda, Bamur, and Sunabeda in Odisha (Fig. 5.5).

Tiger reserves like Indravati, Udanti Sitanadi, Palamau, and wildlife areas like Gadchiroli, Bastar, Pamunuru, Bhamragharh had poor law and order situation due to armed insurgency and were meagerly sampled; thereby limiting our understanding of tiger occupancy dynamics in these areas. However, all other areas were consistently sampled across the landscape. In this landscape habitats in proximity to tiger reserves or those that were connected through habitat corridors with protected forest patches, higher prey and less night time lights (roads, expanding human settlements) were the ones where tiger occupancy had increased. Whereas, tiger reserves (e.g. Satkosia, Similipal, Udanti Sitanadi, Sahyadri, and Palamau) that were isolated, have witnessed forest loss, or decline in prey encounter rates faced local extinction. In many of these areas, the loss in forest coincided with the mining activity, National and state highways and with disturbance caused by political insurgencies.

Figure 5.3

Occupancy parameters (occupancy probability (ψ), colonization probability (γ), extinction probability (ε) and detection probability (p)) of tigers in the Central Indian and Eastern Ghats landscape estimated using multi-season occupancy modelling approach, from the year 2006 to 2018.



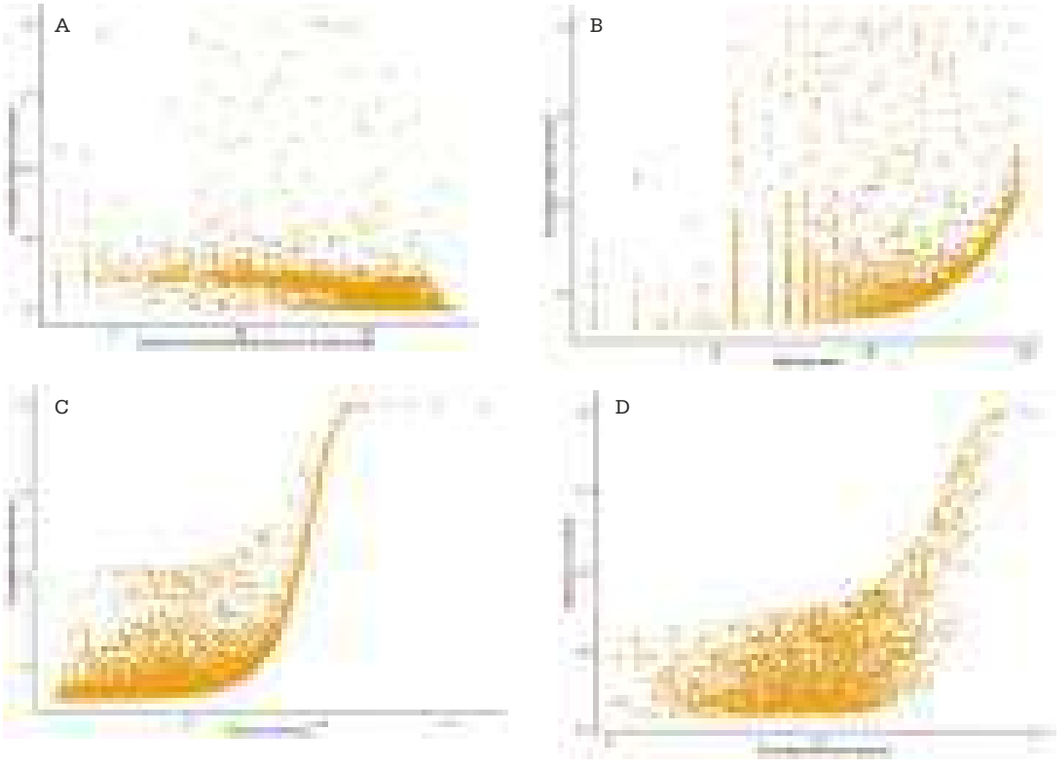


Figure 5.4

The relationship between occupancy parameters and site covariates in the Central Indian and Eastern Ghats landscape. (A) relation in the probability of colonization and distance (km) from protected areas occupied by tigers in the previous season, (B) relation in the probability of extinction and night time light areas (km^2), (C) relation in the probability of extinction and proportion of forested areas lost (km^2), (D) relation in the probability of tiger occupancy and encounter rate of prey species per km.

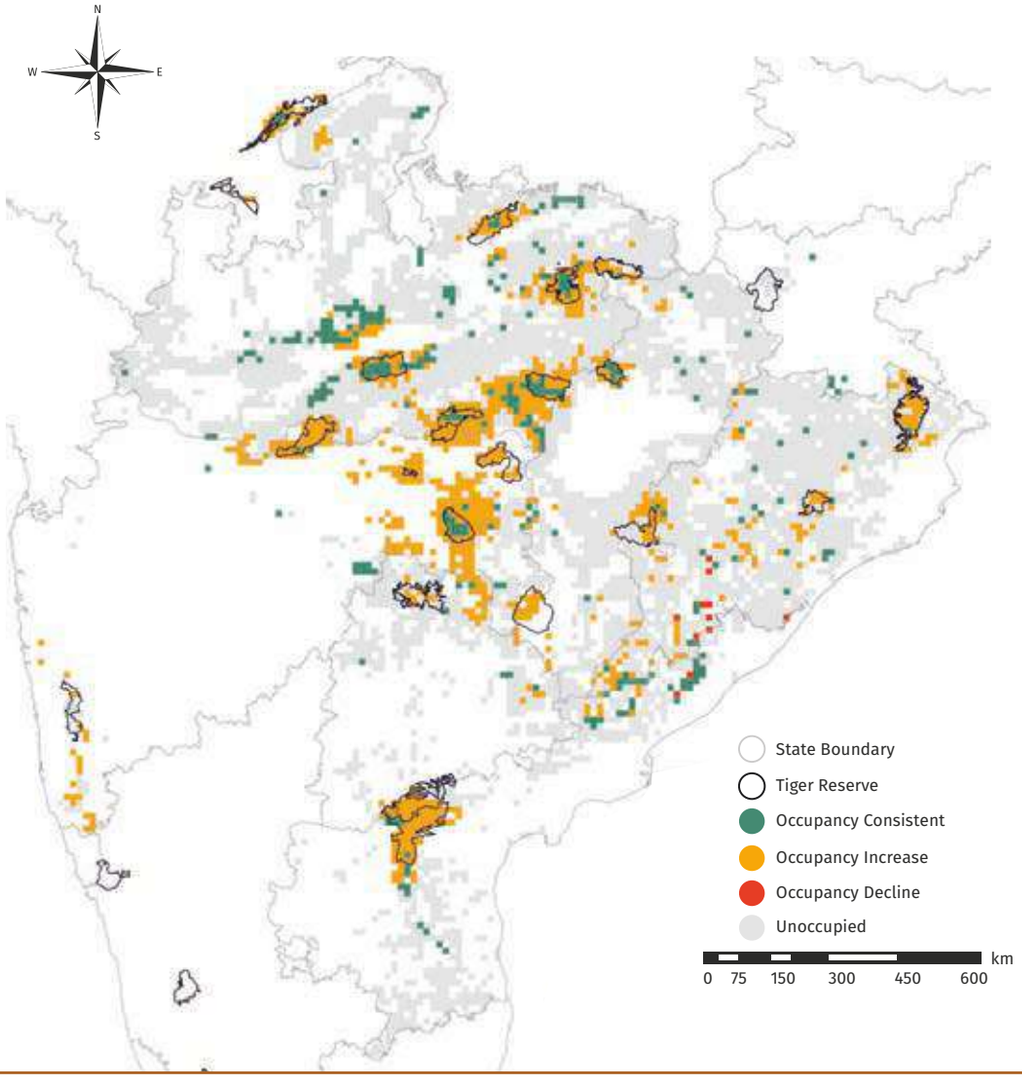


Figure 5.5

Rate of change of tiger occupancy in between the year 2014 and 2018 in the Central Indian and Eastern Ghats landscape.

Tiger Population blocks, corridors, and conservation

Wildlife habitats of Central Indian and Eastern Ghats landscape are the most fragmented in the country. It is in this landscape that maximum flux in tiger occupancy has occurred with maximum patch extinctions as well as colonisations. The landscape now has four populations that have more than 100 adult tigers each (Fig 5.6). The largest of these (Kanha-Pench Block) has over 300 tigers. Some of the major PAs within this landscape remain connected only through linear forest patches and these habitat connectivities are primarily threatened by agriculture, industrial and infrastructural development and are declining rapidly as observed from the expansion of night light data between 2014 and 2018 (Fig. 5.1). However, these degraded corridors still facilitate gene flow between them as reported by Sharma et al. 2013 and Yumnam et al. 2014. Within this landscape, there are smaller sub-units of tiger landscape, which incorporate one, or several PAs that may or may not have tiger populations, yet are essential for long-term persistence of the species in the region. These include:

Sariska

Located in Aravallis hills of Rajasthan. The isolated nature and inadequate protection in the reserve led to the local extinction of the tiger in 2004. Thereafter, tigers have been reintroduced in Sariska Tiger Reserve from Ranthambhore Tiger Reserve, have subsequently bred and are in the process of achieving their potential in Sariska Tiger Reserve. The current tiger population in Sariska Tiger Reserve is eleven and this population needs to be actively managed as a metapopulation with the tiger reserves of Ranthambhore and Mukundara.

Ranthambhore-Mukundara-Kuno-Shivpuri-Madhav

Ranthambhore Tiger Reserve is the only source population of tigers in this landscape with about 53 tigers constituting over 90% of the population in this block. This complex is a mosaic of PAs, highly fragmented forest patches, Chambal ravines, river streams, and agricultural land. Ranthambhore Tiger Reserve is connected to the Kuno-Palpur landscape in Madhya Pradesh through parts of Kailadevi Wildlife Sanctuary, the ravine habitats of Chambal and the forest patches of Sheopur. Tributaries of river Chambal provide easy passage for tigers to move towards Kuno National Park. There has been photographic evidence of individual tigers dispersing out from Ranthambore Tiger Reserve and Kailadevi Wildlife Sanctuary to Kuno National Park (Sadhu et al. 2017). Madhav National Park is connected to Kuno National Park through the upper Vindhya.

Madhya Pradesh State Highway 23 traverses this corridor at Shyampur and Chawwar villages of Morena district. Hence, appropriate wildlife passageways need to be developed for mitigating the long-term impact of these roads as barriers to wildlife movement across them. Ravines (Beehad) of river Chambal, Banas and Mez are unique feature of this landscape. These ravines act as refuge to dispersing tigers. Over the last 4 years, Madhya Pradesh government has initiated projects on reclamations of ravines and converting them to agriculture land. This reclamation can potentially restrict tiger movement across the corridors. Reddy et al. (2012) demonstrated that the tiger populations from this western Indian complex and central India share immigrants. These corridors are thus vital for the long-term persistence of tigers and other wildlife of this region. Kuno National Park and Wildlife Division have been restored for reintroduction of the Asiatic lions from Gir Forests. The area is ready to receive lions from Gir.

Panna-Ranipur

The Panna block is located within the Vindhya range and has become apparently isolated from Bandhavgarh-Guru Ghasidas complex in the recent past. Yet collared tigers were observed to traverse the intervening human dominated landscape and make the perilous journey from Panna Tiger Reserve to Sanjay-Dubri Tiger Reserve. To the north-west, small isolated forest patches connect Panna Tiger Reserve with the Kuno-Sheopur-Madhav landscape. This region has regained its tiger population after local extirpation and subsequent reintroduction and proper law enforcement by Madhya Pradesh forest department. Tigers from Panna Tiger Reserve usually disperse upto Ranipur Wildlife Sanctuary in Uttar Pradesh. The forested landscape is under the jurisdiction of several territorial divisions. A significant part of the biodiversity rich Panna Tiger Reserve is currently under threat from being submerged by the upcoming Ken-Betwa river-linking project. Tiger population in this block is estimated to be 33 (27-39) [Fig. 5.6].

Bandhavgarh-Sanjay-Guru Ghasidas-Palamau

This zone comprises of the Bandhavgarh Tiger Reserve located in Vindhya hills of Madhya Pradesh with patchy connectivity to Sanjay-Dubri Tiger Reserve. Sanjay-Dubri Tiger Reserve is contiguous with Guru Ghasidas National Park in Chhattisgarh. A small population of elephant recently migrated to Bandhavgarh Tiger Reserve from Guru Ghasidas National Park using these corridors. To the north-east, this zone is connected to Palamau Tiger Reserve of Jharkhand.

Bandhavgarh Tiger Reserve is the major source in this landscape and the landscape block was estimated to have a population of 141 (126-156) tigers. It will be beneficial to include Guru Ghasidas National Park into the ambit of tiger reserves as proposed by Jhala et al. (2011) since this will allow appropriate investments for restoring this vast tract of forests and connect Bandhavgarh Tiger Reserve with Palamau Tiger Reserve. This landscape holds promise for accommodating the increasing tiger population of Central India and if prey is recovered here, it can easily support over 500 tigers.Very low tiger density areas like Sanjay Dubri Tiger Reserve and Guru Ghasidas National Park can only be viable if they remain connected to Bandhavgarh Tiger Reserve. State highways (8, 9, 10, and 55) traverse the habitat corridors at various places. Wildlife passageways need to be developed for mitigating the long-term impact of these roads as barriers to wildlife movement across them.

The Bandhavgarh- Achanakmar corridor connects two important tiger reserves of Achanakmar and Bandhavgarh and two important sub-landscape complexes of Kanha-Pench and Bandhavgarh-Sanjay-Dubri. The corridor habitat is mostly narrow ridge top forests. Based on the evidence from camera trap exercise under the national tiger estimation program, a tigress has recently moved from Bandhavgarh to Achanakmar. This corridor is severely impacted by linear infrastructures like Umaria-Sahdol railway line and national and state highways (NH78, SH9A, and SH8). During last four years, various development works related to widening of national and state highways were commissioned. Hence, appropriate wildlife passageways need to be developed for mitigating the long-term impact of these roads as barriers to wildlife movement across them.

The contiguous forest patch of Sanjay-Dubri Tiger Reserve and Guru Ghasidas National Park continue further to Tamorpingla Wildlife Sanctuary. From Tamorpingla Wildlife Sanctuary two habitat linkages (one via Semarsot Wildlife Sanctuary) connect Palamau Tiger Reserve and Lawalang Wildlife Sanctuary further. This landscape complex is a mineral rich area especially known for coal mines. Hence, care need to be taken while permitting mineral extraction. National highways (343, 75) and state highways (1, 3, 10) traverse these corridors and appropriate mitigation measures need to be commissioned.

Achanakmar-Kanha-Pench

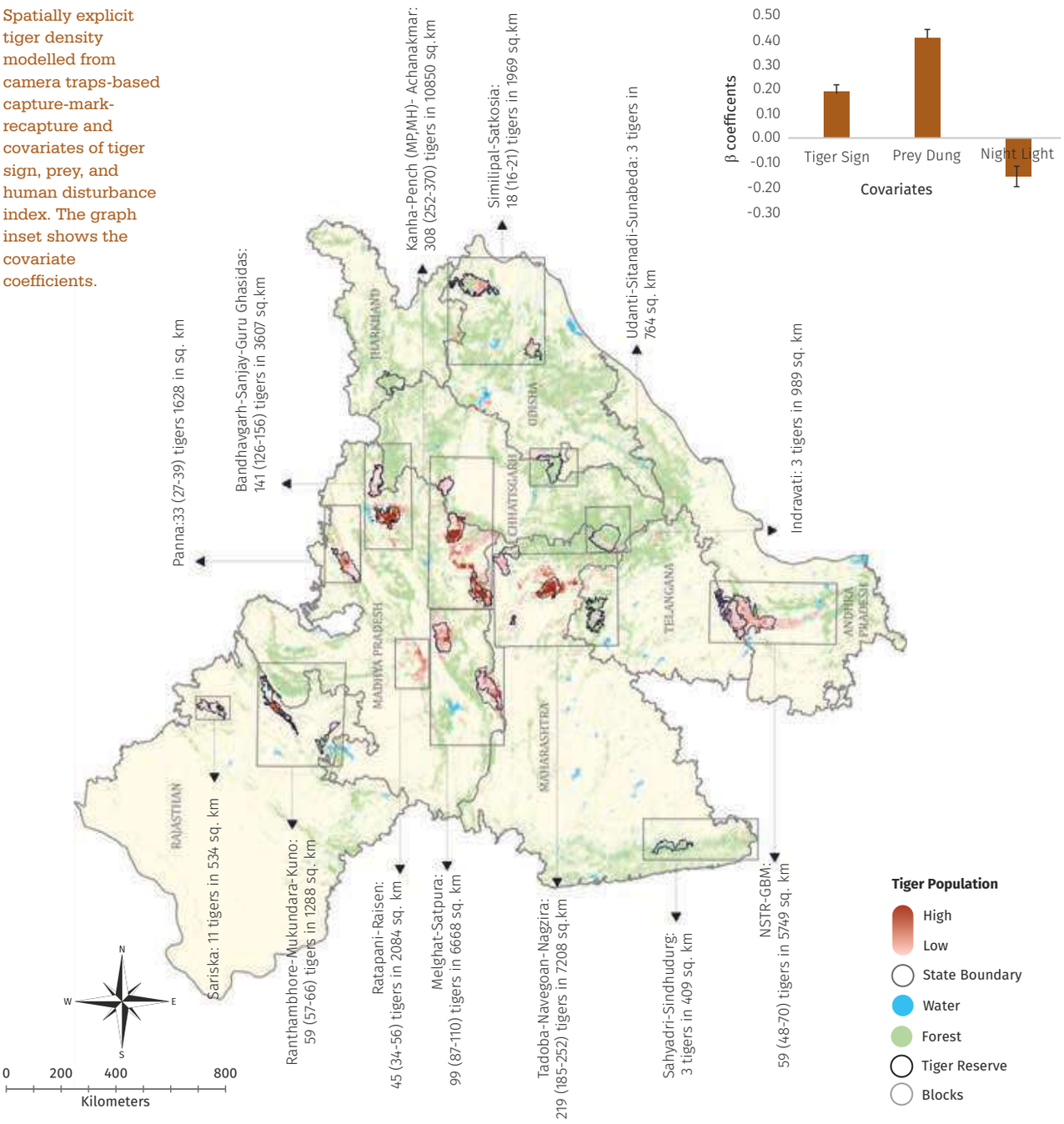
Kanha Tiger Reserve along with Balaghat Territorial Division, Pench Tiger Reserve, Madhya Pradesh, Pench Tiger Reserve, Maharashtra and Achanakmar Tiger Reserve together form the largest contiguous tiger population of 308 (252-370) tigers in the Central Indian landscape (Fig. 5.6). Ecologically Bhoramdeo Wildlife Sanctuary of Chattisgarh is a part of the Kanha system and should ideally be included as part of this tiger reserve. With two source populations, this part of the landscape has shown the best recovery since 2010. However, the status of Achanakmar Tiger Reserve continues to decline and serious investments in improving the protection regime are required here. Tiger populations of Balaghat and Seoni territorial divisions rival those of many tiger reserves and Madhya Pradesh governmental agencies should consider enhancing the status of these forest divisions to tiger reserves (or buffers of existing ones) and promote activities that benefit local community livelihoods. There are several corridors, which connects several PAs within the landscape. Kanha-Achanakmar corridor connects Achanakamar Tiger Reserve and Kanha Tiger Reserve through Phen Wildlife Sanctuary. This is a very important corridor for long-term sustenance of Achanakmar Tiger Reserve in the Achanakmar-Kanha-Pench - metapopulation framework. National Highway 12A traverse between core zone of Kanha Tiger Reserve and Phen Wildlife Sanctuary. The Bodai-Daldali bauxite mines are located within this corridor hence care needs to be taken to minimize activity that can hinder movement of wildlife.

Kanha-Pench corridor connects two major source populations of central India, namely Kanha Tiger Reserve and Pench Tiger Reserve. Functionality of this corridor is well established through genetics (Yumnam et al. 2014), radio-telemetry and camera trap-based studies. The corridor is sufficiently wide at Balaghat Forest Division to support good prey population and serves as refuge to dispersing male tigers and some resident female tigers. This corridor was in the lime light for the expansion of National Highway 7 and the broad-gauge conversion of Gondia-Mandla railway line, where wildlife passageways were developed in consultation with the Wildlife Institute of India. Kanha to Bandhavgarh connectivity via Dindori is patchy but functional and requires restoration. However, several state highways (11, 54) and major district roads also traverse this corridor at various places and these in turn need to be mitigated with appropriate wildlife passages.

Kanha Tiger Reserve is connected to southern Maharashtra tiger populations (tiger reserves of Nagzira-Navegaon and Tadoba) and to Indravati Tiger Reserve through forested patches of Chhattisgarh. These corridors maintain the sink populations of the tiger reserves of Navegaon-Nagzira Tiger Reserve and Indravati Tiger Reserve with the two major source populations of Kanha Tiger Reserve and Tadoba Tiger Reserve.This corridor complex is weakest at the junction of the three states of Madhya Pradesh, Maharashtra and Chhattisgarh where the forest connectivity is only in the form of fragmented patches interspersed with agriculture and small residential hamlets. The corridor connecting Indravati Tiger Reserve to Navegaon-Nagzira Tiger Reserve is threatened by the presence of Dina dam and reservoir of Regadi village where agriculture and irrigation project activities area likely restrict wildlife movement. The connectivities between Tadoba Tiger Reserve and Indravati Tiger Reserve as well as between Tadoba Tiger Reserve and the northern Telangana population are made of forests patches, which are relatively intact and at times interspersed with agriculture. National Highway 6 traverse through this corridor complex at two places, one between Navegaon and Nagzira, and another near Chabuknala in Chhattisgarh. There are various state highways, major district roads traversing through these corridors in Maharashtra, and many of them are under consideration of widening. Development along these roads needs to be monitored and controlled within forested areas.

Figure 5.6

Spatially explicit tiger density modelled from camera traps-based capture-mark-recapture and covariates of tiger sign, prey, and human disturbance index. The graph inset shows the covariate coefficients.



Tadoba-Navegaon-Bor

This subunit is shared by Tadoba Tiger Reserve , with the neighbouring forest divisions of Brahmapuri, Central Chanda, Chandrapur and Pandharkawada, wildlife sanctuaries of Umred, Karandla and Tipeswar and the tiger Reserve and Bor in Maharashtra. Tiger population in this block is estimated to be 219 (185-252). It is in this landscape that conflicts with humans and tigers are maximum. Predation by tigers on livestock being common and attacks on humans being occasional. A swift, dispassionate, and professional removal of problem individual tigers, as per the protocols of NTCA is essential to permit long-term tiger occupancy in this forest-agriculture-pasture mosaic and prevent community retaliation towards the population and species as a whole.

Ratapani-Bhopal-Dewas

This tiger subunit encompasses the human dominated area of Bhopal, the capital city of Madhya Pradesh. Ratapani Wildlife Sanctaury and forest divisions of Dewas, Bhopal and Sehore of Madhya Pradesh together form this block having around 45 (34-56) tigers.

Satpura-Melghat

Melghat Tiger Reserve is located on the Gawilgarh ridge of Satpura hills on the Madhya Pradesh-Maharashtra border while the Satpura Tiger Reserve is located within the same range in the north-east. This area has high potential for tiger recovery and can sustain about 400 tigers if the prey base can be built up through grassland management. Both tiger reserves have shown recovery after massive incentivised voluntary village relocation. This block has around 99 (87-110) tigers. This population block is tenuously connected to Pench Tiger Reserve. There are two important corridor complexes. Pench-Satpura: the habitat linkages between the tiger reserves of Pench and Satpura are through patchy forests intermixed with agriculture land, human habitation and mines. Camera trap and genetic studies ascertained the functionality of this corridor (Yumnam et al. 2014). National Highway 26B and State Highways (19B, 26) traverse through these corridors and appropriate mitigation measures need to be commissioned urgently. Part of this corridor near Satpura, passes through the coal belt and is under intense pressure from mining infrastructure in the form of roads and railway lines that connect coal-bearing region with industries. Satpura-Melghat: This corridor complex connects tiger reserves of Pench, Satpura and Melghat through two habitat linkages. One of the corridors is an offshoot of the Pench-Satpura linkage while the other is composed of the forested area of Hosangabad, Betul and Harda forest divisions of Madhya Pradesh. National Highways (59A, 69) and State Highway 26 traverse through the corridors at various places.

Sunabeda- Udanti Sitanadi

This block consisting of Sunabeda Wildlife Sanctuary of Odisha and Udanti-Sitanadi Tiger Reserve of Chhattisgarh is not only important for tiger recovery but also home to a small wild buffalo population. Tiger population in this block is estimated to be 3. Biotic pressure on the forest and the corridor is high as the area has Maoist presence.. Sunabeda Wildlife Sanctuary is contiguous with Udanti-Sitanadi Tiger Reserve.The corridor complex of Sunabeda-Udanti-Sitanadialso connects Indravati Tiger Reserve both to Udanti-Sitanadi Tiger Reserve and to Pamed Wildlife Sanctuary. This region has a law and order problem due to insurgency. However, due to the large size of the forested habitat in this landscape the area has potential for future tiger recovery through protection, restoration of law and order and management to augment prey. During last four years, new road network and widening of existing road network traversing these corridors are being carried out so as to combat the insurgents and for the mineral extraction by the mining sector . Appropriate mitigation measures for wildlife passageways need to be thus planned and implemented for maintaining habitat connectivity in this landscape.

Gadhchiroli-Indravati-Adilabad

This block covering some of the best forests of this landscape spans the insurgency prone areas of Chhattisgarh, Telangana and Maharashtra. This block along with Udanti-Sitanadi Tiger Reserve and Pamed Wildlife Sanctuary also holds the last surviving free-ranging population of the Asiatic wild buffalo in Central India, numbering close to 30-50 individuals. Minimum tiger number in this block was estimated to be 3. Due to the law and order situation, these forests could not be sampled appropriately by camera traps or phase I protocols and tiger presence was inferred through faecal DNA. Once law and order is restored, this block has high potential for recovery of wildlife.

Similipal-Satkosia

The tiger reserves of Similipal and Satkosia represent a unique lineage of tigers (Kolipakam et al. 2019). It is in this population that occasional melanistic tigers occur. Tiger population in this block is severely depressed and is estimated to be around 18 (16-21). Therefore, all efforts should be made to recover this population by controlling poaching of tigers and their prey through snaring. It may be essential to

supplement tigers and the closest genetic cluster that can be used for supplementation is from Bandhavgarh Tiger Reserve. The tiger reserves of Similipal and Satkosia are connected through adjoining the forest divisions of Keonjhar, Dhenkanal, Kendujhar and Anugul and the wildlife sanctuaries of Hadgarh, Kuldiha and Kapilas in Odisha. These areas have some of the prime habitats for tigers and elephants. However, this area has high mineral deposits and is earmarked for mining activities. National Highways (215, 23, 42, 200) traverse these corridors at various places.

Nagarjunsagar Srisailam-Amrabad

This landscape block has one of the largest contiguous forests blocks which can sustain ~400 tigers if appropriate prey base is restored. Currently, it harbours 59 (48-70). The erstwhile Nagarjunsagar-Srisailam Tiger Reserve was administratively bifurcated into two tiger reserves-Amrabad Tiger Reserve and Nagarjunsagar Srisailam Tiger Reserve after reorganization of the state of Andhra Pradesh. There are several protected areas with suitable prey base and habitat in this area such as Sri Lankamalleswara Wildlife Sanctuary, Sri Penusila Narasimha Wildlife Sanctuary and Sri Venkateswara National Park in the Eastern Ghats, which can together form a metapopulation. Nagarjunsagar -Sri Venkestwara corridor: This habitat corridor between Nagarjunsagar Srisailam Tiger Reserve and Sri Venkestwara National Park is mostly through forested habitat and passes through the wildlife sanctuaries of Gundla Brahmeswaram, Sri Lankamalleswaram and Sri Penusila Narasimha. State Highways (31, 34,56,57) traverse the corridors at various places and appropriate mitigation measures such as wildlife passageways need to be constructed. Development activity in the township of Sidhavatam, the major bottleneck of this corridor, requires restorative management.

Sahyadri-Radhanagri

This population block is the northern most limit of Western Ghats population which consists of Koyna Wildlife Sanctuary, Chandoli National Park, Radhanagri Wildlife Sanctuary and forests of Sindhudurg. This block has poor prey base and recovery of tiger population is possible once prey base is restored. Sahyadri Tiger Reserve and Radhangari Wildlife Sanctuary are connected to the tiger habitats of Goa which in turn is contiguous with Kali Tiger Reserve of Karnataka. Currently there are no major source populations of tigers in this region. Within and around the corridors, changes in habitat quality coincide with mining activities (around the forest ranges of Mollem, Kulem, Malpon in Goa), agricultural expansion (around the forested areas of Chandgad, Sawantwadi, Kankavali, Kurang, Pachal and Amba in Maharashtra) and roads. National Highways (4A, 204), State Highways of Maharashtra (116, 277, 111) and State Highway 4 of Goa traverse through the corridors at various places; appropriate wildlife passageway need to be constructed. Major land-use change is also visible around the popular tourist destinations in the corridors (e.g. the forested areas of Amboli, Radhanagri, and Chandoli).

Spatial Occupancy of Co-predators in Central Indian and Eastern Ghats landscape, 2018-19

Leopard

(Panthera pardus)

[Wildlife (Protection) Act 1972

Schedule I

IUCN Red List: Vulnerable

Leopard occupancy within the forested areas of the central indian landscape was 110,653 km^2 (Fig. 5.7). Leopard occupancy can be distinguished into four large contiguous patches: (a) the central block which extends across entire Madhya Pradesh, Chattisgarh, Jharkhand, Odhisa,Maharashtra and Northern Telengana. (b) the southern block covering Amrabad Tiger Reserve, Nagarjunsagar -SrisailamTiger Reserve, and extending into Sri Venkateshwara Wildlife Sanctuary. (c) the western block which comprises of western ghats of Maharashtra (Sahyadri hills) and the agricultural areas of adjoining Deccan. (d) the northern block comprises of Sariska, Ranthambore, Mukundhara tiger reserves and northern Madhya Pradesh comprised by the forests of Kuno-Palpur National Park, Madhav National Park and Sheopur forests. Leopards were found to occupied all the PAs and major forest tract of corridors of Central India landscape. Madhya Pradesh had the highest leopard occupancy in the landscape followed by Odisha and Maharashtra.

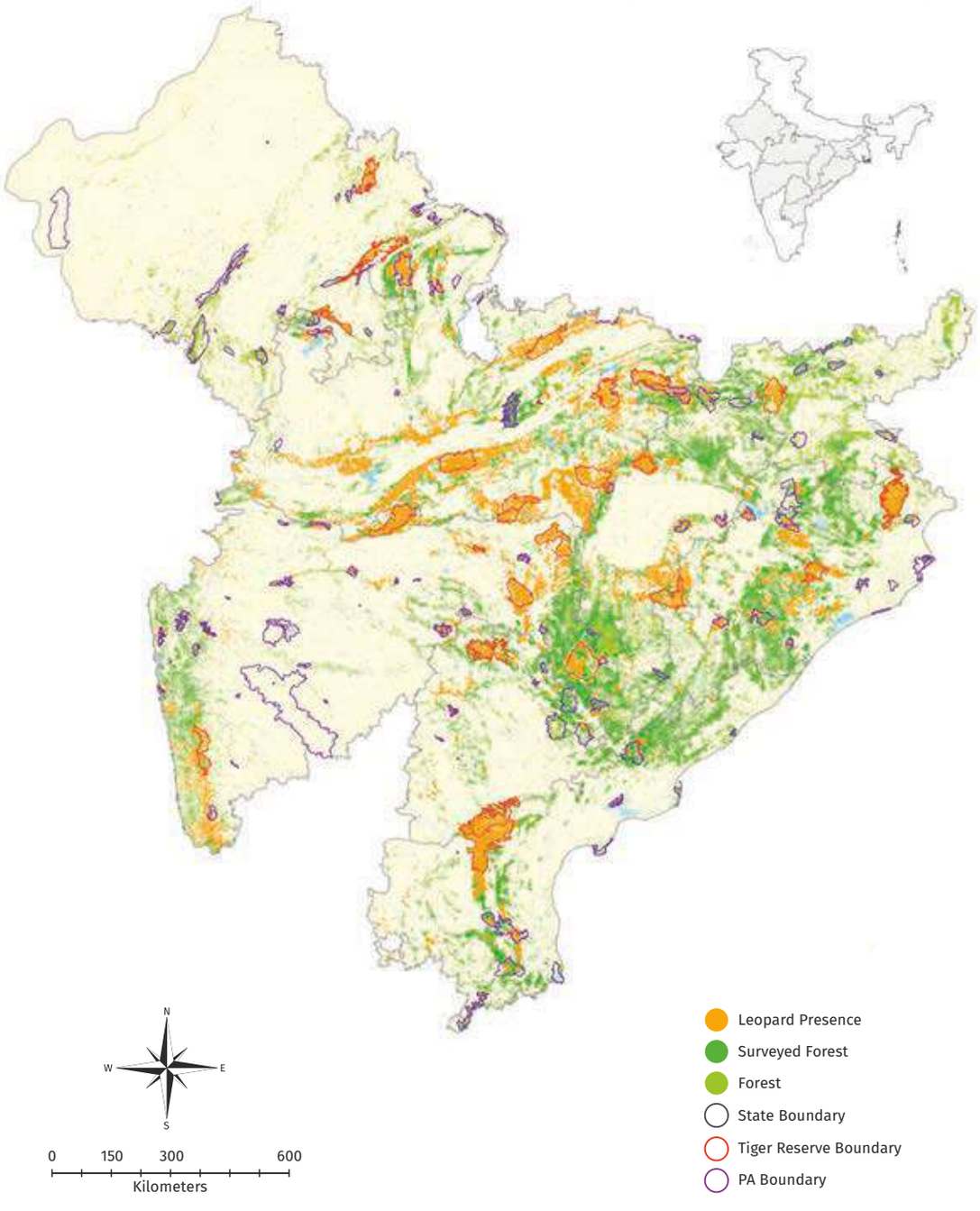


Figure 5.7
Leopard distribution in Central Indian and Eastern Ghats Landscape

Dhole or Wild Dog

(Cuon alpinus)

[Wildlife (Protection) Act 1972

Schedule II; IUCN Red List

Endangered]

Dhole had an occupancy of 67,576km^2 across the forested areas of central Indian landscape (Fig. 5.8). Dhole sign were recorded from tiger occupied forests of Madhya Pradesh, Maharashtra, Telangana and Andhra Pradesh. Dhole occupancy could be distinguished into four large contiguous patches a) the central block covering entire Madhya Pradesh, Chhattisgarh, Palamau in Jharkhand, Eastern Maharashtra and Northern Telangana. b) the southern block covering Amrabad, Nagarjunsagar -Srisailam Tiger Reserve, and extending into Sri Venkateshwara WLS. c) the western block comprising of the western Ghats of Maharashtra Sahyadri and Sindhudurg d) the eastern block which comprised of southern Jharkhand and some parts of Odisha. Majority of the Dhole occupancy was within the tiger reserves. Dhole seem to have become extinct from the northern block comprising the forests of Sheopur, Kuno, Madhav, Ranthambore, Mukundhara and Sariska.

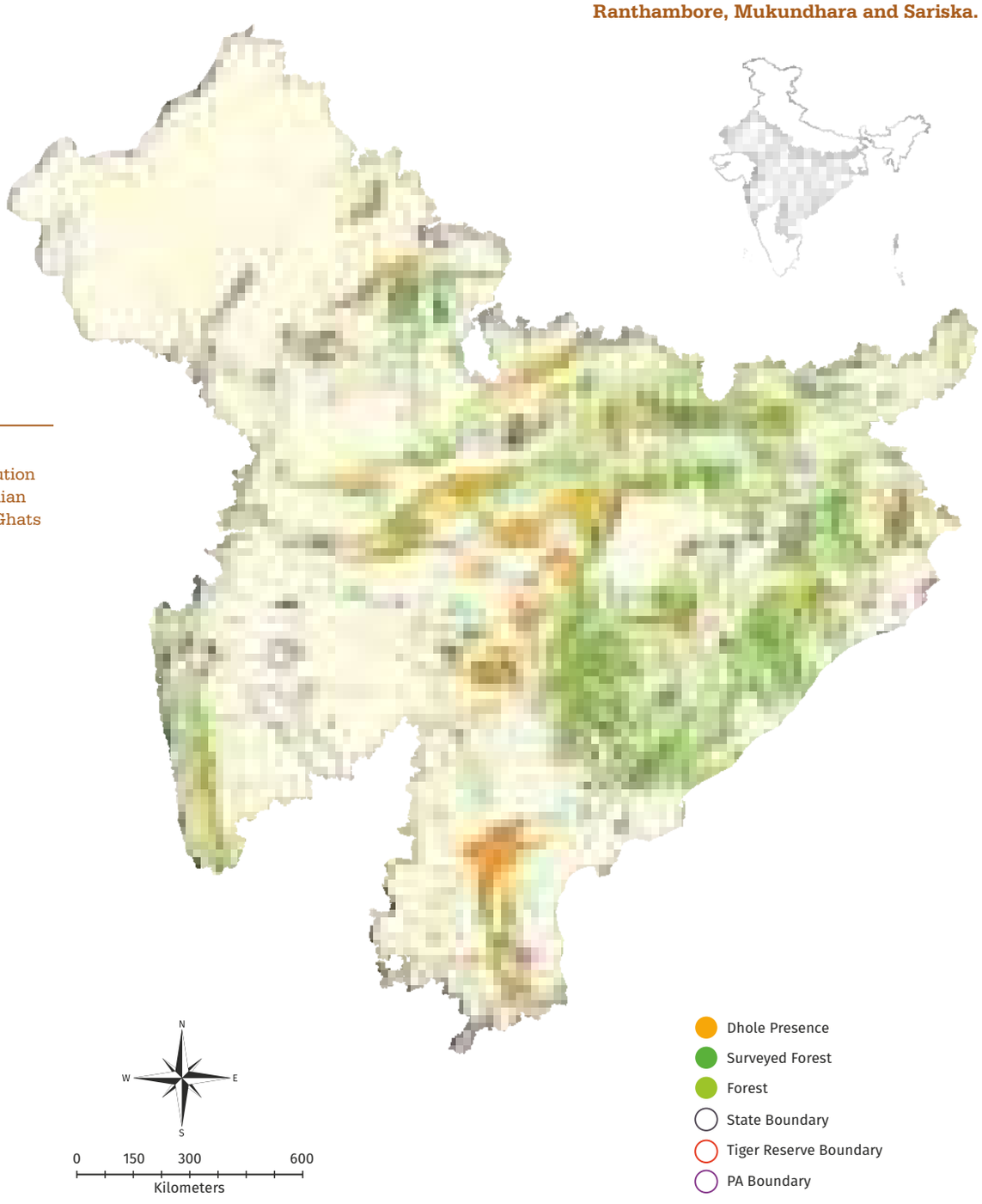


Figure 5.8

Dhole distribution in Central Indian and Eastern Ghats landscape

Striped Hyena

(Hyaena hyaena)

[Wildlife (Protection) Act 1972 Schedule III; IUCN Red List Near Threatened]

Hyena presence was recorded primarily from the dry deciduous and semi-arid forests of this landscape covering an area of 91,072 km^2 (Fig. 5.9). Hyenas were not observed to occupy high tiger density tiger reserves like Kanha, Bandhavgarh, Pench and Tadoba. Hyenas occupied dry forests of Betul and Bhopal forest circles of Madhya Pradesh, Palamau tiger reserve and Hazaribag of Jharkhand. The drier forests of eastern Rajasthan and northern Madhya Pradesh including Ranthambore, Sariska and Panna tiger reserves had contiguous occupancy of hyenas.

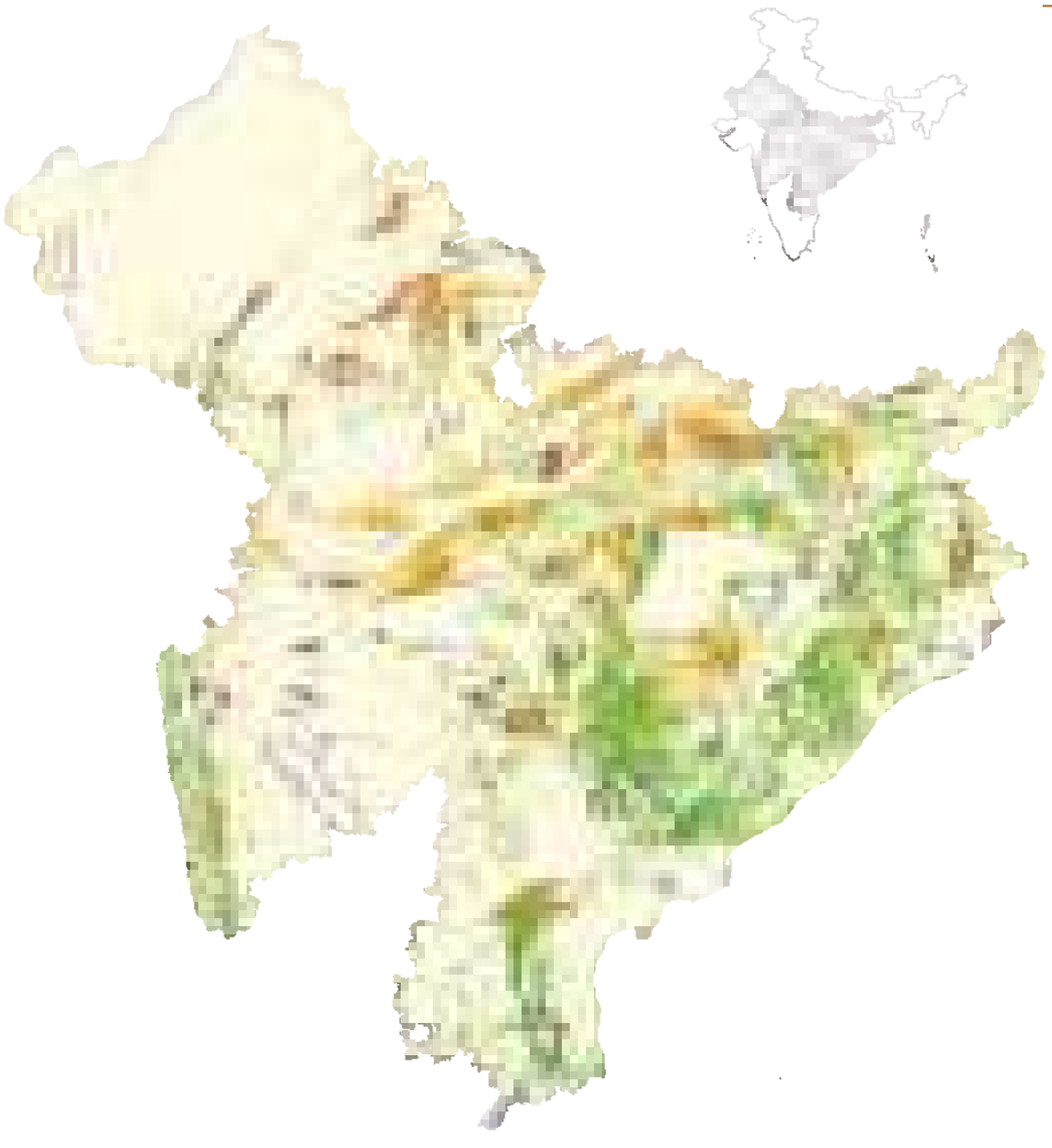


Figure 5.9
Hyena distribution in Central Indian and Eastern Ghats landscape

Sloth Bear

(Melursus ursinus)

[Wildlife (Protection) Act 1972 Schedule I; IUCN Red List Vulnerable]

Sloth bear signs were recorded from an area of 136,492km^2 (Fig. 5.10) from the forested areas of this landscape. Sloth Bear distribution was across all tiger occupied forests in Madhya Pradesh and Maharashtra, and Rajasthan except Sariska tiger reserve. Sloth bear occupancy could be distinguished into five sub units (a) Northern block comprising of Ranthambore, Mukundhara Tiger Reserves and northern Madhya Pradesh comprising of the forests of Kuno-Palpur, Madhav National Parks and Sheopur forests, (b) Central block comprising of Madhya Pradesh, Chhatishgarh, Maharashtra and Jharkhand (c) Southern block covering Amradab , Nagarjuna Nagarjunsagar -Srisailam Tiger Reserves, and extending into Sri Venkateshwara Wildlife sanctuary (d) Western Ghats of Maharashtra and the forested areas of adjoining Deccan (e)Eastern block formed by the PAs and forests of Odisha

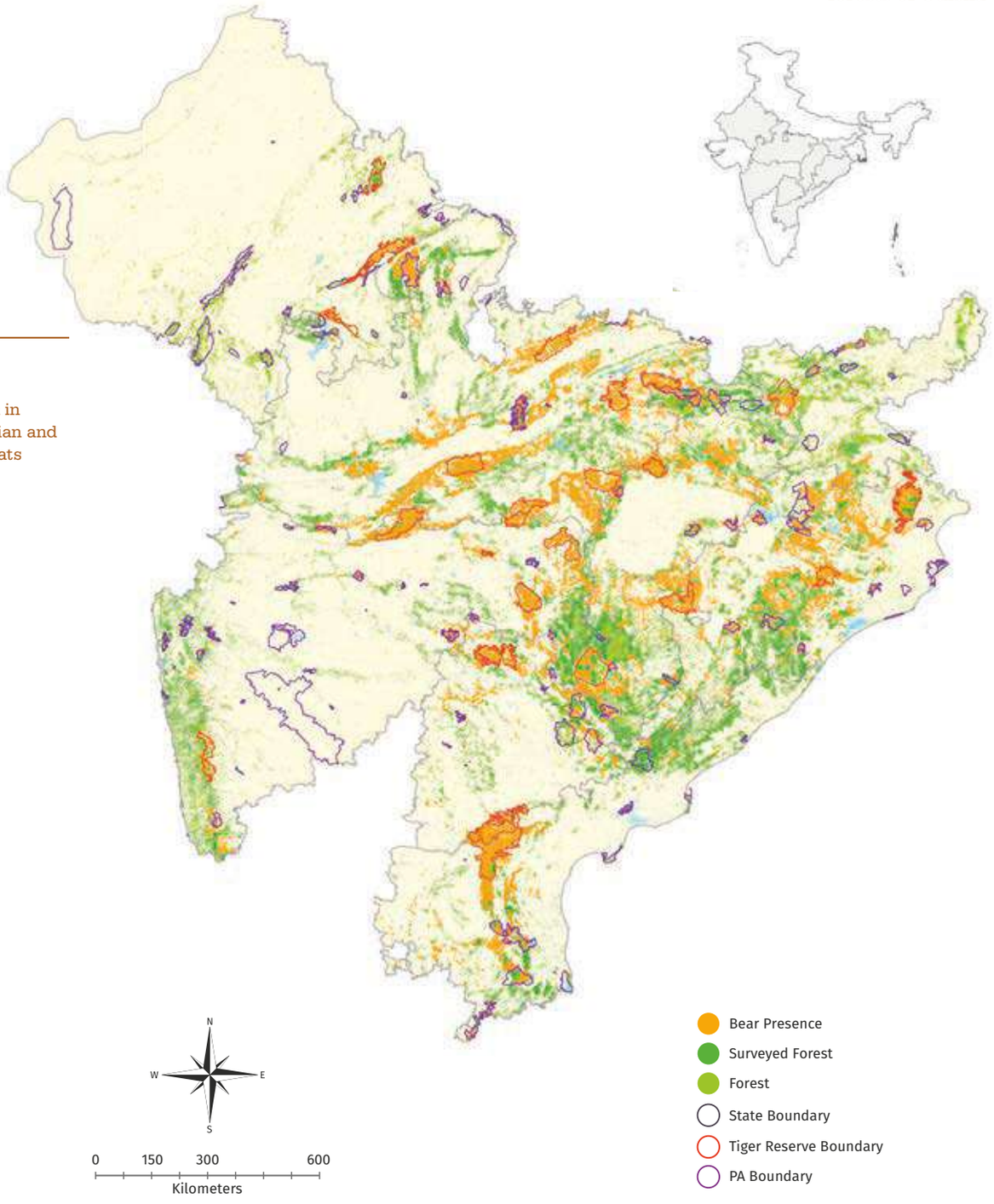


Figure 5.10
Sloth bear distribution in Central Indian and Eastern Ghats landscape

Golden Jackal

(Canis aureus)

[Wildlife (Protection) Act 1972 Schedule II; IUCN Red List Least Concern]

Jackal occupancy was recorded from 110,157 km² of the central Indian landscape (Fig. 5.11). Jackal signs were recorded almost across the entire sampled forests of Madhya Pradesh and Rajasthan except in a few ranges of Satpura tiger reserve. Protected areas and adjoining territorial forests of Odisha and Chhattisgarh also had presence of jackals in the landscape, while Maharashtra, Andhra Pradesh and Telangana recorded a comparatively low occupancy.

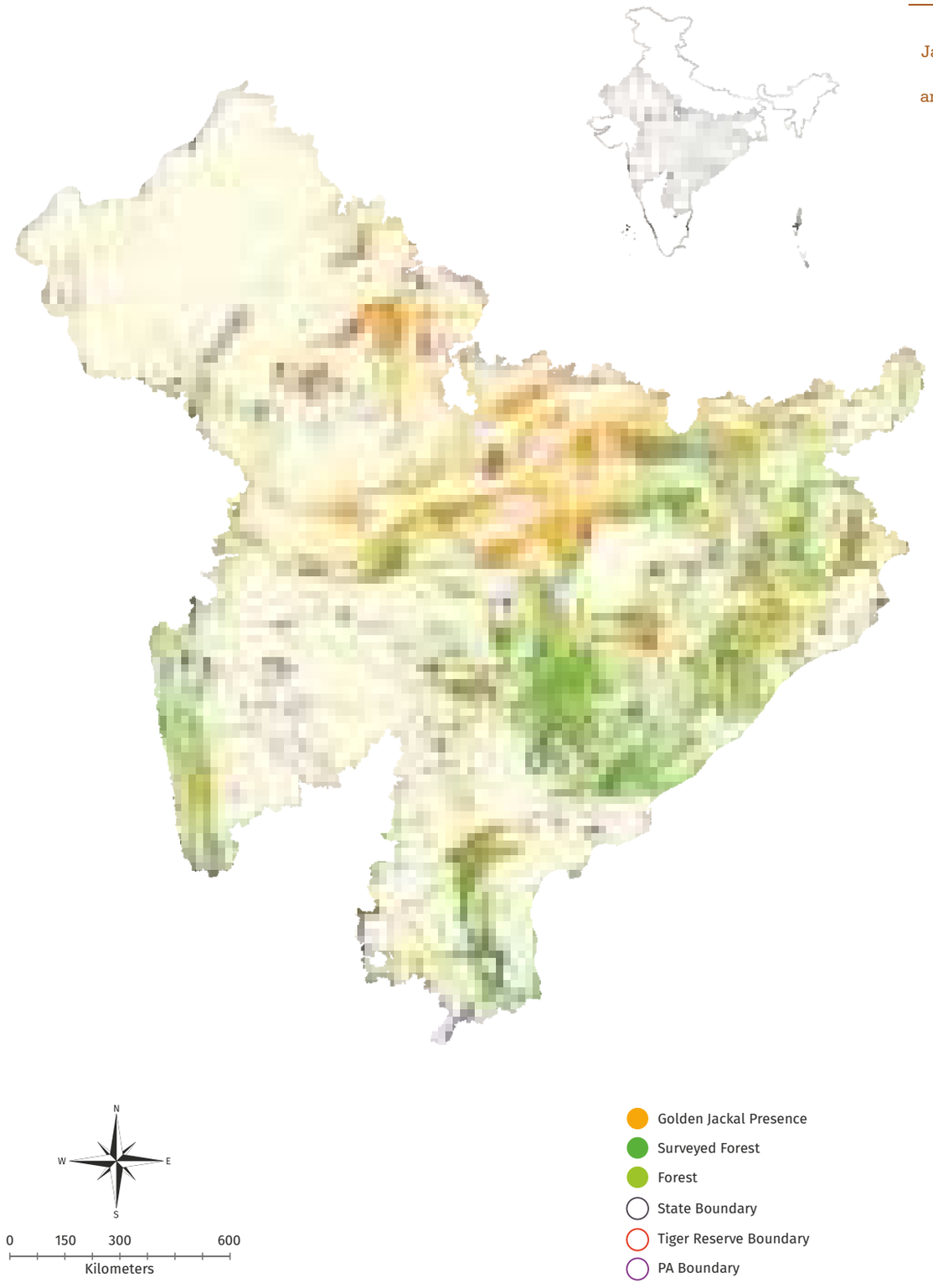


Figure 5.11
Jackal distribution in Central Indian and Eastern Ghats landscape

Indian Wolf

(Canis lupus pallipes)

[Wildlife (Protection) Act 1972

Schedule I; IUCN Red List

Least Concern]

Wolf presence was recorded primarily from the dry deciduous forests of this landscape covering an area of 63,291 km^2 (Fig. 5.12). Wolf occupancy could be distinguished into four population blocks (a) the northern block comprising of Ranthambore, Mukundhara Tiger Reserves and northern Madhya Pradesh (b) the central block comprising of Madhya Pradesh, Maharashtra and North Telangana (c) the eastern block comprising of Chhattisgarh, Odisha and Jharkhand (d) Isolated forests of Andhra Pradesh and southern Maharashtra.

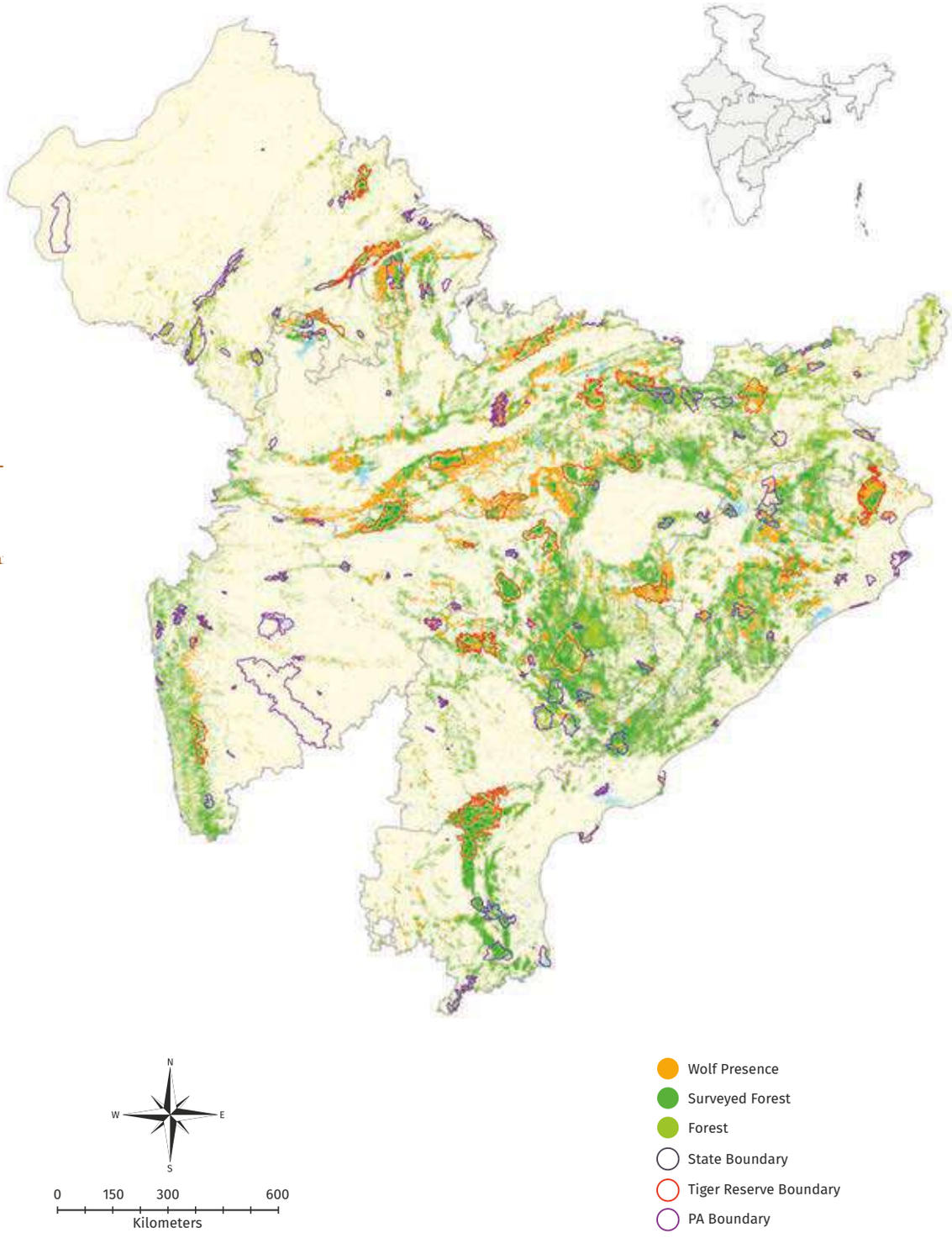


Figure 5.12
Indian wolf distribution in Central Indian a Eastern Ghats landscape

Occupancy of major prey species in Central India and Eastern Ghats Landscape, 2018-19

Elephant

(Elephas maximus)

[Wildlife (Protection) Act 1972

Schedule I; IUCN Red List

Endangered]

Occupancy of elephants in this landscape was 4,867km^2 of the forested area (5.13). Elephants were recorded from Jharkhand, Odisha and Chhatisgarh. Jharkhand and Odisha are known to have resident populations of elephants in central India. Elephants colonized the forests of Chhattisgarh in the last 25 years and sporadic presence has been observed in Andhra Pradesh as well. They have also been reported from Sindhudurg and Kolhapur district of Maharashtra. During the last 4 years, elephants have colonized parts of eastern Madhya Pradesh and very recently Bandhavgarh Tiger Reserve, Sanjay-Dubri Tiger reserve and the adjoining areas of Kanha Tiger Reserve (Fig 5.13).

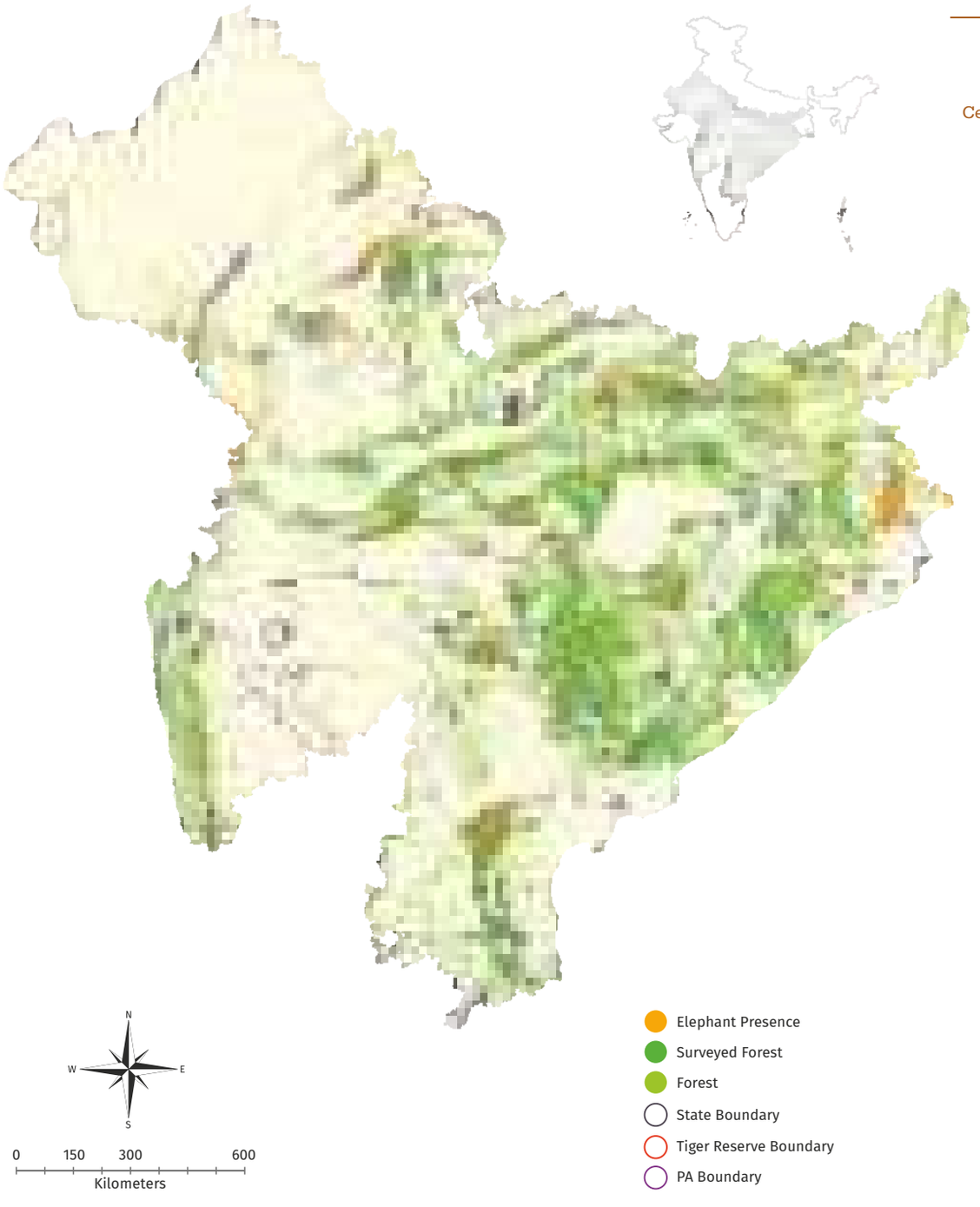


Figure 5.13
Elephant distribution in Central Indian and Eastern Ghats landscape

Barking Deer

(Muntiacus vaginalis)

[Wildlife (Protection) Act 1972 Schedule III; IUCN Red List Least Concern]

Barking deer showed continuous distribution across the Central India landscape except in the semi-arid regions of Rajasthan and Northern Madhya Pradesh with an occupancy of 109,075 km^2 of forested landscape (Fig. 5.14).

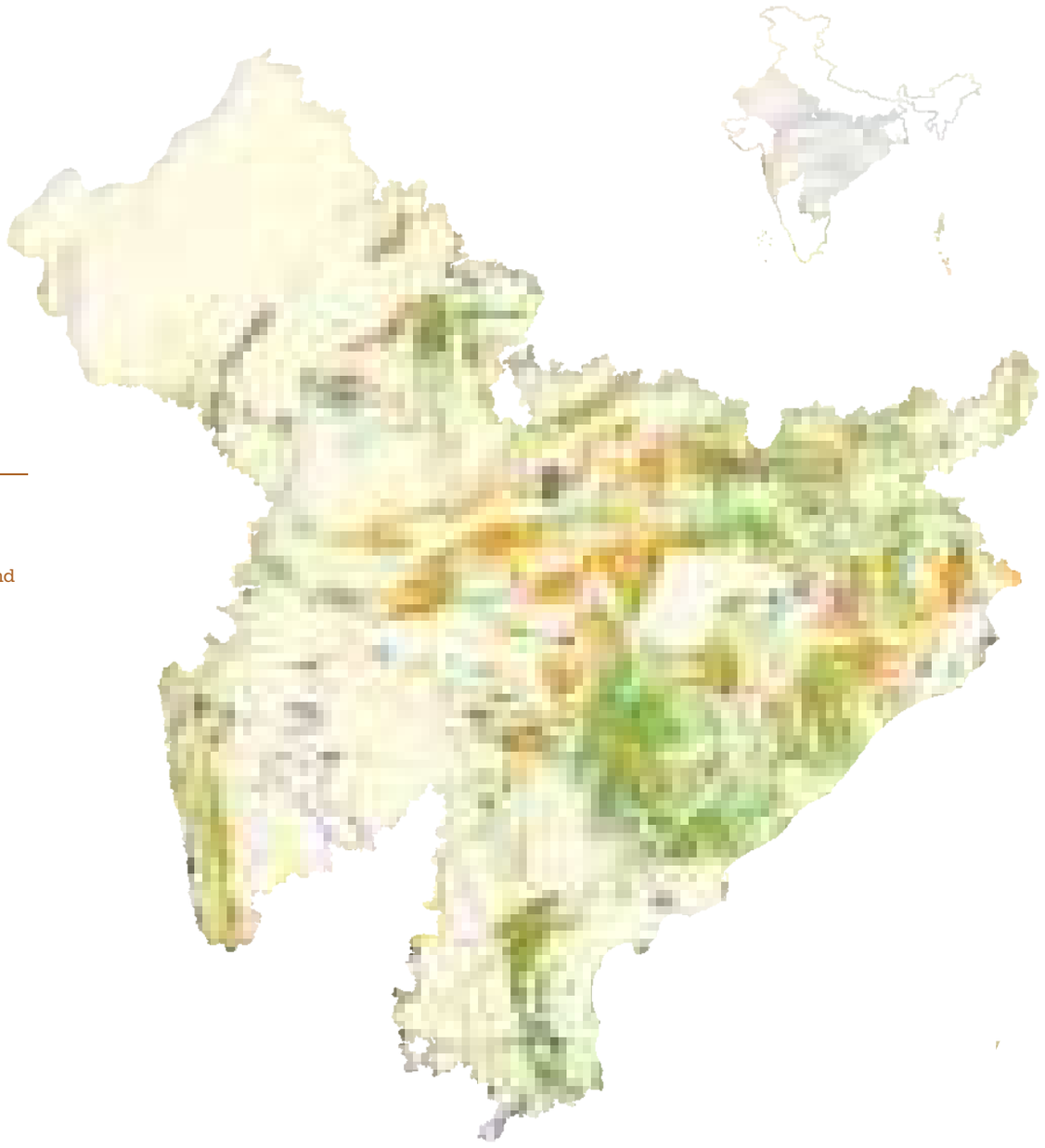


Figure 5.14
Barking deer distribution in Central Indian and Eastern Ghats landscape

Chital

(Axis axis)

[Wildlife (Protection) Act 1972 Schedule III; IUCN Red List Least Concern]

Chital was recorded to occupy a total area of 104,556 km² of forested landscape (Fig. 5.15). Chital distribution is contiguous with tiger occupancy. In Rajasthan, chital occupancy was restricted only to the Tiger Reserves due to sampling inadequacy; while in other parts of the landscape, chital was distributed in the forested areas around the protected areas and in many of the corridor habitats as well. The recorded occupancy was highest in the South Eastern Madhya Pradesh and Eastern Maharashtra landscape. Chhattisgarh and Odisha has relatively low occupancy of chital probably due to bush meat consumption that is rampant in this part of the landscape.

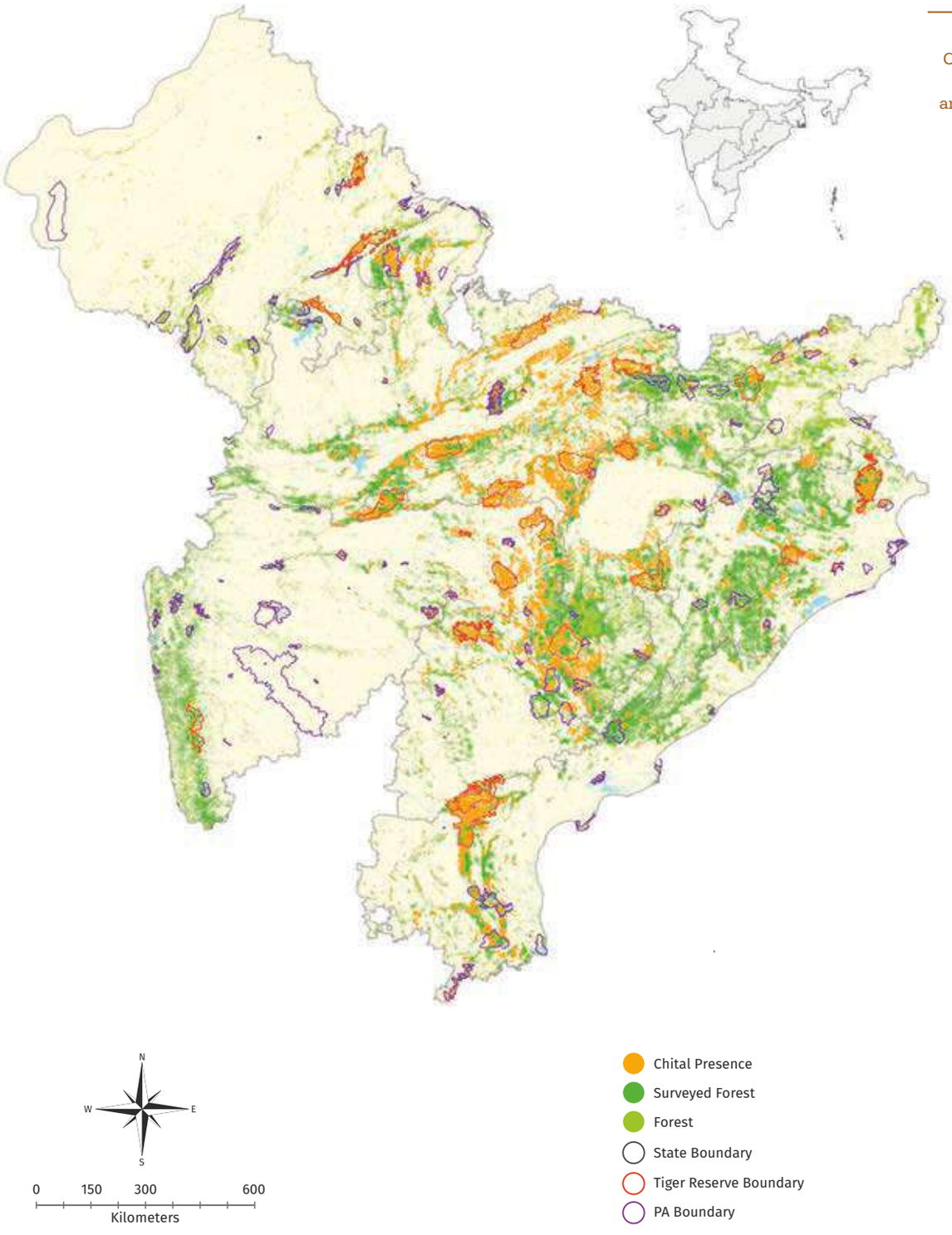


Figure 5.15
Chital distribution in Central Indian and Eastern Ghats landscape

Sambar

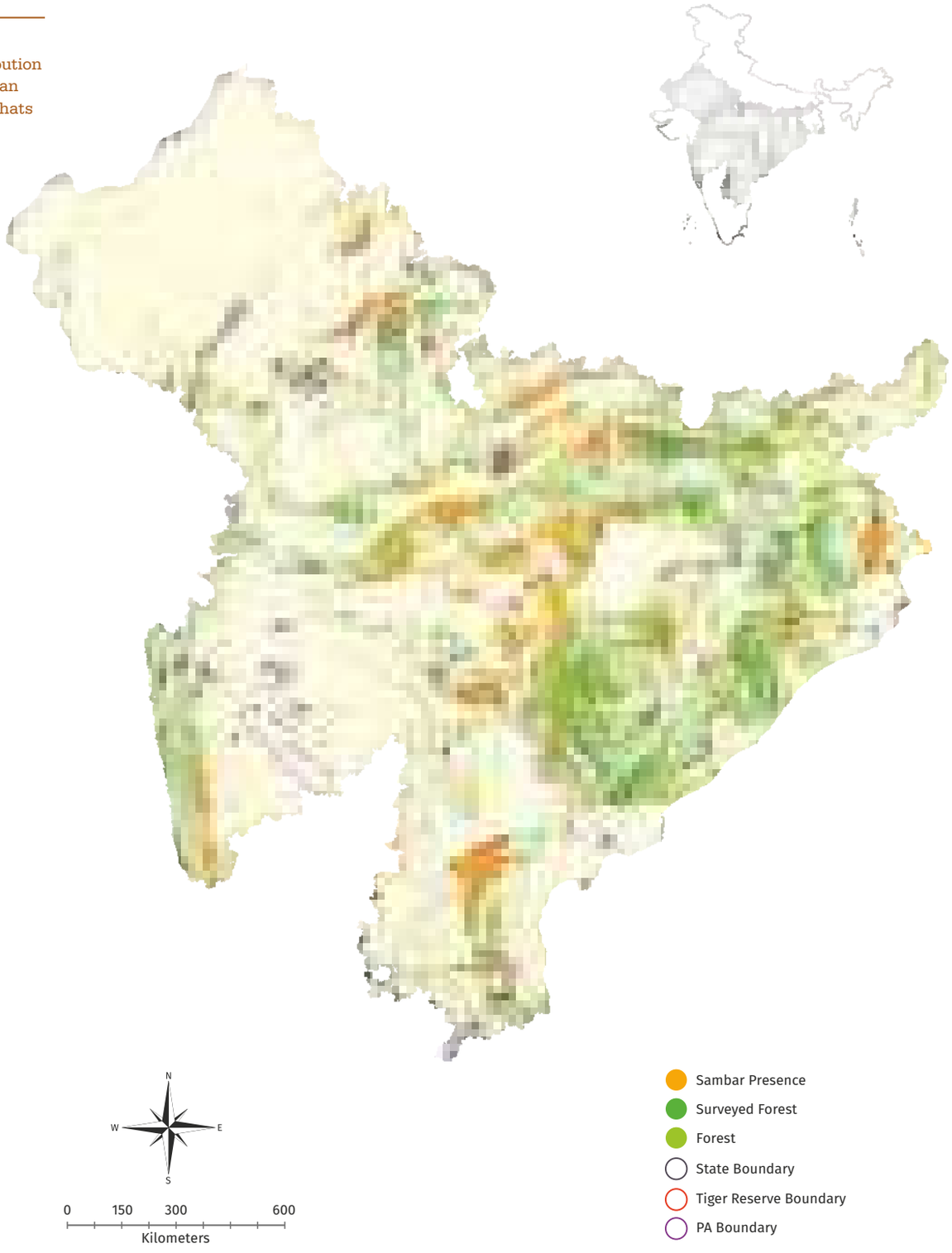
(Rusa unicolor)

[Wildlife (Protection) Act 1972 Schedule III; IUCN Red List Vulnerable]

Sambar was recorded in 84,734 km² area of the forests in the landscape (Fig. 5.16). Odisha had sambar occupancy only in the protected areas and adjoining forest divisions, while sambar was recorded only from Hazaribag and the adjoining forest divisions of Jharkhand. In Rajasthan due to sampling inadequacy, sambar was reported only from tiger reserves. In southern side of this landscape, sambar occupancy was recorded from Amrabad, Nagarjunsagar Srisailam Tiger Reserves, and extending upto Sri Venkateshwara Wildlife sanctuary.

Figure 5.16

Sambar distribution in Central Indian and Eastern Ghats landscape



Gaur

(Bos gaurus)

[Wildlife (Protection) Act 1972

Schedule I; IUCN Red List

Vulnerable]

Gaur distribution was recorded from south of the river Narmada, with an occupancy of 19,092 km^2 (Fig. 5.17). Gaur presence was primarily restricted to Protected Areas and was reported from Achanakmar- Kanha - Pench - Navegaon - Nagzira Navegaon - Tadoba complex, which represents a potential metapopulation. Bandhavgarh had a small population, which was reintroduced between 2011-2012. Gaur was also recorded from the tiger reserves of Satkosia and Similipal of Odisha and had low occupancy in Palamau Tiger Reserve. The northern Western Ghat complex of Sahyadri-Sindhudurg recorded good occupancy of gaur.

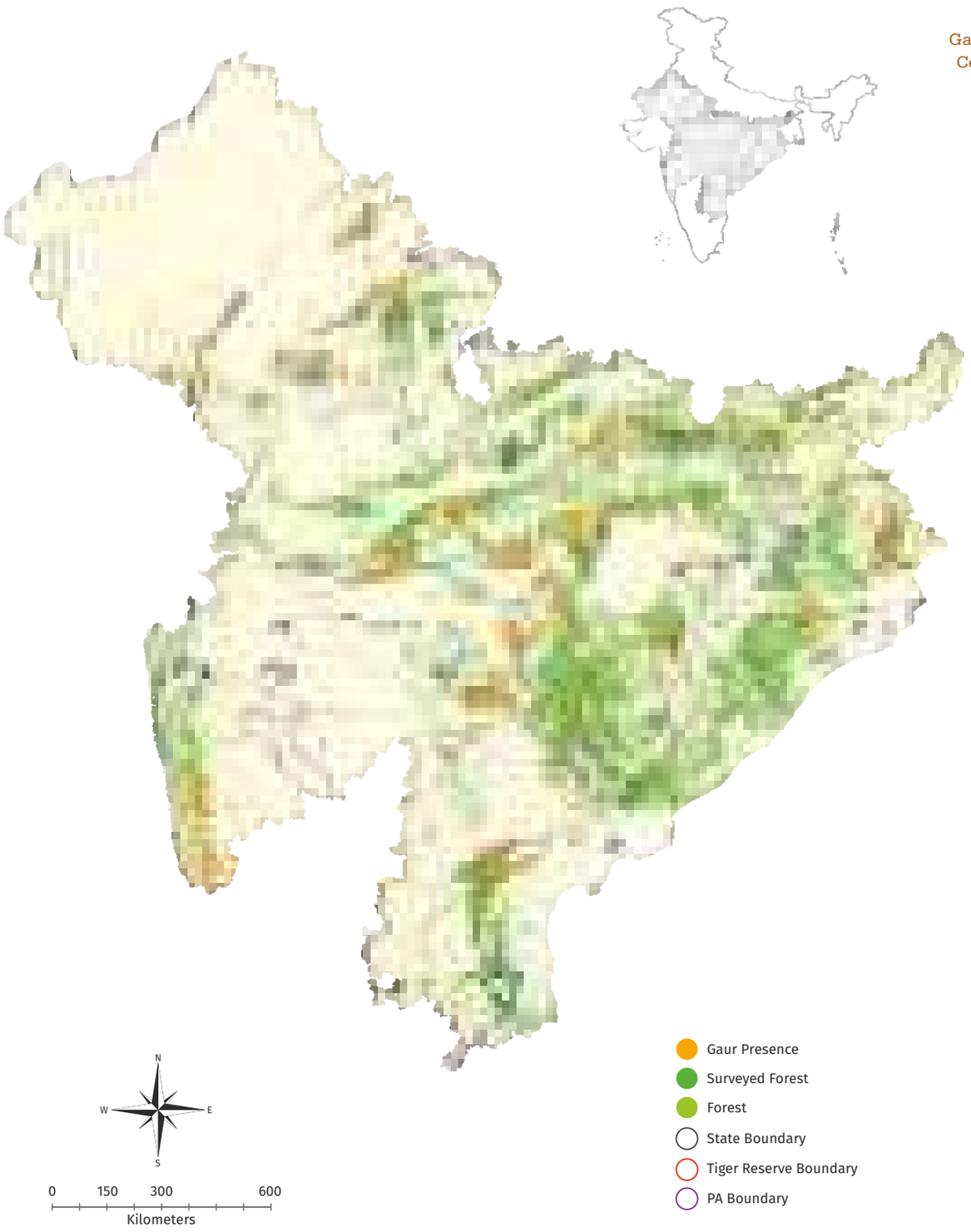


Figure 5.17
Gaur distribution in Central Indian and Eastern Ghats landscape

Wild pig

(Sus scrofa)

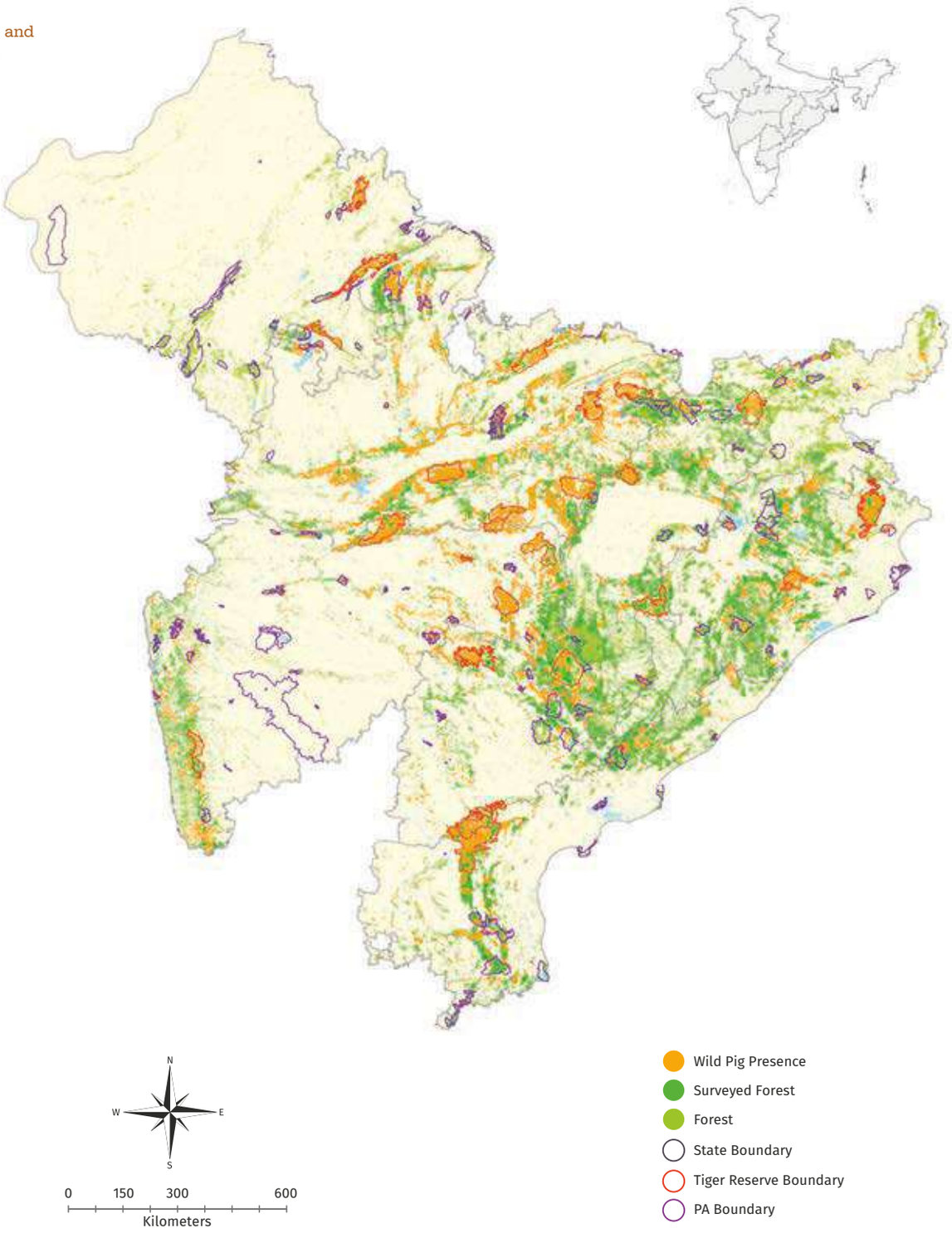
[Wildlife (Protection) Act 1972

Schedule III; IUCN Red List

Least concern]

Wild pig is the most widely distributed ungulate in the landscape which was recorded to occupy an area of 111,403 km^2 (Fig. 5.18). Although not declared as pest in this landscape it is attributed to cause severe crop depredation in parts of this landscape.

Figure 5.18
Wild pig distribution in Central Indian and Eastern Ghats landscape



Nilgai

(Boselaphus tragocamelus)

[Wildlife (Protection) Act 1972 Schedule III; IUCN Red List Least concern]

Nilgai was widely distributed in the agro pastoral patches of the landscape, however it was also recorded in the forested landscape of central India (100,503 km^2 area, Fig 5.19). In Odisha it was recorded only from Satkosia-Kalasuni Wildlife Sanctuary and the adjoining forests. Its occupancy was low in Kanha Tiger Reserve and Palamau Tiger Reserve while it was not recorded from Achanakmar Tiger Reserve and northern Western Ghats.

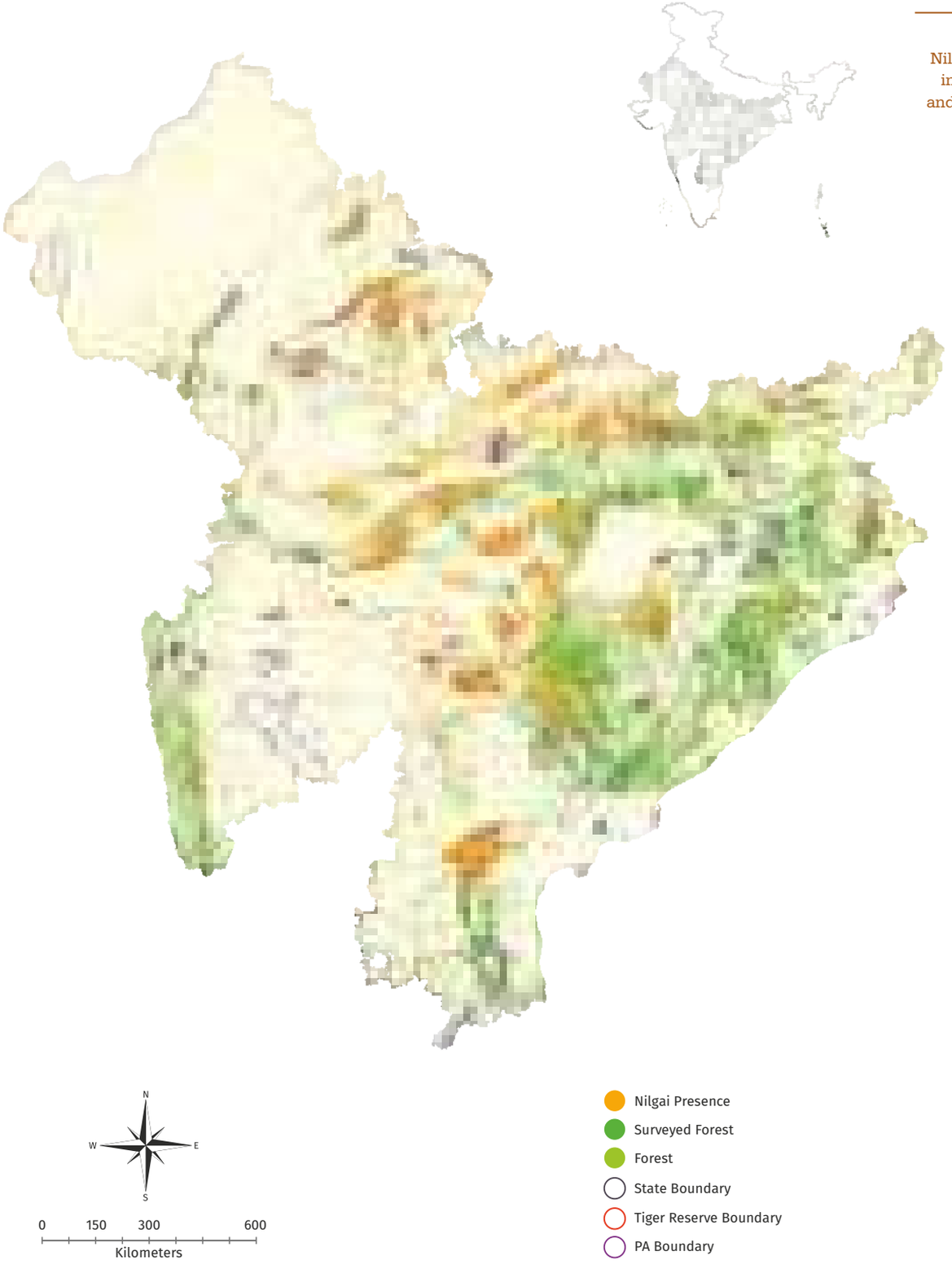


Figure 5.19
Nilgai distribution in Central Indian and Eastern Ghats landscape

Wild Buffalo

(Bubalus arnee)

[Wildlife (Protection) Act 1972 Schedule I; IUCN Red List Endangered]

Wild buffalo was recorded from two different pockets in India; one in North Eastern India and another within this landscape of Central India. The total area occupied by wild buffalo in Central India was 337 km^2 (Fig. 5.20). Its distribution was reported only from Udanti-Sitanadi, Indravati Tiger Reserves and Gadchiroli district of Maharashtra along with unconfirmed reports from Pamed Wildlife Sanctuary Chhattisgarh. The species mainly inhabits well watered and swampy grasslands areas, which are facing degradation and serious law and order issues due to extremism. The current population is critically low and also face threats in the form of extreme competition for resources with livestock, conflicts and habitat degradation. Conservation efforts, like those done for Barasingha in some tiger reserves, where buffalo are allowed to increase within large secure enclosures in well protected Tiger Reserves seems to be the only option for securing long term survival of this species in this landscape.

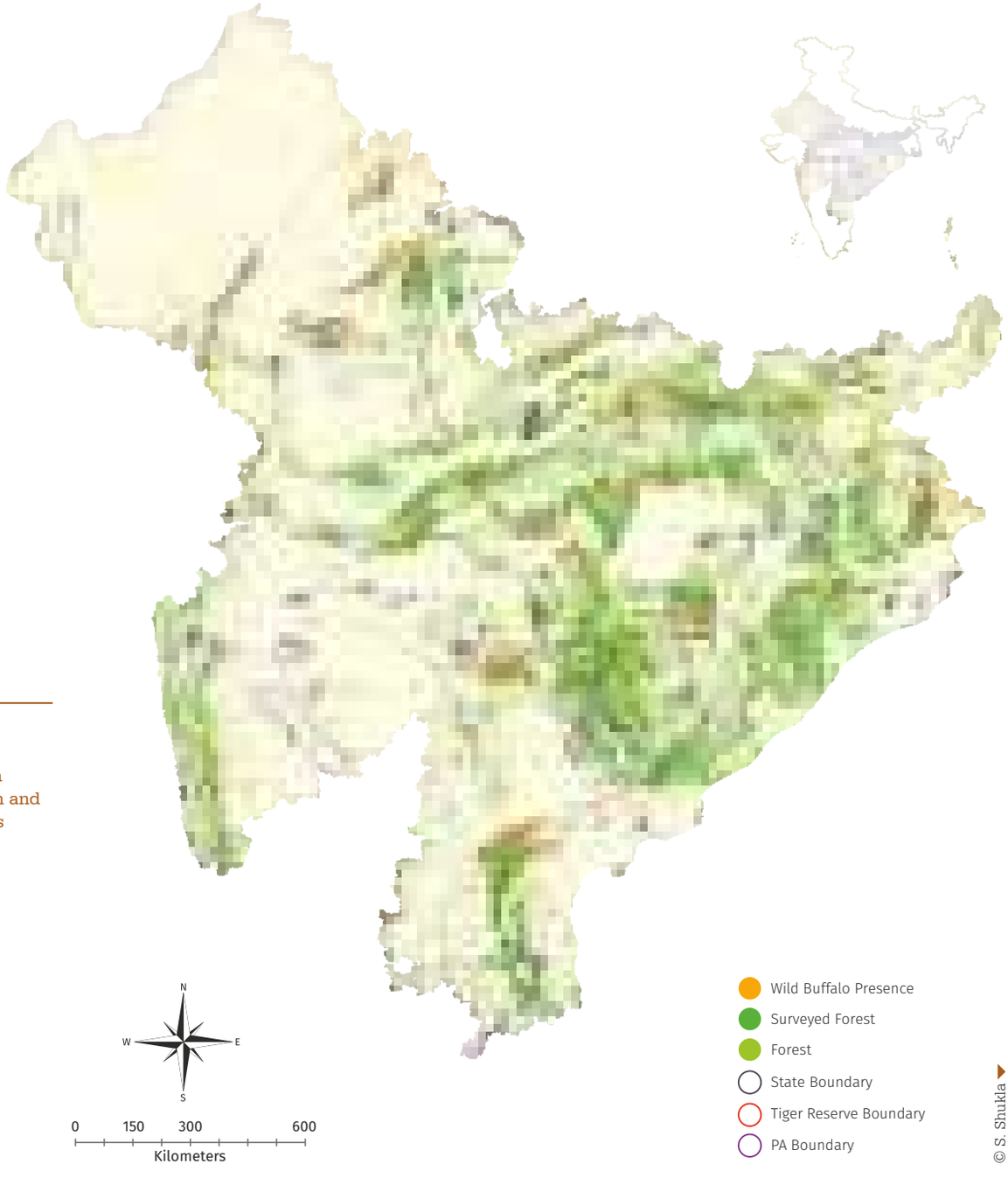


Figure 5.20
Wild buffalo distribution in Central Indian and Eastern Ghats landscape

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06

THE WESTERN GHATS LANDSCAPE

Background

The term Western Ghats refers to the unbroken hill chain (with the exception of the Palakkad/Palghat Gap) running roughly in a north-south direction, for about 1,600 km, parallel to the Arabian sea coast, from the river Tapi (about 21° 16' N) down to just short of Kanyakumari (about 8°19' N) at the tip of the Indian peninsula traversing through six Indian states (Daniels 1992). In some accounts, the term Western Ghats or Sahyadris is restricted only to the western escarpment of the peninsular plateau from the Tapi river, southwards to the region of Kodagu, (about 12 degrees N) while the higher mountain ranges further south, including the Nilgiris, the Anamalais, the Cardamom hills and the Agasthyamalai range, are referred to as a distinct geological entity named the Southern Block (Mani 1974). For our purposes we use the term Western Ghats in the broader sense to include the entire tract of hills from the Tapi to Kanyakumari.

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Location

The coastal plains of Konkan in the north, Kanara in the centre and Malabar in the south, bound the Western Ghats on the west. The coastline varies in width, from 30-60 kilometers, being the narrowest around 14-15^0 N (Daniels 1992). In the north, the Ghats are bounded by the Satpura range positioned in an east-west direction, forming an important bio-geographical barrier between the Western Ghats and the remaining parts of India. The Vindhya and Ajanta ranges in the north further strengthen this barrier. The contiguity of the Western Ghats is disrupted at three locations. Around 16^0 N is the Goa gap, then the 40 kilometer wide Palakkad/Palghat Gap around 11^0 N, followed by the southernmost and the narrowest Shencottah gap at 9^0 N. Recent studies indicate that such geographical barriers have impacted the population and genetic structure of wildlife populations across the gaps (Robin et al. 2010).

The Western Ghats mostly follow a south-south-eastern direction with about 60% of the range located within the State of Karnataka. Anshi-Dandeli covers the hill ranges of northern Uttara Kannada district in the taluks of Joida and Haliyal. The Kudremukh and Baba Budangiri hills around Chikamagalur are located in the central zone while the Brahmagiri hills situated towards the southern regions of the State form a barrier between Coorg and Wayanad. South-east of Mysore, the Biligiri Ranganaswamy hills in Karnataka link the Western and Eastern Ghats which extend further east as the Shevaroy and Tirumala hills in Andhra Pradesh. These hills are considered to be a 'dislocated' part of the Western Ghats owing to the northwesterly movement of this area and are an important corridor for movement of biogeographical affinities of flora and fauna between the two regions. The Nilgiris (Blue Mountains) located between the Coimbatore plains and the Mysore plateau (900-1,200 m) at the western-most part of Tamil Nadu and the junction of Kerala and Karnataka are separated from the Mysore plateau by the Moyar gorge (Mani 1974). The 2,600 km^2 Nilgiri plateau is at an elevation of 1,800-2,500 m and rises abruptly on all sides and has several Protected Areas. This plateau has a precipitous drop of 1,800 m on the east within three kilometers and is home to indigenous tribes such as the Todas, Kotas, Kurumbas and Badagas (Hockings 1989).

Between the Palakkad and the Shencottah Gaps is located the Anamalai Range along with the Nelliampathi hills. This region has a large network of Protected Areas around the Valparai plateau which covers about 200 km^2 in the Anamalai Range. The region is home to several indigenous communities of different ethnic origins such as the Kadar, Muthuvar and Malai Malasar (Chandi 2008). The highest peak in peninsular India, Anaimudi (2,695 m) is located in this region within Eravikulam National Park in Kerala.

East of the Anamalais is the Palni range (Kodaikanal hills) in Tamil Nadu which extends further into the Sirumalai-Ammayanayakkanur-Ayyalur hills and the Varshanad-Andippatti range towards the Vaigai valley. South-west of the Palnis are the Cardamom hills that partly shape the boundary of Kerala and Tamil Nadu. To the south of the hills lies the Periyar Tiger Reserve and to its east in the rain-shadow region, is the Srivilliputtur Wildlife Sanctuary in Tamil Nadu. Watersheds of important rivers like the Periyar and Pamba are located within this region.

Towards the southern end of the Western Ghats, the range becomes narrow with steep slopes on both sides until about 20 kilometers from Kanyakumari. The Agasthyamalai hills (Ashambu hills) are located within this zone between the Cardamom hills and the Aryankavu as with the Agasthyamalai peak (1,868 m) being the highest part of the region. Kanikkaran, one of the oldest hunter-gatherer tribes is known to live here.

Ecological Background

The major biogeographic zones of this region include the Western Ghats-Malabar plains, Western Ghats-mountains, Deccan Peninsula-Central plateau, Deccan Peninsula-Deccan south), East coast and West coast with nine ecoregions as per Rodgers and Panwar's (1988) classification. From an ecological perspective, this region with a total forested area of 1,01,467 km^2 (Qureshi et al. 2006) comprising of eleven (Sayhadri TR, Maharashtra was included in Central India for convenience) notified tiger reserves, about 20 national parks and 68 wildlife sanctuaries forms one of the largest Protected Area networks in India.

The climate is humid and tropical in the lower reaches tempered by the proximity to the sea. Elevations of 1,500 m and above in the north and 2,000 m and above in the south have a more temperate climate. Average annual temperature here is around 15 °C. In some parts frost is common, and temperatures touch the freezing point during the winter months. It has also been observed that the coldest periods in the southern Western Ghats coincide with the wettest. During the monsoon season between June and September, the unbroken Western Ghats chain acts as a barrier to the moisture laden clouds. The heavy, eastward-moving rain-bearing clouds are forced to rise and in the process deposit most of their rain on the windward side. Rainfall in this region averages 3,000-4,000 mm with localized extremes touching 9,000 mm. The eastern region of the Western Ghats which lie in the rain shadow, receive far less rainfall averaging about 1,000 mm bringing the average rainfall figure to 2,500 mm. Some areas to the north in Maharashtra while receiving heavier rainfall are followed by long dry spells, while regions closer to the equator receiving less annual rainfall, have rain spells lasting almost the entire year.

The main types of soils found in the Western Ghats are red soils, laterites, black soils and humid soils. The red soils are developed on the Archean crystalline and are brown, grey or black, is deficient in organic matter, phosphoric acid and nitrogen (Subramanyam and Nayar 1974). Evergreen forest of *Calophyllum, Dipterocarpus, Hopea*, *Myristica* and *Xylia* are characteristic of red-soil areas. The laterites consist of 90-95% of iron, aluminum, titanium and manganese oxides and are deficient in lime and organic material, and extend up to 1600 m in the Western Ghats. *Shorea* and *Xylia* are the dominant species in lateritic soils of Western Ghats. Black soils, formed out of the basaltic Deccan lava, are deficient in organic matter, nitrogen and phosphoric acid, but generally have enough lime and potash.

Flora and Fauna

The great topographic heterogeneity (from sea level to 2,695 m at its highest point, the Anaimudi peak) and a strong rainfall gradient (annual precipitation of <50 cm in sheltered valleys in the east to >700 cm along west-facing slopes) combine to give rise to a tremendous diversity of life forms and vegetation types, including tropical wet evergreen forest, montane stunted evergreen forest (shola) and grassland, lateritic plateaus, moist deciduous and dry deciduous forest, dry thorn forests, and grassland. Many of these are critical habitats for instance, the lateritic plateaus of Maharashtra, harbor unique floral elements as well as provide seasonal foraging grounds for large mammals such as gaur; the shola forests and grasslands of the southern Western Ghats are unique as well as highly vulnerable to future climate change; the riparian vegetation along the numerous east and west-flowing rivers and streams of the Ghats shelter high levels of plant and animal diversity in addition to acting as corridors, while the relict lowland dipterocarp forests and *Mysristica* swamps to the west are highly threatened.

The richness of floristic diversity of the region has been brought out by Cooke 1908, Fyson 1932, Gamble 1936, Rao 1984, Nair and Daniel 1986, Nayar, 1996. Nearly 5,800 species of flowering plants occur hereof which 56 genera and 2,100 species are endemic representing about 27% of the country's total species (Rao 1984). Of 645 species of evergreen trees (>10 cm dbh), about 56% are endemic to the Ghats (Gadgil et al. 2011). Among the lower plant groups, the diversity of bryophytes is impressive with 850-1000 species; of these 682 species are mosses with 28% endemics and 280 species are liverworts with 43% endemics. Another unique feature of the endemic flora of Western Ghats is the prevalence of monotypic genera such as *Adenon, Calacanthus, Polyzygus, Erinocarpus, Frerea, Griffithella, Haplothismia, Jerdonia, Lamprochaenium, Nanothamnus, Wagatea* and *Willisia* (Rao 1984). The medicinal plant diversity in Western Ghats is also of a very high order. The region with about 1,500 species of documented medicinal plants is known as the 'Emporium of Medicinal Plants' (Yoganarasimhan 1996, 2000).

Over 500 species of birds and 120 species of mammals are also known from this region. The Western Ghats region harbours the largest global populations of the Asian elephant, and other mammals such as

tiger, dhole, and gaur (Gadgil et al. 2011). Among the invertebrate groups, about 350 (20% endemic) species of ants, 330 (11% endemic) species of butterflies, 174 (40% endemic) species of odonates (dragonflies and damselflies), and 269 (76% endemic) species of mollusks (land snails) have been described from this region. The known fish fauna of the Ghats is 288 species with 41% of these being endemic to the region. The Western Ghats are particularly notable for its amphibian fauna with about 220 species of which 78% are endemic; the recent discovery of a new genus of frog, *Nasikabatrachus sahyadrensis*, with Indo-Madagascan affinity, in the southern Western Ghats affirms the importance of the region in harbouring these ancient Gondwanan lineages.

Similarly, the Ghats are unique in its caecilian diversity harbouring 16 of the country's 20 known species, with all 16 species being endemic. Of the 225 described species of reptiles, 62% are endemic; special mention must be made of the primitive burrowing snakes of the family Uropeltidae that are mostly restricted to the southern hills of the Western Ghats.

The Western Ghats also harbours a number of wild relatives of cultivated plants, including pepper, cardamom, mango, jackfruit and plantain. This biological wealth has paid rich dividends over the years. In fact, the tract was famous for its wild produce of pepper, cardamom, sandal and ivory.

Conservation Significance

The Western Ghats are second only to the North Eastern Hills as a treasure trove of biological diversity in India. Originally recognized as among the several global 'hotspots of biodiversity', the Western Ghats along with its geographical extension in the wet zone of Sri Lanka are now also considered one of the eight 'hottest hot spots' of biodiversity (Myers et al. 2000) and is a UNESCO World Heritage Site. The importance of the Western Ghats in terms of its biodiversity can be seen from the known inventory of its plant and animal groups, and the levels of endemism in these taxa (Gunawardene et al. 2007).

While the entire landscape has a human density of 318.7 persons/ km^2 (Qureshi et al. 2006), it is distributed irregularly with Kerala state having amongst the highest human density in India. The high human populations of the three States exert enormous pressure on these fragile systems for hydro-electric power, timber and agricultural output from plantations, livestock grazing, hunting etc. With this the biological diversity of the Ghats has been in continual decline over the last century and more especially in recent decades, with many biological communities and types being almost totally eliminated.

In the Western Ghats of Karnataka alone, nearly 12 percent of the forests have been completely lost in the past two decades (Ramesh 2001). Of the 62,000 square kilometers of potential area of evergreen forests in the Western Ghats, Gadgil and Meher-Homji (1986) estimated that only between 5,288 square kilometers (8.5 percent) and 21,515 square kilometers (34.7 percent) remained in the mid-1980s along the ranges. A more recent assessment by Myers et al. (2000) estimates that of the 182,500 square kilometers of primary vegetation that was estimated to have existed in the Western Ghats and Sri Lanka, only some 12,450 square kilometers (6.8 percent) remain today.

The remnant natural ecosystems of the Western Ghats are currently subject to a plethora of threats that vary widely in nature and intensity of their impacts on biodiversity. Most prevalent forms of proximate threats to the biodiversity of the Western Ghats include the following:

Human impacts and Conflict

Livestock grazing within and bordering protected areas by high densities of livestock (cattle and goats) is a serious problem causing habitat degradation across the Western Ghats. Illegal local hunting driven by tradition or demand for wild meat is pervasive across the Western Ghats. Hunters employ guns as well as a wide array of ingenious traditional methods such as poisoning, snaring and trapping (Karanth 1986, Madhusudan and Karanth 2002). Given that the Western Ghats exists within an intensely human-dominated landscape, human-wildlife conflicts are a common phenomenon. Very high human population densities in several parts of the hotspot further exacerbate the intensity of conflict. For example, villagers living close to Bhadra Tiger Reserve in Karnataka, lose approximately 11 percent of their annual crop production to raiding elephants about 12 percent of their livestock holdings to large carnivore predation

(Madhusudhan 2003). Human communities living within and adjacent to protected areas in the Western Ghats hotspot are frequently dependent on the extraction of Non-timber forest products (NTFPs) to meet a diversity of subsistence and commercial needs. For example, in the Western Ghats region of Karnataka, out of the 310 NTFP species extracted for various purposes, 40 species are collected for regional and global markets and 110 species are collected for consumption (Hegde et al. 2000). The extraction of fuelwood and fodder constitutes a significant and pervasive consumptive use within the Western Ghats negatively affecting canopy gaps, regeneration (lower fruit and seed production), stand density, basal area, and population structure and frequently resulting in the local extinction of overharvested species. Hill agro-ecosystems in the Western Ghats are dominated by tea, coffee, rubber, and monocultures of various species including the recently introduced oil palm. Nair and Daniel (1986) report estimates of; 750 km^2 of tea plantations above an elevation of 1,500 meters, at least 1,500 km^2 of coffee plantations, and 825 km^2 of cardamom estates. Large-scale planting of coffee in the Western Ghats began in 1854 when the British established themselves in Kodagu (Coorg). Over the years, tea, coffee, eucalyptus, cinchona, wattle, rubber, cloves etc. have displaced extensive patches of natural forests throughout the Western Ghats and are frequently associated with encroachment of surrounding forest areas. Plantations owned by private individuals and corporate sector continue to grow in the Western Ghats and constitute an important source of fragmentation of natural habitat within the hotspot. They also represent potentially important corridor areas for certain wildlife species. In the fragile mountainous regions of Western Ghats, the human population density varied between 100 and 300 habitants per square kilometer and only at a few places was lower than 100 (Pascal 1988). Growing populations within these settlements, in addition to changing lifestyles and consumption patterns are associated with intensifying impacts of human activities in surrounding forest areas. The unrestricted use of agrochemicals in the vicinity of forests, particularly in tea and coffee estates, causes serious damage to forest ecosystems and aquatic biota of the Western Ghats. Until the ban on green felling in early 1980 in India, logging was a significant factor in degradation of biodiversity in the landscape.

A developing country with an increasing human population is ever hungry for power and natural resources. The major threat to contiguous natural landscapes in the Western Ghats Landscape are mining, hydroelectric projects and infrastructure development. These activities especially within and in close proximity to Protected Areas result in irreversible habitat loss, disruption of habitat corridors and in-turn have long lasting impacts on geneflow, metapopulation structure and population persistence of species at the landscape scale.

In addition to the threats described above, other major local level proximate threats to biodiversity within the Western Ghats include fire, poaching for the commercial wildlife trade, illegal quarrying, presence of invasive plant species and unplanned developmental projects such as mini and micro-hydel projects as well as larger irrigation, hydel, wind energy, pipeline projects, power and telecom lines, roads and railroads.

Tiger Occupancy

Out of 2479 grid cells surveyed, tiger signs were detected in 409 cells in 2006, 361 cells in 2010, 370 cells in 2014 and 548 cells in 2018. This yielded in a naïve occupancy of 28,076 km^2 in 2006; 25,599 km^2 in 2010; 26,650 km^2 in 2014 and 39,226 km^2 in 2018.

When these grids were categorised as occupied (1111), colonized (0111, 0011, 0001), extinct (1000, 1100, 1110), absent (0000) and transitional (all other combinations), and compared with site covariates, we observed the hypothesized relation between the occupancy parameters and site covariates (Fig. 6.1). This relationship strengthened the relevance of using these site covariates for modeling occupancy parameters for tigers in this landscape.

Different occupancy models for correcting detection and incorporating the dynamic parameters modelled by covariates are shown in the Table 6.1. The beta estimates of the best model are provided in the Table 6.2. The detection probability consistently increased from 2006 to 2014, and declined in 2018. It was significantly related to the encounter rate of tiger signs in the grid. The initial occupancy of tigers in this landscape was 14%, and was significantly related to larger forest areas with high prey encounter rates (Fig 6.2).

Figure 6.1

The relationship between site covariates and occupancy status of tigers in the Western Ghats landscape. The occupancy categories were: Absent (0000), Extinct (1000, 1100, 1110), Colonized (0111, 0011, 0001), Present (1111) and Transitional (all other combinations).

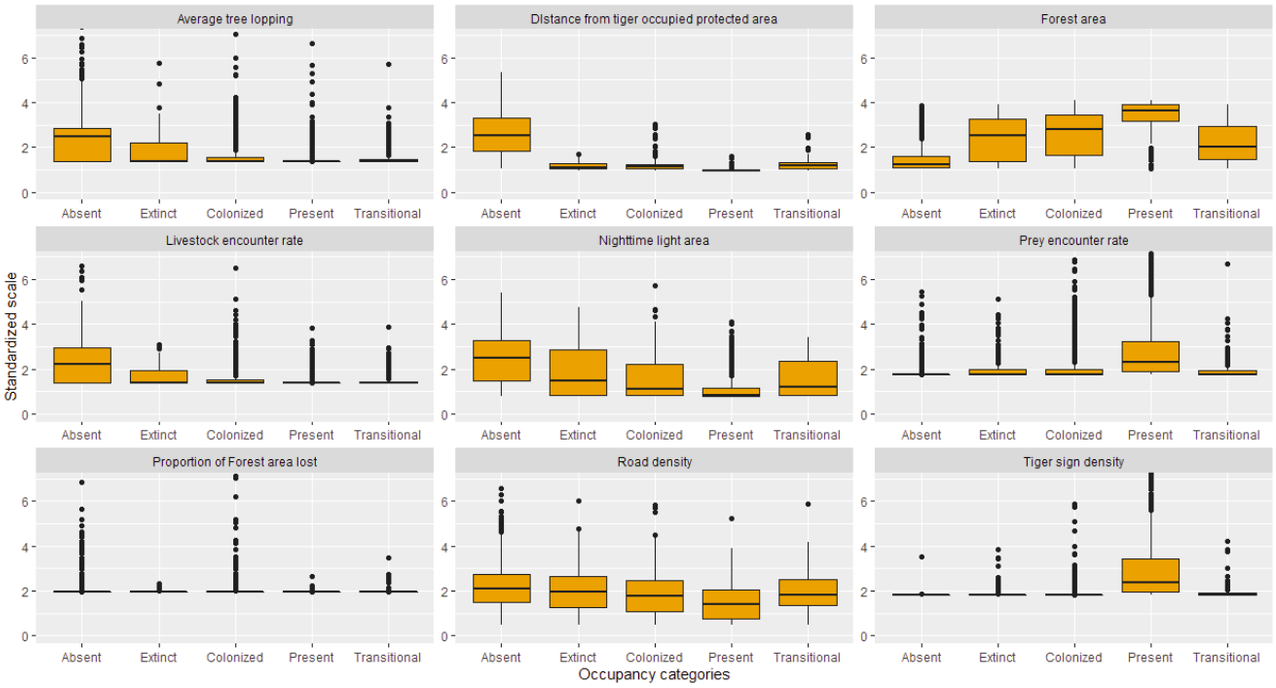

Table 6.1

Model selection statistics for tiger occupancy (Ψ), colonization (γ), extinction (ε) and detection (p) modelled using various combinations of covariates representing prey, habitat, human impacts and tiger sign intensity in the Western Ghats landscaps (2006-18). The most parsimonious model was the one with least AIC and was considered to best explain these occupancy parameters. (prey: encounter rate of prey, dpa: distance from protected areas that were occupied by tigers in the previous cycle (t-1), for: forest area, na: nighttime light area, pso: encounter rate of tiger signs, lvsn: encounter rate of livestock, trail: density of human trails in the forest, road: density of tar road in the grid, 1: one intercept, year: yearly intercept).

Model	AIC	Delta AIC	No. Par	-2*logliklihood
Ψ(prey, for), γ(year, dpa, prey), ε(year, na), p(year, pso)	25689.33	0	26	25637.33
Ψ(prey, for), γ(year, dpa, prey), ε(year, na, flp), p(year, pso)	25692.09	2.76	29	25634.09
Ψ(prey), γ(year, dpa, prey, for), ε(year, na), p(year, pso)	25919.18	229.85	26	25867.18
Ψ(prey, road), γ(year, dpa, prey), ε(year, na), p(year, pso)	25921.42	232.09	26	25869.42
Ψ(prey), γ(year, dpa, prey), ε(year, na), p(year, pso)	25927.39	238.06	25	25877.39
Ψ(prey), γ(year, dpa, for), ε(year, na), p(year, pso)	25938.05	248.72	23	25892.05
Ψ(prey), γ(year, prey, for), ε(year, na), p(year, pso)	26087.41	398.08	23	26041.41
Ψ(prey), γ(year, for), ε(year, na), p(year, pso)	26151.75	462.42	20	26111.75
Ψ(prey), γ(year, prey), ε(year, na), p(year, pso)	26244.51	555.18	22	26200.51
Ψ(prey, for), γ(year, dpa, prey), ε(year, na), p(year)	31327.04	5637.71	22	31283.04
Ψ(prey), γ(year, dpa), ε(year, na), p(year)	31621.77	5932.44	18	31585.77
Ψ(.), γ(year), ε(year), p(.)	33374.17	7684.84	8	33358.17
Ψ(.), γ(.), ε(.), p(.)	33637.72	7948.39	4	33629.72

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Table 6.2

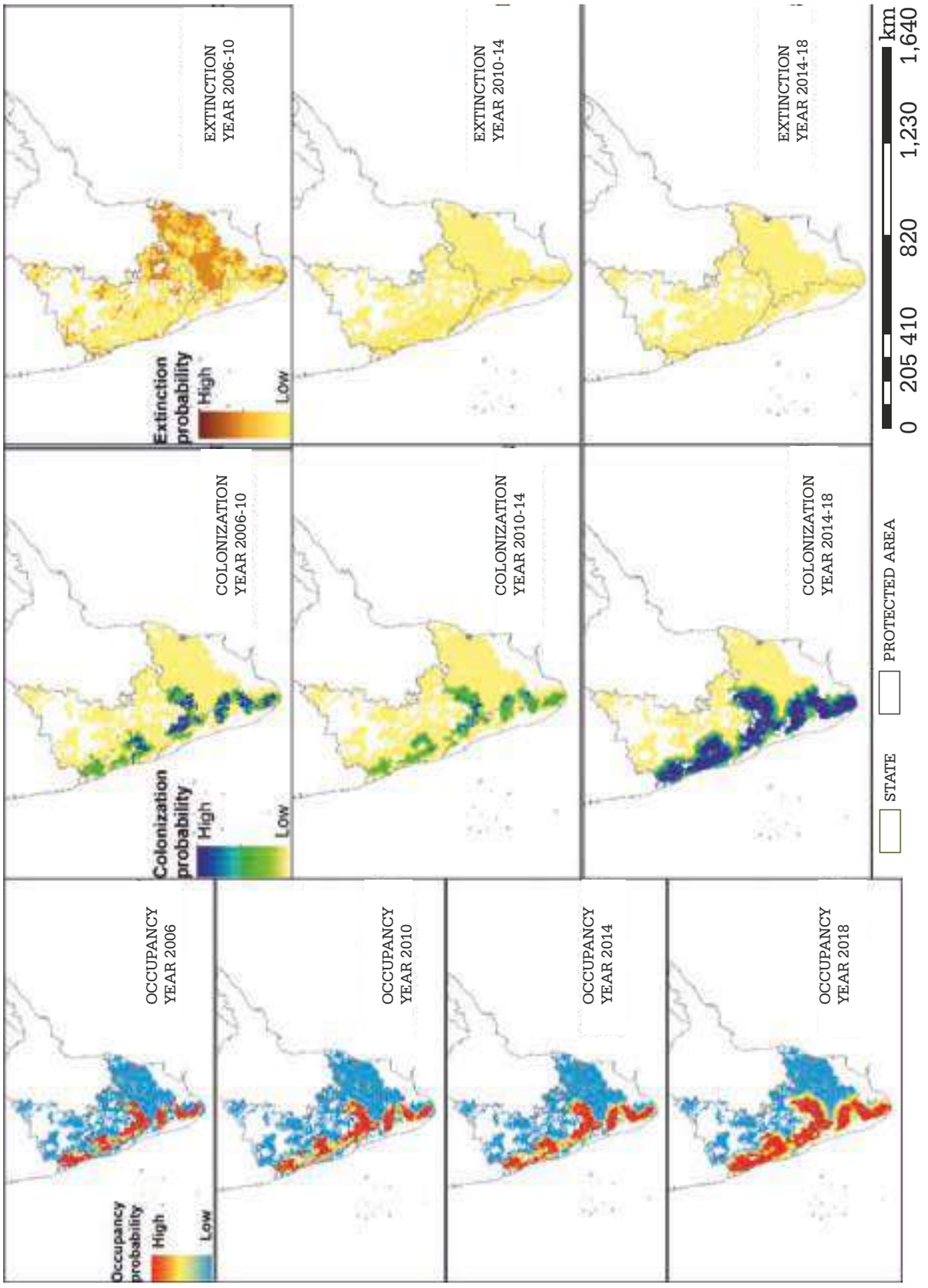
Best model explaining the effect of covariates (Beta Estimate) on tiger occupancy (Ψ), colonization (γ), extinction (ε) and detection (p) in the Western Ghats landscape. The suffix y6, y10, y14 and y18 represents the covariate of the sampling year 2006, 2010, 2014 and 2018.

Covariate	Beta Estimate	Std error
Ψ1.intercept	-1.938301	0.106867
Ψ1.prey_y6	2.05833	0.207934
Ψ1.forest area	1.211102	0.085459
γ1.intercept	-5.001202	0.718776
γ2.intercept	-6.501635	1.319476
γ3.intercept	-4.133574	0.717639
γ1.dpa_y6	-4.208357	0.799173
γ2.dpa_y10	-5.625085	1.473781
γ3.dpa_y14	-5.782875	0.950362
γ1.pre_y10	1.724642	0.389943
γ2.pre_y14	0.231008	0.219793
γ3.pre_y18	4.157264	1.558019
ε1.intercept	-0.998576	0.216948
ε2.intercept	-1.232631	0.293645
ε3.intercept	-8.692775	15.523309
ε1.na_y10	0.516585	0.207209
ε2.na_y14	0.819512	0.268284
ε3.na_y18	1.134291	7.725453
p1.intercept	-1.356488	0.040243
p2.intercept	-1.136509	0.05418
p3.intercept	-1.550282	0.047038
p4.intercept	-1.728178	0.036502
p1.pso_y6	0.420775	0.018083
p2.pso_y10	0.949036	0.03939
p3.pso_y14	0.945965	0.0309
p4.pso_y18	0.604958	0.01791

The initial occupancy of year 2006 revealed tiger being present in and around all the existing Tiger Reserves (Anshi-Dandeli, Bhadra, Nagarhole, Bandipur, Biligiri Ranganatha Temple (BRT), Mudumalai, Sathyamangalam, Parambikulam, Anamalai, Periyar and Kalakad Mundanthurai (KMTR)), protected areas (e.g. Sharavathi Valley, Someshwar, Kudremukh, Talakaveri, Brahmagiri, Pushpagiri, Waynad, Mukurthi, Silent valley, Peechi Vazhani, Chimmony, Thattekadu, Shendurney, Mundanthurai, Peppara, Neyyar, and Kanyakumari) and other forest divisions (e.g. forest between Bannerghatta and Cauvery, Coimbatore, Male Mahadeshwarbetta, Ooty, Ranni, Konni, Thenmala and Sivagiri) (Fig. 6.2). In 2010, the areas around Tiger reserves that had higher prey encounter rates were colonized; but many parts that were away from the protected areas faced extinction (Fig. 6.3). These areas were patch extinction occurred include forest around Mollem, Nitravali, Cotigao, Haliyal, Sirsi, Siddapur, Sharavathi, Coimbatore, Konni, and Sivagiri). However, many of these parts were subsequently colonized in 2014 and 2018, which resulted into consistently increased occupancy after 2010. Most of the forested areas in proximity of the existing Tiger Reserves were consistently colonized throughout the Western Ghats (Fig 6.4), which is reflected in 1.5-fold increase in tiger occupancy in between 2014 and 2018. However, the occupied areas are still fragmented by geographic barriers like the Palaghat gap, and anthropogenic modifications in form of linear infrastructure and land-use change in between Anshi Dandeli - Bhadra - Nagarhole Tiger Reserves, and due to mining in parts of Goa. The edge grids of many Tiger Reserves like Kalakad Mundanthurai, Anamalai, Sathyamangalam, Bandipur and Nagarhole are on interface of agricultural fields or commercial plantations, which can likely influence the occupancy dynamics of tigers in this landscape.

Figure 6.2

Occupancy parameters (occupancy probability (ψ), colonization probability (γ), extinction probability (ε) and detection probability (p) of tigers in the Western Ghats landscape estimated using multi-season occupancy modelling approach, from the year 2006 to 2018.



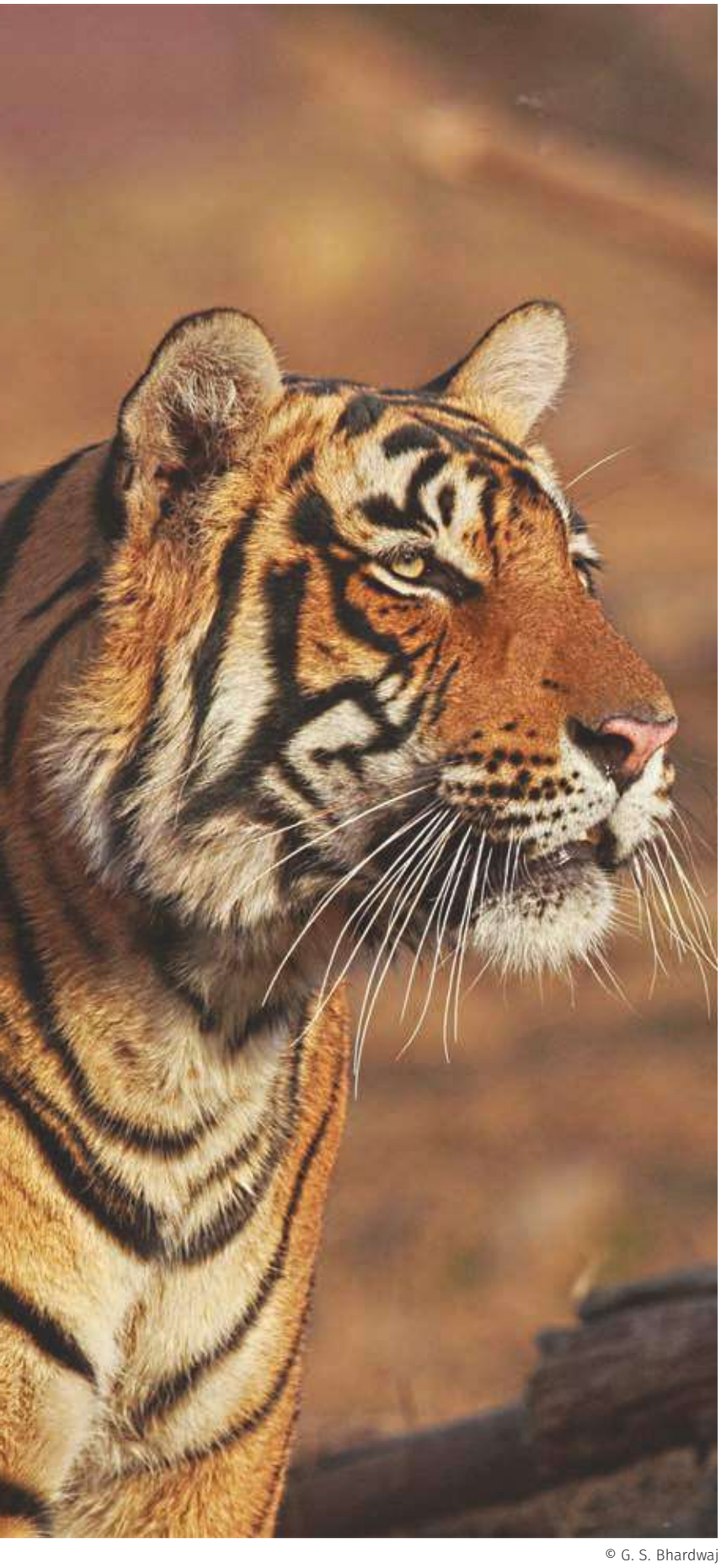


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Figure 6.3

The relationship in between occupancy parameters and site covariates in the Western Ghats landscape. (A) relation in the probability of colonization and distance from protected areas occupied by tigers (km) in the previous season, (B) relation in the probability of extinction and night time light areas (km^2), (C) relation in the probability of tiger occupancy and forested area (km^2), (D) relation in the probability of tiger occupancy and encounter rate of prey species per km.

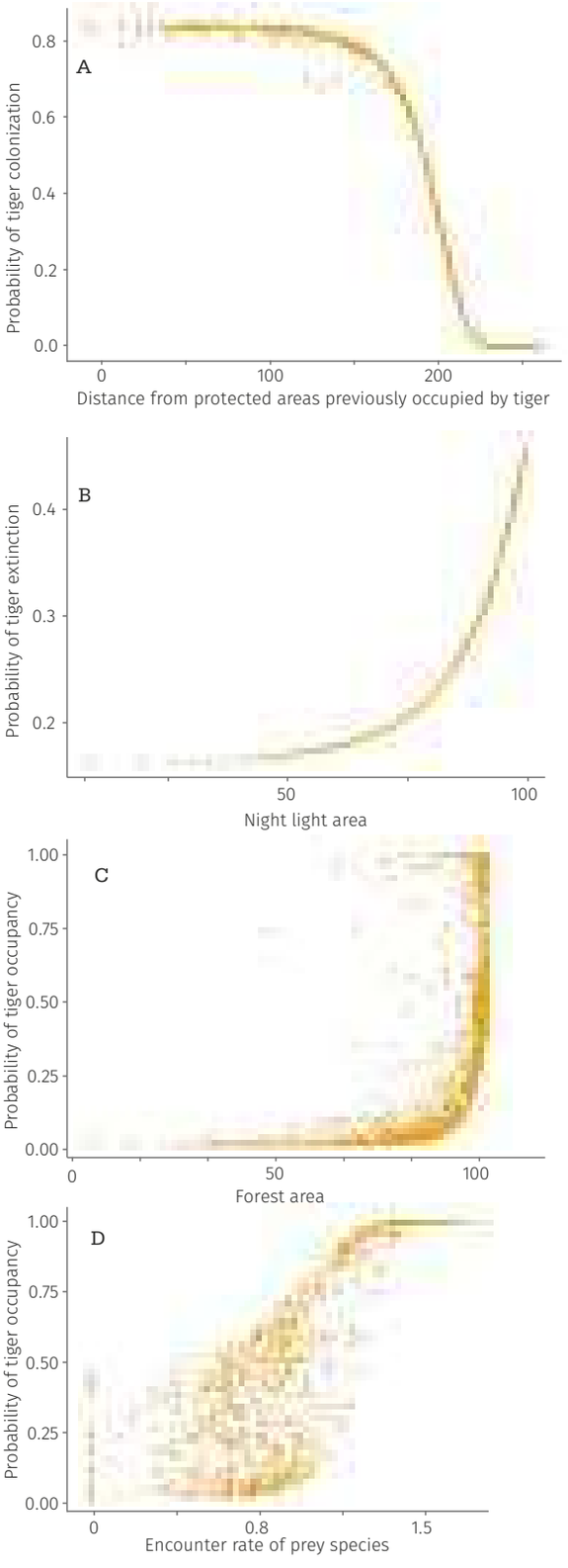
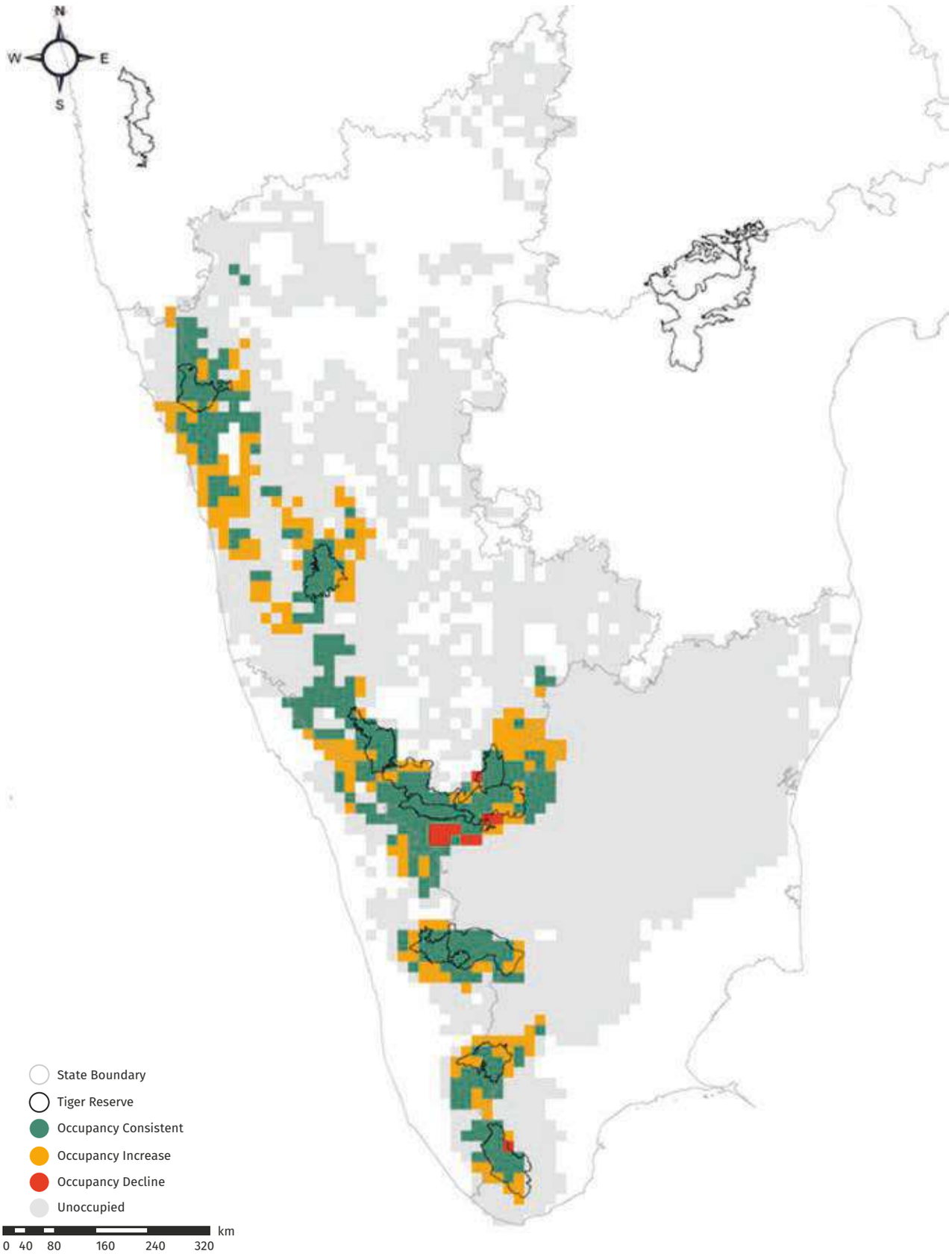


Figure 6.4

Rate of change of tiger occupancy in between the year 2014 and 2018 in the Western Ghats landscape.



Tiger population extents and abundance across the Western Ghats landscape

Mark-recapture population and density estimates of tigers based on camera-trapping were obtained for 48 sites (including 11 TRs) of the Western Ghats landscape. Tiger population for the entire landscape in 2018 was estimated to be 981 (SE 871 - 1,093) tigers with Karnataka supporting the maximum tigers [524 (SE 475 - 573)] followed by Tamil Nadu [264 (SE 227 - 302)] and Kerala [190 (SE 166 - 215)]. Tiger densities in the Western Ghats ranged between 12 (SE 1.08) tigers per 100 km^2 in Nagarhole TR to 0.03 (SE 0.01) tigers per 100 km^2 in Anshi-Dandeli (Kali) TR (see site specific chapters for more details). After joining contiguous grids with tiger presence, four tiger populations were identified within the Western Ghats landscape (Fig. 6.5). These include:

1. Nagarhole-Bandipur-Wayanad-Mudumalai-Sathyamangalam-BRT complex: This contiguous network of Tiger Reserves and Protected Areas (12,134 km^2 of tiger occupancy) with an estimated tiger population of 724 (SE 635-813) supports the highest number of wild tigers in India.

2. Mokambika-Anshi-Mhadei-Kudremukh-Bhadra complex: This contiguous forested block in between Goa and Karnataka has shown remarkable increase in tiger population since last tiger assessment in 2014. In the current assessment the population was estimated at 150 (145-155) with a tiger occupancy of 6,855 km^2.

3. Parambikulam-Anamalai complex: With tiger occupancy of 3,581 km^2, this landscape supports about 58 (SE 48 - 68) tigers.

4. Kalakad Mundanthurai-Periyar complex: This landscape block supports an estimated population of 42 (SE 34 - 49) tigers with an occupancy of 4,483 km^2.

Populations south of the Palghat gap (3&4) are genetically unique, divergent and their status vulnerable. These need to be a priority for conservation.

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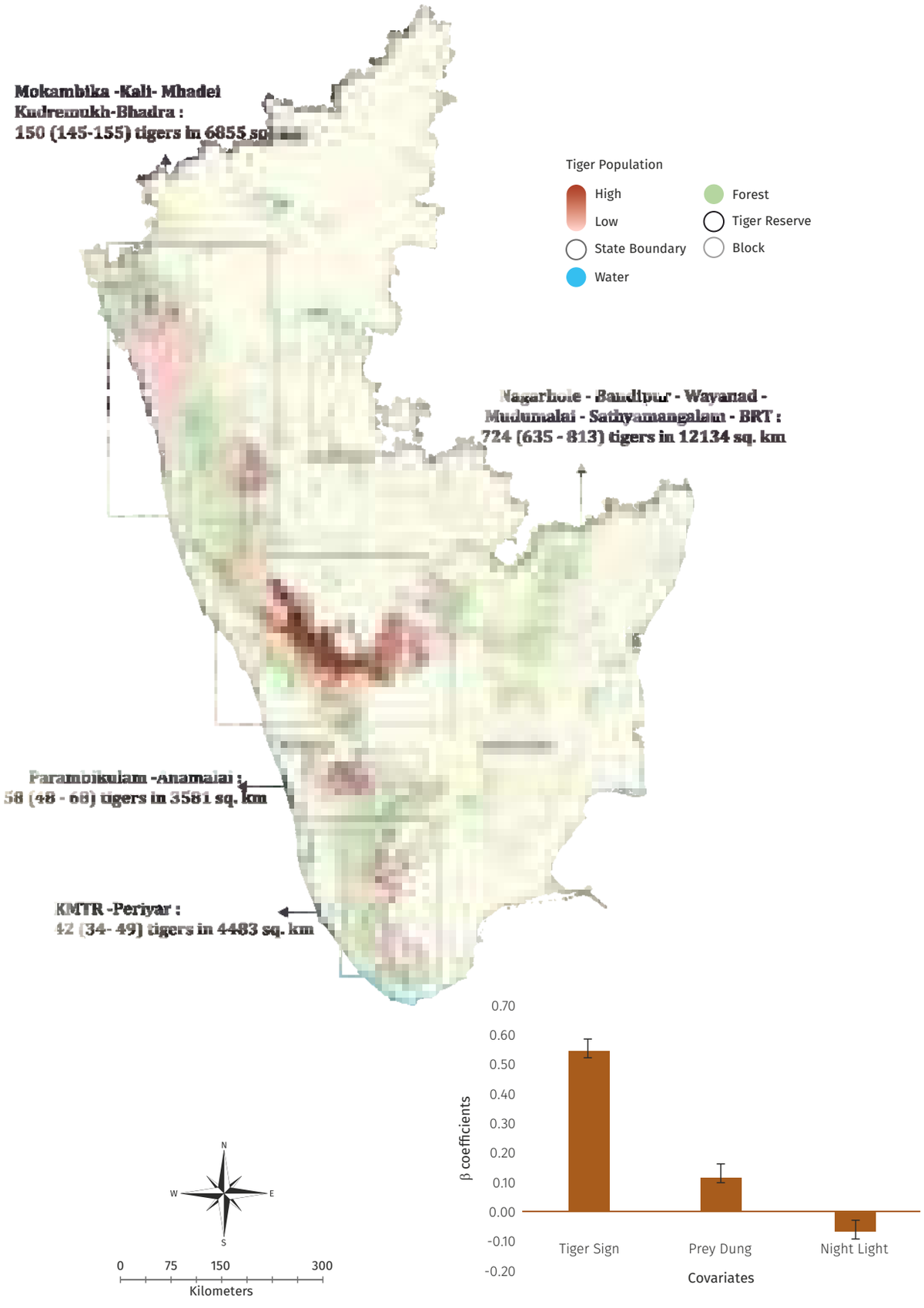
Figure 6.5

Figure 6.5: Spatially explicit tiger density modelled from camera traps-based capture-mark-recapture and covariates of tiger sign, prey, and human disturbance index . The graph inset shows the covariate coefficients.



Critical corridors, habitat connectivity and conservation

Western Ghats landscape has the potential to have contiguous tiger occupancy from the Dang forests in Gujarat up to the Palakkad Gap in Kerala and then again from Parambikulum-Anamalai complex upto Periyar-Kalakad-Mundanthurai-Kanyakumari complex. Within this landscape the most important source population is the Nagarahole-Bandipur-Sathyamangalam-BRT-Mudumalai-Wayanad population which spans across the three states of Karnataka, Tamil Nadu and Kerala. The other sources though occupying sufficiently large patches of habitat are of comparatively low tiger density and their nuclei are centred within Protected Area complexes. These populations are Kalakad Mundanthurai, Periyar and the Parambikulum-Anamalai complex south of the Palakkad Gap, while Kudremukh, Bhadra, Anshi and Dandeli are north of the Palakkad Gap. A few tigers are also recorded from the forests in Goa the viability of which depend significantly on Kali TR becoming a source population and the forest connectivity north across the PA's of Northern Karnataka (Bhimghad and Dandeli Sanctuary).

Major corridors identified for this landscape are as below (Fig. 6.6):

1. Anshi Dandeli-Sharavathi Valley: This complex consists of the Protected Areas of Mollem-Netravali (Goa), Anshi-Dandeli, Sharavathi Valley-Mookambika along with the Reserve Forests of Haliyal and Yellapur. To the north, this landscape is connected to the forests of Goa which are connected further north to the Sahyadri TR in Maharashtra with sporadic records of tiger occupancy. The corridor connectivity between Anshi-Dandeli and Sharavathi Valley is long and traverses through plantation and agriculture mosaics. Since the corridors are part of large forest divisions they have not been majorly impacted by development in the past four years. However, two National Highways traverse through the corridors, one south of Kali TR and North of Aganashini Community Reserve (NH63 Hubli-Karwar Road) and another south of Aganashini Community Reserve and north of Sharavathi WLS (NH206 Bangalore-Honavar road). There are also three state highways (SH 69, 48, 144) that traverse through this section of the corridor. Appropriate wildlife passage ways need to be developed for mitigating the long-term impact of these roads as barriers to wildlife movement across them.

2. Sharavathi-Kudremukh-Bhadra: This complex comprises of the central part of the Western Ghats in Karnataka and includes Kudremukh NP, Bhadra TR, Someshwara WLS, and Shettihalli WLS. The corridors connecting these PAs pass through a mosaic of agriculture, plantations and ridge top forests and are very fragile. The connectivity between Bhadra TR and Shettihalli WLS is getting weaker along the state highway (SH 65) between Sheetur and Shedagaru.

3. Someshwara-Mookambika-Shettihalli-Bhadra WLS corridor: Mookambika WLS is connected to Someshwara WLS in the south through reserve forests of Hulikal, Varahiand Tombattu; which is further connected to Kudremukh NP through contiguous forest. On the east, Mookambika WLS is poorly connected to Shettihali WLS through narrow ridge-top forests, the last part (8-10 km) of which traverses through habitation and agriculture, with small patches of forests providing "stepping stone" connectivity. The reserve forests of Northern Cardamom Hills, Choranayedahalli, Kakanhosudi and Tamadihalli connect Shettihalli WLS to the northern parts of Bhadra TR. While this habitat matrix is permeable for wildlife movement, it is dotted with agricultural developments that could grow into barriers later. Connectivity to the northern portion of Bhadra with Shettihalli was only through ridge top forests and is at risk of being broken at some places by agriculture development especially along the state highway 65 between the towns of Seethur and Shedagaru.

4. Bhadra-Kudremukh-Pushpagiri-Talakaveri-Brahmagiri-Nagarahole corridor complex: The connectivity to the south from Kudremukh NP to Pushpagiri WLS, and then via Talakaveri-Brahmagiri onto Wayanad connecting to Nagarahole is one of the most precarious corridor systems within the Western Ghats. Movement of tigers from the high density source of Nagarahole-Mudumalai-Wayanad to sink habitats of Kudremukh-Bhadra complex is likely to be an important component for tiger population dynamics in this low density landscape. Two National Highways (234, 48) and State Highways (8, 27, 37, 85, 88, 89, 91, 114) traverse through these corridors at various places. Development along these roads needs to be monitored and controlled within forested areas. Also wildlife passage ways need to be commissioned to prevent these roads becoming barriers to wildlife passage. Wayanad WLS shares its north-eastern border with Nagarahole and Bandipur in Karnataka and Mudumalai in Tamil Nadu. Expansion of the urban sprawl of Kutta township threatens the habitat connectivity of Wayanad with Brahmagiri and Brahmagiri with Nagarhole. Wayanad is connected to the Silent Valley NP in Kerala through Mudumalai and Mukurti in Tamil Nadu.

5. Mudumalai-Mukurthi-Silent Valley Corridor: The Mudumalai landscape is connected through the forested slopes of the Nilgiris to the Mukurthi NP in the south which is further connected to Silent Valley. The National Highway 67 from Gudalur bisects this corridor and has heavy vehicular traffic. Wildlife passage ways in the form of under and over passes are required here.

6. Towards the east, Sathyamangalam TR connects with the corridor formed by the Moyar river valley connecting the Bandipur-Mudumalai complex with BRT Hills TR and on to Cauvery WLS. Though wildlife habitat in this landscape is contiguous, villages like Thengumarahada, Kallampalayam, Ittarai, Hasanur, Kottadai, Gedasal, Kadaganahalli, Basubanapuram, Guthiyalathur, Kadambur, Gundri, Germalam, Sujjal Karai, Iggalore,Kongadai, Dhurusana palayam , Thattakarai, Solakanai, Sunndapur, Ponnachi, Konanagara, Changadi, Parsalnathas, Gopinatham within the ecological boundaries of PA's and TR's are a major source of human pressures and disturbances. All effort should be made to minimize these impacts through available and innovative means after safeguarding the livelihoods and interests of local communities.

7. Anamalai-Eravikulam-Parambikulam complex is the first major tiger population south of the Palghat Gap. The heavily populated Palghat Gap in the Western Ghat Massif is a major barrier to gene flow from the northern Western Ghats to the southern Western Ghats for most wildlife species including tigers. This southern Western Ghat tiger population is genetically distinct from other tiger populations (Kolipakam et al. 2019) and extends from this complex upto Kanyakumari across Periyar and Kalakad Mundanthurai Tiger Reserves. The Parambikulum-Eravikulum-Anamalai is connected through a mosaic of plantations, ridge top forests and few protected areas (Mathikettan Shola NP) with the Periyar TR. For this corridor habitat to be permeable to wildlife movement plantations and agricultural areas should not be power fenced. The eastern slopes of Western Ghats in Tamil Nadu that are too steep for agriculture are an important part of this corridor.

Periyar-Kalakad Mundanthurai corridor: This corridor passes through reserve forests and mostly privately owned plantations. Tiger occupancy from Periyar is contiguous through Shendurney WLS into Kalakad Mundanthurai TR onto Kanyakumari WLS since 2014 and has remained occupied in 2018. NH 208 traverses through this corridor between from Thenmala, Kerala to Puliyarai, Tamil Nadu. It would be appropriate to install wildlife passage ways in this part of the National Highway. This connectivity is important for persistence of both Periyar and KMTR since they currently house low density tiger populations and a metapopulation structure is beneficial in this landscape.

The Protected Areas of Western Ghats landscape are better connected with each other when compared Protected Areas in Central India and the Shivalik-Gangetic Plains landscapes. The habitat matrix in the Western Ghats is more conducive for tiger occupancy, some areas for high density and potential for long distance dispersal. However, many of the connecting corridor habitats in this landscape are not within the legal domain of protection and are often lost to burgeoning development demands of a growing economy and attrition by human consumptive uses. The habitat connectivity in the Western Ghats is primarily threatened by fenced plantations, agriculture, industrial and infrastructural development. These areas need be factored in the Tiger Conservation Plan (TCP) of the tiger reserves so that they can be safeguarded against any adverse disruptions. However, compared to other areas of India the corridors in this landscape appears to have experienced fewer threats as evidenced from expansion of night light data between 2014 and 2018 (Fig. 6.6). An in-depth analysis at high spatial resolution is required to assess the vulnerability and threats for each habitat corridor. It would be prudent and timely to legitimize the minimal corridors between extant tiger populations for ensuring the conservation objective of gene flow between them.

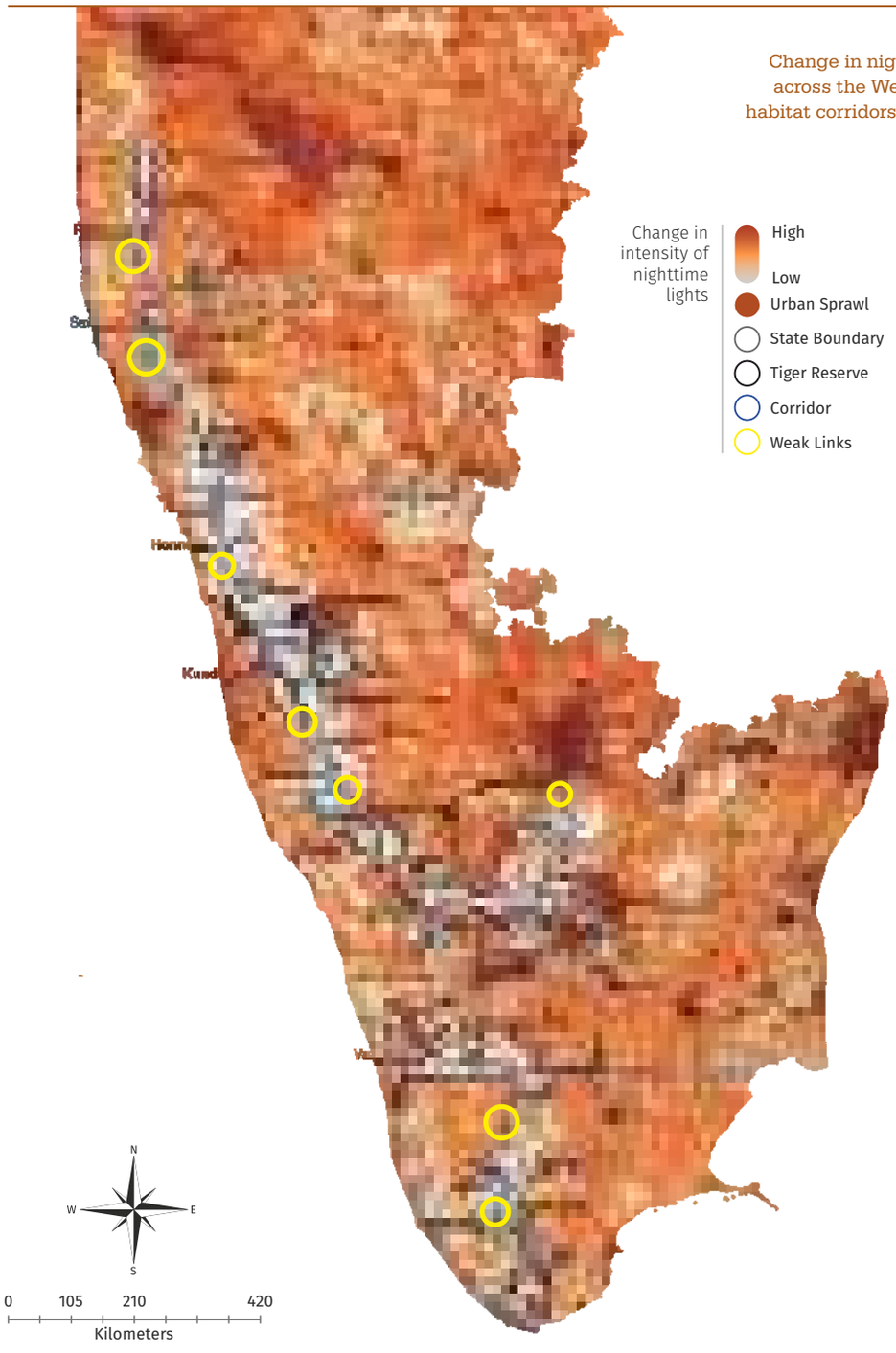


Figure 6.6

Change in night time lights between 2014 to 2018 across the Western Ghats landscape. Connecting habitat corridors are superimposed, bottlenecks and pinch points demarcated by circles.

Spatial Occupancy of Co-predators in Western Ghats Landscape, 2018-19

Leopard

(*Panthera pardus*)

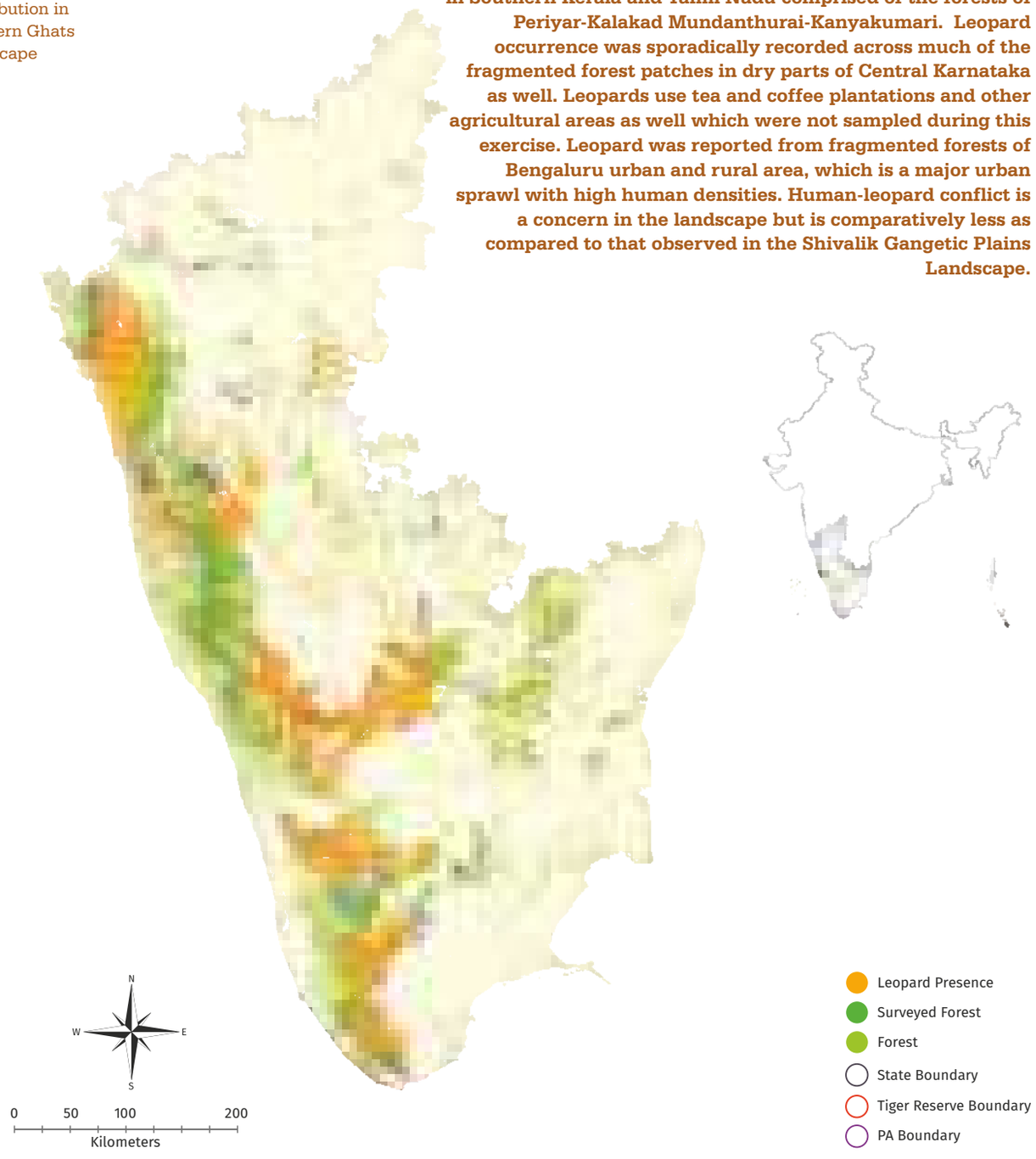
[Wildlife (Protection) Act 1972:

Schedule I;

IUCN Red List: Vulnerable]

Leopard distribution in this landscape was 39,333 km^2 (Fig. 6.7). Leopard population of the Western Ghats landscape was observed to occur in four distinct blocks. The northern block contiguous with Radhanagari and Goa covering Haliyal-Kali TR-Karwar-Honnavar-Madikeri-Kudremukh-Shettihali WLS-Bhadra-Chikmagalur-Hassan. The central population covering southern Karnataka, Tamil Nadu, and Northern Kerala covering the forests of Virajpet-Nagarhole-Bandipur-Mudumalai-Sathyamangalam-Nilgiri-Silent Valley -Wayanad-BRT Hills-MM Hills-Cauvery WLS-Bannerghhata NP. A second central cluster covering central Kerala and Tamil Nadu composed of the Parambikulam-Anamalai-Eravikulum-Vazachal population. The southern leopard population block in Southern Kerala and Tamil Nadu comprised of the forests of Periyar-Kalakad Mundanthurai-Kanyakumari. Leopard occurrence was sporadically recorded across much of the fragmented forest patches in dry parts of Central Karnataka as well. Leopards use tea and coffee plantations and other agricultural areas as well which were not sampled during this exercise. Leopard was reported from fragmented forests of Bengaluru urban and rural area, which is a major urban sprawl with high human densities. Human-leopard conflict is a concern in the landscape but is comparatively less as compared to that observed in the Shivalik Gangetic Plains Landscape.

Figure 6.7
Leopard distribution in Western Ghats landscape



Striped Hyena

(Hyaena hyaena)

[Wildlife (Protection) Act 1972:

Schedule III;

IUCN Red List: Near Threatened]

Hyena presence was recorded primarily from the drier forests of Tamil Nadu and Karnataka covering an area of 2,376 km^2 (Fig. 6.8). The major areas occupied by this species were in Haliyal Forest Division, dry forests of Bandipur - Mudumalai - Sathyamangalam - BRT Hills block and fragmented forests of Central and Northern Karnataka. Hyena was not reported from Western Ghats south of the Palghat gap. As major distribution of this species was found in the forests outside the Protected Areas, conservation of this species is challenging and needs to incorporate involvement of the local communities.

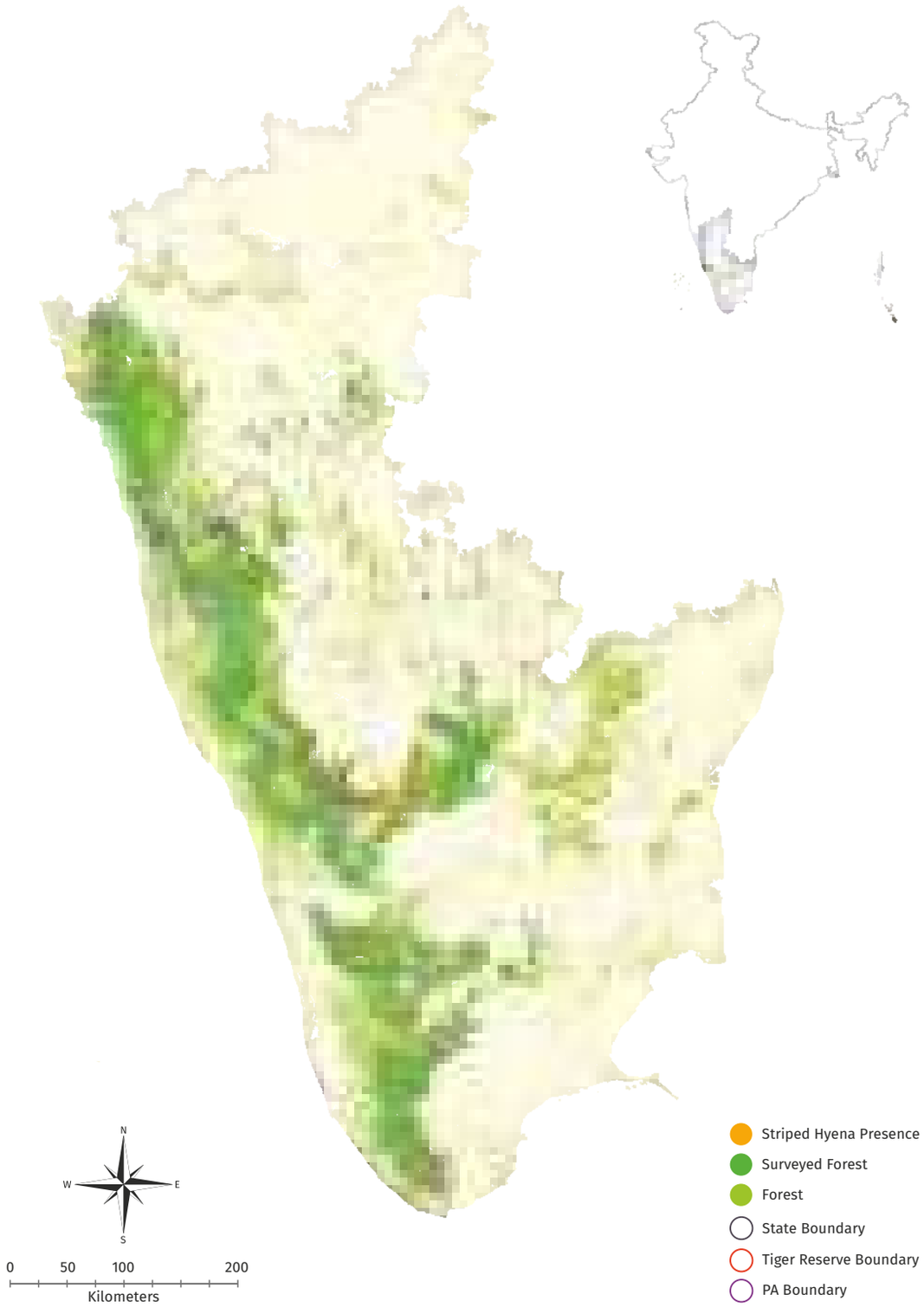


Figure 6.8
Hyena distribution in Western Ghats landscape

Dhole or Wild Dog

(*Cuon alpinus*)

[Wildlife (Protection) Act 1972:

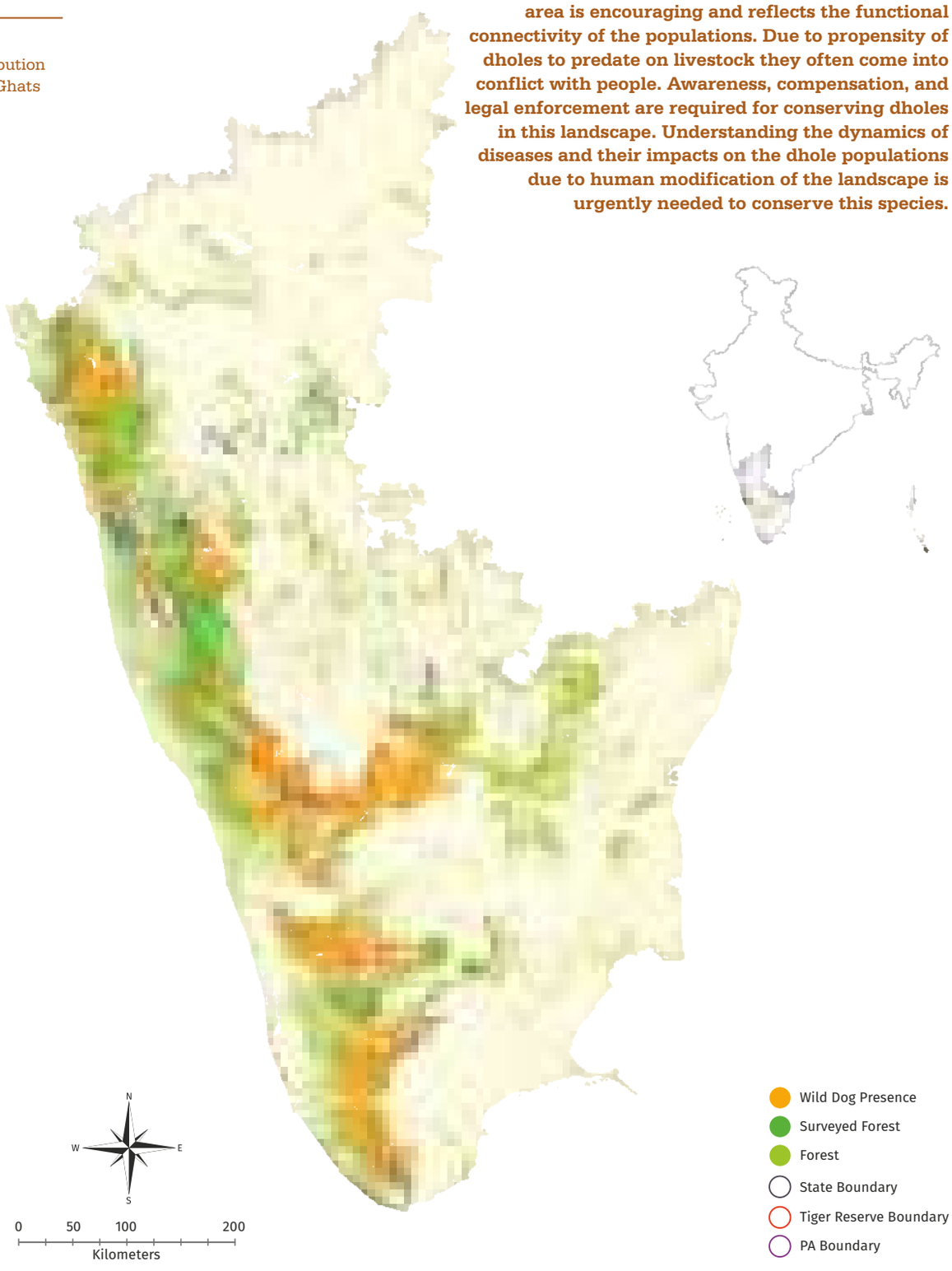
Schedule II;

IUCN Red List: Endangered]

Dhole signs were recorded from most areas where leopard presence was also recorded, excluding the fragmented forests of Central Karnataka. Wild Dog occupied an area of 31,880 km^2 (Fig. 6.9). The only discontinuity in the distribution was observed in between Bhadra and Anshi - Dandeli, Bhadra and Bandipur-Mudumalai-Sathyamangalam forest block and Palghat gap. The species had presence in the forested landscapes of northern Tamil Nadu in 2014 where no sampling was done in 2018. The occupancy of this social canid in the forests outside the protected area is encouraging and reflects the functional connectivity of the populations. Due to propensity of dholes to predate on livestock they often come into conflict with people. Awareness, compensation, and legal enforcement are required for conserving dholes in this landscape. Understanding the dynamics of diseases and their impacts on the dhole populations due to human modification of the landscape is urgently needed to conserve this species.

Figure 6.9

Dhole distribution in Western Ghats landscape



Sloth Bear

(Melursus ursinus)

[Wildlife (Protection) Act 1972:

Schedule I;

IUCN Red List: Vulnerable]

Sloth bear signs were recorded from an area of 30,375 km^2 (Fig. 6.10). The distribution of Sloth bear in Western Ghats was found in five major population blocks of i) Anshi - Dandeli, ii) Bhadra, iii) Nagarhole - Mudumalai -Wayanad - BRT Hills -Cauvery Wildlife Sanctuary, iv) Peechi - Vazhani - Perambikulam - Indira Gandhi WLS and v) Periyar - Kalakad Mundanthurai. Apart from this, sporadic bear occurrence was also reported from forest patches of Central Karnataka. Many forest patches in rural Bengaluru were reported to be occupied by sloth bear. The presence of bears outside the protected area and sub-urban landscape though encouraging, also raises a major concern of human-bear conflict.

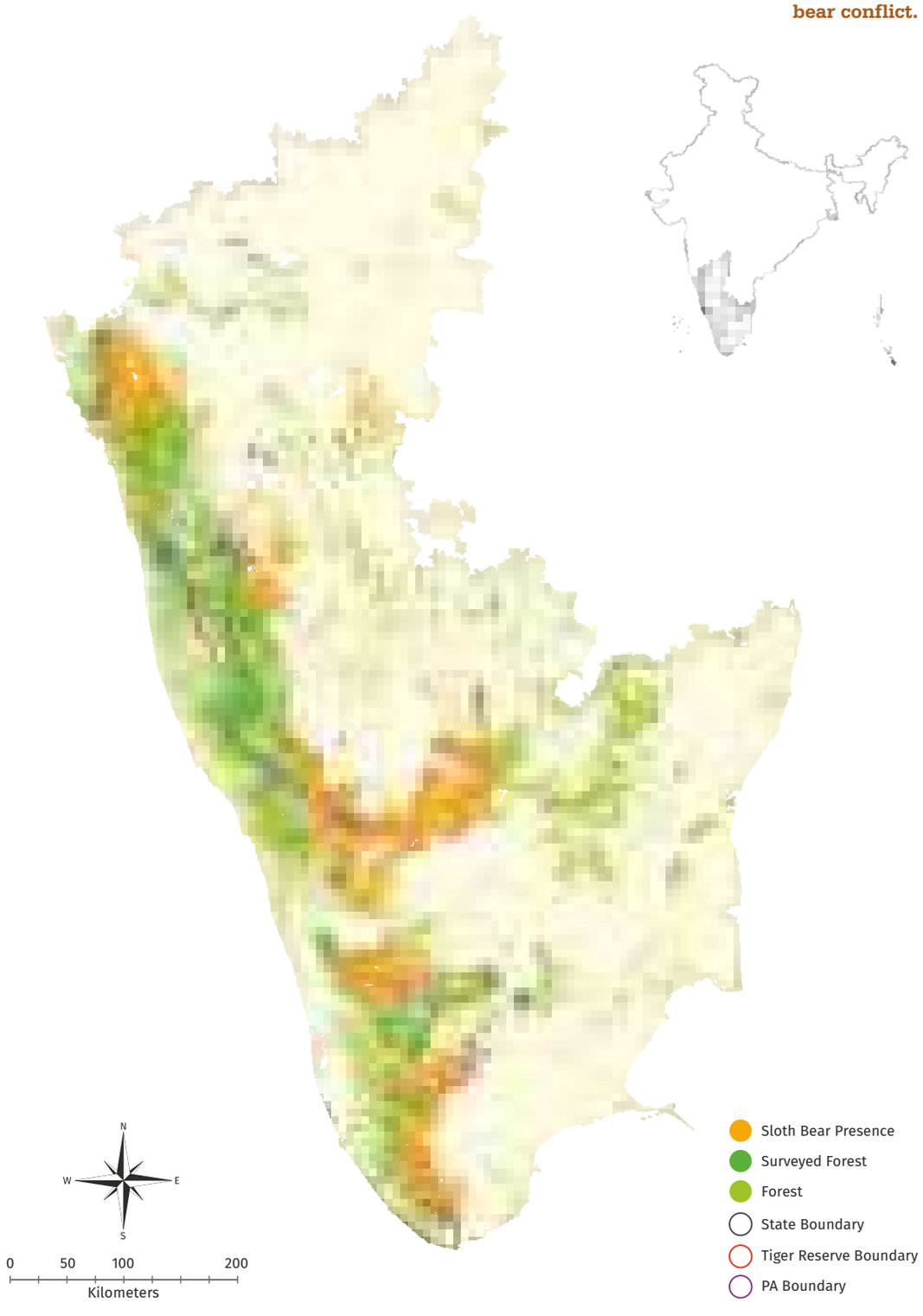


Figure 6.10

Sloth bear distribution in Western Ghats landscape

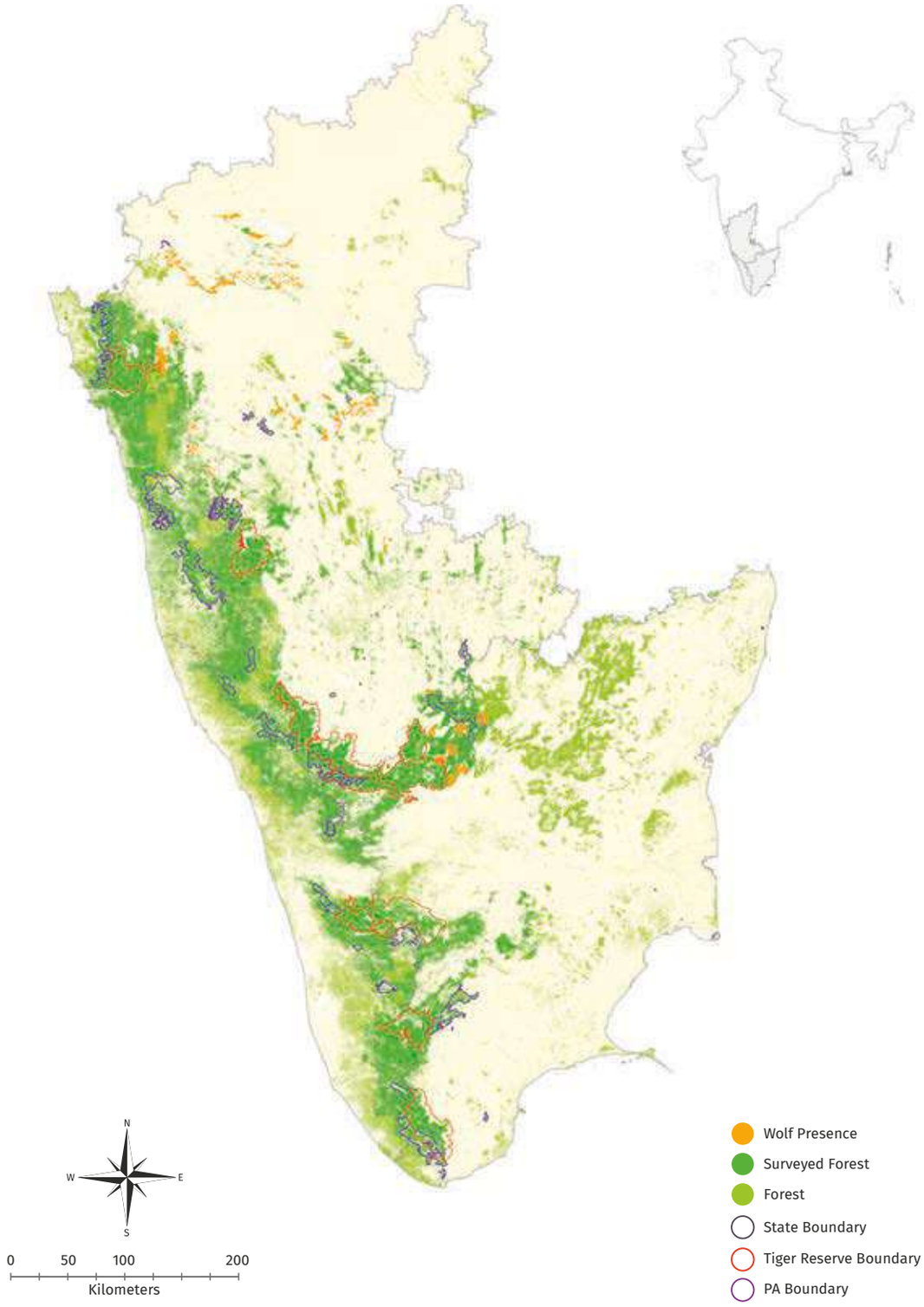
Wolf

(Canis lupus pallipes)

[Wildlife (Protection) Act 1972: Schedule I; IUCN Red List: Least Concern]

Wolves are known to prefer agro-pastoral and scrub forests and avoid thick canopied forests. Within the sampled forests the area occupied by wolves was 2,443 km^2 (Fig. 6.11). Wolf distribution was mainly recorded in flatter scrub forests of Karnataka and drier parts of north-western Tamil Nadu. Due to development driven loss of grasslands and scrublands outside the forested areas that are critical refuges for denning and pup rearing and with persecution of wolves by local communities for livestock predation the species is highly threatened in the landscape.

Figure 6.11
Wolf distribution in Western Ghats landscape



Golden Jackal

(*Canis aureus*)

[Wildlife (Protection) Act 1972:

Schedule II;

IUCN Red List: Least Concern]

Jackal was recorded to occupy 5,325 km^2 (Fig. 6.12). Since jackals also occur in plantations, rural and semi-urban areas which were not sampled, the recorded occupancy is a minimal estimate applicable only to the forested areas of this landscape. Jackal was also found in outside protected areas and forest patches of coastal Karnataka and drier parts of Karnataka and Tamil Nadu. In the southern Western Ghats (south to Palghat) jackal occupancy was mostly confined to the forests adjoining the protected areas. It is interesting to note that jackal signs were not recorded from within high tiger density areas (as well as areas of high density of other large carnivores) such as Nagarhole- Bandipur TRs.

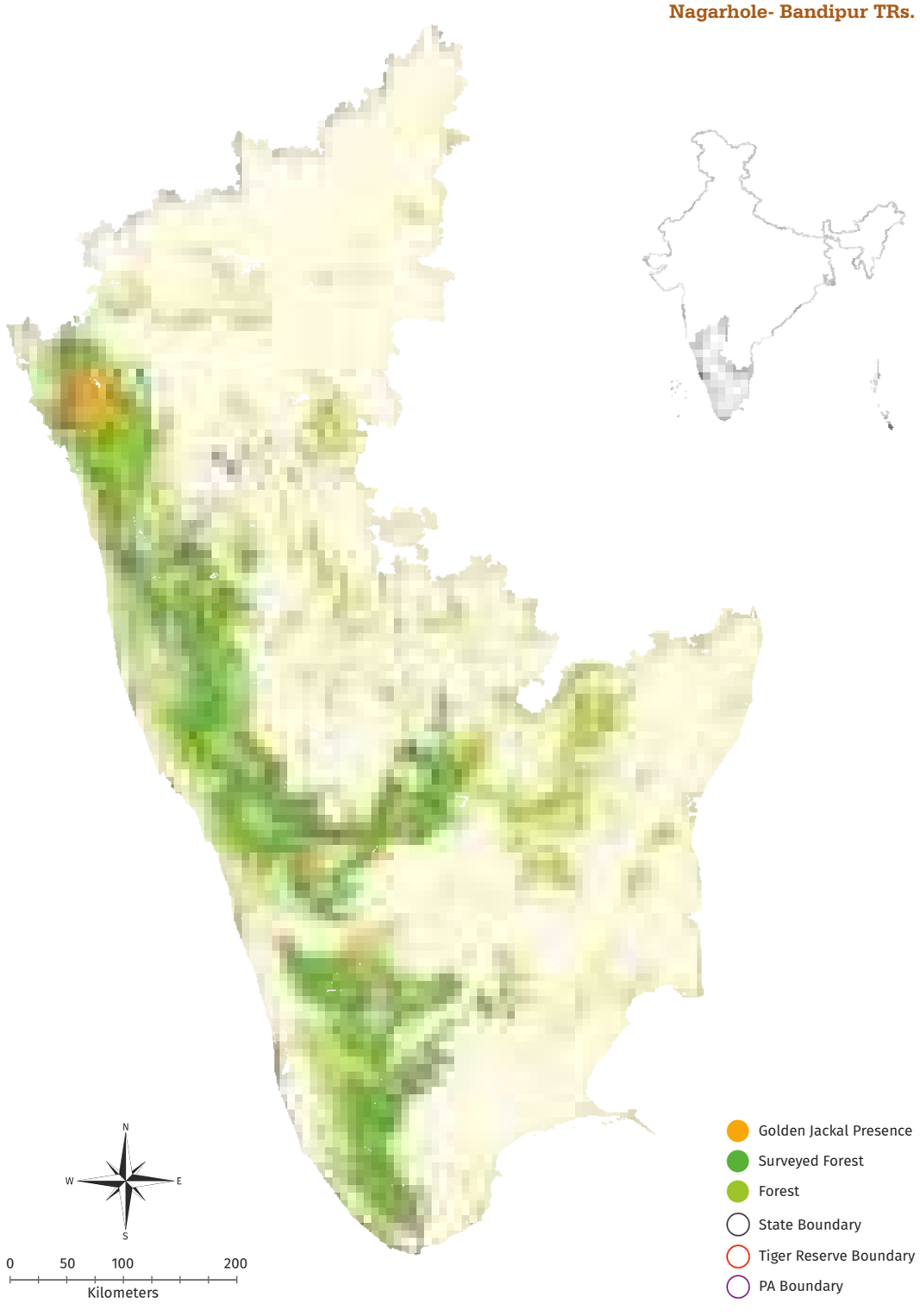


Figure 6.12
Jackal distribution in Western Ghats landscape

Spatial Occupancy of Major Prey Species in Western Ghats Landscape, 2018-19

Barking Deer

(*Muntiacus vaginalis*)

[Wildlife (Protection) Act 1972:
Schedule III;
IUCN Red List: Least Concern]

A continuous distribution throughout the Western Ghats with an occupancy of 29,211 km^2 of forested landscape (Fig. 6.13). Barking Deer was also recorded to occur in the scattered forest patches in the Northern and Central Karnataka.

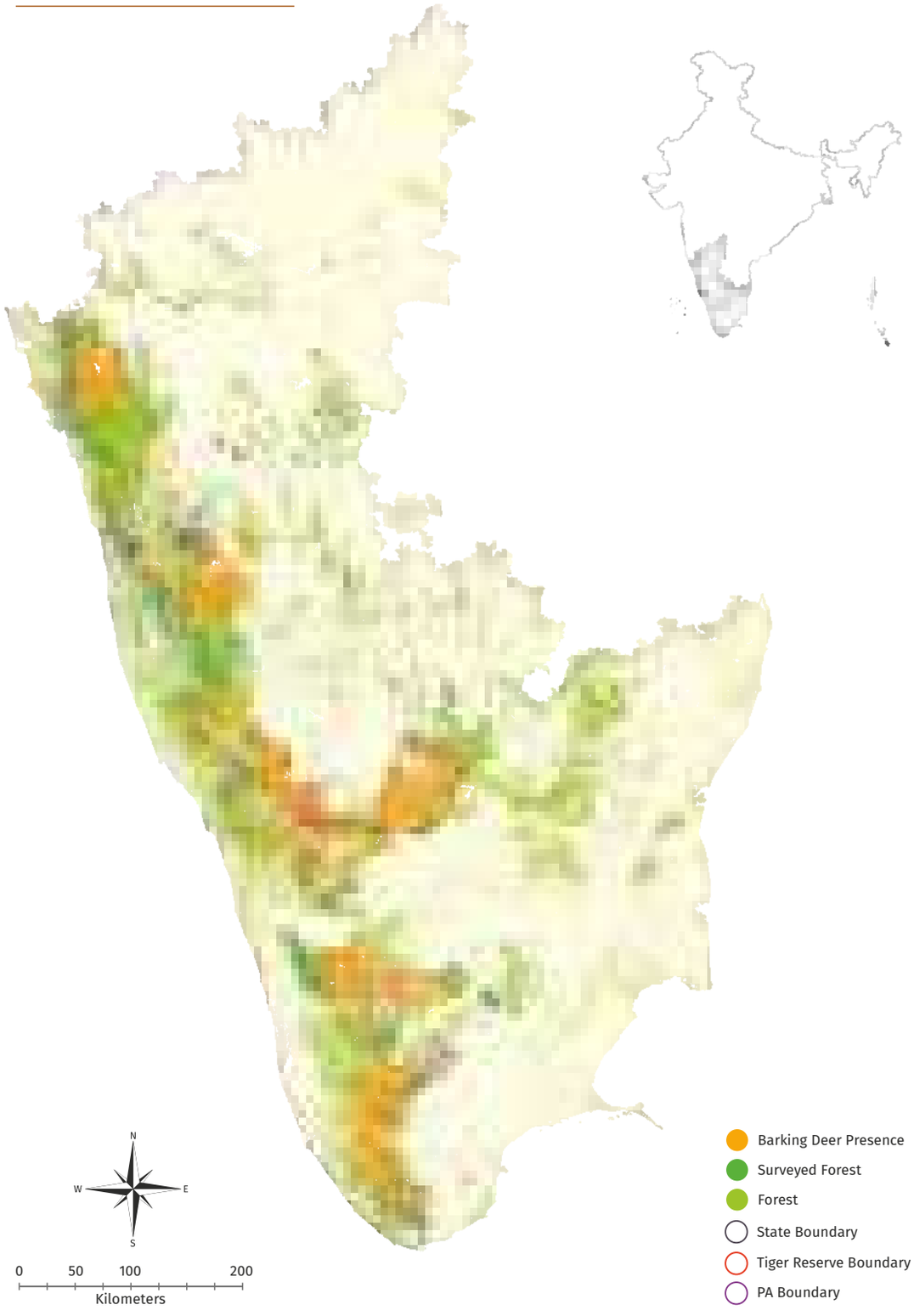


Figure 6.13
Barking deer distribution in Western Ghats landscape

Chital

(Axis axis)

[Wildlife (Protection) Act 1972:

Schedule III;

IUCN Red List: Least Concern]

Chital was recorded to occupy a total area of 20,380 km^2 of forested landscape (Fig. 6.14). The distribution could be classified in five distinct populations of Anshi - Dandeli complex, Bhadra - Kudremukh complex, Nagarhole - Cauvery complex, Anamalai - Cardamom hill complex and Periyar - Kalakad Mundanthurai complex.

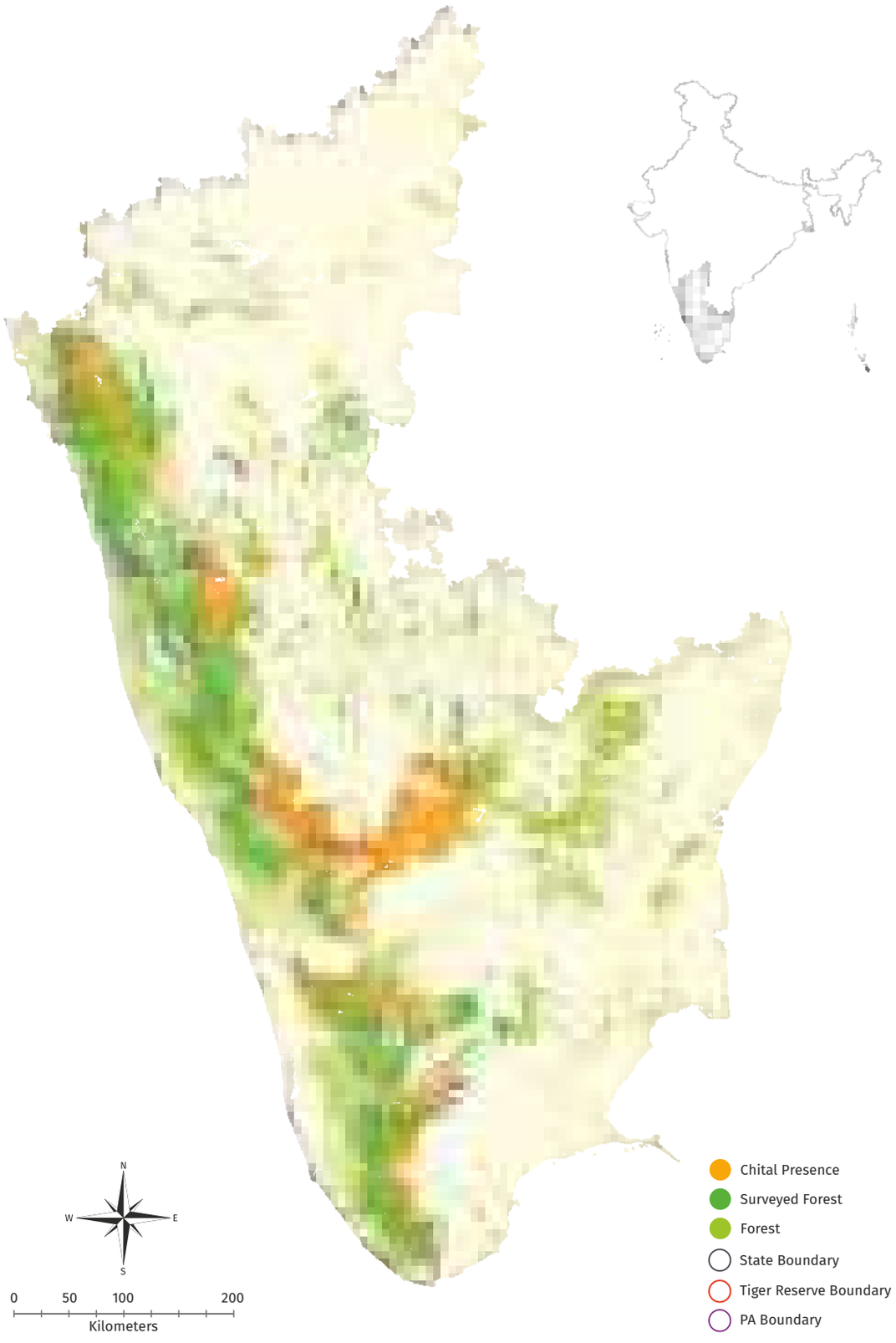


Figure 6.14
Chital distribution in Western Ghats landscape

Elephant

(*Elephas maximus*)

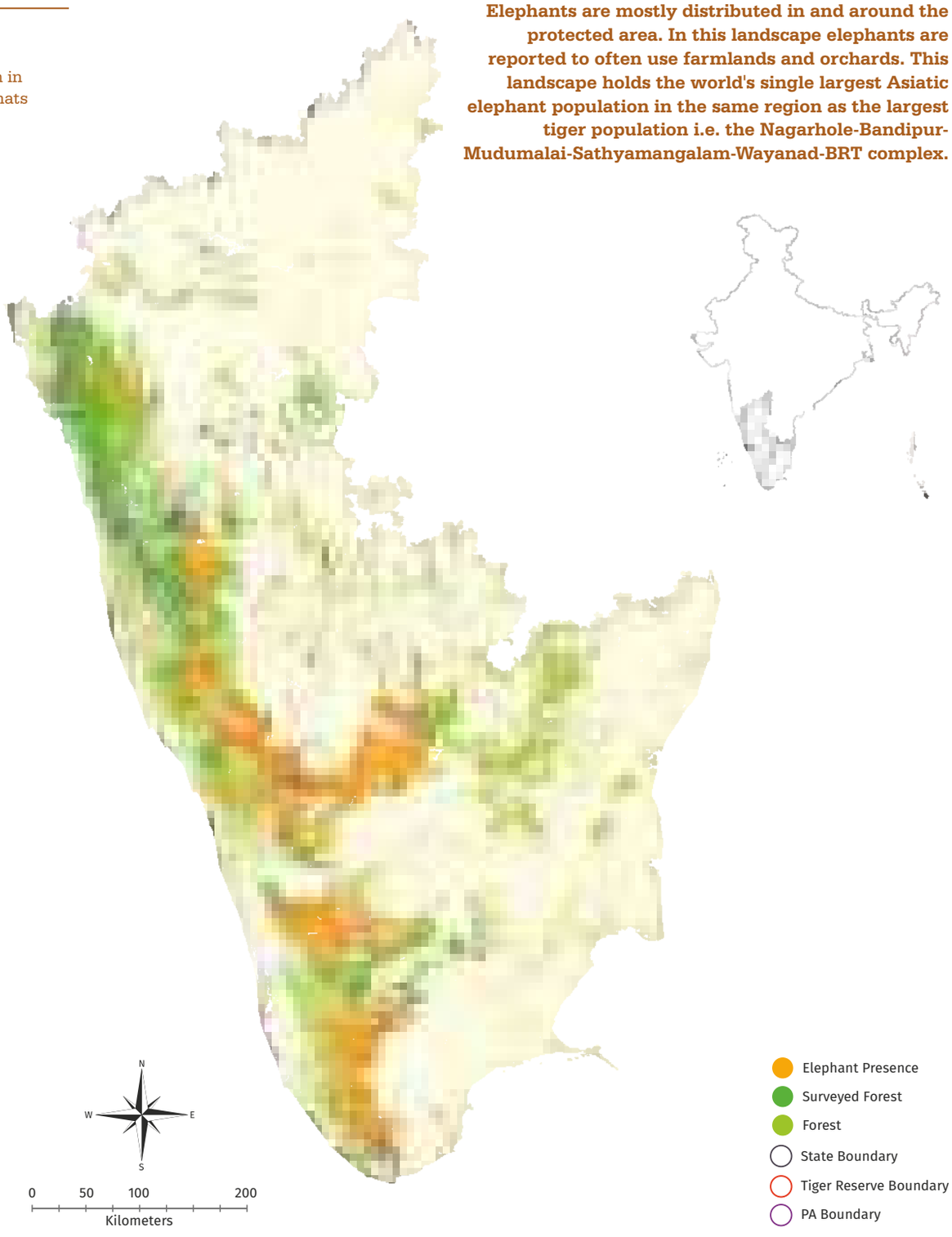
[Wildlife (Protection) Act 1972:

Schedule I;

IUCN Red List: Endangered]

Elephants are one of the flagship species of this landscape and their distribution was recorded mostly from the Southern Western Ghats until 2010. In the current assessment elephants were observed to occur in the Northern portion of Western Ghats as well. The total occupancy of elephants in this landscape was 27,670 km^2 (Fig. 6.15). Based on the occurrence data elephant population could be differentiated into five distinct clusters: Anshi - Dandeli population of sparse elephant occurrence; small Bhadra population, largest Nagarhole - Cauvery - Kaundinya population, the Anamalai hills population and Periyar population. Elephants are mostly distributed in and around the protected area. In this landscape elephants are reported to often use farmlands and orchards. This landscape holds the world's single largest Asiatic elephant population in the same region as the largest tiger population i.e. the Nagarhole-Bandipur-Mudumalai-Sathyamangalam-Wayanad-BRT complex.

Figure 6.15
Elephant distribution in Western Ghats landscape



Gaur

(Bos gaurus)

[Wildlife (Protection) Act 1972:

Schedule I;

IUCN Red List: Vulnerable]

Gaur was well distributed within the Western Ghats Landscape with an occupancy of 26,228 km^2 (Fig. 6.16). There seem to be two major populations, one extending across the Northern Western Ghats and parts of the Eastern Ghats, while the second population is south of the Palghat Gap. Habitat connectivity seems to be of concern between Parambikulum-Anamalai TRs and Periyar TR in the southern population. While in the northern population gaps in the distribution were observed between Anshi-Bhadra TRs and Nagarhole-Bandipur TRs complex.

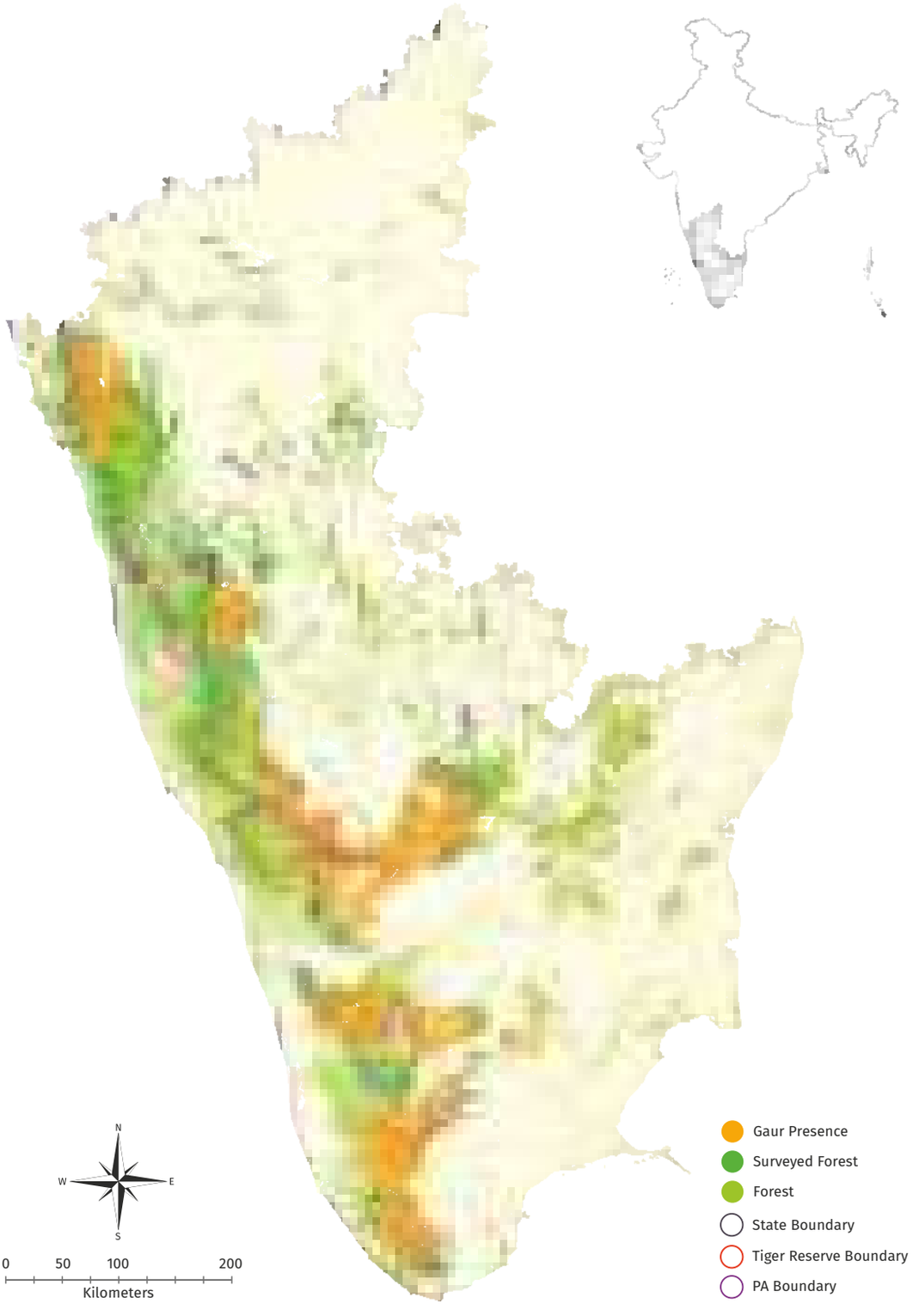


Figure 6.16
Gaur distribution in Western Ghats landscape

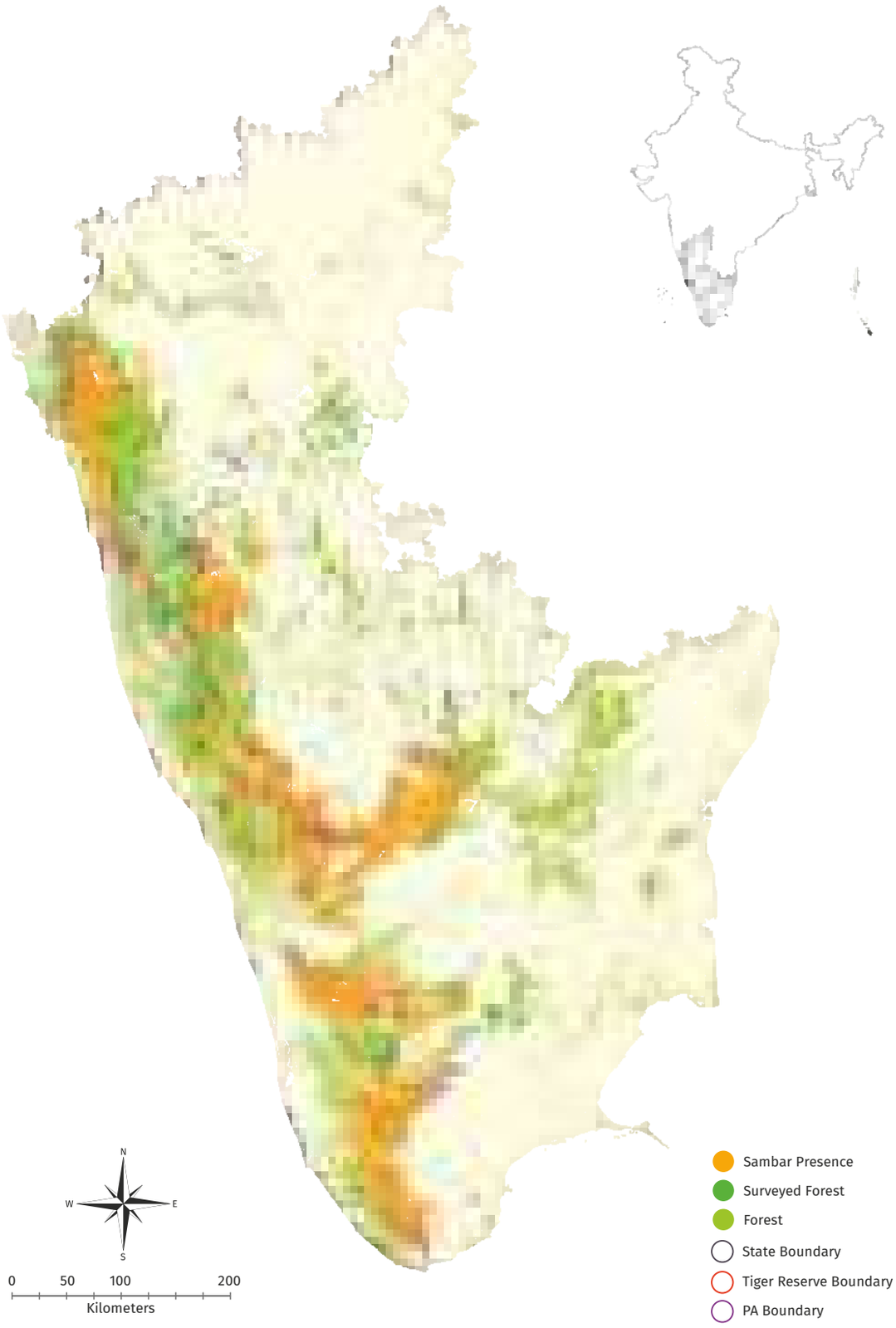
Sambar

(Rusa unicolor)

[Wildlife (Protection) Act 1972:
Schedule III;
IUCN Red List: Vulnerable]

Sambar was recorded to occupy a total area of 36,006 km^2 of forested landscape (Fig. 6.17). Distribution breaks only at the Palghat gap. The distribution south to it is further divided in the Anamalai hills and Cardamom hills; both joined by the population in Idukki WLS which acts as a stepping stone connectivity in this part of the landscape. Sambar distribution also extends eastward till the Cauvery WLS.

Figure 6.17
Sambar distribution in Western Ghats landscape



Wild pig

(Sus scrofa)

[Wildlife (Protection) Act 1972:

Schedule III;

IUCN Red List: Least concern]

Wild pig is the most widely spread herbivore in this landscape. It occupies 30,958 km^2 of forests (Fig. 6.18). Its presence was recorded from almost all the surveyed forests covering the Western Ghats, plain areas of central Karnataka and northern Tamil Nadu. Crop damage by wild pigs is a major concern in this landscape.

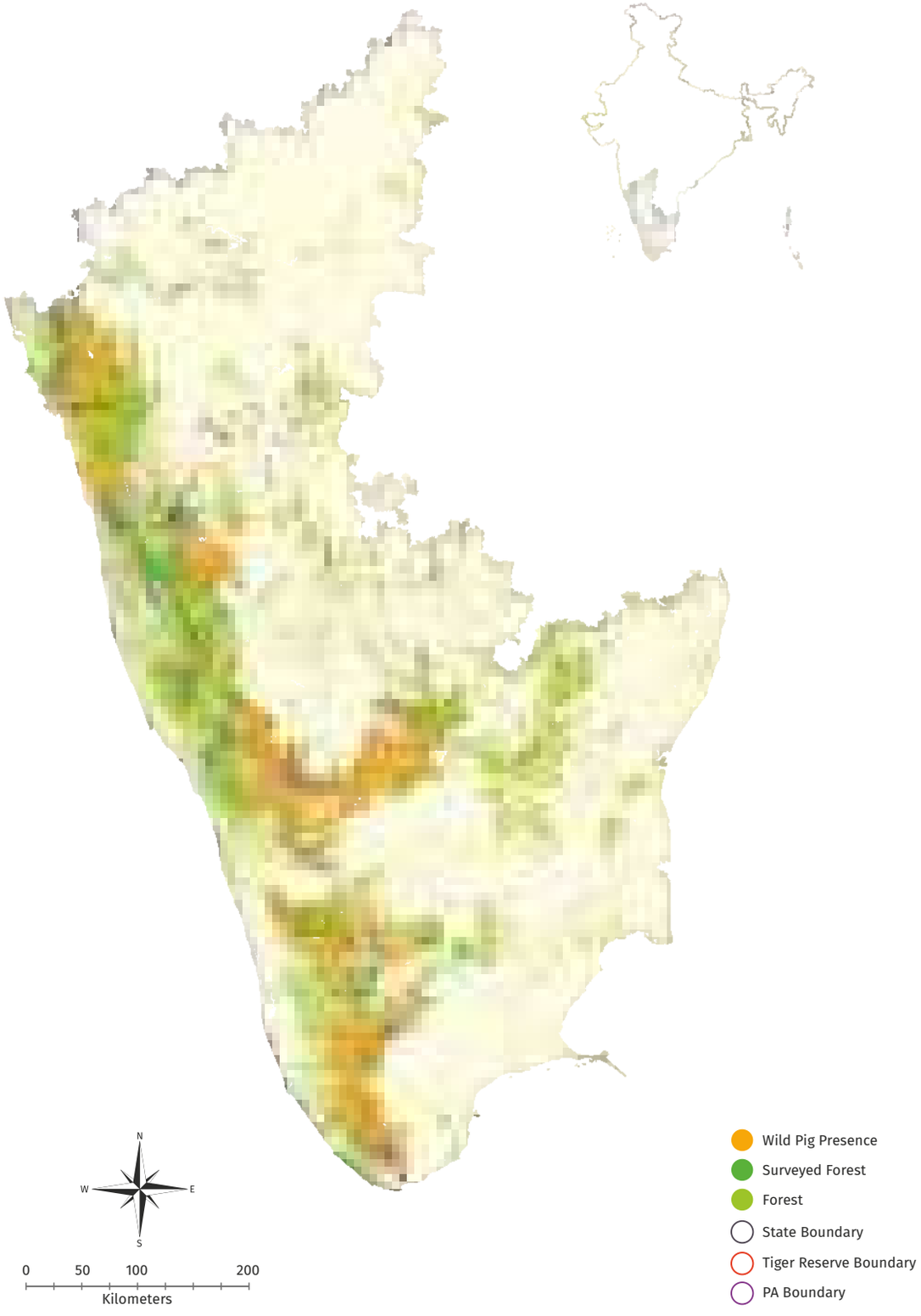


Figure 6.18
Wild pig distribution in Western Ghats landscape

07

NORTH EASTERN HILLS AND BRAHMAPUTRA FLOOD PLAINS

The Brahmaputra flood plains and North East hills landscape comprises of three zones viz. North Bengal Dooars, Brahmaputra Flood Plains and North Eastern hill ranges. The landscape is connected to the eastern part of the country through a narrow Siliguri corridor or 'chickens's neck' which lies between Nepal and Bangladesh (Datta 1995). Geographically, this landscape is situated between two densely populated nations of China and India and faces extreme pressure for development and economic transformation. The fertile plains of Bengal Dooars lie at the foothills of the eastern Himalayas and the vegetation type is primarily tropical moist forests with mosaic of tea plantations and cultivations. The Brahmaputra valley, an extension of Indo-Gangetic alluvial plain, is 750 kilometers long and 80 kilometers wide and surrounded by hills on all sides except the west (Rao 1974). Though much of the original natural habitats have been lost due to human settlements, there are a number of protected areas, reserved forests and wetlands along and across the length of the Brahmaputra. These areas are connected by the numerous river islands of Brahmaputra, which are locally called 'chars' or 'chaporis'.

The north-eastern hill region comprises of several hill ranges and can be categorized as Eastern Himalayas and north-east hills. The eastern Himalayas extend from the Koshi Valley in Central Nepal to northwest Yunan in China and include North East India, and hill districts of West Bengal. The north-east hills are a conglomerate of the hill tracts of Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. The Meghalaya plateau comprises of Garo, Khasia and Jaintia hills. The Lushai hills located in the south-east, lie mostly in Mizoram and a small portion in Tripura. The Naga Hills are narrowly laid out along the India-Myanmar border while the Barail Range, Karbi-Anglong hills and the Cachar hills are located in the state of Assam.

Location

There are eight states in this landscape, viz. Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. This landscape also includes the hilly district of northern West Bengal. It covers an area of 2,71,129 km^2 of which 1,70,541 km^2 (FSI 2019) is forested area. There are nine tiger reserves in this landscape, viz., Buxa in Northern West Bengal, Manas, Kaziranga, Nameri and Orang in Assam, Pakke, Namdapha and Kamlang in Arunachal Pradesh and Dampa in Mizoram. Other than these tiger reserves, several other national parks, wildlife sanctuaries, reserved forests and sacred groves are scattered across the landscape serving as wildlife refuges. This region shares international boundary with Tibet Autonomous region of China in north and north-east; with Bhutan, located between the states of Sikkim and Arunachal Pradesh. It also shares boundaries with Nepal, Bangladesh and Myanmar on the north-west, south and south-east thus making trans-boundary international cooperation an essential requirement for conservation success.

Ecological Background

The whole region is dissected by numerous rivers and their tributaries. The eastern Himalayas are made up of crystalline core and soft rocks. The Meghalaya plateau and Karbi Anglong Hills are mainly comprised of rocks from the Pre-Cambrian age of hard crystalline granites, gneisses and granulites. The Naga Hills and Barail range are dominated by tertiary sand stones and related rocks. The Brahmaputra flood plain and Barak valley are built up by deposition of alluvium.

The geographic complexity of this region has considerable influence on the weather patterns and creates climatic contrast between the valleys and the mountainous region, which lead to unique assemblage of vegetation and wildlife (Chhetri et al. 2001). Being very close to the tropics, this region resembles tropical climate to a large extent, especially in the valleys. The Himalayan range in the north act as a barrier to the southwest monsoon from the Bay of Bengal, causing the moisture to decrease to the western side, whereas comparatively more rain is received in the east. No parts of this landscape receives annual rainfall below 1000 mm.

The fertile lands of both Bengal Dooars and Brahmaputra flood plains had undergone extensive land-use changes since colonial era with large forested areas cleared out for tea plantation and cultivation. The discovery of oil on the banks of the Brahmaputra also led to the construction of the first oil refinery in India at Digboi in 1891. Both the Dooars and Brahmaputra plains were also exposed to exhaustive hunting of big game species, specially tiger, elephant and rhinoceros due to logistic advantages and their proximity to the capital of British India, Calcutta. It was this reason, that led to the near extermination of the once widely distributed rhinoceros population throughout the Brahmaputra valley, the Torsa region, through the forests of Buxa upto Sundarban. Eventually, the Bengal Rhinoceros Act 1932 was initiated to provide protection to the species. The range of the Sumatran rhinoceros extended into this landscape, but it is now extinct in India.

Prior to the advent of the colonial rule, most of the hill area of the north-east was under the control of tribal chieftains and different tribes. Each tribe had its own political system to manage resources. Even today, the six eastern most states of the north-east are a home to 209 major tribes (Datta 1995). Almost all hill tribes historically practiced shifting or 'jhum' cultivation and were hunter-gatherers. Some tribes in Arunachal Pradesh (former North East Frontier Agency) also indulged in some trade.

Conservation Importance

Being located at the junction of the Himalayas and the peninsular India, three biogeographical realms meet in the landscape; namely, the Indian, Indo-Malayan and Indo-Chinese (Mani 1974). The topographical complexity and altitudinal variations ranging from less than 300 meters (flood plains) to more than 6,000 meters (high mountains), contribute to the unique faunal assemblage and different vegetation patterns. This landscape is rich in endemic species that have narrow and restricted ranges of distribution (Root et al. 2003) and also been recognized as 'Endemic Bird Area (EBA)' by Birdlife International (Sttaersfield et al. 1998). Threats to biodiversity due to climate change and habitat loss could be acute to the landscape. Survival of some endemic species like Golden langur (*Trachypithechus geei*) is already at stake due to habitat loss and fragmentation.

An average human density of 174 persons/km^2 (Basic Statistic of NER, North East Council 2015), along with the isolated and rugged nature of terrain makes this one of the least explored areas of the country with many species of flora and fauna still undocumented. Also, by and large, the ethnic groups of people of north east India are animists, leading to formation of several sacred groves and community reserves along with the Protected Areas. The region boasts of the largest number of mammalian discoveries in the last decade. These include, one primate- the Arunachal macaque (*Macaca munzala*) in 2004 (Sinha et al. 2005), one ungulate (range extension in India, albeit not a species new to science) the leaf deer (*Muntiacus putaoensis*) in 2002 (Datta et al. 2003) and one avian species, Bugun liocichla (*Liocichla bugunorum*) in 2006 (Athreya 2006). From the perspective of tiger conservation, this region has two important Tiger Conservation Units (TCUs), one comprising of the Buxa-Manas Tiger Reserve, stretching across Bhutan to Arunachal Pradesh in the north-east, while the other includes the Kaziranga Tiger Reserve in Assam and stretches up to Meghalaya.

Besides tiger, north eastern states, especially Assam, Arunachal Pradesh and Meghalaya are home for more than 10,000 Asian elephants (Synchronized Elephant Population Estimation 2017, Project Elephant, MoEFCC) and the Brahmaputra flood plains has one of the last stronghold of wild water buffalo and the greater one horned rhinoceros with an estimated population of more than 2000, and 2500 individuals respectively (IUCN Red list).

Floristic diversity

The floral diversity of north-eastern India is the richest amongst all landscapes (Chakravarty 2012). This region has about 7500 species of angiosperms, 700 orchids, 63 bamboo species, 28 conifers, 728 lichens long with many ferns and palms (Ramakantha, unpub.). Due to the climatic contrast, climate dependent vegetation can be found depending upon the elevation i.e. tropical, temperate and alpine (Rao 1974). Tropical forest encompasses evergreen, semi-evergreen, moist and dry deciduous, grasslands, riparian forests and swamp up to elevation of 900 meters. Most of the tropical forests are located in the Assamese valley, foothills of the Himalayas, parts of Naga Hills and Manipur hills. The common species amongst such forests are: tall trees- *Dipterocarpus turbinatus, Canarium resiniferum, Artocarpus chaplasha, Ailanthus grandis, Tetrameles nudiflora, Euphoria longana, Kayea assamica, Terminalia chebula, Mesua ferrea* and *Dysoxylum binectariferum*; lower trees-*Amoora wallichii, Lagerstroemia parviflora* and *Terminalia myriocarpa*; lianas-*Bauhinia, Acacia, Derris, Vitis, Unona, Gnetum*; palms- *Caryota, Licuala, Arenga, Pinanga, Didymosperma* etc. The deciduous forests are dominated by *Shorea robusta* in areas with less than 2000 mm of rainfall. Thus, they are found predominantly in the districts of Goalpara, Kamrup, on lower slopes of Garo-Khasi hills and some in north Cachar hills. The associated species in these regions are *Careya arborea, Kydia calycina, Sterculia villosa, Bombax ceiba, Grewia spp., Acacia spp., Terminalia spp., Albizia spp., Adina cordifolia* and *Gmelina arborea* along with climbers, herbaceous plants, grasses and sedges. The grasslands occur mainly in the riparian belts with species of *Saccharum, Arundo donax, Erianthus ravannae* and *Phragmites communis*. The temperate vegetation is found at elevations from 1300-2500 meters in Shillong plateau, Naga Hills, Lushai hills, Mikir hills and parts of Arunachal. These include associations of *Albizia, Acer, Juglans, Quercus, Magnolia, Michelia, Rhododendron* and *Rubus spp*. Higher up, rhododendron dominates with *Pyrus, Prunus, Spiraea* and *Eriobotrya* finally ending in coniferous vegetation with *Tsuga-Picea-Abies* associations. Beyond elevations of 4500 meters alpine vegetation predominates with several species of rhododendron and meadows.

Faunal Diversity

Since the Himalayas are of relatively recent origin, faunal endemism is low, especially among the better known higher taxonomic groups. However, the fauna of the region is extremely diverse with 13 species of primates, viz., slow loris (*Nycticebus bengalensis*), the hoolock gibbon (*Hoolock hoolock*), Hanuman or common langur (*Semnopithecus entellus*), Nepal langur (*Semnopethicus schistaceus*), capped langur (*Trachypithecus pileatus*), golden langur (*Trachypithecus geei*), the Phayre's leaf-macaque (*Trachypithecus phayeri*), rhesus macaque (*Macaca mulatta*), stump-tailed macaque (*M. arctoides*), northern pig tailed macaque (*M. leonina*), Assamese macaque (*M. assamensis*), Pere David's or Tibetan macaque (*M. thibetana*), and the newly discovered Arunachal macaque (*M. munzala*); four large cats, viz., tiger, leopard, snow leopard, clouded leopard along with three species of ursidae, the Asiatic black bear (*Ursus thibetanus*), sloth bear (*Melursus ursinus*) and the Malayan sun bear (*Helarctos malayanus*) along with two canid species, the jackal (*Canis aureus*) and the wild dog (*Cuon alpinus*).

The region also has the highest diversity of small carnivores which includes five species of small cats, viz., the marbled cat (*Pardofelis marmorata*), Asiatic golden cat (*Catopuma temminckii*) , leopard cat (*Prionailurus bengalensis*), fishing cat (*Prionailurus viverrinus*) and the jungle cat (*Felis chaus*) and several species of viverrids and mustelids, viz., yellow-throated marten (*Martes flavigula*), Chinese ferret-badger (*Melogale moschata*), Burmese ferret-badger (*Melogale personata*), hog badger (*Arctonyx collaris*), small Indian civet (*Viverricula indica*), large Indian civet (*Viverra zibetha*), common palm civet (*Paradoxurus hermaphrodites*), masked palm civet (*Paguma larvata*), binturong (*Arctictis binturong*), spotted linsang (*Prionodon pardicolor*), smooth coated otter (*Lutrogale perspicillata*), small clawed otter (*Amblonyx cinereus*) and Eurasian otter (*Lutra lutra*). This area also supports the highest number of squirrel species which include the rare, endemic Namdapha flying squirrel (*Biswamayopterus biswasi*), hairy-footed flying squirrel (*Belomys pearsoni*), parti-coloured flying squirrel (*Hylopetes alboniger*), orange-bellied Himalayan squirrel (*Dremomys lokriah*), Malayan giant squirrel (*Ratufa bicolor*), hoary- bellied squirrel (*Callosciurus pygerythrus*) and Himalayan striped squirrel (*Tamiops macclellandi*) along with over 65 species of bats. This region also has probably the highest diversity of ungulates in the world ranging from species of the lowlands like the Asian elephant (*Elephas maximus*), one-horned rhinoceros (*Rhinoceros unicornis*), water buffalo (*Bubalus arnee*), brow-antlered deer (*Cervus eldi eldi*), swamp deer (*Rucervus duvaucelii*), leaf deer (*Muntiacus putaoensis*), hog deer (*Axis porcinus*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), chital (*Axis axis*) (in the Bengal dooars), wild pig (*Sus scrofa*) and pygmy hog (*Porcula salvania*). The mountain ungulates comprise of Himalayan serow (*Capricornis thar*), Himalayan goral (*Naemorhedus goral*), red goral (*Naemorhedus baileyi*), Tibetan wild ass (*Equus hemionus kiang*), ibex (*Capra ibex*), great Tibetan sheep (*Ovis ammon hodgsoni*) and blue sheep (*Pseudois nayaur*) to name a few. The only species of Ailuropodidae, the red panda (*Ailurus fulgens*) is also endemic to this region along with the endangered hispid hare (*Caprolagus hispidus*) and the rare Chinese pangolin (*Manis pentadactyla*) and Indian or thick-tailed pangolins (*Manis crassicaudata*). The recent camera trap exercise during All India Tiger Estimation has recorded Asiatic brush tailed porcupine (*Atherurus macrourus*) from Pakke, Kamlang and Namdapha Tiger Reserves.

Like the mammalian fauna, this region also supports high number of avian species with Arunachal Pradesh alone having 665 species (Ramakantha, unpubl.). The Eastern Himalayan EBA, which covers parts of Arunachal, Assam and Sikkim, has several endemic species like the chestnut-breasted partridge (*Arborophila mandellii*), rusty-throated wren babbler (*Spelaeornis badeigularis*), white throated tit (*Aegithalos niveogularis*) and orange bullfinch (*Pyrrhula aurantiaca*). Other avian flagships are the white-winged duck (*Asarcornis scutulata*), the endemic white-bellied heron (*Ardea insignis*) and the Bengal florican (*Houbaropsis bengalensis*). Along the India-Myanmar border are found species like the endemic golden-crested myna (*Ampeliceps coronatus*), and wedge-billed wren-babbler (*Sphenocichla humei*) while in the Mizo-Manipur-Kachin rainforests of the 580 bird species, several like the Blyth's tragopan (*Tragopan blythii*), brown-capped laughing thrush (*Garrulax austeni*), long-tailed wren-babbler (*Spelaeornis chocolatinus*), rufous-capped babbler (*Stachyris ruficeps*), broad-billed warbler (*Tickellia hodgsoni*), and white-browed nuthatch (*Sitta victoriae*) are considered endemics.

Tiger Population Extent & Abundance

Camera trap based mark-recapture and density estimates of tigers were obtained from 8 sites of the Brahmaputra flood plain and North East hills landscape. The population of tigers have shown promising trend in Brahmaputra flood plains. However, Nameri and Pakke block has shown a decreasing trend of tiger population. Tiger presence was also recorded from scat samples from newly formed Kamlang Tiger Reserve and Nampdapha Tiger Reserve. In Arunachal Pradesh, Mizoram, Nagaland and parts of Assam (Karbi Anglong Autonomous Council) standard Phase I sampling could not be carried out due to logistic constraints and absence of demarcated administrative units at the beat level. Priority tiger habitats were targeted in those areas based on past surveys and literature to estimate tiger population by combining information from polygon search method, scat based DNA profiling and camera trapping. Tiger occupancy was recorded from an area of 3312 km^2 of forests within the Brahmaputra Valley and North East Hills landscapes, with an estimated population of about 219 (194-244) tigers (Figure 1). About 6040 km^2 areas were not sampled in 2018 where tiger presence was recorded in 2014.

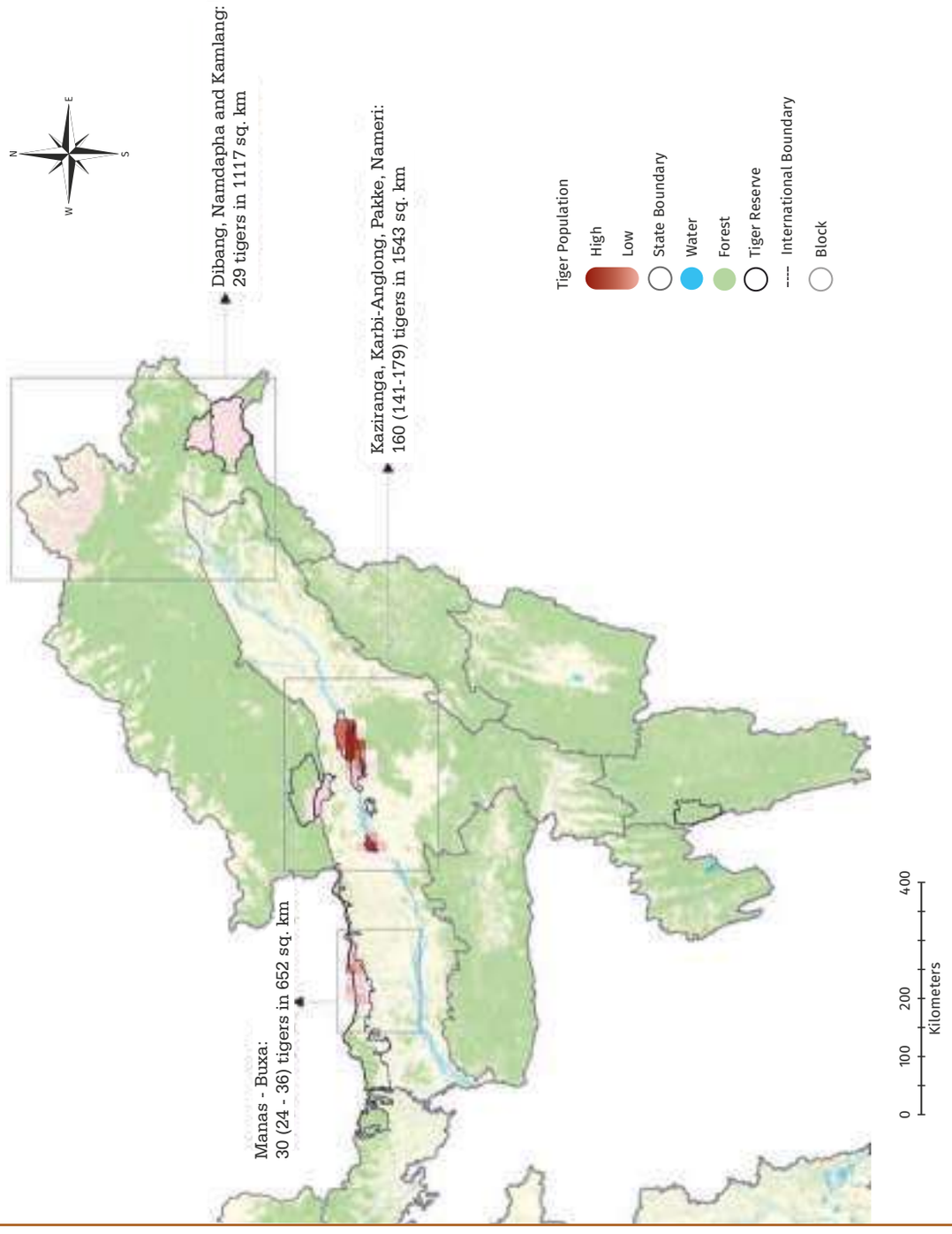


Figure 7.1
Spatially explicit tiger density modelled from camera trap based mark-recapture and MaxEnt

1. The Kaziranga-Nagaon-Orang-Nameri-Pakke Block: This landscape block of Brahmaputra flood plain is the single largest tiger population in the northeast landscape. An estimated 160 (141-179) individuals are present in this block. Pakke and Nameri both share the same tigers as these two Tiger Reserves are contiguous with each other.

2. Manas-Buxa-Gorumara-Jaldapara: A population of 30 (24-36) tigers have been estimated for the Manas Tiger Reserve. The tiger population of Manas Tiger Reserve has shown an increase since last estimation; however, no tiger signs were observed in Bengal (Buxa TR) Dooars during this estimation. Both Manas and Dooars have potential for further growth with some scientific and managerial inputs especially protection.

3. Dibang-Kamlang-Namdapha: Extrapolating tiger density obtained from scat and camera trap images to tiger habitats by MaxEnt gave a potential tiger population of 29 in Dibang-Kamlang-Namdapha block. Dibang Wildlife Sanctuary has a very promising future in terms of tiger conservation with the help and will of the local community. Being animists, the local community treat tiger as their elder brother and has unique perception towards tiger conservation. The community does not hunt tigers and there is hardly any killing of tigers as retaliation to livestock predation. Talks between local community, Central and State Government agencies and scientific fraternities are ongoing for the best conservation strategy to safeguard the unique high altitude tigers. No tiger signs were recorded in Dampa Tiger Reserve during the sampling period.

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Critical Corridors, habitat connectivity and conservation

Although the north-eastern hill landscape has persistently low tiger abundance, but the contiguous forest patch connectivity with the Brahmaputra flood plains provide habitat connectivity despite of high hunting pressure and low prey abundance in the hills. The tiger population of this landscape is genetically unique (Kolipakam et al. 2019) likely because of gene flow with south-east Asian tiger populations of Myanmar. Thus, the North Eastern tigers have a great evolutionary significance and appropriate measures are needed to safeguard the habitat connectivity. This region represents Oriental and Indo-malayan realm and has several other important species, which are threatened and endemic to this landscape as well. Most states of this region share international boundaries with People Republic of China, Bhutan, Myanmar and Bangladesh and make the conservation of trans boundary Protected Areas an important task. In addition, these states are developing infrastructural projects like roads, dams, HEPs and mining activities, which may potentially affect these fragile habitat links. Trans-boundary cooperation, awareness among the native inhabitants and proper mitigation measures while planning any development projects are solicited for conservation success of this landscape.

Status of major corridors of Brahmaputra flood plains and North East Hills (Fig: 7.2)

Kaziranga and other protected areas

The Brahmaputra flood plains have high prey biomass and support high density of tigers. The Kaziranga population is one single largest source tiger population in this landscape. Kaziranga tiger population is connected to Orang Tiger Reserve on the west, Nameri, and Pakke Tiger Reserve in the north through the island systems of Brahmaputra. The river islands or 'chaporis' play an important and vital habitat link to maintain gene flow between plains and hill populations of tigers (in Arunachal Pradesh). But, these river islands being extremely fertile for agriculture and pasture for livestock are mostly encroached being a major hindrance for animal movement. Kaziranga population has almost lost the connectivity to the North Bank of the Brahmaputra. The Orang Tiger Reserve also has a significant tiger population; however the connectivity of this population to Kaziranga in south and Nameri- Pakke in North is being disrupted due to increasing human settlements and 'khutis' (cattle farms). Kaziranga is connected to Karbi Anglong Hills in the south and further to Intanki National Park through some degraded forest areas. This connectivity to the Karbi Anglong is crucial for dispersal of tigers and other wildlife species that use these hills as refuge during flooding season of Brahmaputra. Unfortunately, the limited surveys conducted in the Karbi Hills during this estimation did not record any tiger signs. The NH 37 runs through the southern boundary of Kaziranga National Park. It is crucial to manage traffic on the highway passing through Kaziranga by appropriate mitigation measures so that infrastructure and urban sprawl do not form a barrier for movement of wildlife (especially the megaherbivores) to Karbi Anglong refuge. Also mining and stone quarrying and stone crushing in Karbi-Anglong hills are matter of concern and the Assam Government has already been requested to put a ban on mining in these sensitive areas. Intanki National Park is also connected westwards through forests upto Balphakram National Park. Surveys and camera trapping, though limited, did not record any tiger sign in Intanki as well. This landscape has contiguous forest across the international border with Htamanthi Wildlife Sanctuary in Myanmar. The weak links in this landscape are the forests in the districts of Mon, Mokok Chung, Tuensang, Zuheboto, Wokha, and Pekh in the east. The landscape between Balphakram National Park and Intaki National Park through the districts of Karbi-Anglong, West Khasi Hills, East Khasi Hills and East and West Garo Hills is fragmented. The lack of tiger signs in Karbi Anglong and Intanki is suggestive of deterioration of habitat connectivity probably due to hunting of tiger prey.

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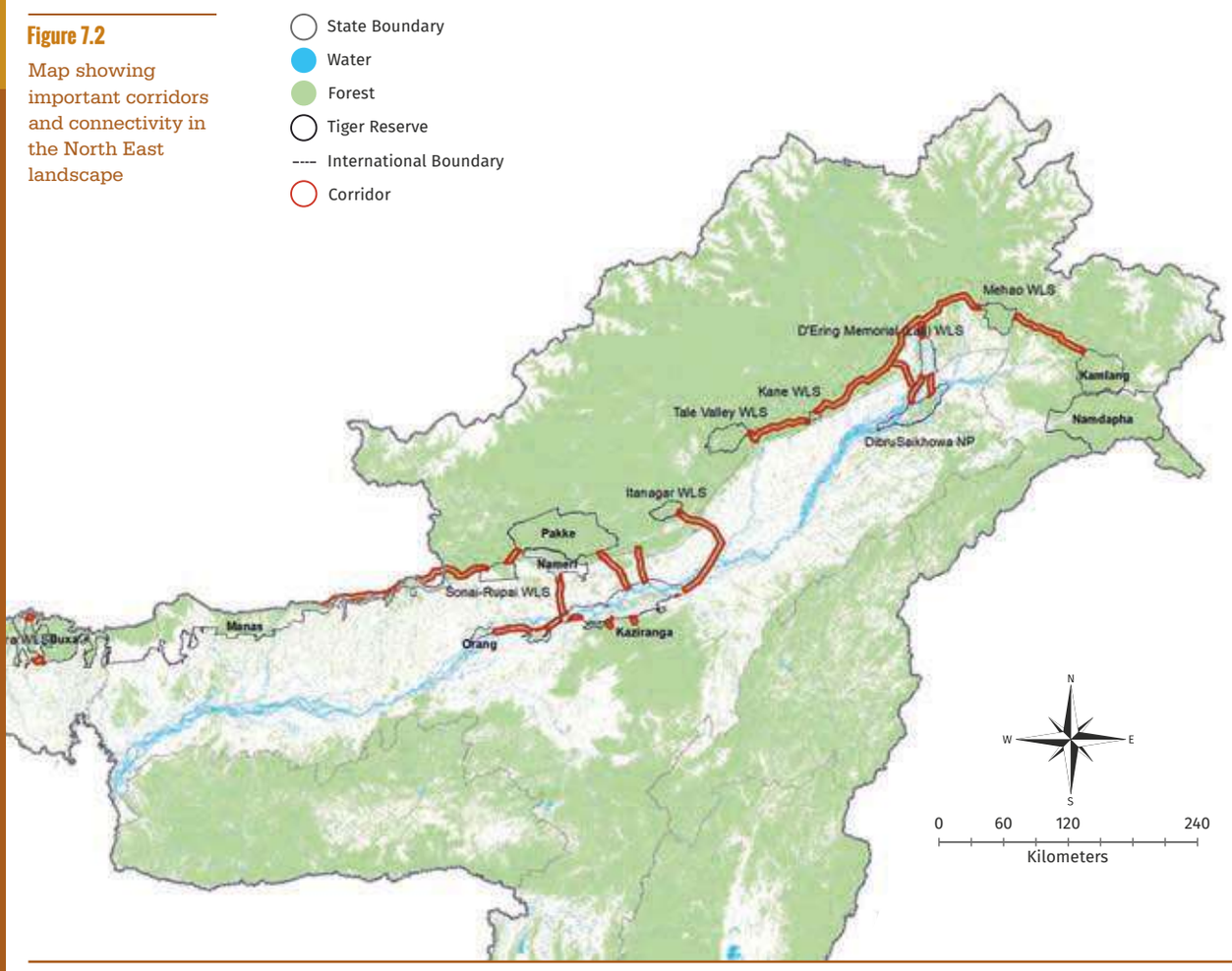
Figure 7.2

Map showing important corridors and connectivity in the North East landscape



Manas-Ripu Chirang and Buxa-Jaldapara- Gorumara

Manas-Ripu Chirang- Buxa-Jaldapara-Gorumara landscape unit on western side of this region also holds importance as the tiger population of this landscape unit and have historical evolutionary significance as they share connecting common gene pool with the south eastern tiger populations and the entry point of tigers into the Indian sub-continent. The area was highly affected by extremist activities and ethno-political conflicts, thus making conservation and scientific monitoring a challenging task. Manas along with Ripu Chirang Elephant Reserve as a part of Bhutan Biological Conservation Complex is connected to the Buxa Tiger Reserve and further to Gorumara National Park and Jaldapara Wildlife Sanctuary. In the east this landscape unit has connectivity towards Sonai-Rupai Wildlife Sanctuary in Assam through Bor Nadi Wildlife Sanctuary in Assam and Jomotsongkha Wildlife Sanctuary in Bhutan (Ahmed et al. 2019). This landscape unit shares connectivity through the forests of Bhutan making this unit a transboundary conservation complex. The landscape needs to be managed through transboundary international cooperation with the Government of Bhutan. However, lack of tiger evidence in the Dooars is due to the absence of a major source population in this landscape. Once tiger population of Manas improves tigers would gradually occupy this landscape, provided corridor connectivity through foot-hill forests of Bhutan remains viable.

Nameri-Sonai Rupai Wildlife Sanctuary

Nameri Tiger Reserve is located in Sonitpur district of north-east Assam. It is contiguous with Pakke Tiger Reserve of Arunachal Pradesh to its north. Its connectivity with Kaziranga through Jia Bhoroli and Borgang River are important and needs policy and managerial inputs for its continued viability. Camera trap evidence suggests that tigers often use this connectivity to disperse from Kaziranga to Nameri. This complex may further be connected to the Sonai Rupai Wildlife Sanctuary in Assam and the larger forest complex of Arunachal Pradesh, that provides connectivity, although with high hunting pressures, to the forests further east into Namdapha, Intanki and maybe even into Myanmar.

Dibru-Saikhowa-D'Ering-Mehao-Kane-Tale Valley - Kamlang and Namdapha Tiger Reserve

Arunachal Pradesh has large contiguous forested region over 136,000 km^2 which includes Pakke Tiger Reserves in the west, Tale Valley Wildlife Sanctuary, Mouling National Park, D'Ering Wildlife Sanctuary, Mehao Wildlife Sanctuary in the centre, Dibang Wildlife Sanctuary in the north, and Kamlamg and Namdapha Tiger Reserve in the east. Compared to earlier surveys this landscape unit shows a persisting low-density tiger population. The landscape continues south through some degraded areas into Intanki National Park, and further South to Dampa Tiger Reserve and Blue Mountain National Park. Pakke-Nameri landscape includes parts of the Sessa orchid Wildlife Sanctuary in Kameng district, Eagle Nest Wildlife Sanctuary, Pakke Tiger Reserve, parts of Nameri Tiger Reserve in Assam and continues via the forests of Tale Valley into lower Subansiri to D'Ering Memorial Wildlife sanctuary in East Siang upto Namdapha Tiger Reserve. The largest tiger population of Arunachal Pradesh is within pockets of this landscape. However, it would be good to plan and execute appropriate mitigation measures and green infrastructure before developing the ambitious the Trans Arunachal Highway, a trunk road of 1811 km, which will inter-connect 12 out of 16 district headquarters of Arunachal Pradesh. As this highway would definitely become a barrier for the movement of the wildlife species in several of these corridor in the years to come.

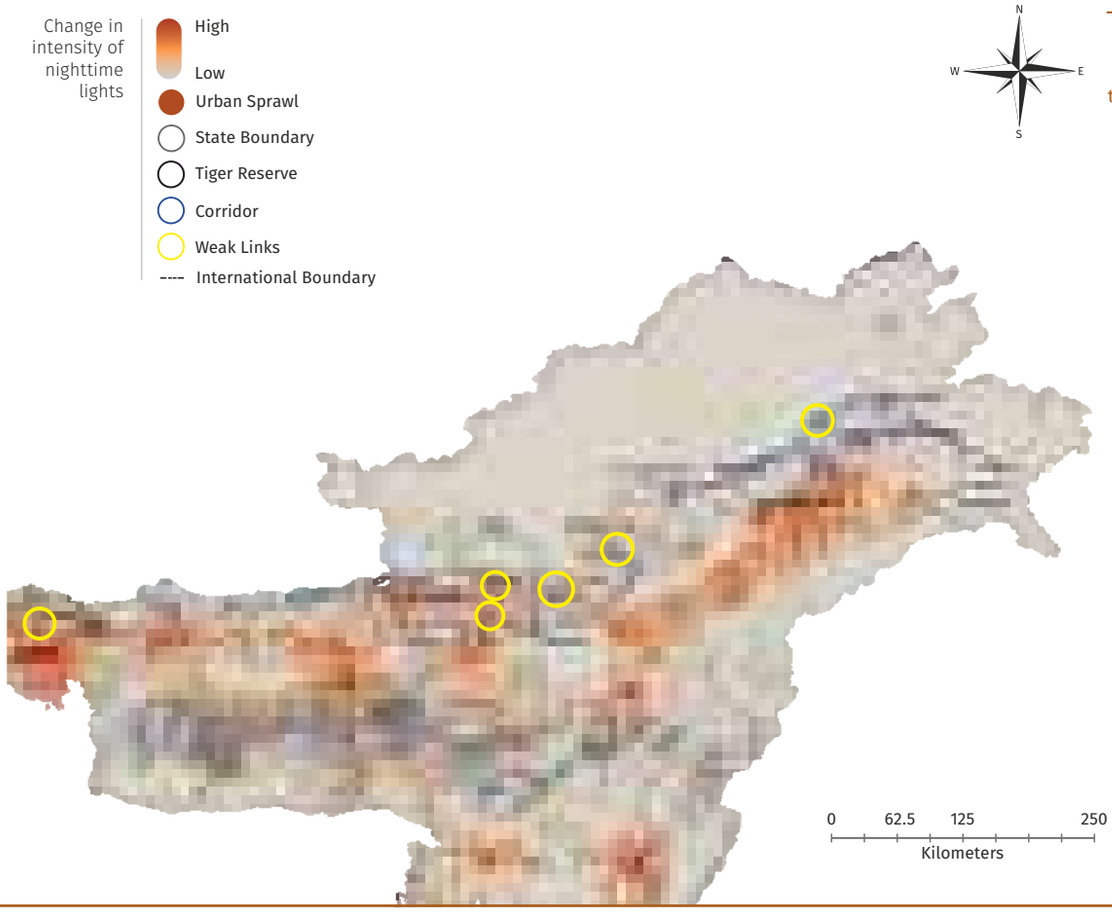


Figure 7.3
Change in night time lights between 2014 to 2018 across the North Eastern Hills & Brahmaputra Flood Plains landscape. Connecting habitat corridors are superimposed, bottlenecks and pinch points demarcated by circles.

08

SUNDARBAN LANDSCAPE

Sundarban is the only mangrove habitat which harbours tigers and is a global priority Tiger Conservation Landscape Unit (Dinerstein et al. 1997). These mangrove forests are also the world's largest contiguous halophytic mangrove habitat covering an area of 10,000 km^2, with about 66% of the landscape in Bangladesh and 34% in India (Naskar and Mandal 1999). It is also a globally important wetland (Junk et al. 2006) and was declared a World Heritage Site in 1987 by United Nations Educational, Scientific and Cultural Organisation (UNESCO).

The entire land mass of Sundarban is of recent origin. The Himalayan orogenesis, carriage of world's largest sediment load to the sea by rivers Ganga and Brahmaputra and the tectonic movement of the continental plates have built the unique geological characteristics of Sundarban (Morgan and Mcintire 1959, Milliman et al. 1995). Neotectonic movements induced an easterly tilt in the Bengal Basin in the 12-15th AD (Morgan and McIntire, 1959). In the 16th century, Ganga shifted its course eastward to join the Brahmaputra (Snedaker 1991). These two combined rivers then further shifted their course to join river Meghna (Snedaker 1991). These constant shifts due to tectonic movements leading to changing sedimentation patterns have greatly influenced the hydrology of Sundarban (Gopal and Chauhan 2006). Sundarban is shaped into many islands crisscrossed by a maze of tidal rivers, estuaries and creeks formed by the regular tidal action (Gopal and Chauhan 2006).

Location

The Indian Sundarban differs substantially from its Bangladesh counterpart in the nature of conservation, management and the level of exploitation by humans (Gopal and Chauhan 2006). Major parts of the Indian Sundarban are under the highest protection and management regime associated with a tiger reserve, with some parts set aside for forest produce extraction and tourism. Bangladesh Sundarban, on the other hand has three small sanctuaries which act as wildlife 'hot-spots' and the majority of the forest is open to harvesting of forest produce. The Indian Sundarban covers an area of about 4,266km^2 (Naskar & Guha Bakshi 1987) situated within 21°31' N - 22°30' N latitudes and 88°10' E - 89°51' E longitudes in the coastal districts of North and South 24 Parganas, West Bengal. The sea-land inter-phase comprises of about 55% forest land and 45% water. The land area consists of around 56 forested islands. Indian Sundarban has been declared as 'Sundarban Biosphere Reserve'. This includes the tiger reserve and the protected mangrove tracts in the South 24-Parganas. The tiger reserve is further made up of the core area (declared as a national park and comprising of the ranges West and East), the buffer zone (Basirhat range) and the wildlife sanctuary (Sajnekhali range). Sundarban Tiger Reserve is also divided into 15 management sub-zones or 'beats' which are further divided into 71 'compartments' for management purpose (Working Plan of Sundarban Tiger Reserve).

Landscape characteristics

The landscape is highly influenced by the natural phenomena of tidal cycles. Sundarban is subjected to semidiurnal tide where two tide cycles in a day, each of 12 hrs 25mins duration (Nagelkerken 2009) occur. The gradient of salinity varies spatio-temporally due to the freshwater flow of the rivers and the tidal influx. Salinity decreases as we move from west to east. Most of Indian Sundarban is polyhaline with salinity between 18 and 30 parts per thousand. The predominant soil type is clay loam along with silty and sandy loam soils (Gopal & Chauhan 2006). The climate is characterized by high temperature and high humidity (over 80%) throughout the year (Gopal & Chauhan 2006). Thunderstorms known as nor'westers are common during April and can often be accompanied by tidal waves as high as 7.5m (Seidensticker & Hai 1983).

Floristic diversity

The mangroves are the dominant geomorphic agent in the evolution of tidal shoals (Gopal and Chauhan 2006). Conversely, the vegetation of this region is influenced by several factors like salinity levels, soil composition and structure, silt deposition rates and rates of humus formation. Interestingly, Sundarban supports fewer species than other mangrove areas in India and Southeast Asia. This area is home to around 35 true mangrove species and 117 other halophytic mangrove associates (Qureshi et al. 2006). Altogether, about 350 vascular plant species belonging to 254 genera are found here (Chakrabarti 1980). Sundarban forests are classified under the sub-group 4B tidal swamp forests with sub-divisions of mangrove type (4B/TS1 and 4B/TS2), salt water type mixed forest (4B/TS4), brackish type (4B/TS4), and palm swamp type (4B/E1) (Champion and Seth 1968). Dominant tree species include *Avicennia alba, Avicennia marina, Aegiceras carniculatum, Bruguiera sexangula, Ceriops decandra, Exocoecaria agallocha, Nypa fruticans, Phoenix paludosa, Rhizophora apiculata, Sonneratia apetala, Xylocarpus granatum* and *Xylocarpus mekongensis*. Besides these, there are many species of climbers, grasses and herbs as well.

Faunal diversity

Mangrove habitats are amongst the most productive ecosystems, however, most of the productivity is confined to aquatic systems with terrestrial species being low in numbers. Thus, the ability of this region to sustain large mammals is restricted. The main prey species of the tiger in Sundarban are chital (*Axis axis*), wild pig (*Sus scrofa*), Rhesus macaque (*Macaca mulatta*) and lesser adjutant stork (*Leptoptilos javanicus*) (Khan 2004). Tigers are also likely to prey on water monitor (*Varanus salvator*), young salt water crocodiles (*Crocodylus porosus*) and possibly fish. Other purported native fauna of the region which included Javan rhinoceros (*Rhinoceros sondaicus*), swamp deer (*Rucervus duvaucelii*), water buffalo (*Bubalus bubalis*), gaur (*Bos frontalis*), hog deer (*Axis porcinus*) and marsh crocodile (*Crocodilus palustris*) are now extinct from this area (Chakrabarti 1980). Estuarine crocodile, water monitor, northern river terrapin (*Batagur baska*), softshell turtle (*Pelochelys bibroni*), green sea turtle (*Chelonia mydas*), along

with Irrawaddy dolphin (*Orcaella brevirostris*) and Gangetic dolphin (*Platanista gangetica*) are some of the rare and endangered species found in Sundarban. This landscape supports about 300 species of birds, 7 species of amphibians, 59 species of reptiles, 165 species of fishes, 110 species of molluscs, 64 species of crabs (Working Plan of Sundarban Tiger Reserve). Crustaceans form the largest proportion of animal biomass (Hendrichs 1975).

Conservation importance

The tiger is an integral part of Sundarban. These tigers differ in their morphology from that of their geographically closest conspecifics (*Panthera tigris tigris*, Linnaeus and *P. tigris corbetti*, Mazak) (Barlow 2009) and have adapted successfully to a more amphibious, saline, pneumatophore-filled existence. This area attracts publicity largely for the claimed highest number of tigers in the world along with a high prevalence of man-eaters amongst them. While the former claim has now been debunked (Jhala et al. 2016), the latter remains a mystery. Beyond the tiger, Sundarban also assumes both anthropogenic and economic importance. This tiger habitat is in close proximity to one of the densest (1437.4 persons/km^2, Qureshi et al. 2006) and poorest (Kanjilal et al. 2010) human populations. Sundarban plays a critical role in coastal ecology by buffering inlands from cyclones, stabilising sediments and aiding land maturation (Blasco et al. 1996). Alongside, it is also a very important nursery for many estuarine and marine fishes. Acting as bio-shield against storms, cyclones, this forest provides livelihood to the local communities in the form of forest-sea produce like fish, giant tiger shrimp (*Penaeus monodon*, Fabricius) and honey (Blair 1990; Rahman 2000; Islam and Wahab 2005).

Tiger presence

For the 2018 phase I cycle, Sundarban Forest Department conducted extensive khal (water channel) surveys across the entire forested landscape with an effort of 2976 kms. Figure 8.1 depicts tiger presence recorded during these surveys. As we can see, the occupancy of tigers across the landscape is almost hundred percent.

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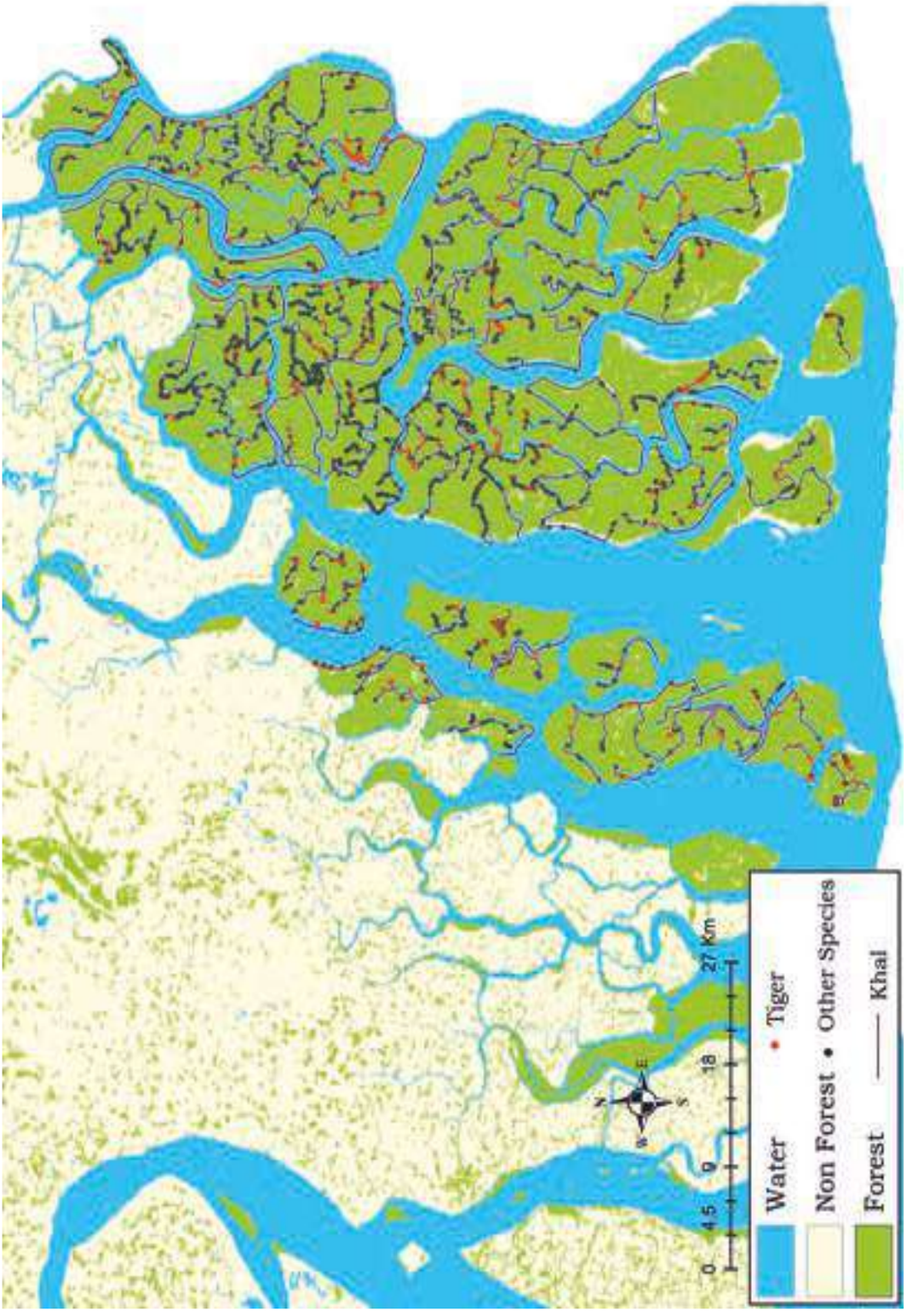


Figure 8.1
Khal (channel) survey conducted by the forest department across Sundarban with recorded tiger pugmarks

Tiger density

Spatially explicit mark recapture based camera trapping was carried out by the Sundarban Forest Department across the entire Indian Sundarban landscape in 712 camera stations (Figure 8.2) with an effort of 24,595 trap nights resulting in the photo-capture of 85 tiger individuals.

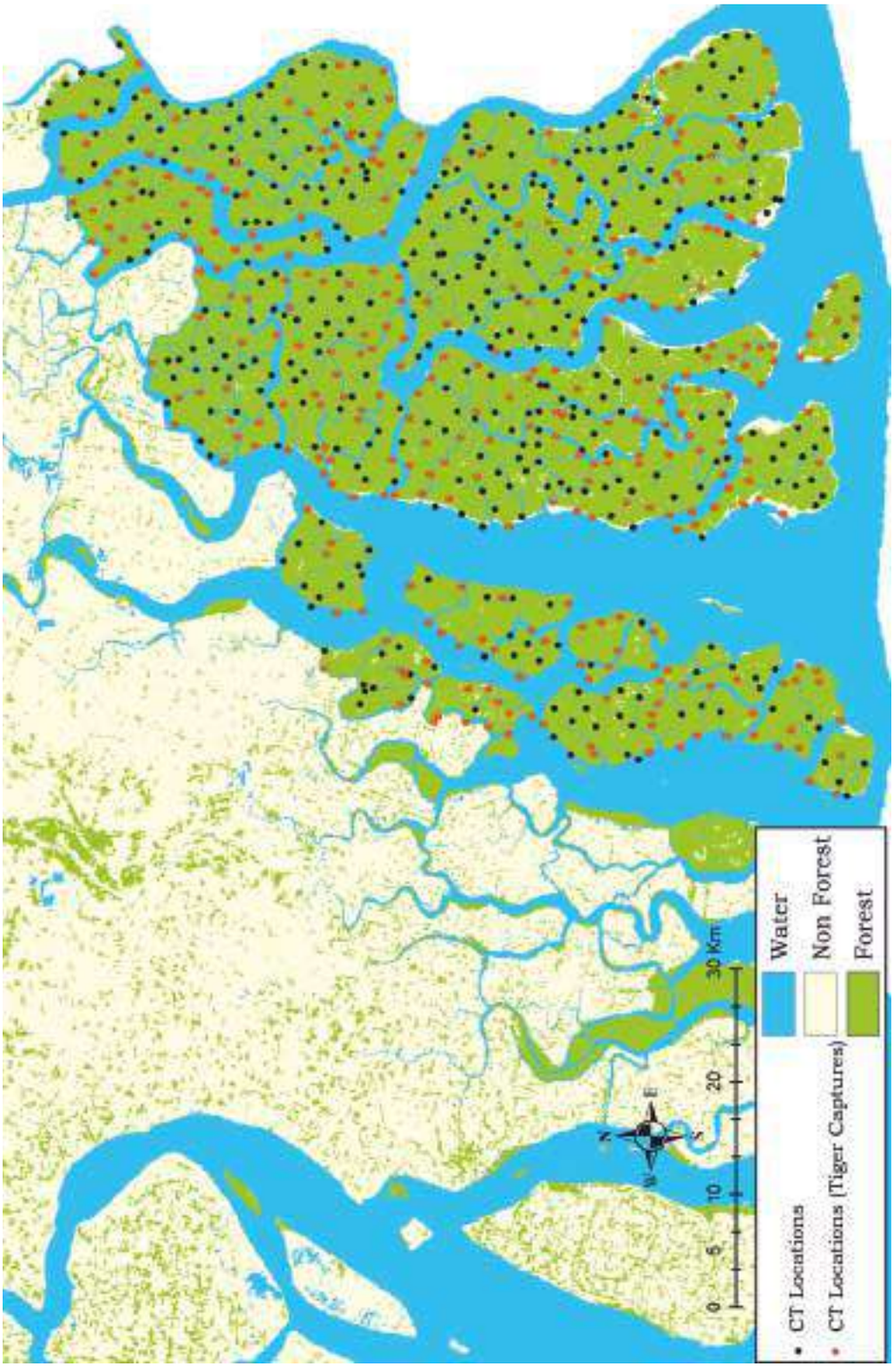
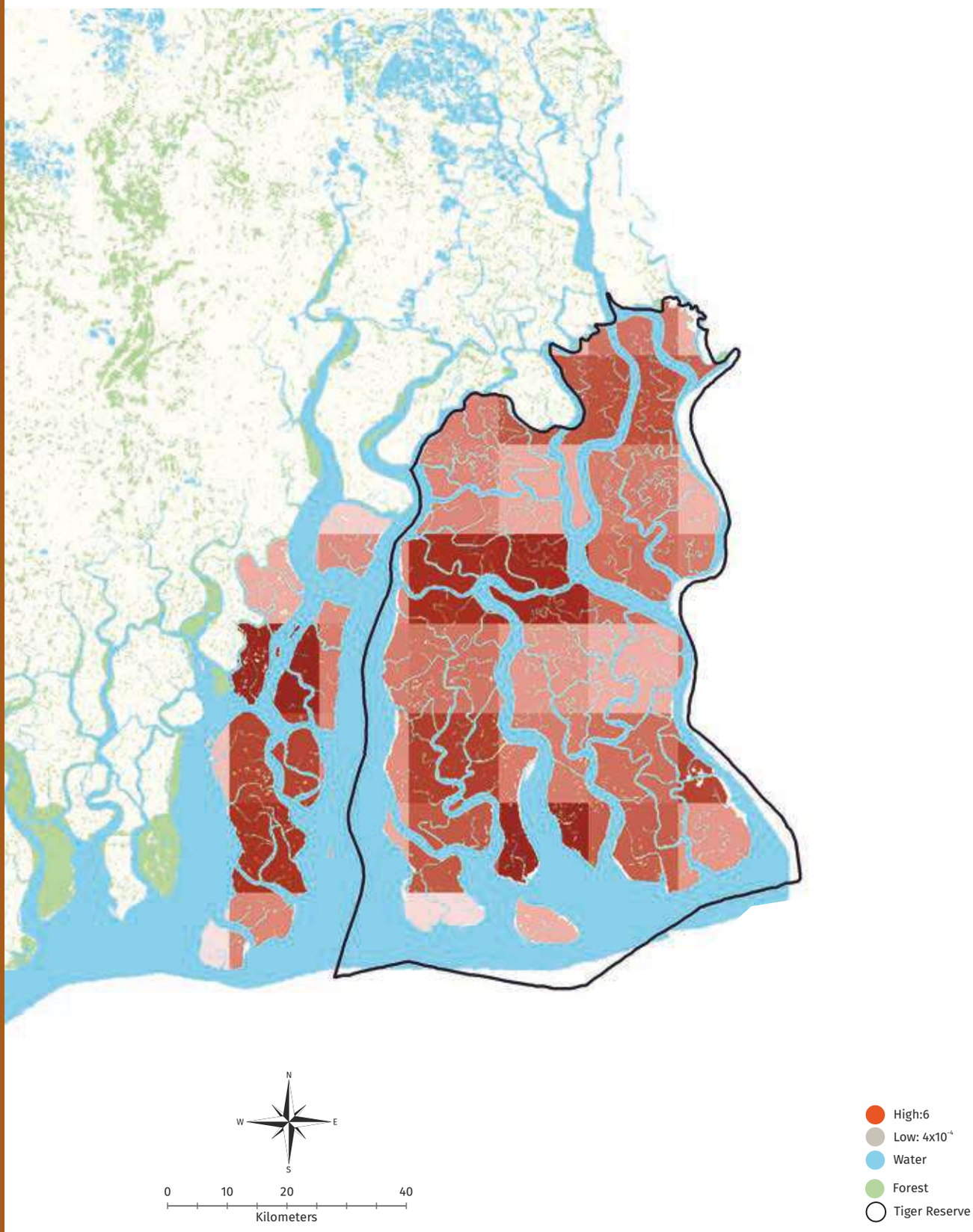


Figure 8.2
Camera trap locations across Sundarban (camera traps (CT) with tiger captures have been highlighted in orange)

The best model for estimating tiger density took into account the heterogeneity associated with tiger gender for both the detection probability at the activity centre and the movement parameters. Tiger density was estimated at 3.6 (SE 0.38) tigers per 100 km^2. The g_0 (detection at activity centre) for females was 0.13 (SE 0.01) while for males it was 0.09 (SE 0.009). The σ (movement/scale parameter) for females was 3.2 (SE 0.1) km while for males it was 4.6 (SE 0.18) km. The female to male detection ratio was 0.64:0.36. A total of 6 young tigers were photo-captured.

Figure 8.3
Spatial density of tiger in Sundarban, 2018

Parts of the Sundarban Biosphere Reserve and Sajnekhali and West ranges of Sundarban Tiger Reserve had the highest density of tigers as depicted in Figure 8.3.



Tiger abundance over the past four cycles of All India Tiger Monitoring

The tiger abundance in the four cycles of the All India Tiger Monitoring is detailed in Table 8.1.

Year	Tiger abundance (Range)
2010	74 (64-90)
2014	76 (62-96)
2018	88 (86-90)

Table 8.1
Tiger abundance estimated through camera trap based spatially explicit capture-recapture over the four cycles of All India Tiger Monitoring

Over the years there has been a positive trend in tiger abundance which is not statistically significant and therefore the population can be considered stable (Table 8.1, Roy et al. 2015). The low coefficient of variation (high precision) of 11% in tiger abundance of 2018 was largely due to the extensive camera trap coverage and high recaptures of tiger individuals.

Status of prey

During the phase I khal survey, Sundarban Forest Department conducted boat transects for prey base density estimation. However, as the perpendicular distances were estimated ocularly, we use the previous cycle's effective strip width (Jhala et al. 2015) in tandem with 2018 cycle's encounter rates for estimating chital and wild pig densities; we assume that the detectability has remained constant (a reasonable assumption).We report only the encounter rates of the other purported tiger prey species, viz. Rhesus macaque and monitor lizard (Table 8.2).

Species	# Detections	Effective strip width in 2014 in meters (SE)	Encounter rate per km	Mean group-size (SE)	Group density (SE)	Individual density (SE)
Chital	64	29.09 (4.35)	0.053	1.93 (0.12)	1.89 (0.36)	3.65 (SE 0.73)
Wild pig	23	29.09 (4.35)	0.02	1.54 (0.16)	0.71 (0.19)	1.09 (SE 0.32)
Rhesus macaque	35	-	0.03	2.95 (0.58)	-	-
Monitor lizard	67	-	0.05	1.06 (0.02)	-	-

Table 8.2
Model statistics and parameter estimates of transect (n=213, Total effort 1478 km) based distance sampling for prey species in Sundarban, 2018

Corridor and connectivity

With Bay of Bengal on one side, Sundarban is surrounded by human settlement and agriculture on its three sides. This forest has long been isolated from the nearest tiger occupied habitats by agricultural lands and human settlements (Sanderson et al. 2010), thereby removing any opportunity of gene flow across nearby tiger populations (Aziz et. al. 2018a). Within the Sundarban tiger population, low to medium level of genetic diversity has been reported (Aziz et al. 2018a, Singh et al. 2013). The primary concern regarding threats to the genetic heterogeneity of this population is the probable isolation induced by the wide rivers prevalent in the landscape. Naha et al. 2016 found that tigers rarely crossed channels wider than 400m. Aziz et al. (2018a) reported a fine-scale genetic structure and clustering within the tiger population of Bangladesh Sundarban which could largely be attributed to the river systems. Various studies have revealed that river systems can have profound influence on genetic structure of a species where rivers are wide enough to act as a geographical barrier (Moritz et al. 2000; Hayes and Sewlal 2004). Though tigers have been observed to occasionally disperse across wide rivers, increased continuous use of these water channels inside the forest as conduit for commercial boat traffic can transform the rivers to barriers to tiger movement. Hence along with trans-boundary collaboration, regulation of cargo vessel movement to avoid tiger peak activity periods (5 AM to 10 AM) should be enforced (Naha et al. 2016).

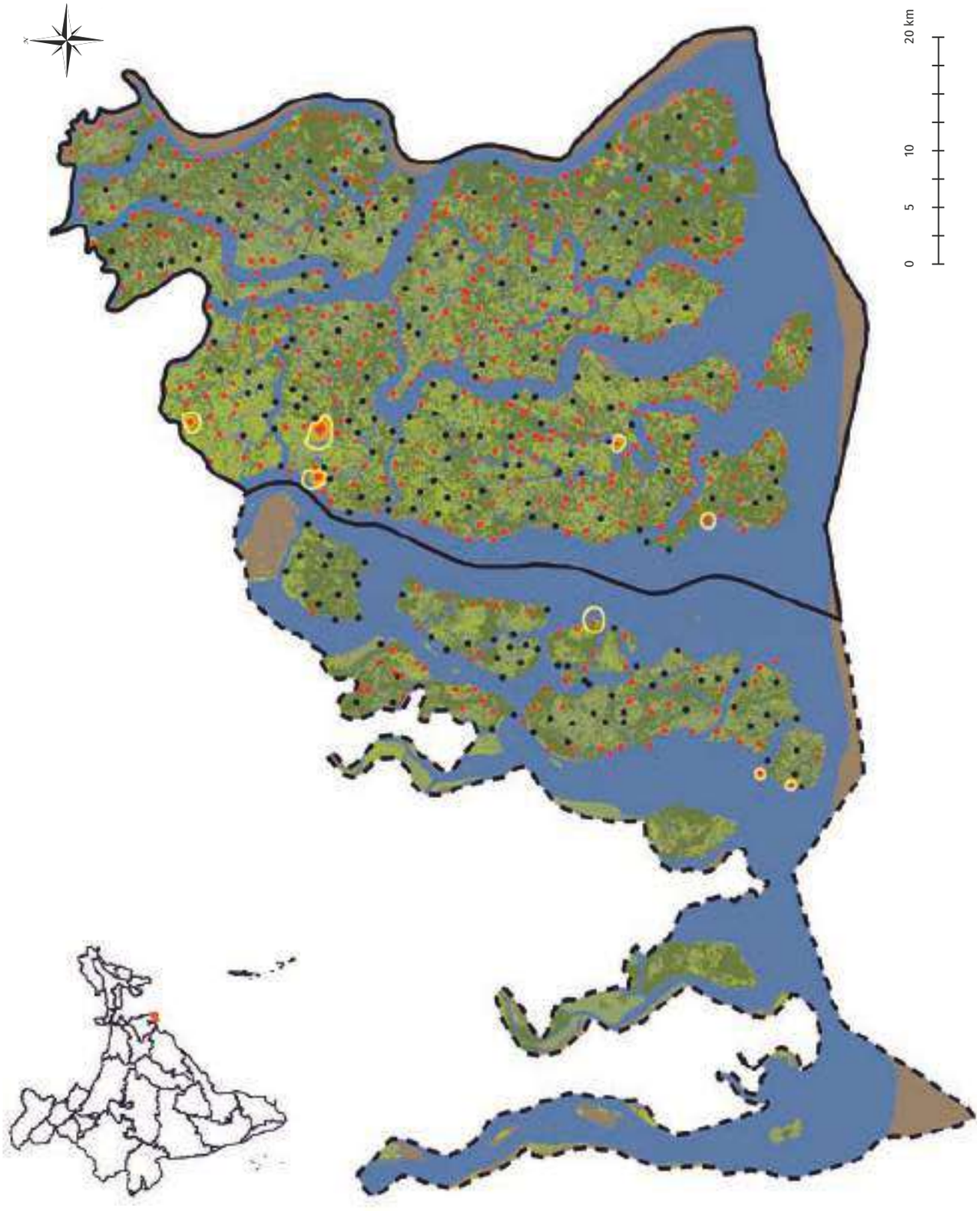
Species distribution

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The dotted line represents the boundary of the Sundarban Biosphere Reserve while the black line delineates the tiger reserve boundary.

Figure 8.4

Distribution and relative spatial abundance of chital in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Chital was captured throughout Sundarban landscape with highest concentration of photo-captures in Sajnekhali Wildlife Sanctuary. Two of the capture hotspots in this sanctuary coincide with the location (Dobanki camp) where chital had been released in the late 2000s.



Wild pig was distributed throughout the Sundarban landscape with highest concentration of photo-captures in the biosphere reserve. Prevalence of more capture hotspots in the biosphere reserve concurs with higher sightings of wild pig during boat transects in this area.

Figure 8.5

Distribution and relative spatial abundance of wild pig in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

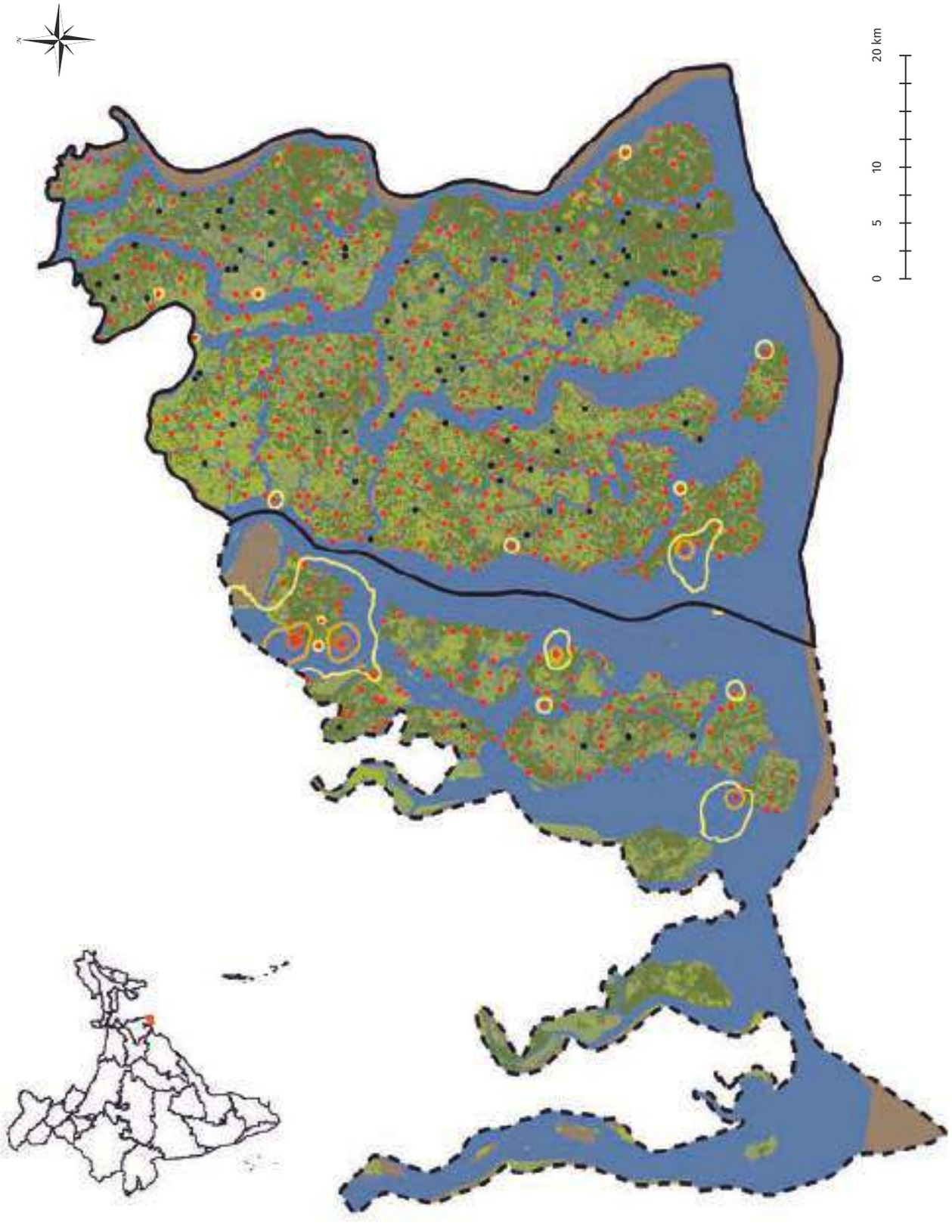
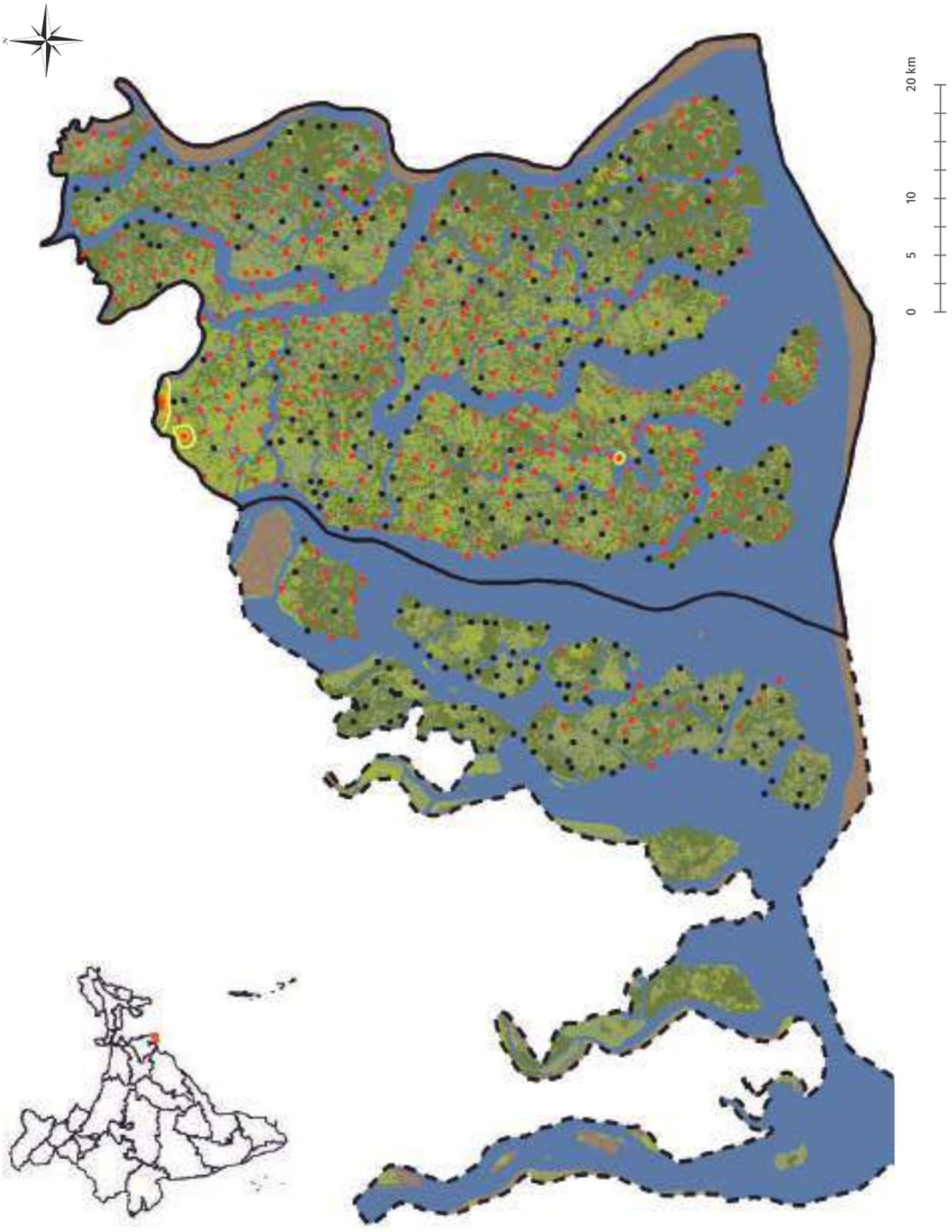


Figure 8.6

Distribution and relative spatial abundance of Rhesus macaque in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Rhesus macaque was captured more or less throughout Sundarban landscape with highest concentration of photo-captures in Sajnekhali beat of Sajnekhali Wildlife Sanctuary. The capture hotspot in this beat coincide with the location of the beat and range offices where there is maximum instantaneous human presence inside the tiger reserve on any given day as these offices issue tourist and fishing permits.



Monitor lizard distribution was primarily in the tiger reserve with very few photo-captures in biosphere reserve. The capture hotspots in the tiger reserve were in the Sajnekhali Wildlife Sanctuary, the buffer zone of Basirhat range and the core area of the national park, viz. West range.

Figure 8.7

Distribution and relative spatial abundance of monitor lizard in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

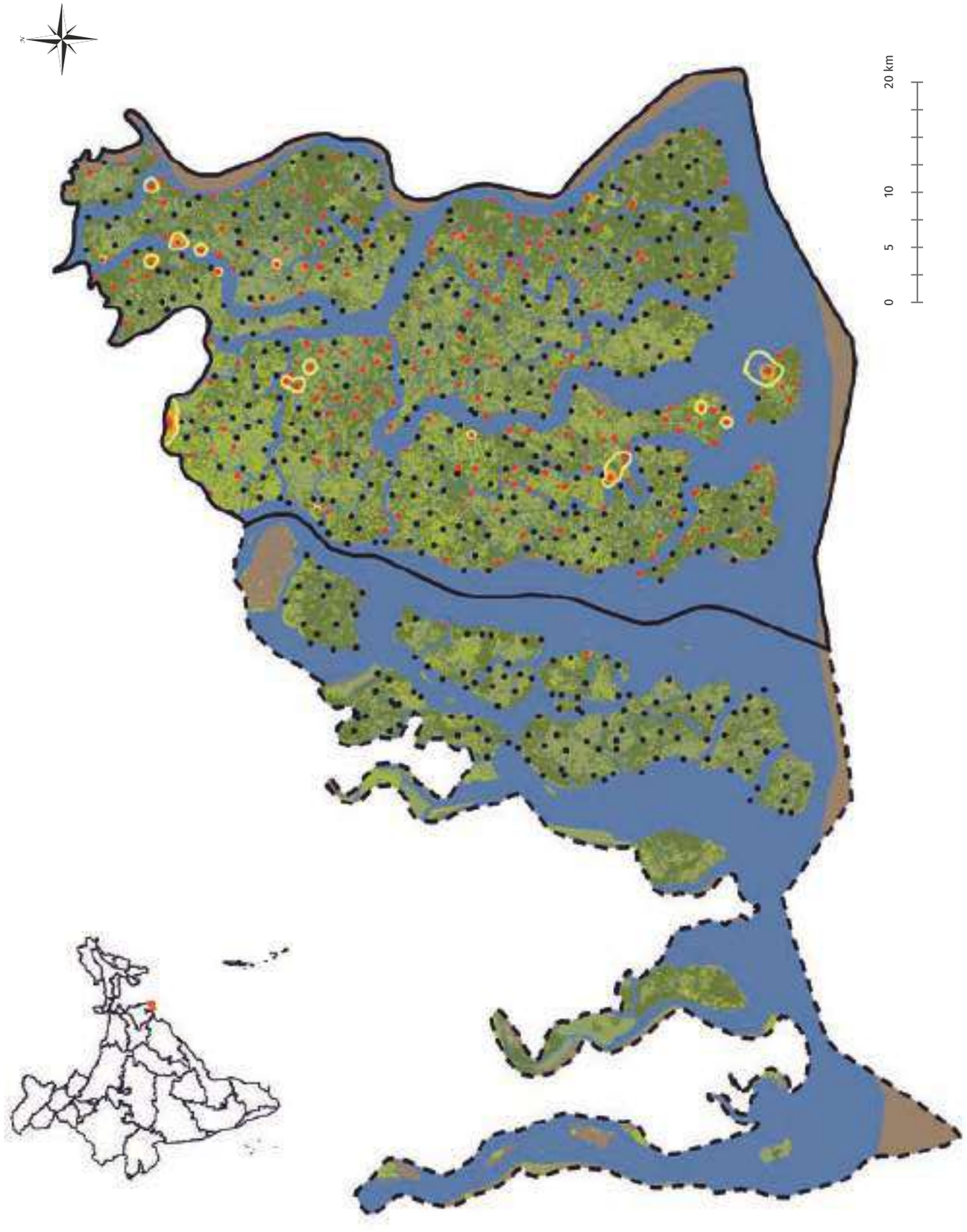
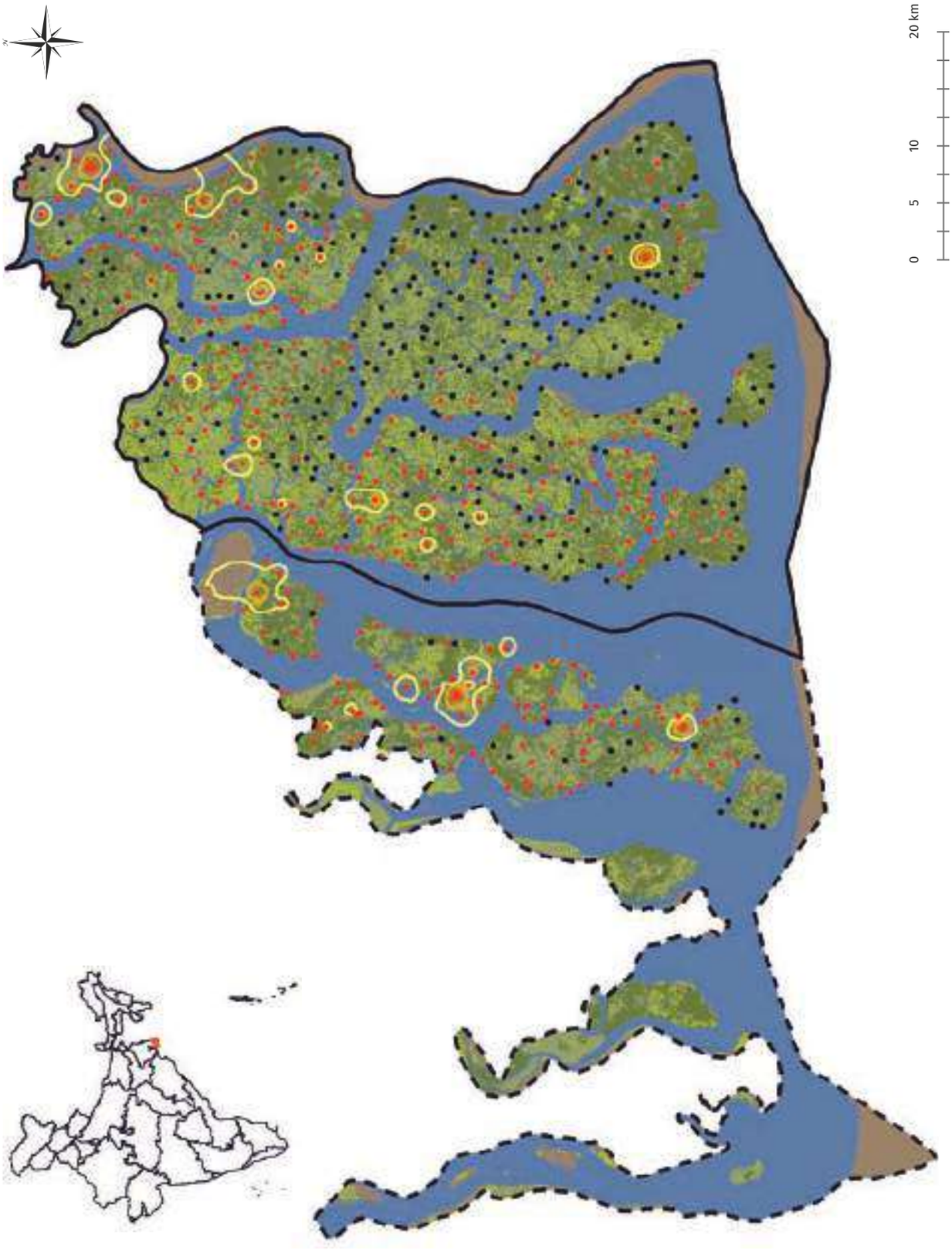


Figure 8.8

Distribution and relative spatial abundance of fishing cat in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Fishing cat was captured throughout the landscape, however there were fewer photo-captures in the East range of the national park in the core area.



Leopard cat was captured throughout the landscape and its abundance is indicated by the numerous capture hotspots both in the tiger reserve as well as the biosphere reserve.

Figure 8.9

Distribution and relative spatial abundance of leopard cat in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

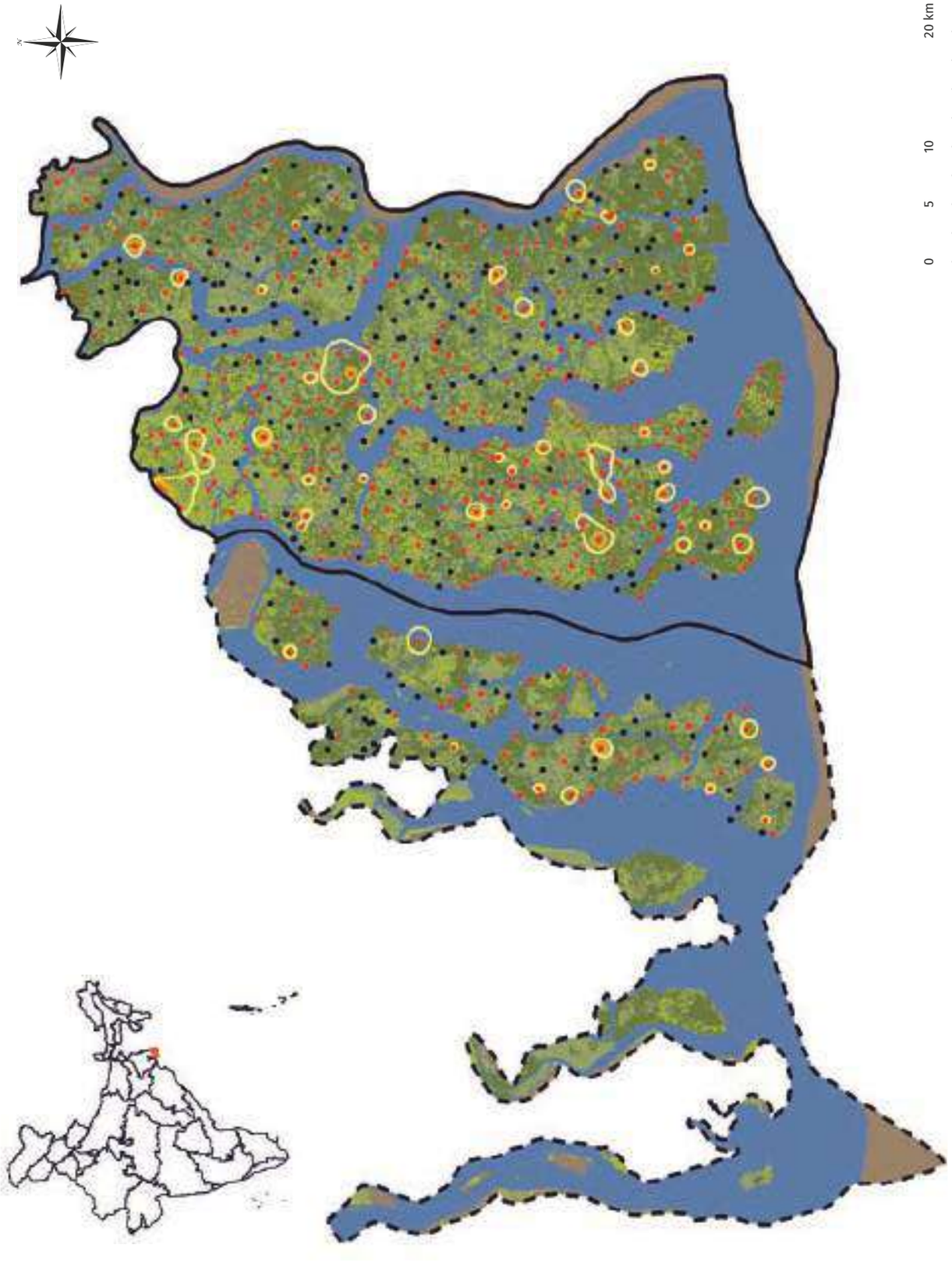
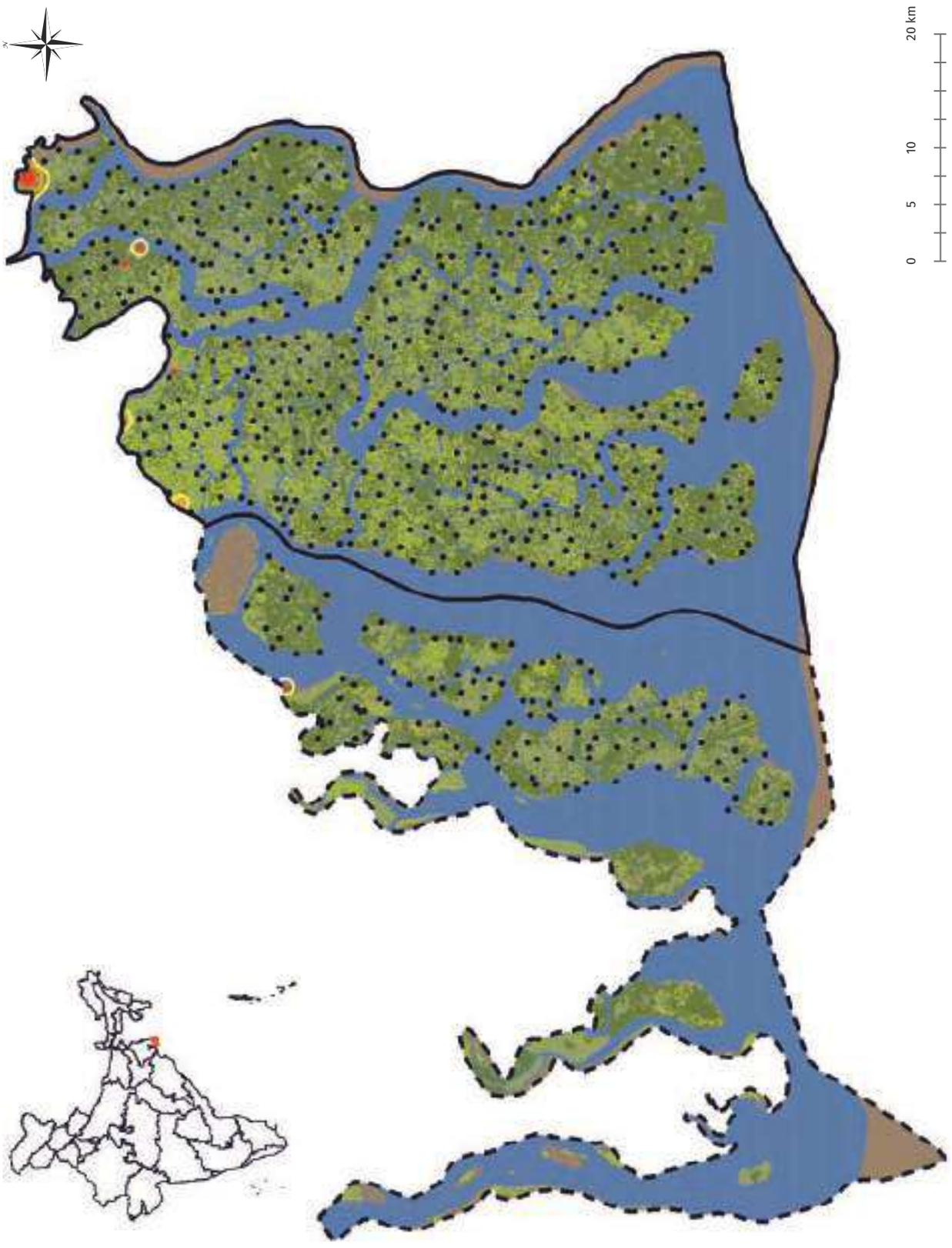


Figure 8.10

Distribution and relative spatial abundance of jungle cat in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was captured only at the fringe areas of the mangrove forests, with its highest photo-captures in the buffer zone of Basirhat range.



Golden jackal was captured for the first time in Sundarban and seems to be a recent colonizer restricted to the mangrove forest edges of Sajnekhali Wildlife Sanctuary and islands of the biosphere reserve adjacent to the human habited islands.

Figure 8.11

Distribution and relative spatial abundance of golden jackal in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

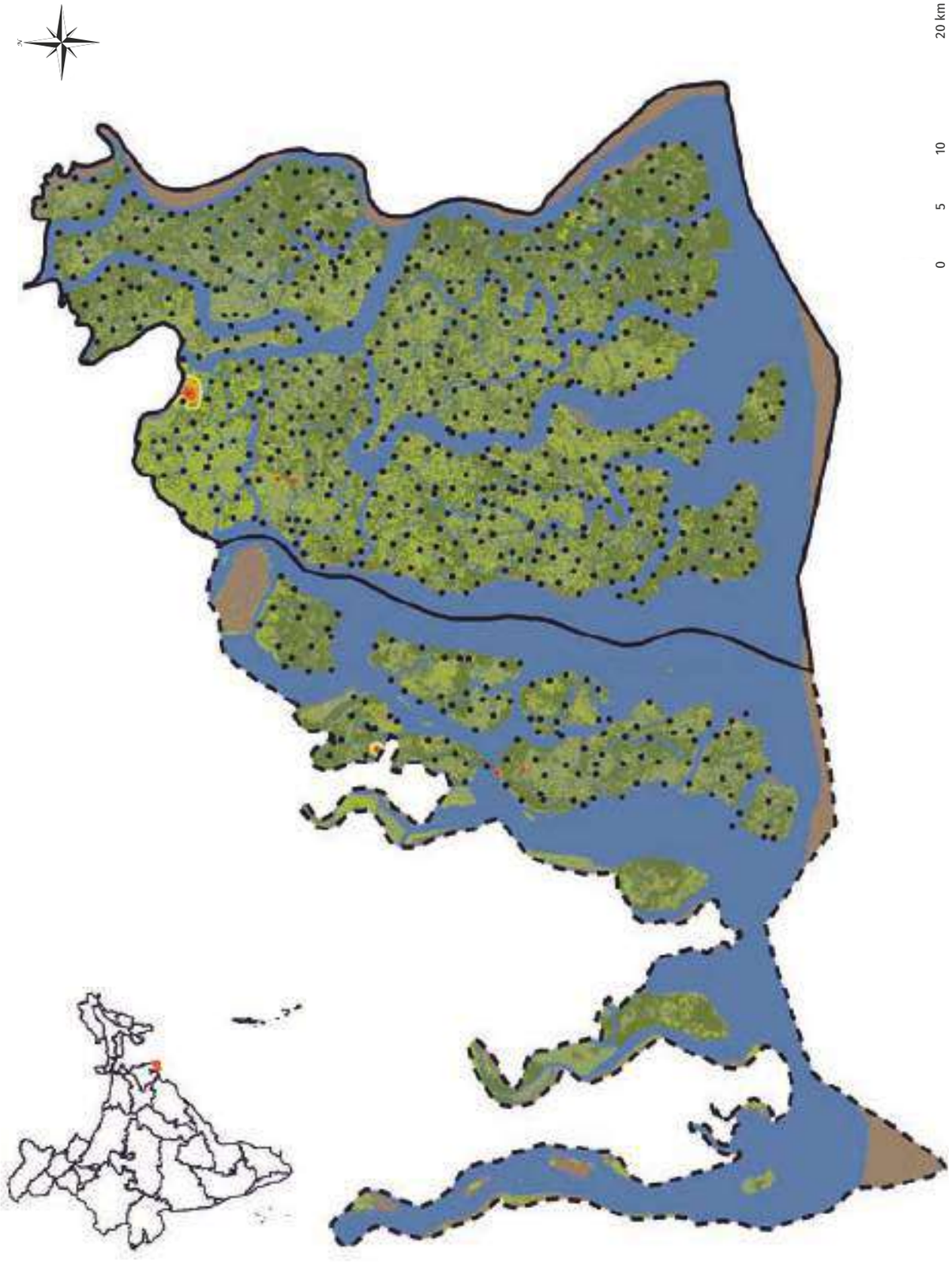
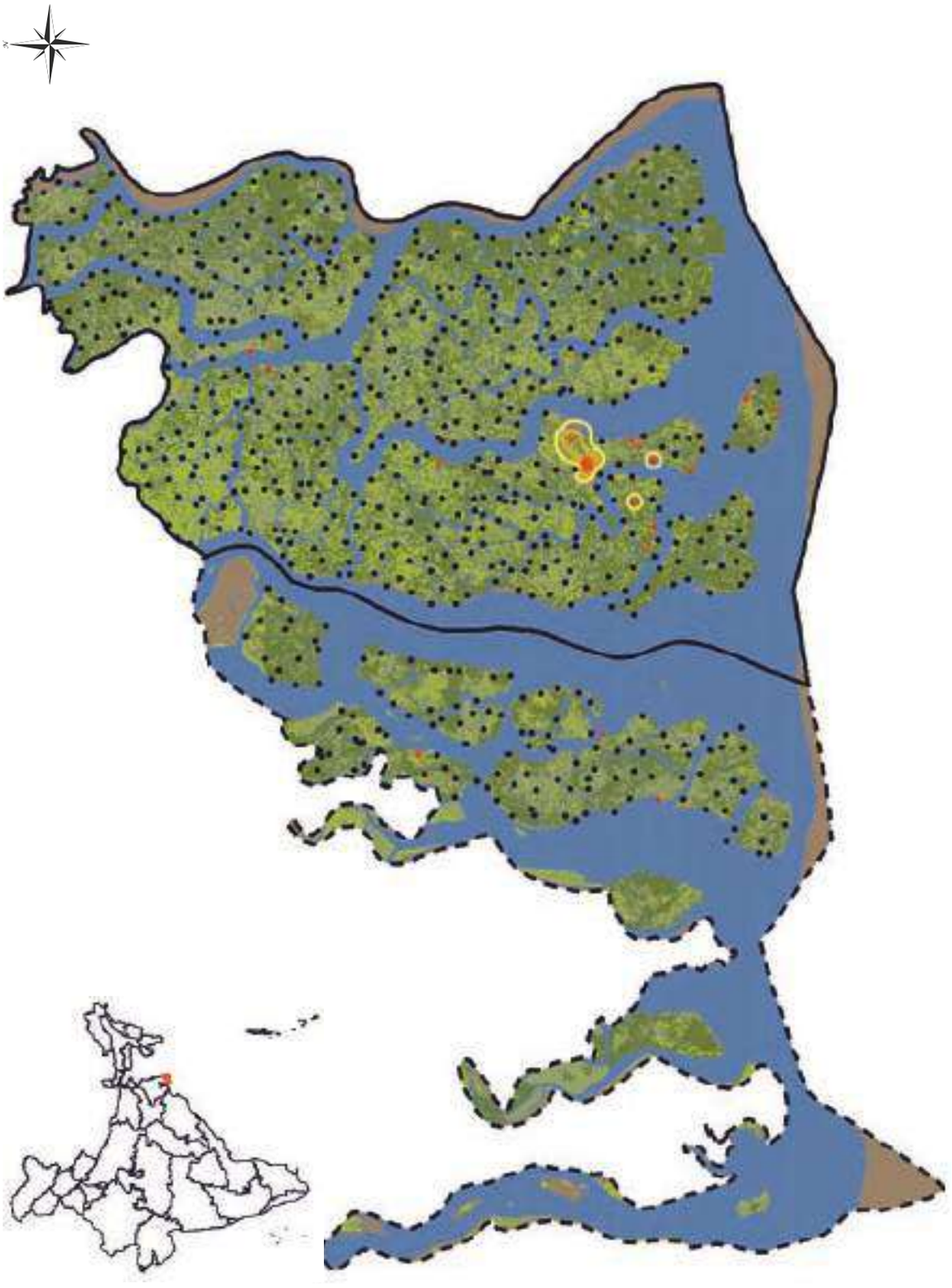


Figure 8.12

Distribution and relative spatial abundance of otter (please refer to the text for classification of otters) in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

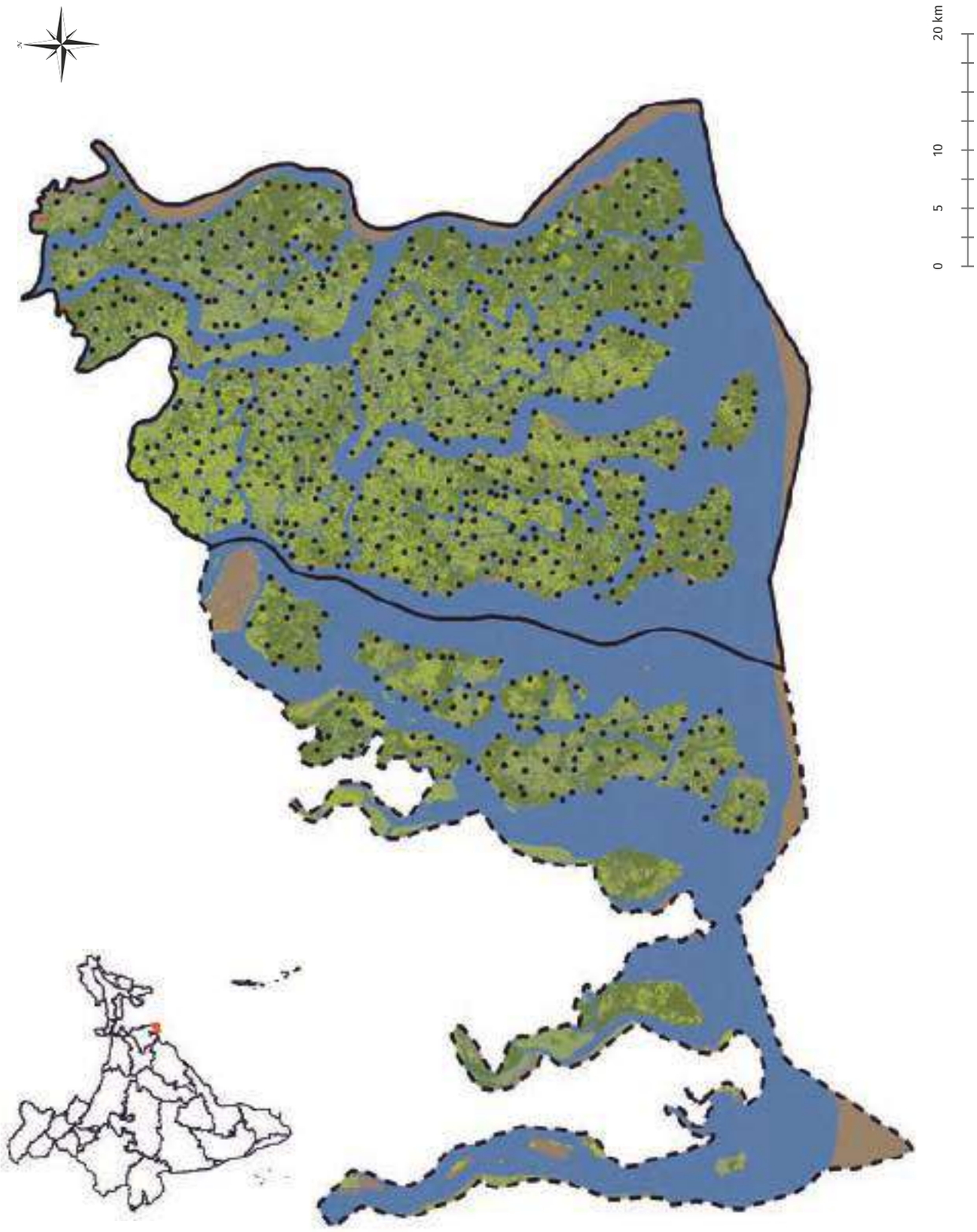
Sundarban is home to three species of otter, viz. smooth coated otter (*Lutrogale perspicillata*), Eurasian otter (*Lutra lutra*) and oriental small-clawed otter (*Aonyx cinereus*). However, it was not possible to identify the individual species from the camera trap photographs. Hence, the map depicts the varying intensity of photo-captures of all three species combined together. The capture hotspots were primarily in the core zone of the national park beside wide channels.



Palm civet was captured only at the edges of the buffer zone of Basirhat range, adjacent to the human habited islands.

Figure 8.13

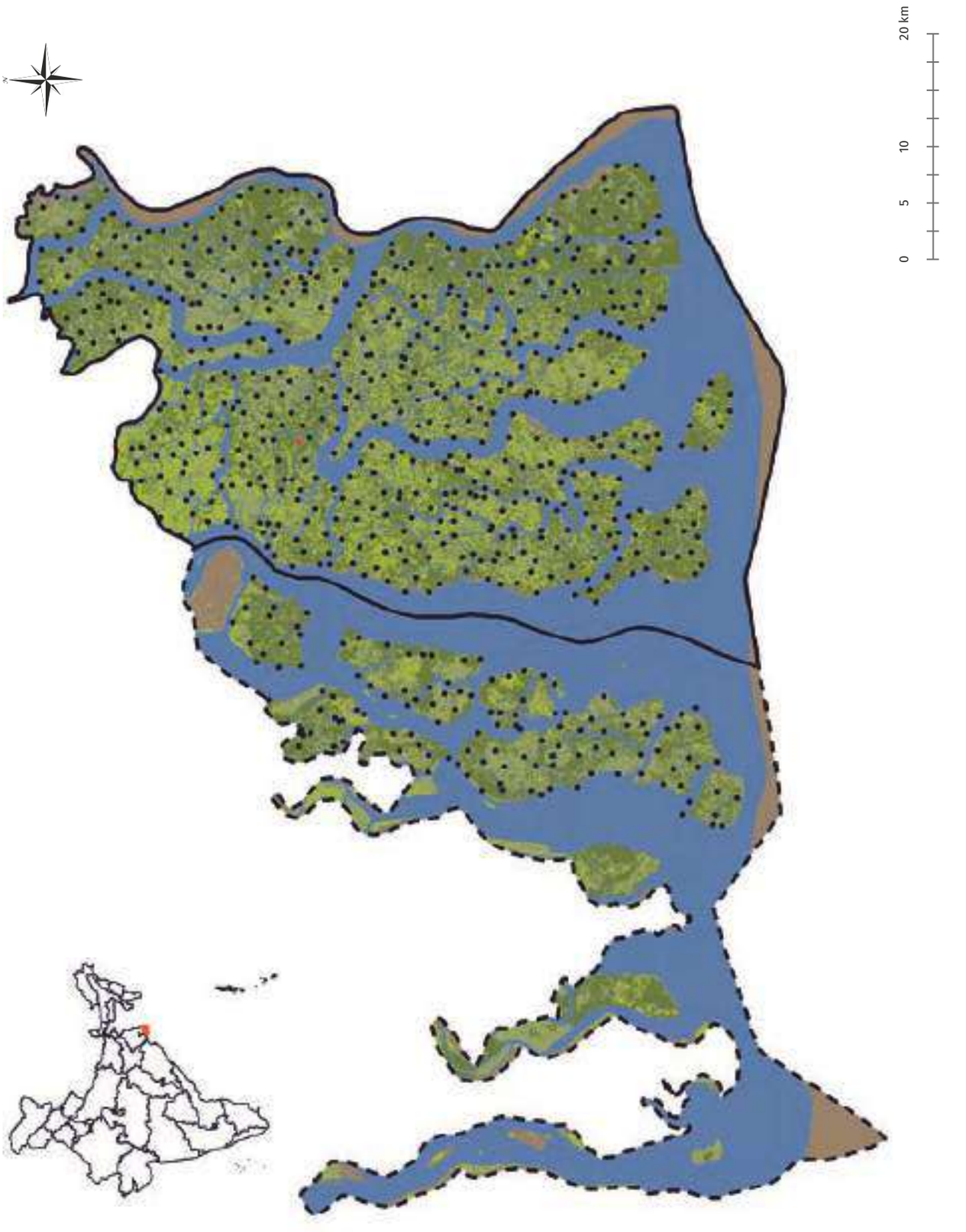
Distribution and relative spatial abundance of palm civet in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.



Estuarine crocodile was one of the rarest species to be photo-captured, however, one should keep in mind that camera traps are not the most ideal equipment to evaluate this semi-aquatic reptile's distribution.

Figure 8.14

Distribution and relative spatial abundance of estuarine crocodile in Sundarban. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.



A total of 14 species of ungulates, carnivores, ominvores and galliformes were photo-captured in Sundarban. Wild pig and chital were apparently the most common species (Table 8.3) where it took only 5 and 10 trap nights respectively to capture one photo while estuarine crocodile and common palm civet were the rarest photo-captured species.

TABLE 8.3
Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in the Sundarban landscape.

Species	No. of photos per 100 trap night	No. of trap nights to get one photo
Chital	9.90	10
Common palm civet	0.01	12298
Estuarine crocodile	0.01	12298
Fishing cat	4.77	21
Golden jackal	0.03	3514
Junge cat	0.06	1757
Leopard cat	3.57	28
Monitor lizard	2.26	44
Otter	0.11	911
Red jungle fowl	6.41	16
Rhesus macaque	6.01	17
Rodent	0.09	1171
Tiger	3.34	30
Wild pig	18.78	5

The camera trap photo index (RAI) for various species should be viewed in the context of using lures for camera trapping in the Sundarban landscape (lures are not used at other sites). The lures enhance chances of attracting species of carnivores and wild pigs to camera traps. Therefore, these RAI can be used for future population trend comparisons within these species in Sundarbans but not for interspecies relative abundance or comparisons between other sites. However, species like chital and red jungle fowl are unlikely to be affected by lures and their RAI are comparable across sites.

Discussion

The tiger population in the Sundarban landscape seems to be at stable density. Together with Bangladesh (Aziz et al. 2018b), Sundarban holds about 200 tigers which have uniquely adapted to the mangrove forests and are therefore of global importance. It is important that this transboundary population is managed as a single population. Despite efforts by forest departments of both countries, joint patrolling and joint management activities have yet to commence. In our rush to use waterways for economic transportation we have to be careful that these do not become barriers to tiger (and other wildlife) dispersal.

RAJAJI TIGER RESERVE

INTRODUCTION

Rajaji Tiger Reserve is spread over three districts of Uttarakhand viz. Haridwar, Dehradun and Pauri Garhwal. It is named after the famous freedom activist and first Governor General of independent India, Shri Rajgopalachari. It was formally granted the status of tiger reserve in April 2015 and has an area of 1150 km^2 approximately.

Rajaji Tiger Reserve is characterized by broadleaved deciduous forests, which mainly consist of *Malollotus philippinensis, Cassia fistula, Dalbergia sissoo, Shorea robusta, Butea monosperma, Terminalia arjuna, Acacia catechu, Dendrocalamus strictus, Bombax ceiba, Ougeinia oojeinensis, Ehretialaevis, Emblica officinalis, Bauhienia variegata, Ziziphus mauritiana*, *Casearia tomentosa*, *Aegle marmelos*. Other vegetation types in the tiger reserve include riverine vegetation, scrubland, grasslands and pine forests.

Major carnivores found here are tiger, leopard, striped hyena, jackal, jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*) rusty spotted cat (*Prionailurus rubiginosus*), occasional Himalayan black bear (*Ursus thibetanus*), and sloth bear (*Melursus ursinus*). Major herbivores include Asian elephant, chital, sambar, barking deer, goral, and wild pig. It is home to more than 328 bird species, 49 species of fresh water fishes, 12 species of amphibians and more than 20 species of reptiles (Management Plan of Rajaji National Park, 2012-13 to 2021-22).

RESULTS

Tiger Density Estimates

A total of 1279 tiger images were obtained from which 37 tiger individuals were identified. In the western part of the tiger reserve 43 photographs of two tiger individuals (both females) were obtained. A total of 1236 tiger images yielded 35 tiger individuals in the eastern part of the tiger reserve where tiger density was estimated as 8 (SE 1.4) tiger per 100 km^2 (Table 9.1). Tiger population using the tiger reserve was 52 (SE 5), while the tigers in the tiger reserve was 38 (SE 1). The detection corrected tiger male to female sex ratio in Eastern Rajaji was 0.27:0.73 (Table 9.1). A total of 12 cubs were photo-captured.

Table 9.1

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Rajaji Tiger Reserve, 2018.

Variables	Estimates
Model space (km^2)	706
Camera points	253
Trap nights (effort)	13689
Unique tigers captured	37
Model	P_{mix}(sex), g_0(sex), σ(sex)
$\hat{D}$ SECR (per 100 km^2)	8.0 (1.40)
σ Female (SE) km	1.1 (0.29)
σ Male (SE) km	2.35 (0.89)
g_0 Female (SE)	0.08 (0.006)
g_0 Male (SE)	0.03 (0.002)
Pmix Female (SE)	0.73 (0.07)
Pmix Male (SE)	0.27 (0.07)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

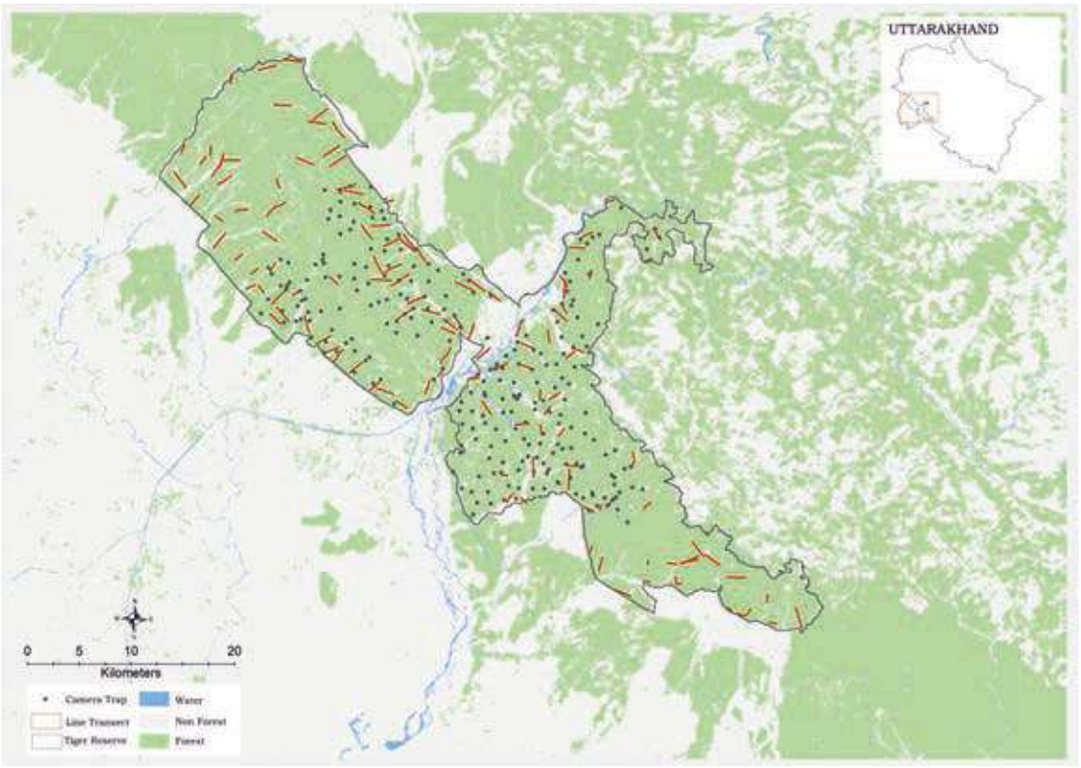


Figure 9.1

Camera trap and transect layout in Rajaji Tiger Reserve, 2018

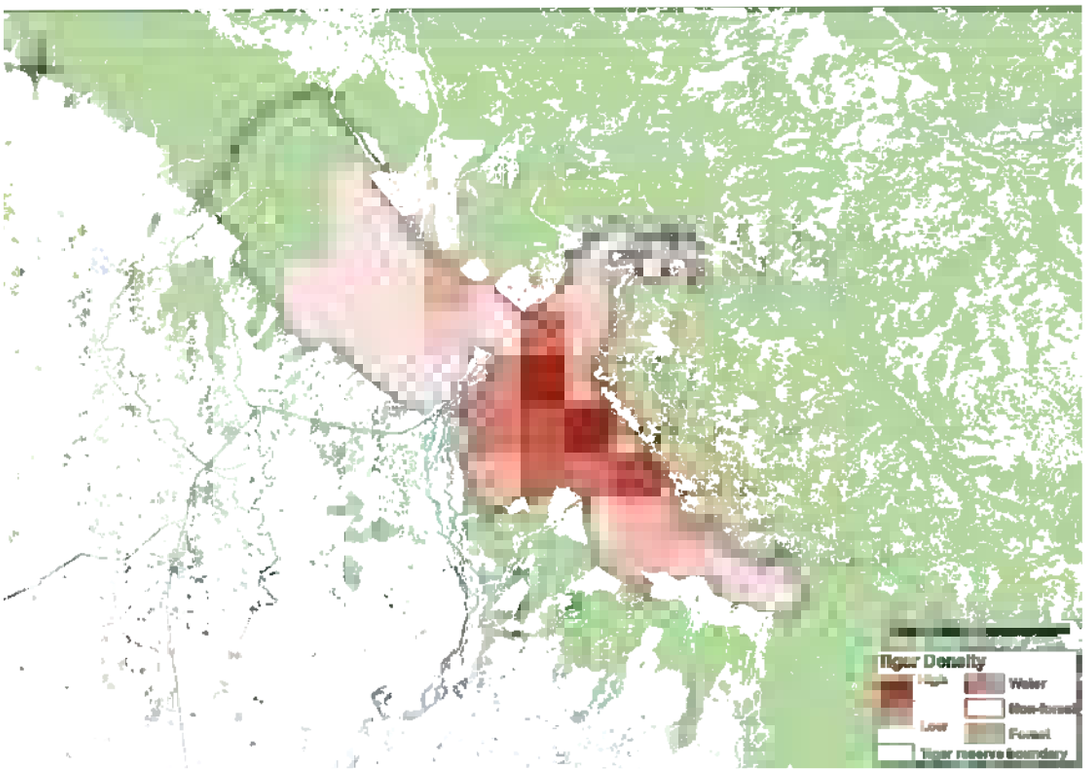


Figure 9.2

Spatial density of tiger in Rajaji Tiger Reserve, 2018

Eastern ranges of Rajaji Tiger Reserve had higher tiger density, with higher density in the valley of Chilla range.

Prey Density Estimates

A total of 143 transects were sampled in Rajaji Tiger Reserve which amounted to an effort of 690 km. Chital was found to be the most abundant ungulate with a density of 66.03 (SE 9.95) chital per sq.km followed by Sambar (Table 9.2).

Table 9.2
Model statistics and parameter estimates of line transect (n=143, Total effort 690 km) based distance sampling for prey species in Rajaji Tiger Reserve, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ sq.km (SE)	Individual density/sq. km (SE)
Chital	27.69 (2.17)	316	7.99 (0.51)	0.17 (0.01)	0.45 (0.05)	8.26 (1.12)	66.03 (9.95)
Sambar	29.11 (1.20)	310	2.34 (0.10)	0.40 (0.01)	0.44 (0.03)	7.7 (0.70)	18.06 (1.82)
Barking Deer	20.46 (2.86)	41	1.31 (0.08)	0.62 (0.08)	0.06 (0.01)	1.45 (0.32)	1.91 (0.45)
Wild Pig	19.10 (1.79)	60	3.24 (0.36)	0.63 (0.06)	0.09 (0.01)	2.27 (0.43)	7.38 (1.63)
Elephant	62.63 (7.22)	37	2.86 (0.93)	0.62 (0.07)	0.05 (0.01)	0.42 (0.11)	1.22 (0.50)
Nilgai	27.57 (3.70)	42	3.79 (0.55)	0.70 (0.1)	0.06 (0.01)	1.10 (0.28)	4.18 (1.23)
Langur	14.16 (2.77)	29	6.93 (1.03)	0.31 (0.06)	0.04 (0.01)	1.48 (0.44)	10.27 (3.45)

Distribution of Major Mammalian Species Found in Rajaji Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates.

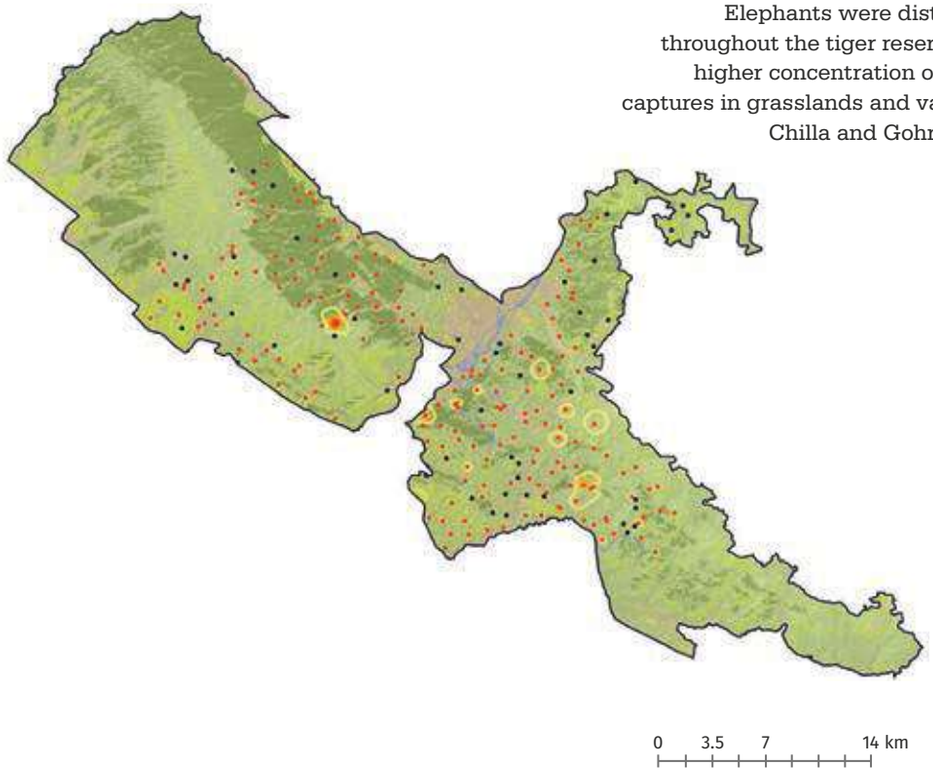


Figure 9.3
Distribution, and relative spatial abundance of elephant in Rajaji Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Elephants were distributed throughout the tiger reserve with higher concentration of photo-captures in grasslands and valleys of Chilla and Gohri range.

Leopards were distributed throughout the tiger reserve with higher concentration of photo-captures in the hilly to moderate terrain of Gohri range in the northern boundary and also near the boundary of Chilla range in the southern part of the reserve.

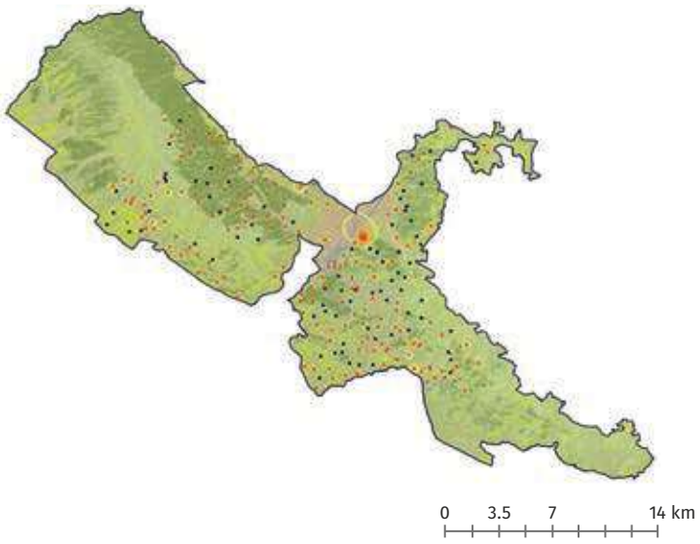


Figure 9.4
Distribution, and relative spatial abundance of leopards in Rajaji Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Jackals were recorded in very low numbers in the sign surveys from this area and there was only one photo capture of jackal in the entire tiger reserve. This is a matter of concern and needs further investigation to determine the cause of this poor status.

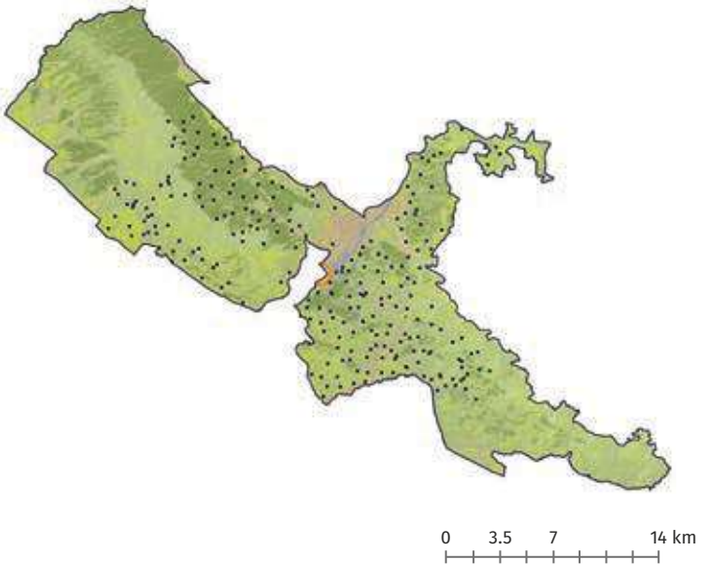


Figure 9.5
Distribution, and relative spatial abundance of golden jackals in Rajaji Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Sloth bear was present in the eastern part of the tiger reserve. Sloth bear are absent from western Rajaji and the reason for this absence is not known.

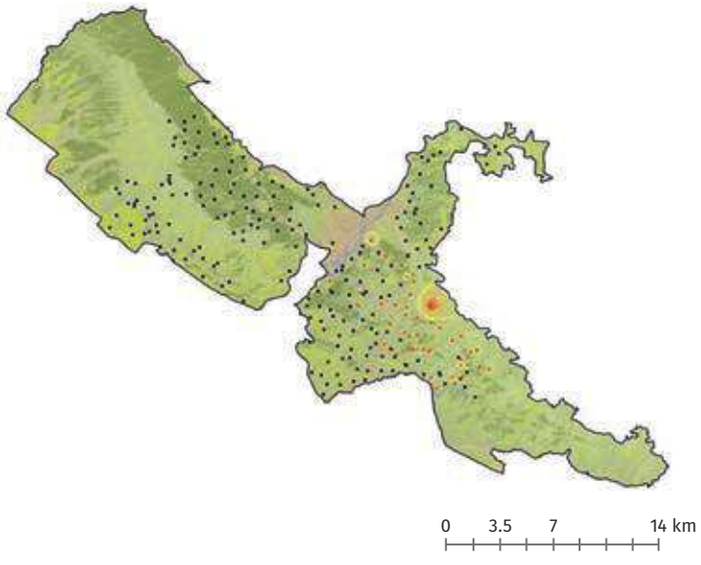


Figure 9.6
Distribution, and relative spatial abundance of sloth bears in Rajaji Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

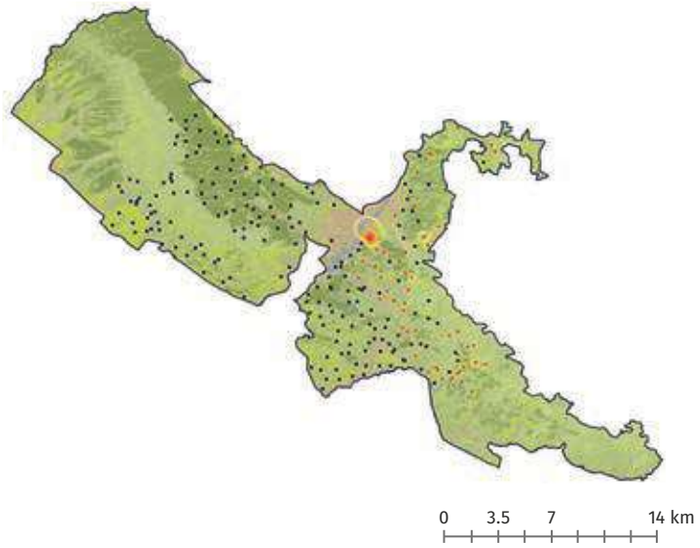


Figure 9.7

Distribution, and relative spatial abundance of black bears in Rajaji Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Black bears were distributed throughout the eastern part of Rajaji TR with higher concentration of photo-captures in hilly to moderately hilly terrain. Their absence from western Rajaji could be attributed to the barrier caused by the city of Dehradun in the Doon valley preventing black bears from the Himalayas to winter in these forests.

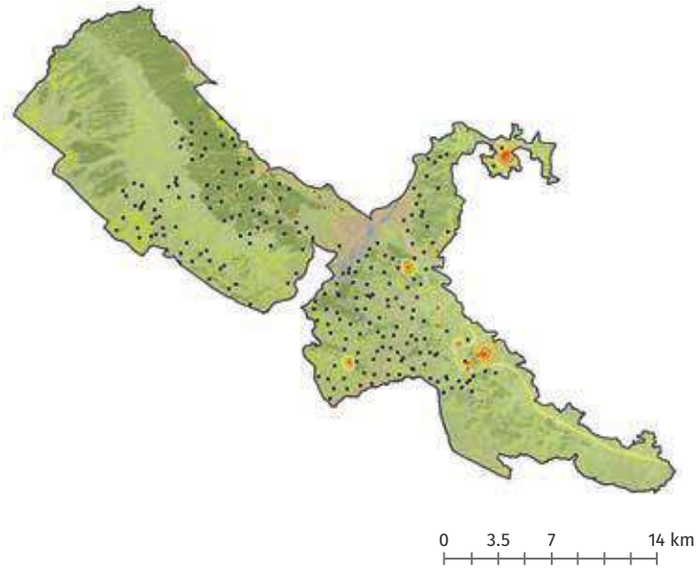


Figure 9.8

Distribution, and relative spatial abundance of leopard cats in Rajaji Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Leopard cat was distributed throughout the park, but photo-captures of the species were few with no clear habitat or terrain type being apparently preferred.

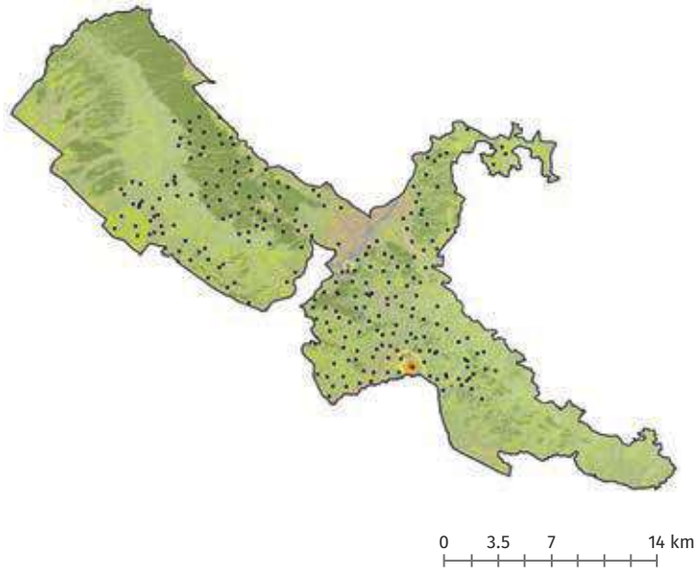


Figure 9.9

Distribution, and relative spatial abundance of jungle cats in Rajaji Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

There were very few Jungle cat photo-captures and only from eastern Rajaji.

Rusty spotted cat was found in flat terrain as well as the Shivalik hills area of the tiger reserve. No captures of rusty spotted cat were obtained from western Rajaji.

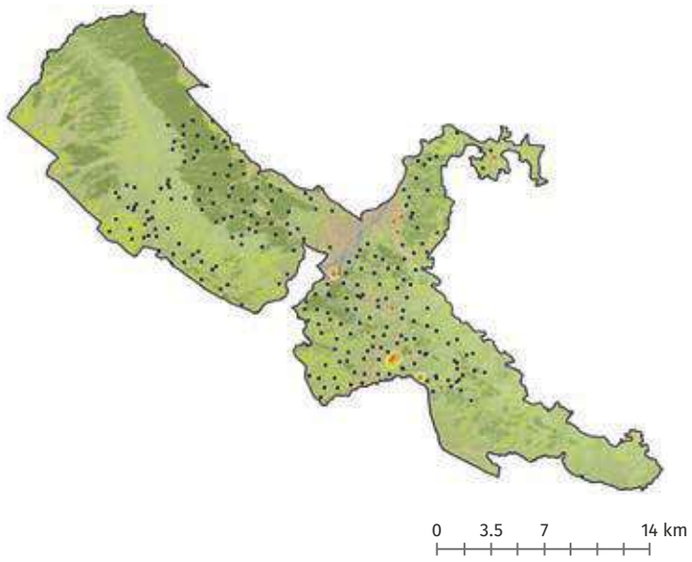


Figure 9.10

Distribution, and relative spatial abundance of rusty spotted cat in Rajaji Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Striped hyaena was photo-captured only in the eastern part of the tiger reserve with concentration of photo-captures near human settlements and in flat terrain.

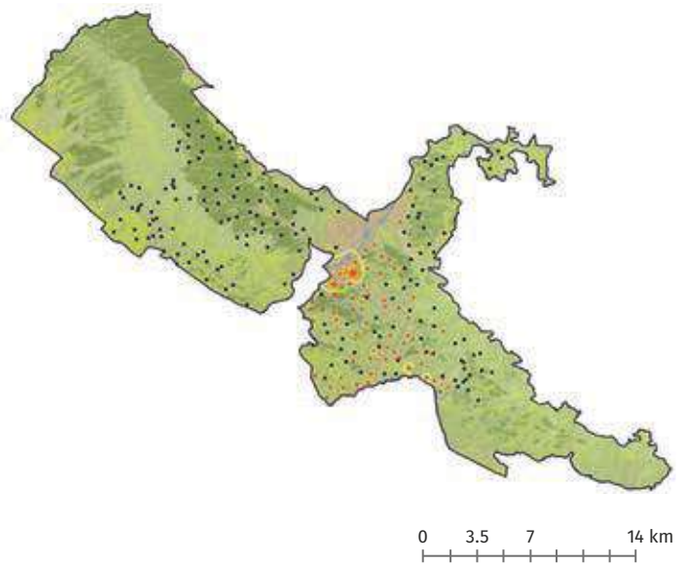


Figure 9.11

Distribution, and relative spatial abundance of striped hyenas in Rajaji Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Relative Abundance of all Photocaptured Species in Rajaji Tiger Reserve

A total of 30 species of ungulates, carnivores, ominvores and galliformes were photo-captured in Rajaji tiger reserve. Chital and sambar were the most common species with 1-2 days (Table 9.3) to obtain one photograph and 42-55 photos obtained per 100 days of camera trapping. Otter, pangolin and jungle cat were the rarest photo-captured species. It was interesting to note that sloth bear, black bear, striped hyena, rusty spotted cat, jungle cat and jackal were photo-captured only from eastern Rajaji. The river Ganges seems to act as a boundary or some form of disturbance which has caused local extinction of these common species from western Rajaji.

Table 9.3

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Rajaji Tiger Reserve, 2018

Species	No. of photos per 100 trap nights	No. of days to get one photo
Barking Deer	4.86	20.58
Black naped hare	3.62	27.65
Chital	42.81	2.34
Domestic cat	0.01	6844.50
Domestic dog	0.46	217.29
Elephant	12.21	8.19
Golden Jackal	0.09	1053.00
Goral	0.66	152.10
Himalyan Black Bear	1.07	93.12
Indian Pangolin	0.07	1521.00
Jungle cat	0.07	1521.00
Khalij	0.85	117.00
Langur	3.64	27.49
Large Indian Civet	2.46	40.62
Leopard	6.55	15.26
Leopard cat	0.40	248.89
Livestock	31.41	3.18
Mongoose	0.53	187.52
Monitor lizard	0.20	488.89
Nilgai	2.18	45.94
Otter	0.01	13689.00
Palm civet	0.40	248.89
Peafowl	20.72	4.83
Porcupine	13.00	7.69
Red Jungle Fowl	8.24	12.14
Rhesus macaque	1.19	83.98
Rodents	0.05	1955.57
Rusty spotted cat	0.12	805.24
Sambar	55.62	1.80
Sloth Bear	0.77	129.14
Striped Hyaena	3.40	29.44
Tiger	5.55	18.01
Wild Pig	14.27	7.01
Yellow throated marten	0.09	1140.75

DISCUSSION

Compared to the previous tiger density estimates obtained in 2014 (2.90±0.87, Jhala et al. 2015), Rajaji Tiger Reserve has experienced a substantial increase in tiger density in its eastern part while the western part continues to have only two tigresses.

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LANSDOWNE FOREST DIVISION

INTRODUCTION

Lansdowne Forest Division forms the crucial link between Rajaji and Corbett Tiger Reserve. Two ranges of Lansdowne Forest Division viz, Kotri and Dugadda along with Laldhang and Kotdwar range of Rajaji Tiger Reserve form part of the important Rajaji-Corbett connectivity, covering a total area of 433 km^2.

The altitude in the forest division varies from 300m to 1000m and dominant forest type is sal mixed forest. The terrain in Lansdowne is primarily hilly and is characterized by luxuriant growth of grass species such as *Eulaliopsis binata, Chrysopogon fulvus, Nerodia arundinaria, Vetiveria zizanoides* and *Aplud amutica*. The southern slopes in particular are characterized by miscellaneous tree species such as *Terminalia tomentosa, Adina cordifolia, Kydia calycina, Lannea coromandelica, Diospyros melanoxylon*.

Lansdowne is home to major carnivores such as tiger (*Panthera tigris*), leopard (*Panthera pardus*), striped hyaenas (*Hyaena hyaena*) along with Himalyan black bear (*Ursus thibetanus*) and sloth bear (*Melursus ursinus*).

Livestock grazing and lopping for providing fodder to livestock by resident Gujjar communities have resulted in habitat degradation in parts of this forest division. However, despite tremendous anthropogenic pressure from the villages located in the south, Lansdowne Forest Division continues to be an important tiger and wildlife habitat in western part of Terai Arc Landscape.

RESULTS

Tiger Density Estimates

A total of 413 tiger images were obtained from which 34 tigers were identified and tiger density was estimated as 4.36 (SE 0.76) tiger per 100 km^2 (Table 9.4). The detection corrected tiger male to female sex ratio was 0.40:0.60 (Table 9.4). A total of 3 cubs were photo-captured.

Table 9.4 Sampling details and tiger density parameter estimates in spatially explicit capture -recapture analysis using likelihood framework for Lansdowne Forest Division, 2018.

Variables	Estimates
Model space (km^2)	1222
Camera Points	187
Trap Nights (effort)	7252
Unique tigers captured	34
Model	P_{mix}(sex), g_0(sex), σ(sex)
$\hat{D}$ SECR (per 100 km^2)	4.36 (0.76)
σ Female (SE) km	2.3 (0.14)
σ Male (SE) km	2.7 (0.22)
g_0 Female (SE)	0.02 (0.003)
g_0 Male (SE)	0.02 (0.004)
Pmix Female (SE)	0.60 (0.09)
Pmix Male (SE)	0.40 (0.09)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

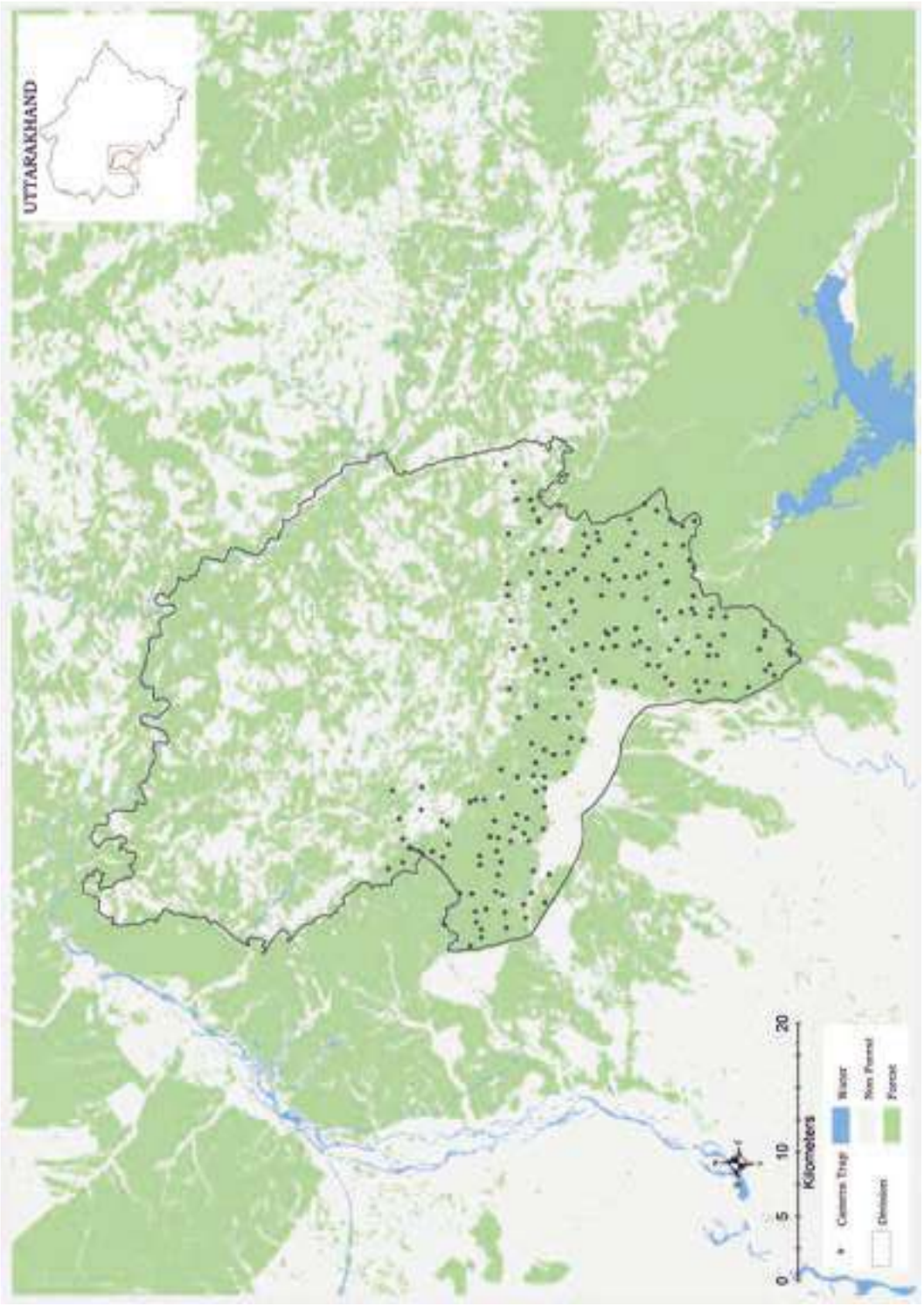
σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Figure 9.12

Camera trap layout in Lansdowne Forest Division, 2018.



DISCUSSION

Lansdowne Forest Division has shown increase in tiger individuals photo-captured with regular movement of tigers from Rajaji and Corbett Tiger Reserve.

CORBETT TIGER RESERVE

INTRODUCTION

Corbett Tiger Reserve encompasses a multitude of habitats since it is spread across the Terai, Shivalik Hill Range, Bhabhar tract, Ramganga valley and the foothills of Himalayas. It is located within Nainital and Pauri Garhwal districts of the state of Uttarakhand. It lies between 29^0 25' N to 29^0 40' N latitudes and 78^0 5'E to 79^0 5'E longitudes. Corbett Tiger Reserve covers an area of 1288.32 km^2 which includes 520.82 km^2 of Corbett National Park, 301.18 km^2 of adjoining Sonanadi Wildlife Sanctuary and 466.32 km^2 of buffer zone (Bhartari 1999). The forest divisions of Uttar Pradesh surrounding the tiger reserve like Bijnore Forest Division (80 km^2) and Najibabad Forest Division (71.60 km^2) have been incorporated as buffer to the tiger reserve. Corbett Tiger Reserve is the largest source population for tigers in Shivalik-Gangetic landscape and responsible for the remarkable recovery of tiger population in this landscape (Bisht et al. 2019). The corridors connecting Corbett with the surrounding forest divisions and protected areas are crucial for the long-term survival of this metapopulation.

The forests of Corbett Tiger Reserve are classified into three major forest types viz. Northern moist deciduous (3C), Northern tropical dry deciduous (5B) and Himalayan sub-tropical pine forest (9) (Champion and Seth 1968). *Shorea robusta* is the dominant tree species growing gregariously in the park. Amongst the evergreen species *Mallotus philippinensis* and *Syzygium cuminii* are most common; and other dominant medium sized evergreens include *Litsea monopetala, L. glutinosa, and the fragrant Murraya panniculata. Terminalia alata, T.chebula, Semicarpus anacardium, Lannea coromandelica, Sapium insigne, Lagerstormia parviflora, Butea monsperma, Cassia fistula* and *Ehretia laevis* are the deciduous species that are found in the park. Riverine vegetation abutting the open places near sots (seasonal riverbeds) along the grasslands include amla (*Phyllanthus emblica*), *Acacia catechu, Kydia calycina, Dalbergia sissoo* and *Holoptelia integrifolia*. Eastern and southern boundaries of the park has teak (*Tectona grandis*) and *Eucalyptus* spp. plantations.

Other than the tiger (*Panthera tigris*) the park supports felids like leopard (*Panthera pardus*), leopard cat (*Prionailurus bengalensis*), jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*) and fishing cat (*Prionailurus viverrinus*). Other carnivores include the golden jackal (*Canis aureus*), sloth bear (*Melursus ursinus*) and Himalayan black bear (*Ursus thibetanus*). Herbivores include elephants (*Elephas maximus*), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), hog deer (*Axis porcinus*), goral (*Naemorhedus goral*) and serow (*Capricornis thar*). Nilgai (*Boselaphus tragocamelus*) is seen only in the disturbed fringes. Small Indian civet (*Viverricula indica*) and common palm civet (*Paradoxurus hermaphroditus*) are found along with mustelids like yellow throated marten and mongoose. Black-naped hare and Indian porcupine are of common occurrence. The Ramganga river system also supports a good population of otters. Among reptiles, a good population of gharial and mugger can be seen in the river as well as the reservoir. Snakes like king cobra, cobra and python are also found in the park. Among other reptiles are the rock agama, monitor lizard and various turtle species like, Indian black turtle and tricarinate hill turtle (Bhartari 1999). The avifauna of Corbett Tiger Reserve and its adjoining forest divisions is very rich and more than 549 species of resident and migratory birds have been reported from Corbett National Park alone.

RESULTS

Tiger Density Estimates

A total of 5004 tiger images were obtained from which 231 tigers were identified with tiger density estimated at 14 (SE 0.91) tigers per 100 km^2. Tiger population using the tiger reserve was 266 (SE 6), while the number of tigers present only in the tiger reserve were 231 (SE 0.3). The detection corrected tiger male to female sex ratio was 0.40:0.60 (Table 9.5). A total of 16 cubs were photo-captured.

Table 9.5

Sampling details and tiger density parameter estimates in spatially explicit capture recapture in likelihood framework for Corbett Tiger Reserve 2018

Variables	Estimates
Model space (km^2)	2001
Camera Points	529
Trap Nights (effort)	27425
Unique tigers captured	231
Model	P_{mix}(sex), g_0(sex), σ(sex)
$\hat{D}$ SECR (per 100 km^2)	14 (0.91)
Female (SE) km	1.4 (0.15)
Male (SE) km	2.5 (0.29)
g_0 Female (SE)	0.04 (0.002)
g_0 Male (SE)	0.02 (0.005)
Pmix Female (SE)	0.60 (0.03)
Pmix Male (SE)	0.40 (0.03)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Prey Density Estimates

A total of 502 line transects were walked by the forest department staff and Wildlife Institute of India biologists (Table 9.6). Chital had the highest density (71.31 (SE 5.33) per km^2) followed by sambar (Table 9.6).

Table 9.6

Model statistics and parameter estimates of line transect (n=502, Total effort 1075 km) based distance sampling for prey species in Corbett Tiger Reserve, 2018

Species	Effective strip-width (SE)	#groups detected	Mean group-size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital	34.33 (1.34)	611	8.61 (0.35)	0.29 (0.01)	0.56 (0.02)	8.27 (0.51)	71.31 (5.33)
Sambar	35.76 (1.85)	387	2.26 (0.07)	0.42 (0.02)	0.36 (0.01)	5.03 (0.36)	11.38 (0.90)
Barking Deer	26.68 (1.55)	272	1.33 (0.03)	0.34 (0.02)	0.25 (0.01)	4.74 (0.40)	6.33 (0.55)
Wild Pig	27.76 (2.39)	107	4.74 (0.40)	0.34 (0.03)	0.10 (0.01)	1.79 (0.23)	8.50 (1.31)
Elephant	56.30 (4.77)	58	5.74 (0.91)	0.28 (0.02)	0.05 (0.007)	0.48 (0.10)	2.75 (0.63)
Langur	33.50 (2.66)	111	13.23 (0.87)	0.58 (0.04)	0.10 (0.01)	1.54 (0.20)	20.39 (3.02)
Nilgai	NA	11	NA	NA	0.01 (0.003)	NA	NA

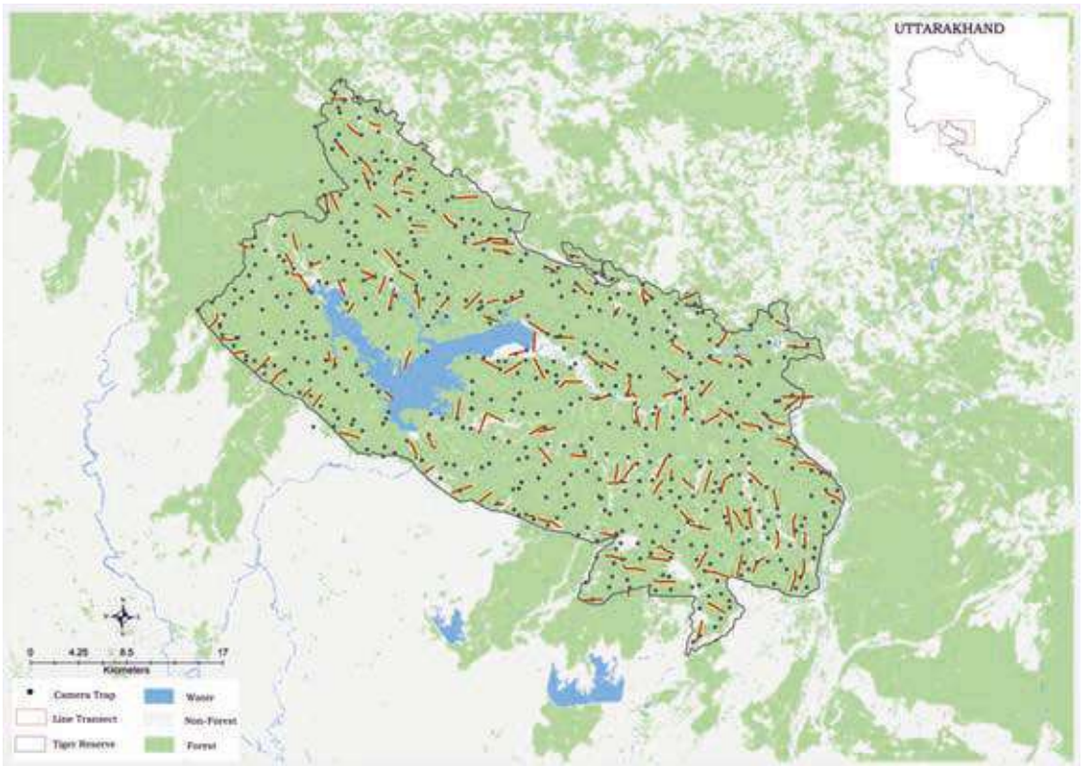


Figure 9.13

Camera trap and line transect layout in Corbett Tiger Reserve, 2018.

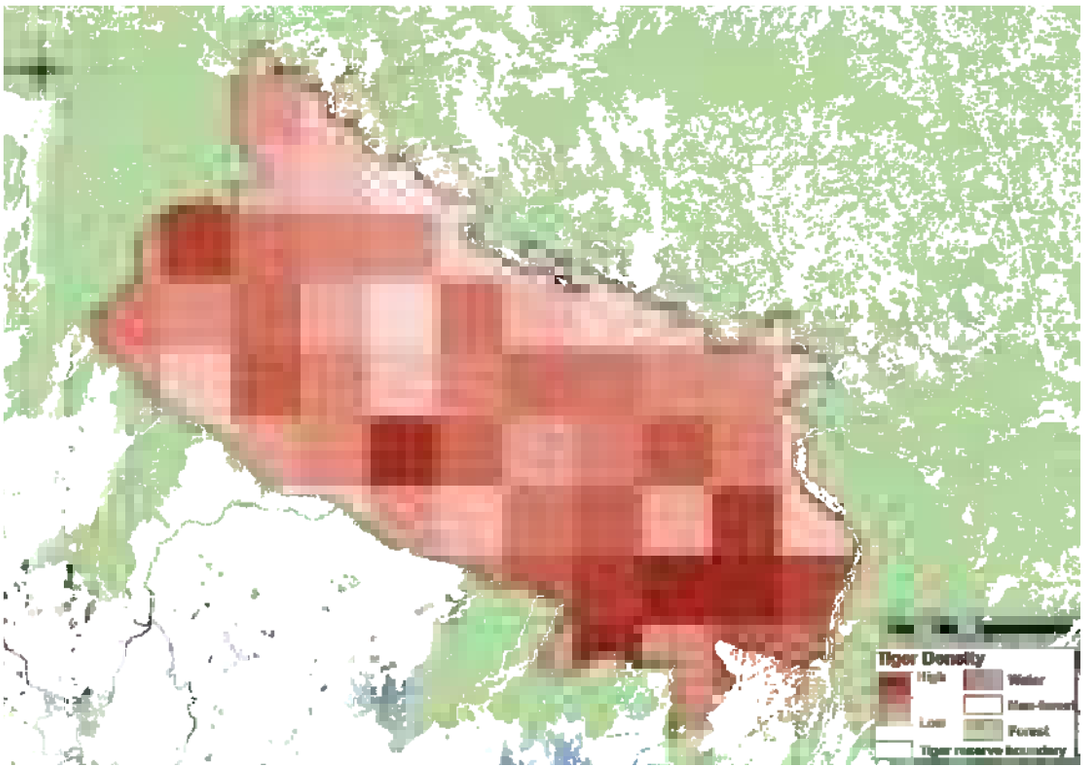


Figure 9.14

Spatial distribution of tigers in Corbett Tiger Reserve, 2018

Corbett Tiger Reserve has the highest tiger density in the world. Within the Tiger Reserve the National Park area has high tiger density.

Distribution of Major Mammalian Species Found in Corbett Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Corbett Tiger Reserve.

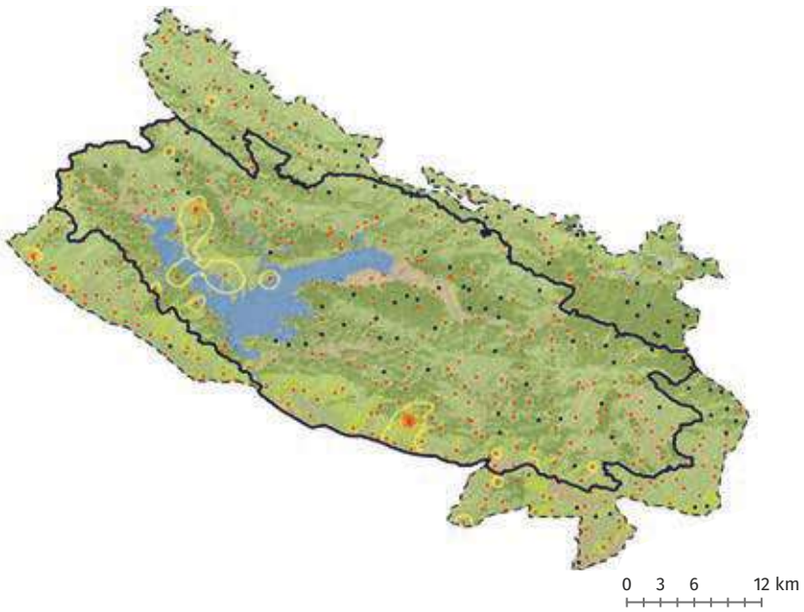


Figure 9.15

Distribution, and relative spatial abundance of elephants in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Elephants were photo-captured across the tiger reserve with higher concentration of photo-captures near the boundaries abutting agricultural fields along the southern boundary of the park and in the grasslands and moderately hilly terrain of Haathikund in Sonanadi wildlife sanctuary.

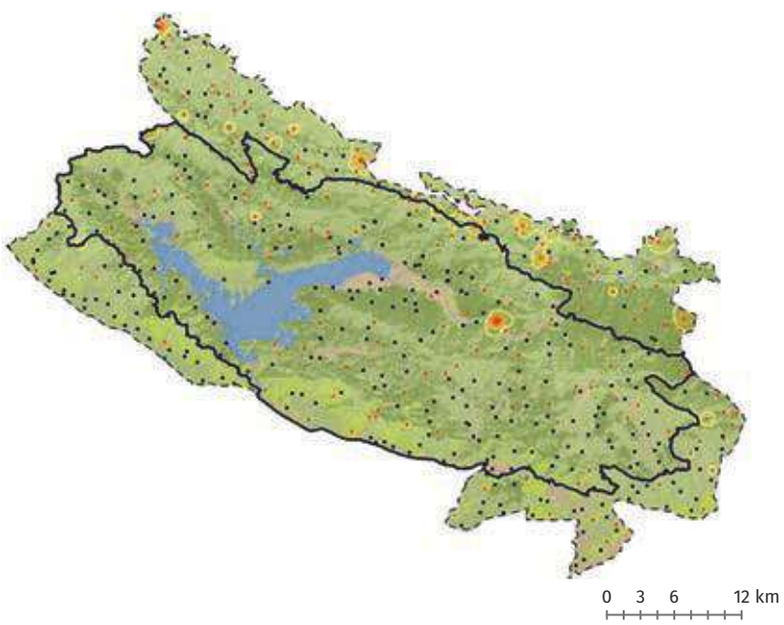


Figure 9.16

Distribution, and relative spatial abundance of leopards in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Leopard was distributed throughout the park with very low to single captures in the National Park but present in more hilly parts of the Sonanadi wildlife sanctuary in Mandal and Palain ranges of the park that are near Almora forest division.

Hog deer, a flood-plain grassland specialist, was photo-captured in small pockets of grasslands and flat terrain in Dhikala, Dhela and Sarpdhuli in Corbett Tiger Reserve. This species had poor status and needs urgent conservation measure for its continued survival in Corbett Tiger Reserve.

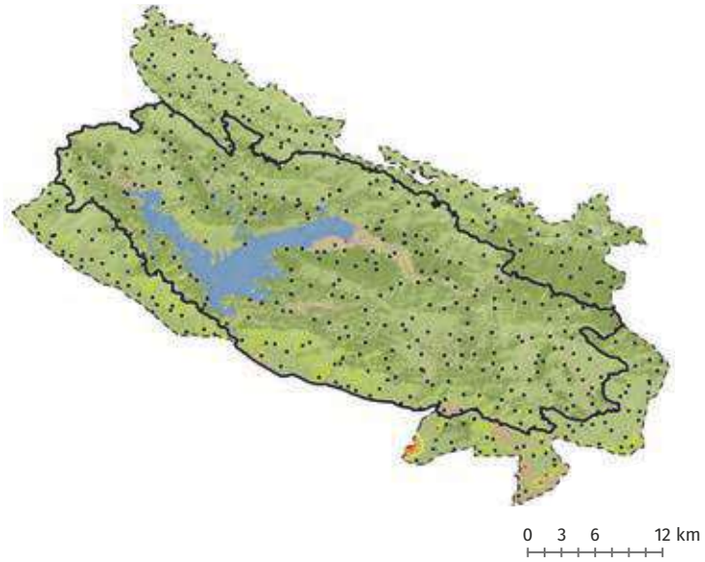


Figure 9.17

Distribution, and relative spatial abundance of hog deer in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

The endangered serow was found in the north ranges of the tiger reserve that have connectivity with hilly forests of Almora Forest Division. Serow was photo-captured in Mandal range with concentration of photo-captures in the hilly terrain of the tiger reserve.

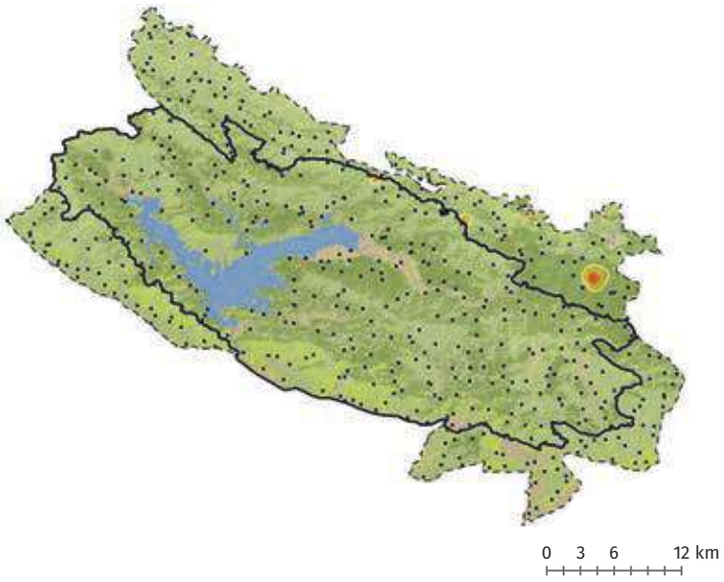


Figure 9.18

Distribution, and relative spatial abundance of serow in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Striped hyaena was not recorded in Corbett Tiger Reserve core areas during earlier assessments and is a recent colonizer. Hyaena photo-captures were obtained from the Sonanadi wildlife sanctuary where most of the captures were in the area near Lansdowne forest division (where hyaenas are common) and southern boundary of Corbett, near Najibabad.

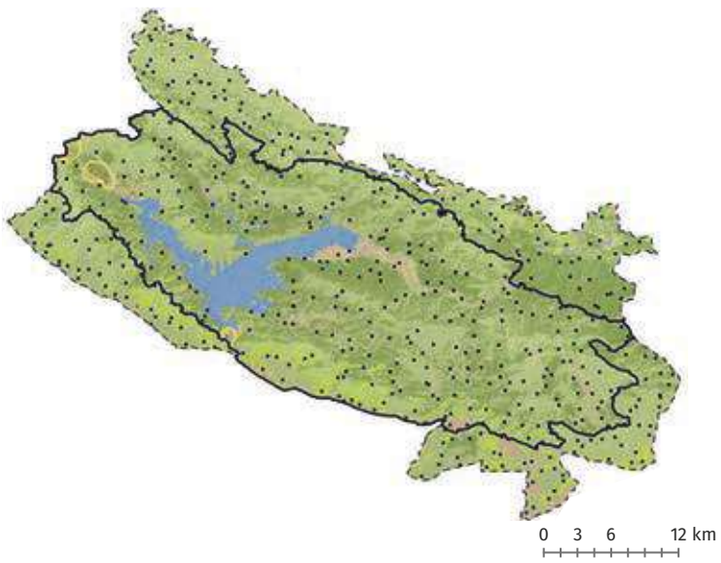


Figure 9.19

Distribution, and relative spatial abundance of striped hyena in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

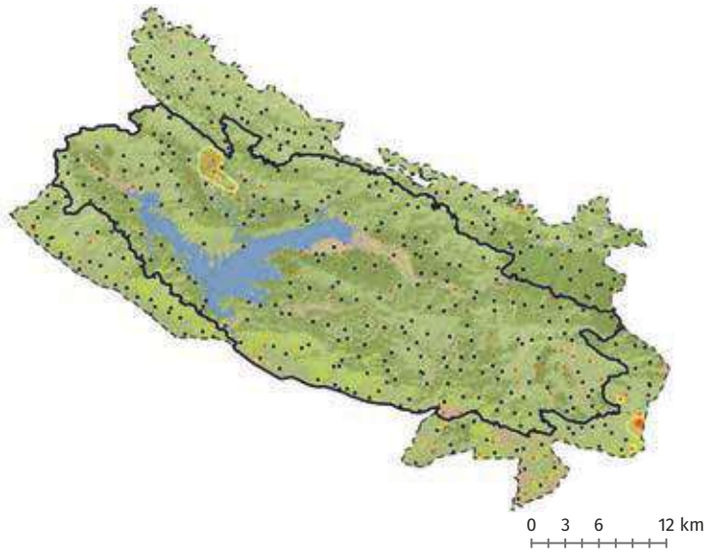


Figure 9.20

Distribution, and relative spatial abundance of golden jackal in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Golden jackal was distributed across the tiger reserve, with higher concentration of photo-captures in the grasslands and moderately hilly to flat areas of Dhikala, Bijrani and Haathi Kund. The good distribution of jackal in Corbett Tiger Reserve is in stark contrast with Rajaji Tiger Reserve, suggestive of some mortality factor like disease likely operating in Rajaji Tiger Reserve.

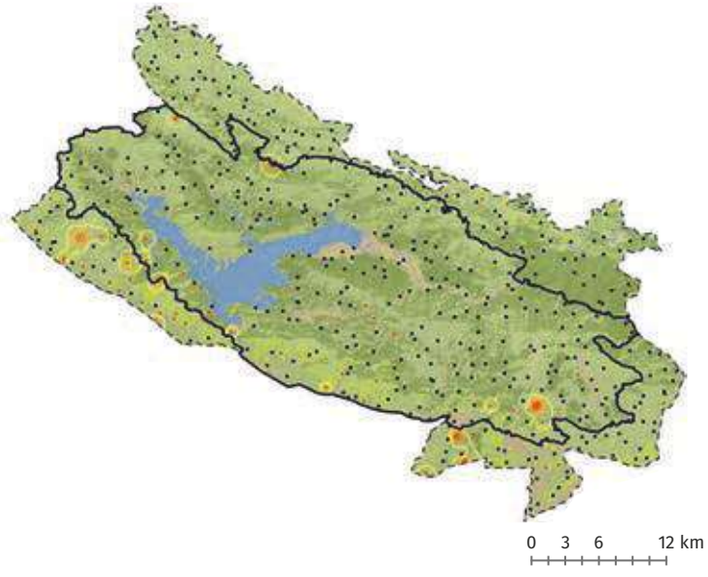


Figure 9.21

Distribution, and relative spatial abundance of sloth bear in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Sloth bear was distributed more on the southern boundary of the tiger reserve, with higher concentration of photo-captures in moderately hilly to flat terrain.

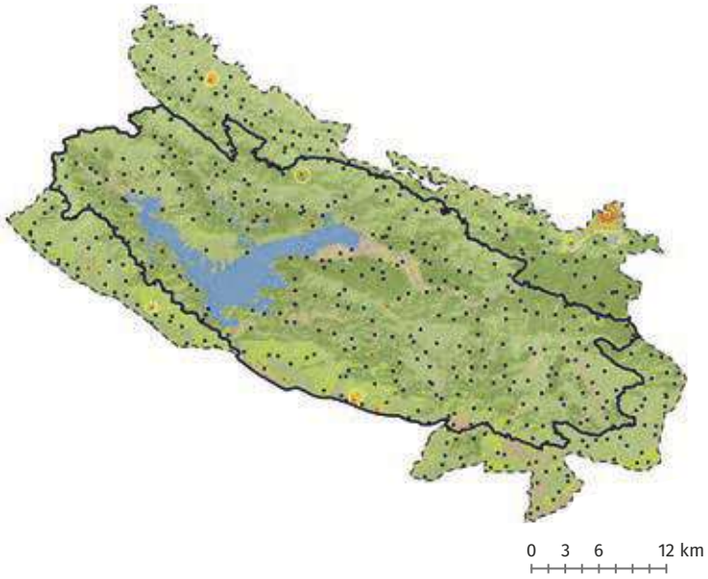


Figure 9.22

Distribution, and relative spatial abundance of Himalayan black bear in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Himalyan black bear were photo-captured in hilly areas as well as flat terrain with no clear pattern. Higher concentration of their photo-captures were obtained from higher elevation and hilly terrain of the tiger reserve.

Jungle cat distribution was majorly found in grassland areas of the tiger reserve, with higher concentration of captures in flat terrain in the grasslands of Dhikala, Bijrani and Dhela.

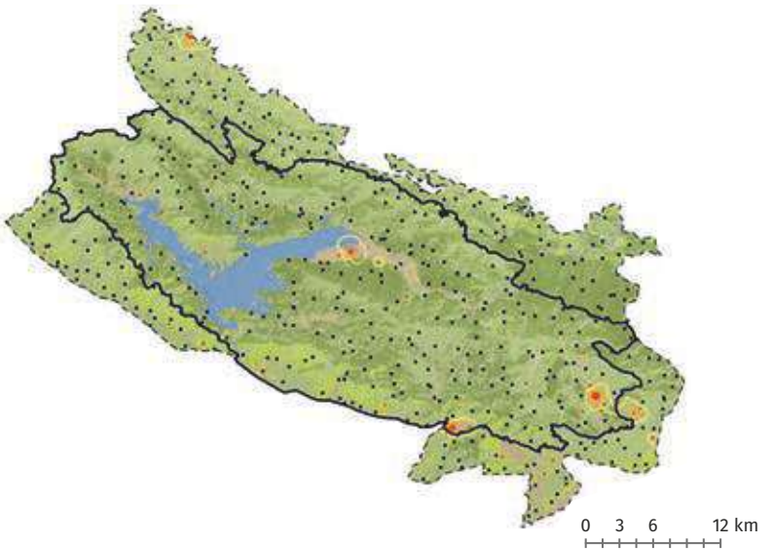


Figure 9.23

Distribution, and relative spatial abundance of jungle cat in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Rusty spotted cat had very few photo-captures which were along the southern boundary of the tiger reserve in flat terrain.

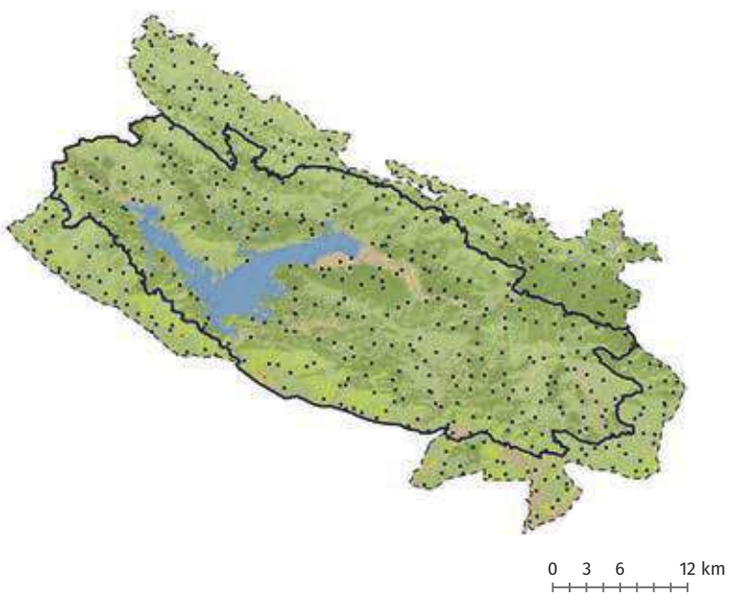


Figure 9.24

Distribution, and relative spatial abundance of rusty spotted cat in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Yellow throated Marten was distributed across most of the tiger reserve, with higher concentration of photo-captures in moderately hilly to wooded flat terrain.

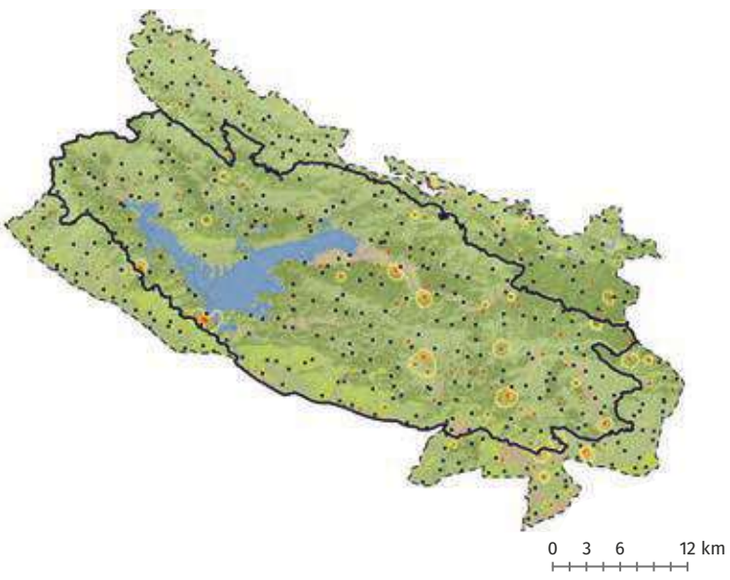


Figure 9.25

Distribution, and relative spatial abundance of yellow throated marten in Corbett Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Table 9.7

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Corbett Tiger Reserve,2018

Species	No of photos per 100 Trap nights	Number of days to get one photo
Barking Deer	18.02	5.55
Black naped hare	1.31	76.61
Chital	29.45	3.40
Domestic cat	1.29	77.69
Domestic dog	0.01	6856.25
Elephant	12.02	8.32
Golden Jackal	1.39	72.17
Goral	0.10	979.46
Himalyan Black Bear	0.08	1246.59
Himalyan Thar	0.03	3047.22
Hog Deer	0.05	2109.62
Indian Pangolin	0.01	13712.50
Jungle cat	0.34	291.76
Khalij	0.54	185.30
Langur	2.11	47.28
Leopard	1.82	55.07
Leopard cat	1.90	52.64
Livestock	3.11	32.15
Mongoose	0.39	258.73
Monitor lizard	0.01	6856.25
Nilgai	0.24	409.33
Palm civet	0.33	301.37
Peafowl	1.25	79.96
Porcupine	9.49	10.53
Red Fox	<0.01	27425.00
Red Jungle Fowl	1.67	59.88
Rhesus macaque	8.38	11.93
Rodent	0.03	3917.86
Rusty spotted cat	0.02	5485.00
Sambar	21.38	4.68
Sloth Bear	0.34	294.89
Small Indian civet	2.03	49.33
Striped Hyaena	0.03	3428.13
Tiger	12.78	7.82
Wid Pig	7.54	13.27
Yellow throated marten	0.64	156.71

Relative Abundance of all Photocaptured Species in Corbett Tiger Reserve

A total of 32 species of ungulates, carnivores, omnivores and galliformes were photo-captured in Corbett Tiger Reserve. Chital, sambar and barking deer were the most common species (Table 9.7). Red fox was photo-captured for the first time in the tiger reserve and with only one photo-capture was the rarest camera trapped species, followed by pangolin (Table 9.7).

DISCUSSION

With a high ungulate biomass in the park Corbett Tiger Reserve maintains a high tiger density acting as a source of dispersing tigers to neighbouring protected areas (Lansdowne, Terai West, Amangarh and Ramnagar forest division) and is therefore of great importance for tiger and wildlife conservation in this landscape. Corbett Tiger Reserve has the largest tiger population in any single Protected Area in the world.

AMANGARH TIGER RESERVE

INTRODUCTION

Amangarh is situated in Bijnore district of Uttar Pradesh on the southern boundary of Corbett Tiger Reserve. Amangarh forest division is spread across 95 km^2 comprising primarily of *Shorea robusta* dominated forests, teak plantations, grasslands and wetlands. It has been declared as a buffer area of Corbett Tiger Reserve which has led to its effective protection and management and is now known as the Amangarh Tiger Reserve.

RESULTS

Tiger Density Estimates

A total of 273 tiger images were obtained from which 20 individual tigers were identified with an estimated tiger density of 2.06 (SE 0.05) tigers per 100 km^2. The detection corrected male to female tiger sex ratio was 0.08:0.92 (Table 9.8). A total of 2 cubs were photo-captured.

Table 9.8

Sampling details tiger density parameter estimates in spatially explicit capture mark-recapture analysis using likelihood framework for Amangarh, 2018.

Variables	Estimate
Model space (km^2)	345
Camera points	42
Trap nights (effort)	1981
Unique tigers captured	20
Model	P_{mix}(sex), g_0(sex), σ(sex)
$\hat{D}$ SECR (per 100 km^2)	2.06 (0.05)
σ Female (SE) km	0.78 (0.06)
σ Male (SE) km	1.89 (0.13)
g_0 Female (SE)	0.14 (0.002)
g_0 Male (SE)	0.07 (0.008)
Pmix Female (SE)	0.92 (0.06)
Pmix Male (SE)	0.08 (0.007)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

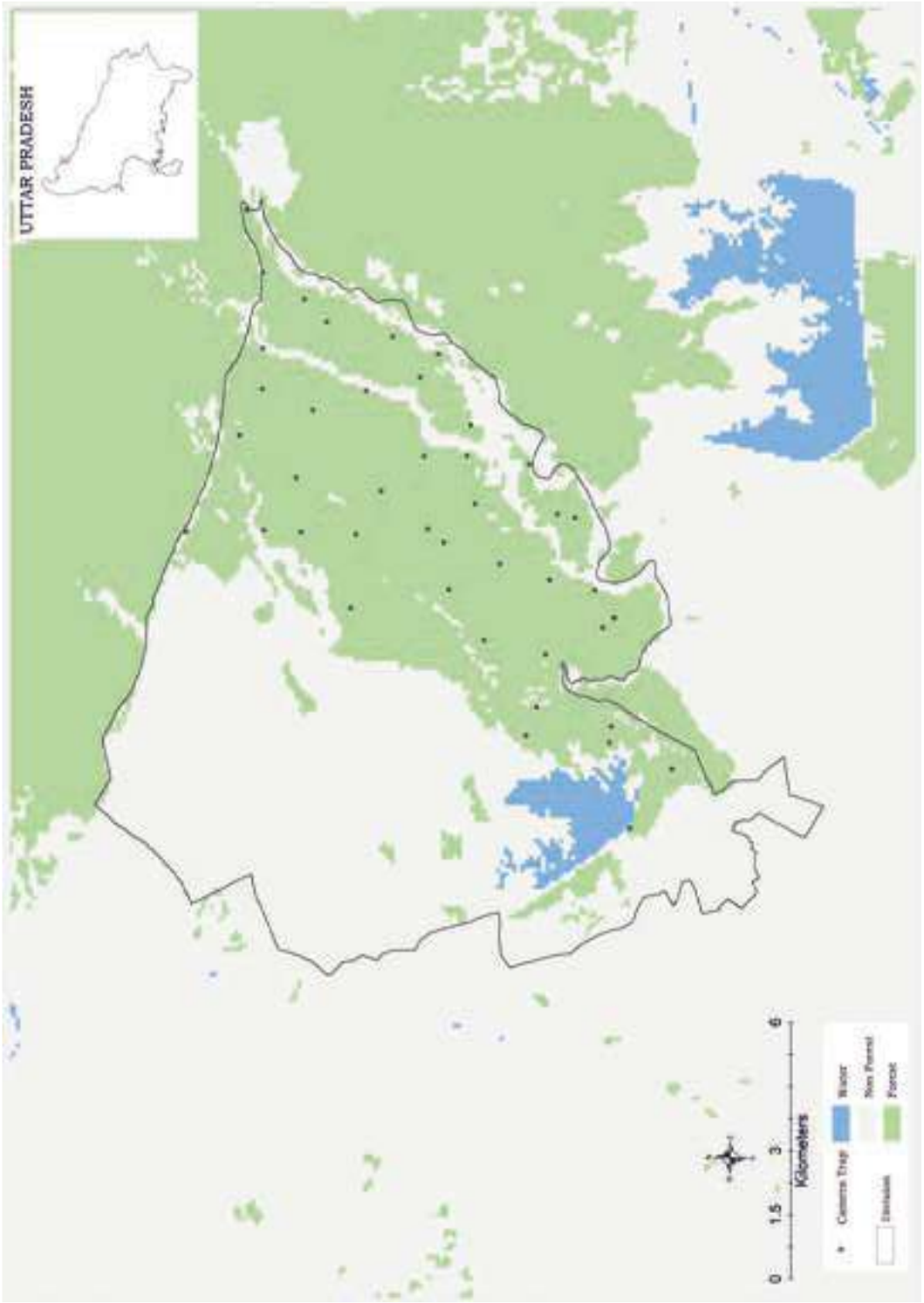


Figure 9.26

Camera trap layout in Amangarh Tiger Reserve, 2018.

DISCUSSION

Compared to the previous estimates of tigers (10 individuals photo-captured 2014 (Jhala et al. 2015) there has been an increase in tiger numbers in Amangarh. It shares tigers with Corbett tiger reserve in the north and with terai west on its east.

TERAI WEST FOREST DIVISION

INTRODUCTION

Three forest divisions (Terai West, Terai Central and Terai East) encompass the Terai tract of Uttarakhand. These three forest divisions lie immediately south of the Bhabar tract of Uttarakhand that support some of country's best tiger populations. Terai West Forest Division shares its boundary with Amangarh Tiger Reserve of Uttar Pradesh in the north west and Corbett Tiger Reserve as well as Ramnagar Forest Division in the north. The forests of Terai West Division are contiguous with the forests of Terai Central Division on the east. The forest division lies entirely in the terai zone with characteristic flat topography and fine alluvial soil deposits. Extensive plantations of commercially valuable species are dominant forest type here and have replaced much of the natural vegetation. Vegetation type here is dominated by exotics like teak and eucalyptus. In the south these forests give way to agricultural fields and fast urbanizing settlements. Disturbance is reported to be high due to pressure 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 who practice grazing and agriculture in the forest. Other major pressures on wildlife habitat are from resource extraction such as boulder mining and timber removal. The forest division harbours a good population of tigers and leopards.

RESULTS

Tiger Density Estimates

A total of 511 tiger images were obtained from which 39 tigers were identified with an estimated tiger density of 6.23 (SE 0.91) tigers per 100 km^2. The detection corrected male to female tiger sex ratio was 0.56:0.43 (Table 9.9). A total of 4 cubs were photo-captured.

Table 9.9 Sampling details tiger density parameter estimates in spatially explicit capture mark-recapture analysis using likelihood framework for Terai West Forest Division, 2018.

Variables	Estimates
Model space (km^2)	1004
Camera Points	63
Trap Nights (effort)	2011
Unique tigers captured	39
Model	P_{mix}(sex), g_0(sex), σ(sex)
$\hat{D}$ SECR (per 100 km^2)	6.23 (0.91)
σ Female (SE) km	4.5 (0.25)
σ Male (SE) km	2.5 (0.43)
g_0 Female (SE)	0.06 (0.016)
g_0 Male (SE)	0.07 (0.011)
Pmix Female (SE)	0.43 (0.09)
Pmix Male (SE)	0.56 (0.09)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
σ (Sigma): Spatial scale of detection function,
g_0: Magnitude (intercept) of detection function
Pmix: Detection corrected estimate of proportion of males and females

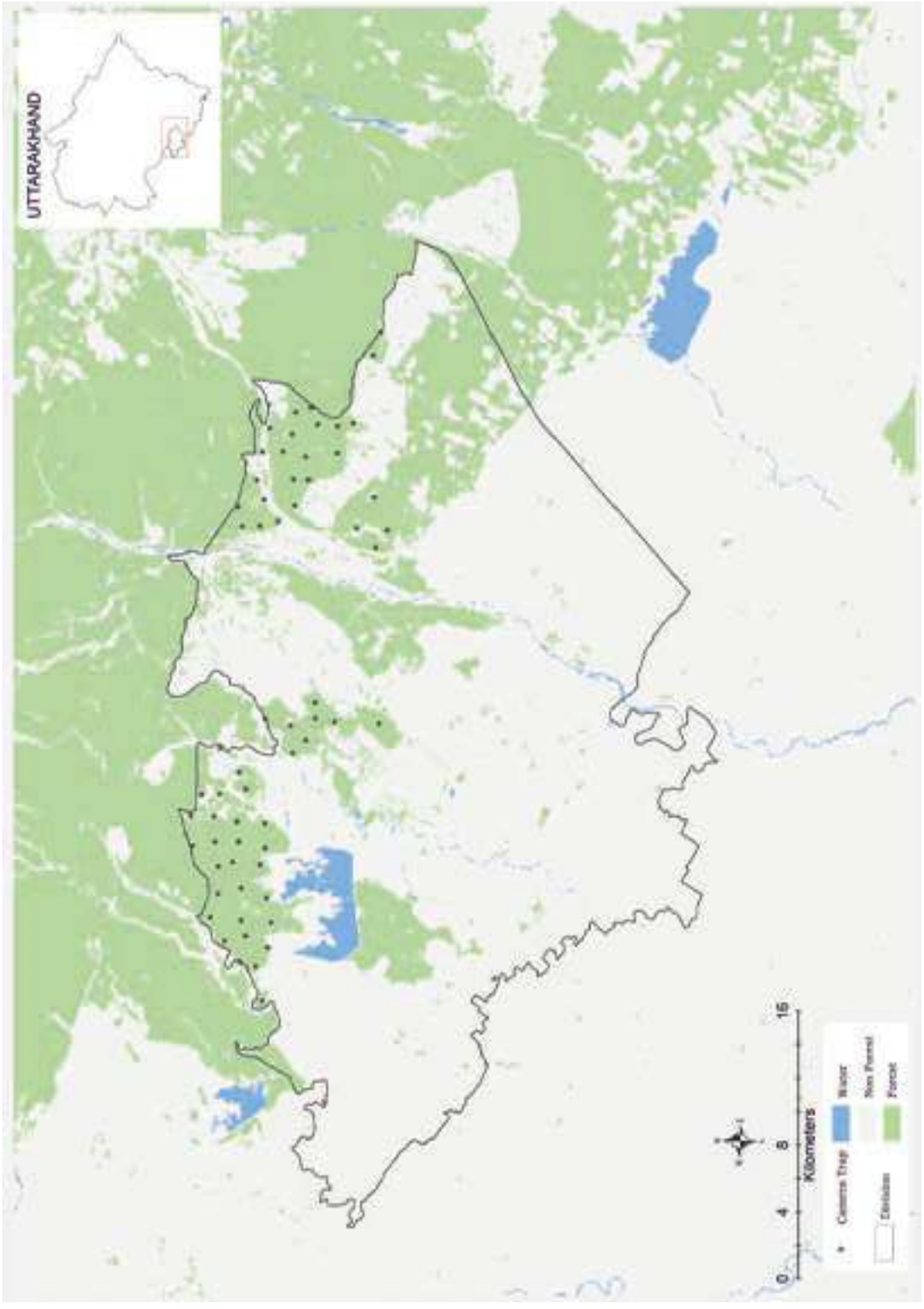


Figure 9.27

Camera trap layout in Terai West Forest Division, 2018.

DISCUSSION

Compared to the previous estimates obtained in 2014 (3.88±1.60, Jhala et al. 2015) with only 8 individuals photo-captured in 2014, Terai West has shown substantial increase in tiger numbers. Its connectivity with Amangarh to the west and Corbett to the north is one of the reasons for this increase in tiger numbers. This increase in tiger numbers has also been a cause of enhanced tiger-human conflict, since most of the villages relocated from Corbett Tiger Reserve have been resettled in areas adjoining this forest division.

RAMNAGAR FOREST DIVISION

INTRODUCTION

Ramnagar Forest Division is located between rivers Kosi and Gola, and administratively it comes under the district of Nainital of Uttarakhand State. The geo-coordinates of this division range between latitude N 29° 13' 30", N 29° 34' 15" and longitude E 79° 06', E 79° 33'. In the north of this division are Almora and Nainital divisions while Terai West and Terai Central divisions are adjoining its southern boundary. The forests of Corbett tiger reserve and Haldwani divisions are in the west and east of the Ramnagar FD respectively. Five rivers namely Kosi, Dabka, Boar, Nihal and Bhakra flow through the region. Many seasonal and perennial streams are also present in the forest of this division.

The forest division comprises of rocky area, plateau region and low lying area which gets affected by floods during the rainy season and the soil has a lot of mineral content. According to Champion and Seth (1968), major forest types that occurs in Ramnagar FD are a) Northern tropical semi-evergreen, b) North Indian moist deciduous, c) Tropical fresh water swamp, d)North tropical dry deciduous and d) Himalayan subtropical chir pine forest. The area is mostly covered by moist Sal forest and mixed type of forest and some areas also show presence of Teak plantation. Common trees found in this division are *Anogeissus latifolia, Terminalia bellerica, Syzygium sp., Lagerstroemia parviflora, Mallotus phillipinensis, Cassia fistula, Adina cordifolia* and *Linnea coromandelica*. Major understory vegetation comprises of *Clerodendron viscosum, Lantana camara, Parthenium sp., Adhatoda vasica* and *Colebrookia oppositifolia*. This region has a diverse biodiversity including animals like tiger (*Panthera tigris*), leopard (*Panthera pardus*), leopard cat (*Prionailurus bengalensis*), jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*) and fishing cat (*Prionailurus viverrinus*), red fox (*Vulpes vulpes*), jackal (*Canis aureus*), sloth bear (*Melursus ursinus*), Himalayan black bear (*Ursus thibetanus*) Indian porcupine (*Hystrix indica*), elephants (*Elephas maximus*), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), hog deer (*Axis porcinus*), goral (*Naemorhedus goral*) and serow (*Capricornis thar*). Nilgai (*Boselaphus tragocamelus*) and Indian pangolin (*Manis crassicaudata*).

RESULTS

Tiger Density Estimates

A total of 947 tiger images were obtained from which 37 tigers were identified with a density estimated at 4.13 (SE 0.68) tigers per 100km^2. The detection corrected tiger male to female sex ratio was 0.33:0.67 (Table 9.10). A total of 8 cubs were photo-captured.

Table 9.10 Sampling details and tiger density parameter estimates using spatially explicit capture mark-recapture analysis using likelihood framework for Ramnagar Forest Division, 2018

Variables	Estimates
Model space (km^2)	795
Camera Points	266
Trap Nights (effort)	9338
Unique tigers captured	37
Model	P_{mix}(sex), g_0(sex),σ(sex)
$\hat{D}$ SECR (per 100 km^2)	4.13 (0.68)
σ Female (SE) km	1.9 (0.08)
σ Male (SE) km	2.6 (0.15)
g_0 Female (SE)	0.02 (0.002)
g_0 Male (SE)	0.02 (0.002)
Pmix Female (SE)	0.67 (0.08)
Pmix Male (SE)	0.33 (0.08)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

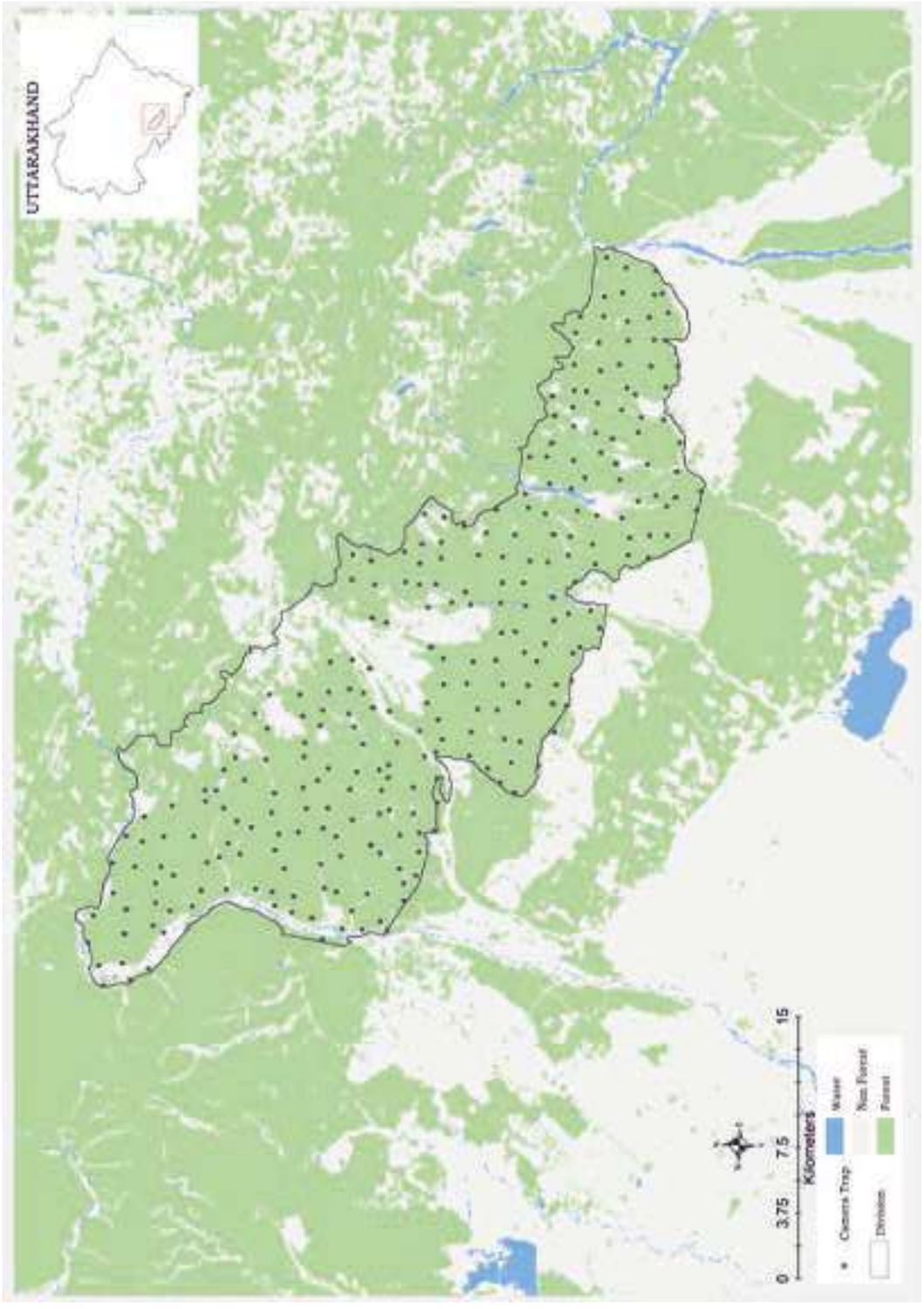


Figure 9.28
Camera trap layout in Ramnagar Forest Division, 2018.

DISCUSSION

Ramnagar forest division has one of the highest tiger density in the territorial forests of Uttarakhand. Its connectivity with Corbett Tiger Reserve through the Kosi River corridor helps maintain this high tiger density and habitat connectivity eastwards for tiger dispersal in this landscape.

HALDWANI FOREST DIVISION

INTRODUCTION

Haldwani forest division together with Champawat and Terai East Forest Divisions forms a compact patch of nearly 1,200 km^2 of important tiger habitat on the eastern most part of Uttarakhand. The five ranges of Haldwani forest division (Chakata, Nandhour, Danda, Jaulasal and Sharada) cover an area of about 600 km^2 and are bound by Gola River in the West and Sharada River in the east. To the west of Haldwani division across the Gola River lies the forests of Ramnagar and Terai Central Forest Divisions. In the north-east Dogadi range of Champawat Forest Division forms an important connectivity with forests of Haldwani. In the south, forest of Haldwani is surrounded by the forests of Ransali, South Jaulasal and Kilpura ranges of Terai East Forest Division. Across the Sharada River, Haldwani is contiguous with forests of Nepal through the Boom-Brahmadev corridor above Tanakpur.

Haldwani forest division is characterized by hilly terrain with loose substratum made up of coarse sediments and bisected by numerous seasonal and few perennial streams. The forests of Haldwani are intersected by Nandhour River, a perennial water source. Nandhour has large swathes of undisturbed forest which are devoid of human habitation. In the center of the Haldwani division lies the Nandhour Wildlife Sanctuary, comprising an area of nearly 380 km^2 which is an important tiger habitat in the forest division.

Haldwani supports significant population of tigers (*Panthera tigiris*) and leopards (*Panthera pardus*) owing to plentiful prey, such as sambar (*Rusa unicolor*), wild pig (*Sus scrofa*) and chital (*Axis axis*). Other herbivores of the area include elephant (*Elephas maximus*), goral (*Naemorhedus goral*), barking deer (*Muntiacus vaginalis*) and serow (*Capricornis thar*). Both sloth bear (*Melursus ursinus*) and Himalayan black bear (*Ursus thibetanus*) occur in the forests of Haldwani. Alongside its mammalian fauna the region hosts a rich diversity of bird species comprising of Himalayan endemics and vagrants from Nepal. Although, past studies have indicated a declining status of large mammals in this region (Johnsingh et al. 2004, 2010), conservation efforts in Haldwani has gained considerable momentum with the declaration of Nandhaur Wildlife Sanctuary. Haldwani division holds enormous potential for conserving tigers and is one of the important recovery zones in the country.

RESULTS

Tiger Density Estimates

A total of 418 tiger images were obtained from which 23 tigers were identified, with a density of 3.18 (SE 0.68) tigers per 100 km^2.The detection corrected tiger male to female sex ratio was 0.23:0.77 (Table 9.11).

Table 9.11 Sampling details and tiger density parameter estimates using spatially explicit capture mark-recapture analysis using likelihood framework for Haldwani Forest Division, 2018

Variables	Estimates
Model space (km^2)	1122
Camera Points	203
Trap Nights (effort)	8930
Unique tigers captured	23
Model	P_{mix}(sex), g_0(sex),σ(sex)
$\hat{D}$ SECR (per 100 km^2)	3.18 (0.68)
σ Female (SE) km	1.9 (0.14)
σ Male (SE) km	3.6 (0.39)
g_0 Female (SE)	0.02 (0.004)
g_0 Male (SE)	0.01 (0.003)
Pmix Female (SE)	0.77 (0.09)
Pmix Male (SE)	0.23 (0.09)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

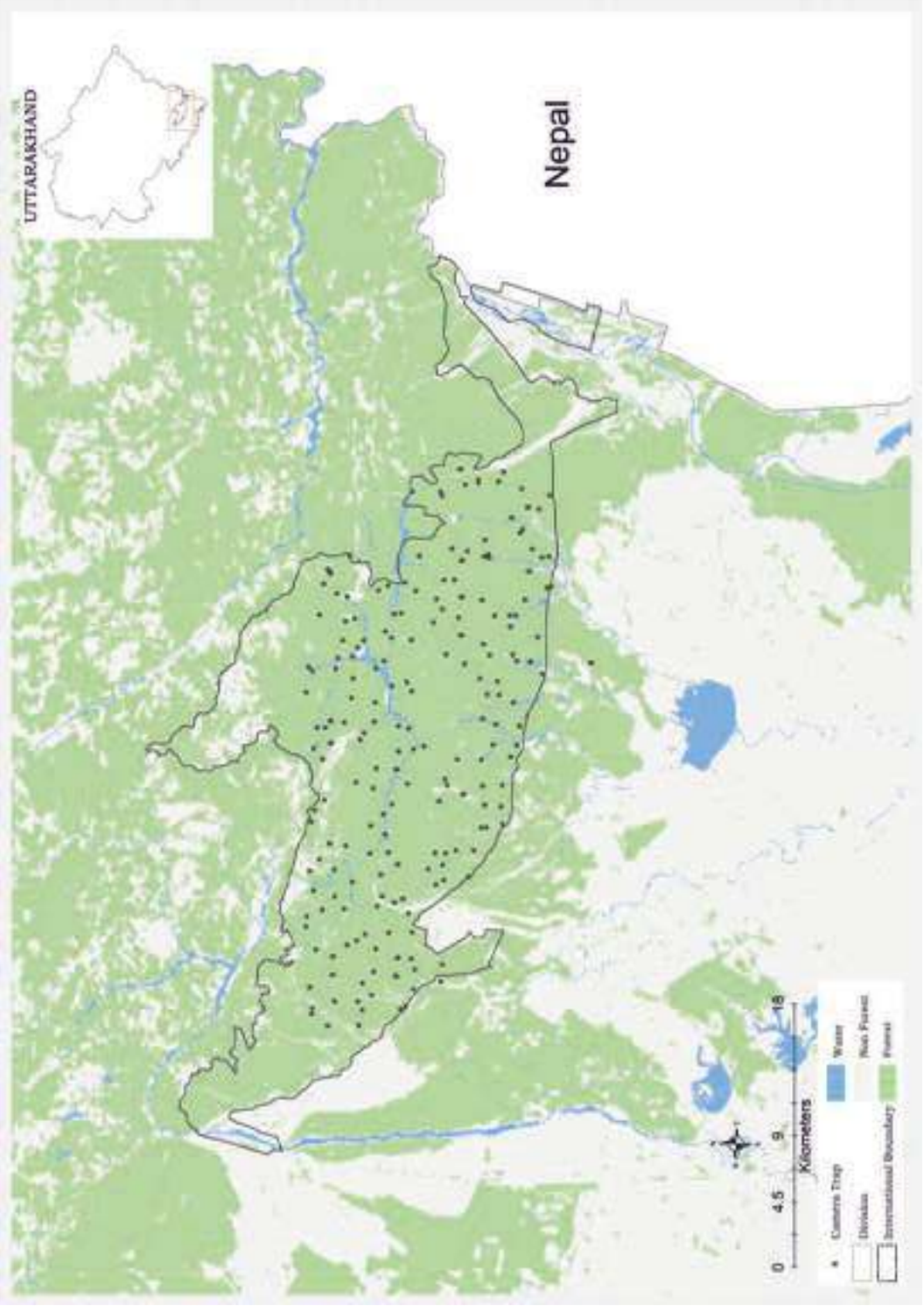
σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Figure 9.29

Camera trap layout in Haldwani Forest Division, 2018.



DISCUSSION

Haldwani tiger population is connected to Champawat Forest Division in the north and through Terai East forest division forms the important part of the Surai corridor connecting the Uttarakhand terai region with Pilibhit Tiger Reserve. Nandhaur Wildlife Sanctuary has recently been identified as an important region for tiger conservation in the landscape and this area holds a lot of potential for accommodating further increase in tigers in the landscape and constitutes an important linkage in the overall connectivity of the tigers in the landscape.

CHAMPAWAT FOREST DIVISION

INTRODUCTION

Champawat forest division is in the Kumaon forest circle of the state of Uttarakhand, infamous for its man-eating tigress as documented in "Maneaters of Kumaon" by Jim Corbett. This forest division has sub-tropical forest type and hilly terrain.

Figure 9.30
Camera trap layout in Champawat forest division, 2018.

RESULTS

Camera Trap Results

Camera trapping was carried out by the forest department, where 25 tiger photo-captures yielded 9 tiger individuals (Table 9.12). Due to insufficient photo-captures, density of tigers for this site was not estimated.

Parameters	Estimate
Camera points	34
Trap-nights (effort)	1566
Number of tiger photos	25
Unique tigers captured	9

Table 9.12
Sampling details and number of tigers photo-captured in Champawat Forest Division, 2018

DISCUSSION

Champawat forest division was camera trapped following the All India Tiger Monitoring protocol for the first time and has a good tiger population. Two tigers were common with Haldwani Forest Division.

NAINITAL FOREST DIVISION

INTRODUCTION

Nainital region has a unique geographical location, situated between the lower Himalaya in the north and Bhabar region in the south. The region is very rich in flora and the vegetation in the region can be classified into 1) sub-tropical deciduous forests 2) Himalayan sub-temperate and 3) Moist temperate deciduous forest. Sub-tropical deciduous forests extend all along the southern part of the region and over the outer zone of the Shivalik range. The main species here are *Shorea robusta, Dalbergia sissoo, Adina cordifolia, Tectona grandis, Acacia catechu, Eucalyptus* and Bamboo. A wide part of the region is under high elevation range having comparatively cool climate, with good water conditions, favourable for Pine forests. Lower variety of Oak is found almost all over this region and also Chir Pine forest occur in plenty. Camera trapping following the All India Tiger Monitoring protocols was carried out for the first time in the forest division.

Figure 9.31
Camera trap layout in Nainital forest division, 2018.

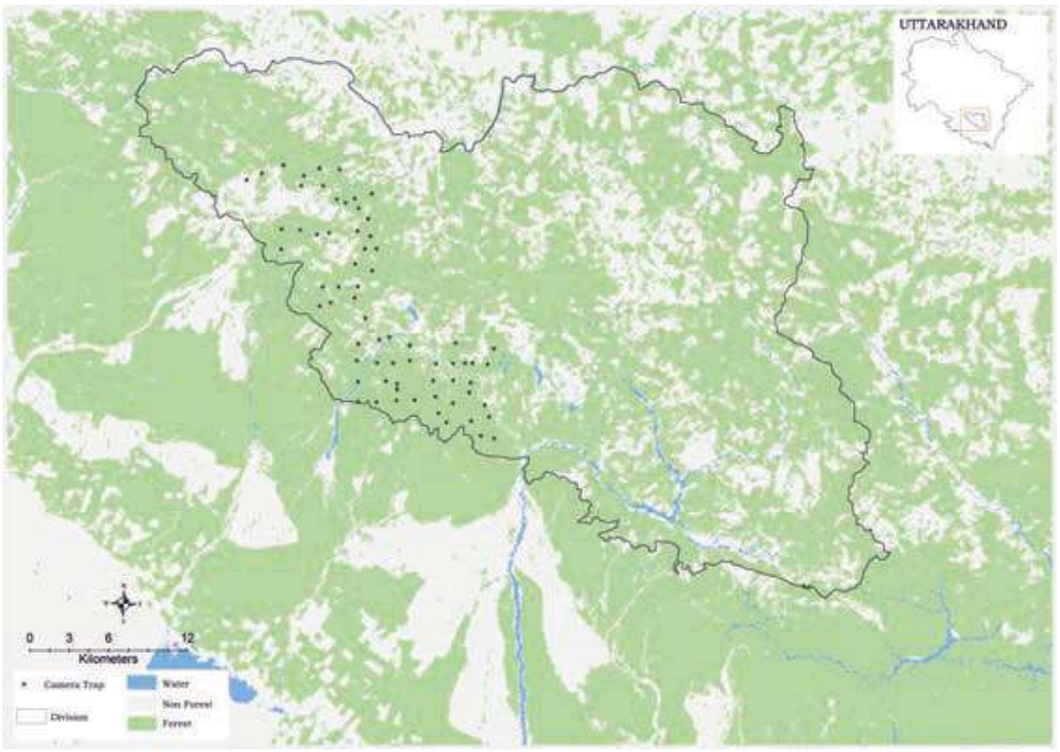


Table 9.13
Sampling details and number of tigers photo-captured in Nainital Forest Division, 2018

Parameters	Estimate
Camera points	70
Trap-nights (effort)	3072
Number of tiger photos	10
Unique tigers captured	4

RESULTS

Camera Trap Results

Camera trapping was carried out by the forest department, where 10 tiger photo-captures yielded 4 tiger individuals (Table 9.13). Due to insufficient photo-captures, density of tigers for this site was not estimated.

TERAI CENTRAL FOREST DIVISION

INTRODUCTION

Terai Central forest division lies south of the Bhabar tract of the state of Uttarakhand, it maintains its connectivity with Ramnagar Forest Division through two important corridors; Boar River corridor and Nihal-Bhakhra corridor (Johnsingh et al. 2004). Terai Central Forest Division extends up to Lalkuan in the east. With the loss of Gola River corridor, the connectivity between Terai Central and Terai East Forest Divisions has been totally lost. East of Gola River, Terai East Forest Division extends all the way up to Pilibhit Tiger Reserve in Uttar Pradesh.

Terai central is characterized by flat topography and fine alluvial soil deposits of the terai zone. Disturbance is reported to be high due to pressures from high human densities, particularly along the southern boundary of this region.

RESULTS

Camera Trap Results

Camera trapping was carried out by the forest department, where 29 tiger photo-captures yielded 5 tiger individuals (Table 9.14). Due to insufficient photo-captures, density of tigers for this site was not estimated.

Table 9.14 Sampling details and number of tigers photo-captured in Terai Central Forest Division, 2018

Parameters	Estimate
Camera points	17
Trap-nights (effort)	534
Number of tiger photos	29
Unique tigers captured	5

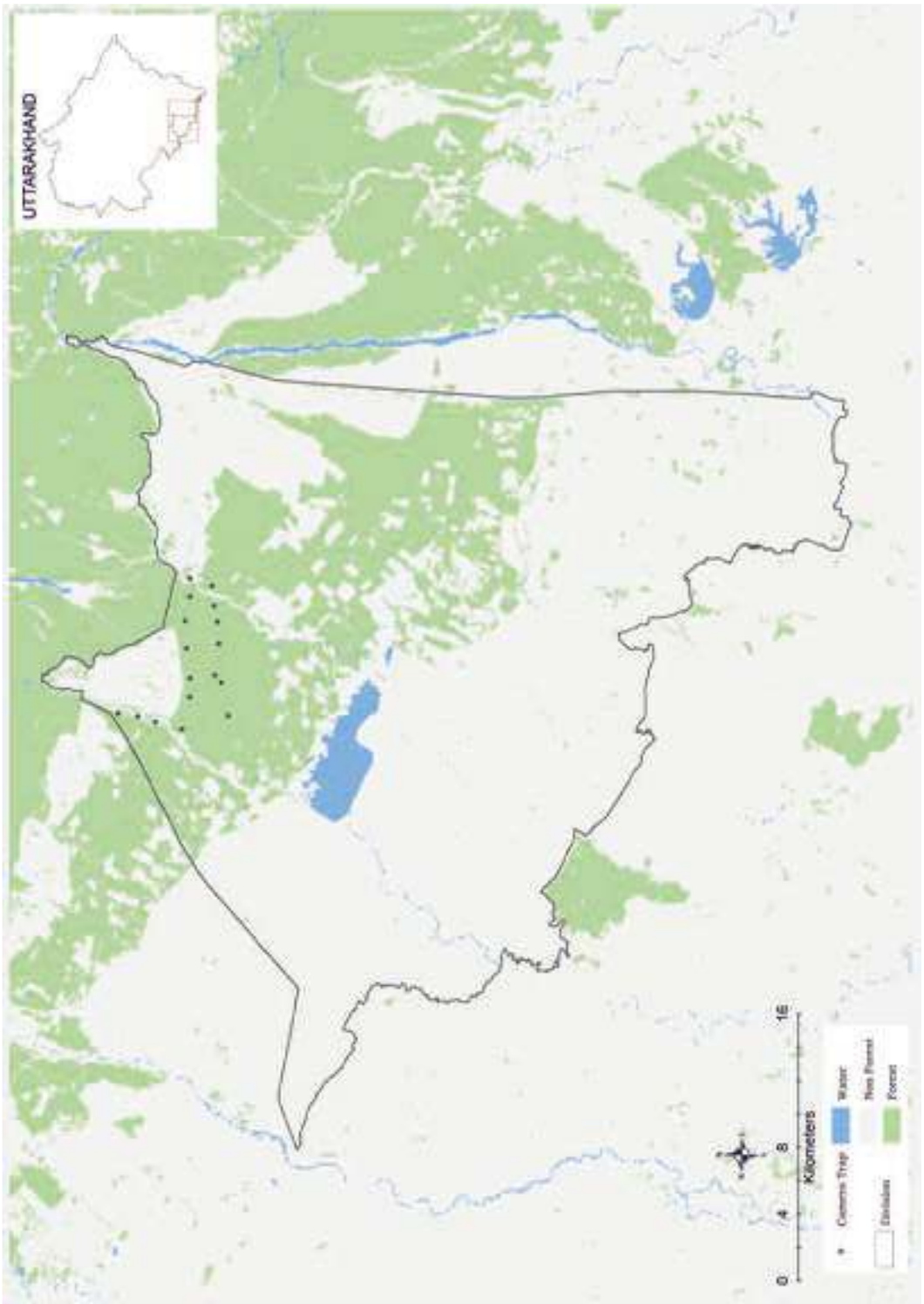


Figure 9.32
Camera trap layout in Terai central forest division, 2018.

DISCUSSION

Terai Central forest division is an important corridor which connects the Ramnagar Forest Division forest with Haldwani and Terai East forest divisions. Despite high level of disturbances low density tiger population was observed to use these forests suggesting continuity of geneflow across this bottleneck in the Terai Arc landscape.

TERAI EAST FOREST DIVISION

INTRODUCTION

Terai East comes under the Udhamsinghnagar district of Uttarakhand State. The forested area of three ranges of Terai East forest division namely, Kilpura, Khatima and Suraiforms an important wildlife corridor, which connects Pilibhit tiger reserve with the Nandhaur wildlife sanctuary. This important corridor is as narrow as 1 km at places and completely disjointed by a canal and human habitation near Lal Kothi. The forests of Khatima range are a vital link in the chain of connectivity between Nandhour (Haldwani forest division), Pilibhit and the forest of Nepal, and serve as a corridor for several large mammal species, including tigers and elephants.

Perennial source of water in the area are Jagbora and Sharada rivers, and Sharada canal. Important tree species recorded in this forest division are *Shorea robusta, Mallotus phillipinensis, Terminalia alata, Trewia nudiflora, Syzizium cumini, Holoptelia integrifolia,* and *Lagerstroemia parviflora*. Plantations of *Eucalyptus* sp., *Tectona grandis* and *Milius avelutina* are also found here. Large mammalian fauna of this forest are tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), nilgai (*Boselaphus tragocamelus*) and wild pig (*Sus scrofa*). Smaller cats are represented by jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*) and rusty-spotted cat (*Prionailurus rubiginosus*).

Terai east forest division faces severe encroachment which is exemplified by Khatima range, of which, at least 6 km^2 is under encroachment by about 800 families. The forests of Khatima range are highly disturbed from settlements along the right bank of the Sharada canal. As a result, the movement of large mammals between Kilpura and Surai ranges has virtually come to an end. Encroachment related habitat loss has been exacerbated by the linear breakages in the forests resulting from the alignments of the Sharada canal and Tanakpur-Khatima highway road (Johnsingh et al. 2004). A number of Gujjar families along with their livestock are also known to reside in the Kilpura and Surai range.

RESULTS

Tiger Density Estimates

A total of 186 tiger images were obtained from which 23 tigers were identified with a density of 3.30 (SE 0.74) tigers per 100km^2. The detection corrected tiger male to female sex ratio was 0.67:0.33 (Table 9.15).

Table 9.15 Sampling details and tiger density parameter estimates using spatially explicit capture mark-recapture analysis in a likelihood framework for Terai East Forest Division, 2018

Variables	Estimates
Model space (km^2)	1209
Camera Points	139
Trap Nights (effort)	7252
Unique tigers captured	23
Model	P_{mix}(sex), g_0(sex),σ(sex)
$\hat{D}$ SECR (per 100 km^2)	3.30 (0.74)
σ Female (SE) km	3.2 (0.45)
σ Male (SE) km	3.7 (0.52)
g_0 Female (SE)	0.007 (0.002)
g_0 Male (SE)	0.003 (0.0006)
Pmix Female (SE)	0.33 (0.14)
Pmix Male (SE)	0.67 (0.14)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

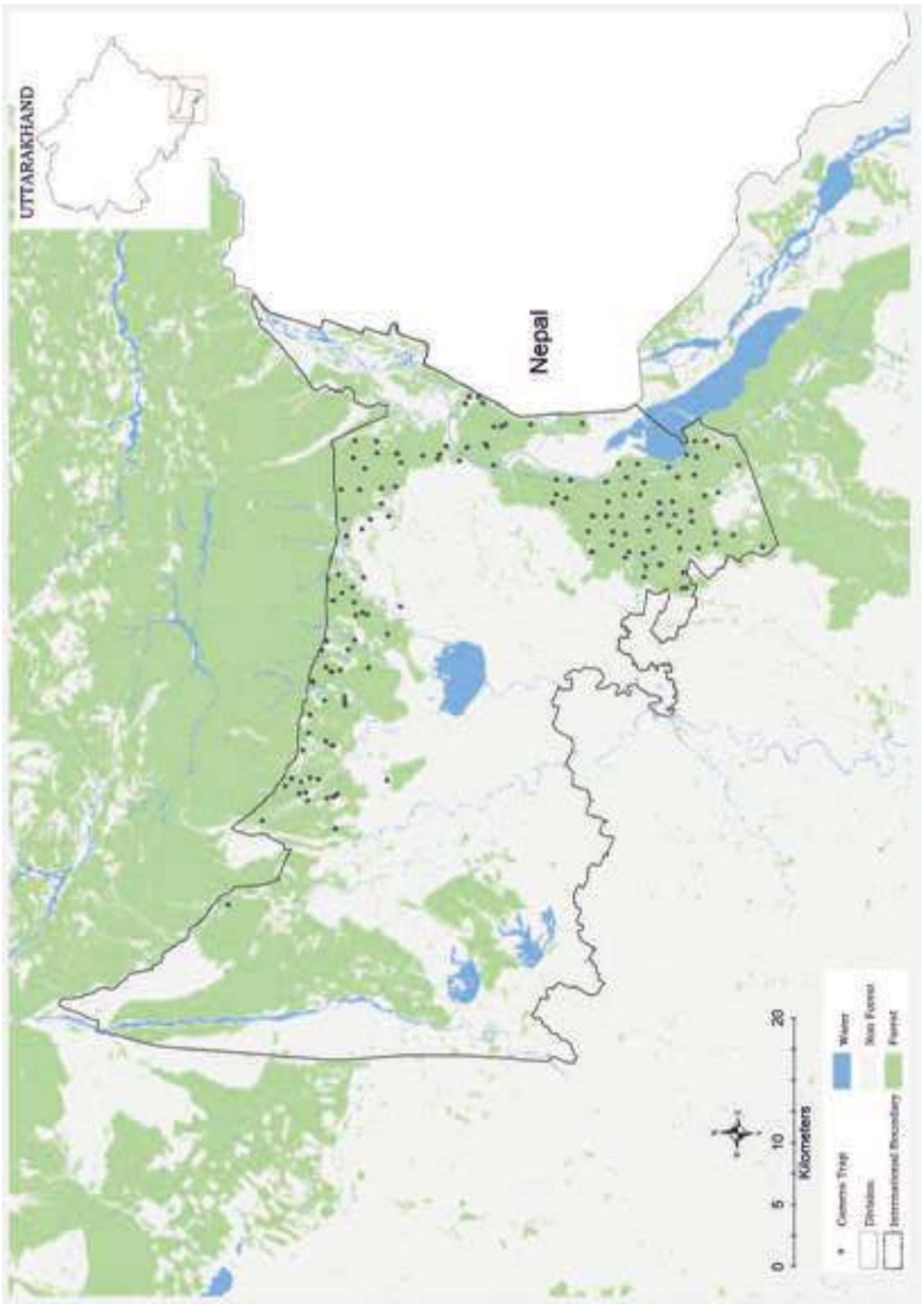


Figure 9.33
Camera trap layout in Terai east forest division, 2018.

DISCUSSION

Camera trap photo-captures have shown that tigers move between Terai East and Pilibhit Tiger Reserve. Despite all the barriers to dispersal in the corridor connecting Terai East and Pilibiht, four tiger individuals were common between these areas. Major conservation challenge in this important corridor is to preserve it in the face of the increasing anthropogenic pressures and linear infrastructure (National Highway 125, Khatima-Tanakpur railway line and Sharada Canal) in the area.

PILIBHIT TIGER RESERVE

INTRODUCTION

Pilibhit Tiger Reserve located at 28°38'17.00"N 79°57'18.12"E covers an area of 1074 km^2 and is located in Pilibhit District of Uttar Pradesh, India. It is connected with the terai-bhabar forests of the Surai range in the Terai East Forest Division in the north-west, and with Kishanpur WLS in the south-east. This reserve also provides connectivity to Shukla Phanta wildlife reserve in Nepal, and with Kishanpur Widlife Sanctuary in India, through the Lagga-Bagga forest block, and Tatarganj area of North Kheri Forest Division. Pilibhit Tiger Reserve was a reserve forest before being declared as tiger reserve and its forest mainly consists of *Shorea robusta* as well as some *Tectona grandis* plantations. The reserve also has a small area of grassland and all these are nurtured by various canals, rivers and a reservoir.

The reserve has a rich fauna which includes large and small carnivores like the tiger (*Panthera tigris*), leopard (*Panthera pardus*), fishing cat (*Prionailurus viverrinus*), jungle cat (*Felis chaus*) and rusty spotted cat (*Prionailurus rubiginosus*), along with large Indian civet, small Indian civet, Asian palm civet, jackal, otters and honey badger. The important herbivores of the reserve include rhinoceros (*Rhinoceros unicornis*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), sambar (*Rusa unicolor*), barasingha (*Cervus duvaucelii duvaucelii*), hog deer (*Axis porcinus*), nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*) and four horned antelope (*Tetracerus quadricornis*).

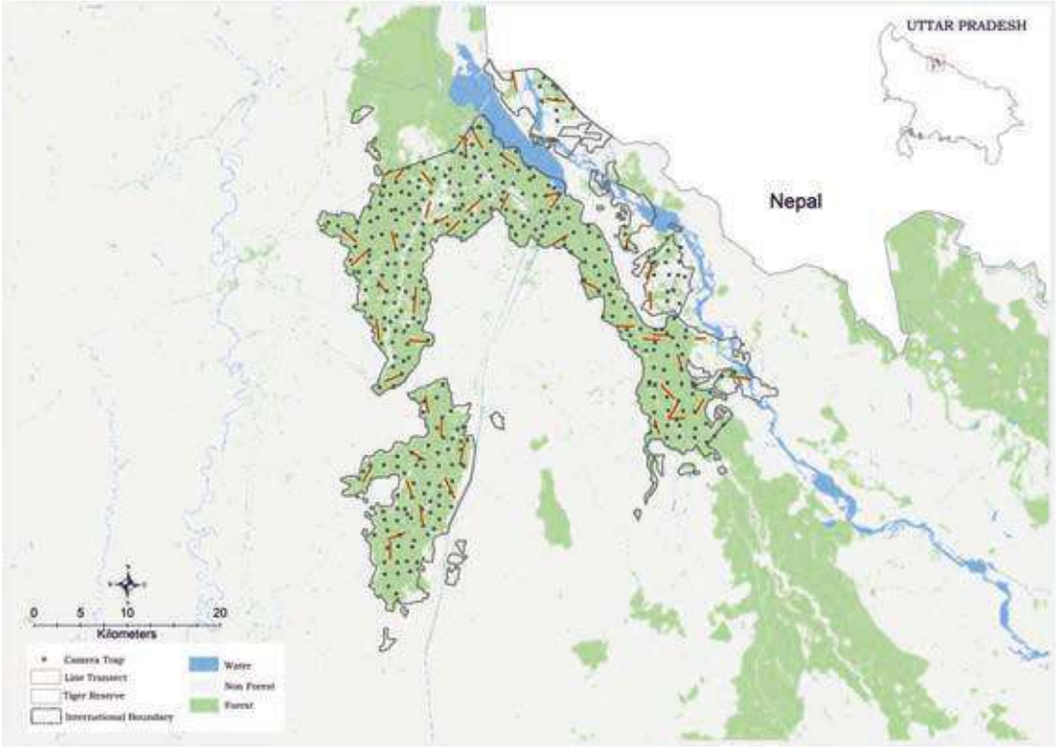


Figure 9.34
Camera trap and line transect layout in Pilibhit Tiger Reserve, 2018.

RESULTS

Tiger Density Estimates

A total of 1279 tiger images were obtained from which 57 tigers were identified with a tiger density of 6.6 (SE 0.87) tigers per 100 km^2. Tigers using the tiger reserve and the surrounding areas was 65 (SE 3), while tigers in the tiger reserve was 57 (SE 0.3). The detection corrected tiger male to female sex ratio was 0.49:0.51 (Table 9.16). Only one cubs was photo-captured.

Table 9.16

Sampling details and tiger density parameter estimates using spatially explicit capture mark-recapture analysis using likelihood framework for Pilibhit Tiger Reserve, 2018

Variables	Estimates
Model space (km^2)	1132
Camera Points	336
Trap Nights (effort)	16188
Unique tigers captured	57
Model	P_{mix}(sex), g_0(sex), σ(sex)
$\hat{D}$ SECR (per 100 km^2)	6.6 (0.87)
σ Female (SE) (km)	1.9 (0.064)
σ Male (SE) (km)	2.7 (0.089)
g_0 Female (SE)	0.02 (0.001)
g_0 Male (SE)	0.01 (0.0009)
Pmix Female (SE)	0.51 (0.07)
Pmix Male (SE)	0.49 (0.07)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Prey Density Estimates

A total of 277 line transects were walked by the forest department (Table 9.17), where chital had the highest density (40.71 (SE 3.35) per km^2) followed by Nilgai (Table 9.17).

Table 9.17

Model statistics and parameter estimates of line transect (n=277, Total effort 528 km) based distance sampling for prey species in Pilibhit Tiger Reserve, 2018

Species	Effective strip-width (SE)	#groups detected	Mean group-size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital	60.76 (2.43)	320	8.90 (0.77)	0.61 (0.02)	0.60 (0.03)	4.98 (0.33)	40.71 (3.35)
Wild Pig	44.89 (5.84)	124	4.75 (0.31)	0.66 (0.08)	0.23 (0.01)	2.61 (0.40)	12.43 (2.04)
Hog Deer	52.69 (4.91)	74	2.24 (0.17)	0.64 (0.06)	0.14 (0.01)	1.32 (0.20)	2.94 (0.48)
Nilgai	59.30 (5.57)	137	6.75 (0.66)	0.46 (0.04)	0.25 (0.02)	2.18 (0.26)	12.78 (1.86)

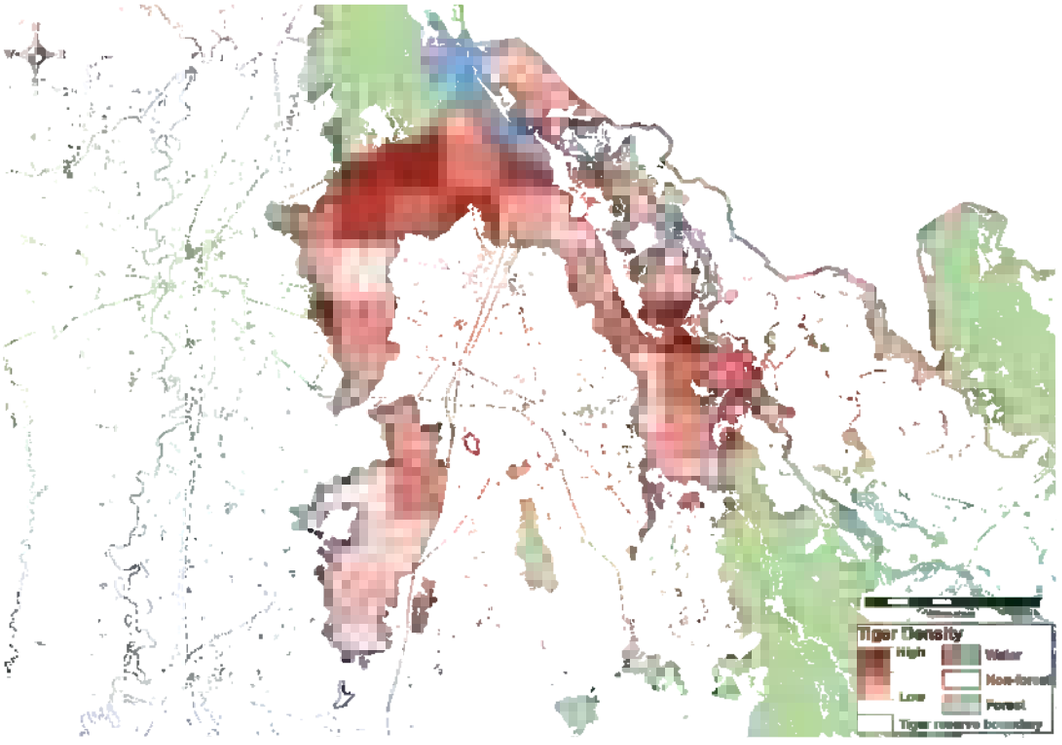


Figure 9.35

Spatial density of tigers in Pilibhit Tiger Reserve, 2018

Tigers in Pilibhit Tiger Reserve had higher density distribution in the northern parts of the tiger reserve with connectivity with the Terai East Forest Division.

Distribution of Major Mammalian Species Found in Pilibhit Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates.

Hog deer was distributed throughout the tiger reserve, implying healthy suitable habitat for this endangered ungulate which is otherwise threatened by habitat (grassland) degradation in the landscape.

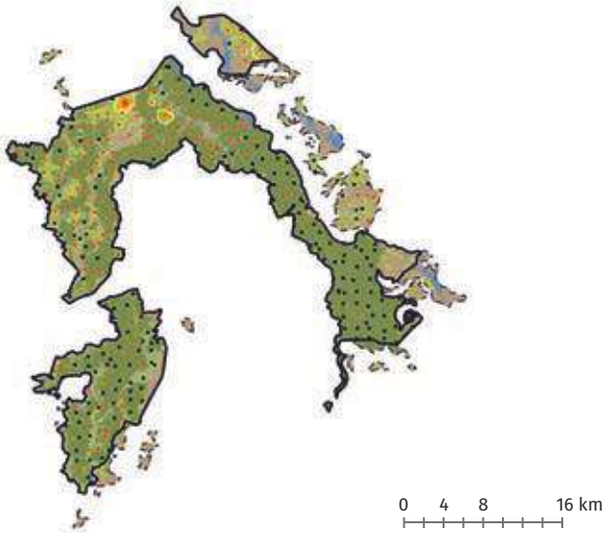


Figure 9.36

Distribution, and relative spatial abundance of hog deer in Pilibhit Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Figure 9.37

Distribution, and relative spatial abundance of swamp deer in Pilibhit Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Swamp deer was photo-captured more in the northern area of the tiger reserve with concentration of photo-captures in grassland patches.

Figure 9.38

Distribution, and relative spatial abundance of greater one horned rhinoceros in Pilibhit Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Rhinoceros was photo-captured in the north grassland patch in the tiger reserve, these are likely dispersing individuals from Shuklaphanta National Park of Nepal.

Figure 9.39

Distribution, and relative spatial abundance of golden jackal in Pilibhit Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Jackal was distributed throughout the tiger reserve, with higher concentration of photo-captures near the park boundary in proximity of human settlements.

Sloth bear was distributed throughout the tiger reserve, except the south west portion that is surrounded by sugarcane crop fields.

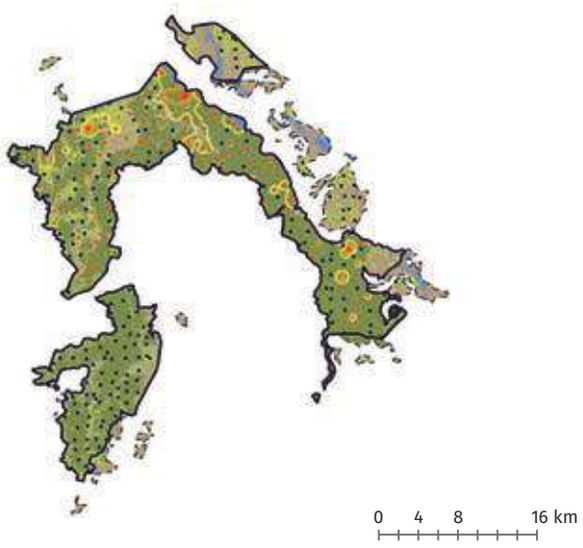


Figure 9.40

Distribution, and relative spatial abundance of sloth bear in Pilibhit Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Leopard was photo-captured throughout the tiger reserve with concentration of photo-captures in the northern boundary away from the core area of the tiger reserve.

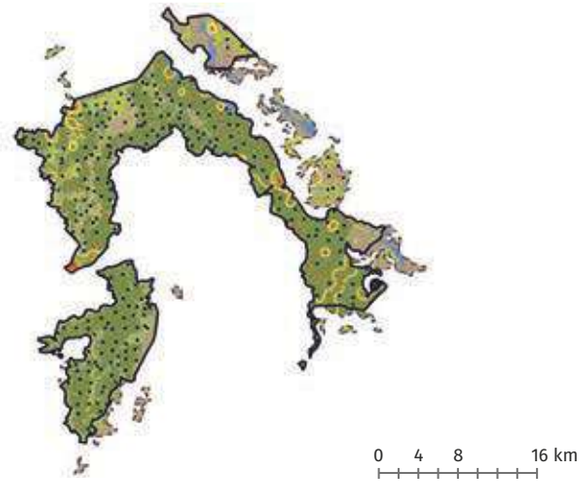


Figure 9.41

Distribution, and relative spatial abundance of leopard in Pilibhit Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Jungle cat was distributed in pockets in the tiger reserve, with higher concentration of photo-captures in open grassland habitat near waterbodies.

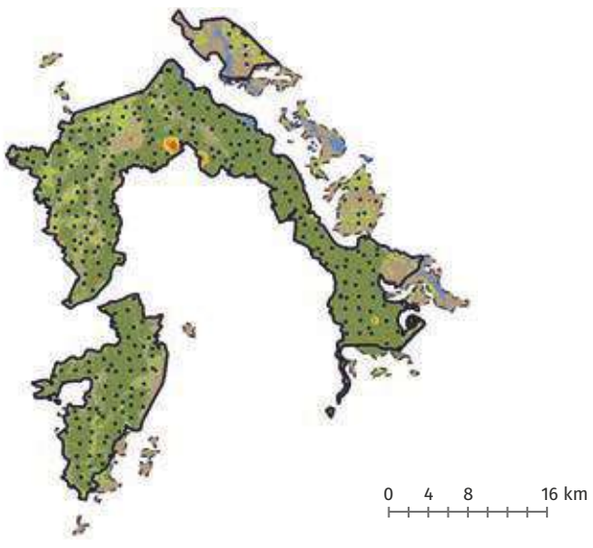
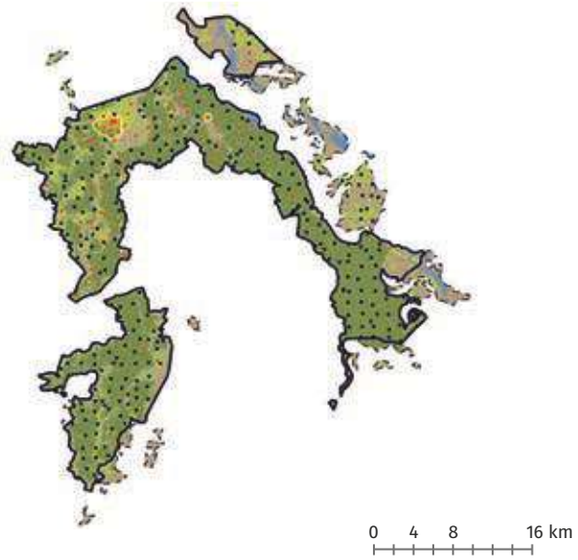


Figure 9.42

Distribution, and relative spatial abundance of jungle cat in Pilibhit Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Figure 9.43

Distribution, and relative spatial abundance of fishing cat in Pilibhit Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.



Fishing cat was distributed in the forested area of the tiger reserve and photo-captures were concentrated more in the less disturbed sal patches of the tiger reserve.

Figure 9.44

Distribution, and relative spatial abundance of rusty-spotted cat in Pilibhit Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Rusty spotted cat was the least photo-captured small cat in the tiger reserve with most of the photo-captures in the forested area of the tiger reserve.

Relative Abundance of all Photocaptured Species in Pilibhit Tiger Reserve

A total of 28 species of ungulates, carnivores, omnivores and galliformes were photo-captured in the tiger reserve. Chital, rhesus macaque, wild pig and peafowl were the most commonly photo-captured species. Otters were the rarest to get one photo-capture, followed by pangolin (Table 9.18).

Species	No of photos per 100 trap days	Number of days to get one photo
Barking Deer	0.87	114.81
Black naped hare	0.16	622.62
Chital	46.18	2.17
Domestic cat	0.36	274.37
Domestic dog	3.22	31.07
Fishing cat	1.26	79.35
Golden Jackal	3.82	26.19
Hog Deer	7.60	13.16
Honey badger	0.57	175.96
Indian Pangolin	0.01	8094.00
Indian Rhinoceros	0.05	2023.50
Jungle cat	0.25	394.83
Langur	2.45	40.88
Large Indian civet	2.01	49.66
Leopard	1.35	74.26
Livestock	13.48	7.42
Mongoose	0.95	105.12
Monitor lizard	0.11	952.24
Nilgai	8.36	11.96
Otter	0.01	16188.00
Palm civet	1.19	83.88
Peafowl	16.81	5.95
Porcupine	7.27	13.75
Red Jungle Fowl	0.56	177.89
Rhesus macaque	19.03	5.26
Rusty spotted cat	0.25	404.70
Sambar	0.83	120.81
Sloth Bear	4.15	24.13
Swamp Deer	2.12	47.20
Tiger	4.73	21.13
Wid Pig	14.98	6.68

Table 9.18

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Pilibhit Tiger Reserve, 2018

DISCUSSION

Pilibhit lies next to Terai East and is connected to Nandhaur wildlife sanctuary and on the south eastern side is flanked by Kishenpur Wildlife Sanctuary and hence occupies a prominent position in the tiger population connectivity in the terai-bhabar area. Through the Lagga-Baggha grasslands and Sharda river flood plains Pilibhit Tiger Reserve connects to Shuklaphanta National Park in Nepal; tigers, rhinos and occasional elephants often disperse between these protected areas. Border roads need to account for this important wildlife connectivity between the two countries and design appropriate animal passage ways.

DUDHWA TIGER RESERVE

INTRODUCTION

Dudhwa tiger reserve comprises of:

1) Dudhwa National Park, located at 28° 30' 30" N, 80° 40' 48" E in an area of 680 km^2 and spread in Lakhimpur Kheri District of Uttar Pradesh, India. The park has a number of large wetlands and alluvial grasslands. Historically, this park was famed for its Sal timber, and later as a premier hunting area.

Dudhwa has two main water sources, the river Mohana to the north and the river Suheli to the south of the park. Dudhwa has a tenuous connectivity to the Basanta and the Laljhari forests in Nepal. Dudhwa is characterized by extensive tracts of Sal forests, interspersed by the tall grass lands, large wetlands and seasonal streams. The park is famous for its small population of reintroduced greater one-horned rhinoceros (*Rhinoceros unicornis*) which are restricted to a fence enclosure in the Suheli flood plains. Some of the major carnivores found here are tigers, leopards, fishing cat, jungle cat, leopard cat, sloth bears, and large Indian civet. Major herbivores of the reserve include elephant, chital, sambar, hog deer, barking deer, barasingha, nilgai and wild pig. This park has a good population of barasingha, Bengal florican and hispid hare.

2) Kishanpur Wildlife Sanctuary (North Kheri division is a part of Kishanpur WLS), located at 28° 24' 0.72" N, 80° 22' 1.2" E straddles Gola Tehsil in Lakhimpur District and the Powayan Tehsil in Shahjehanpur District in Uttar Pradesh, India. It lies on the southern side of the Sharda River and covers an area of 227 km^2. This sanctuary is connected to Pilibhit Tiger Reserve in the north and to the South Kheri Forest Division in the south. A unique feature of the geography of this forest complex is its narrowness and the lack of a well-defined core area that is insulated from human activity. Forest type in the sanctuary is a mosaic of grassland, Sal and planted teak forests. The major attraction here are the large herds of swamp deer (barasingha). Along with this, the pristine habitat is shared by tiger, leopard, fishing cat, jungle cat, sloth bear, while prey species includes the chital, sambar, hog deer, barking deer, nilgai and wild pig.

3) Katerniaghat Wildlife Sanctuary is located along the India-Nepal border in Bharaich District of Uttar Pradesh. The Karnali River which flows through Bardia National Park in Nepal, enters Katarniaghat in its north west corner as the Girwa River, and flows through a portion of the sanctuary, and into a reservoir, that feeds into Ghaghra River. The Khata corridor is a narrow, linear path of riparian forest along the Karnali River in Nepal, and connects Bardia National Park with Katarniaghat , and serves as a conduit for the movement of tigers, elephants and rhinoceros. Other threatened species in Katarniaghat include the Gangetic dolphin and gharial, both of which occur in the Girwa River. The forests of Katarniaghat are diverse since it has riparian forests and flood plains dominated by bombax and acacia trees which grow in grassland areas, and there are extensive tracts of cane as well. The central portions of Katarniaghat are dominated by sal, Terminalia alata and Mallotus phillippiensis. By contrast, the eastern ranges of the sanctuary are dominated by teak plantations, and mixed deciduous forests with lower prevalence of sal.

Katerniaghat is highly disturbed, on account of high levels of cattle grazing across the sanctuary, because there are >13 villages within the forest, with multiple roads and a railway line that bisects the sanctuary. It is home to a number of endangered species including gharial, tiger, rhino, Gangetic dolphin, swamp deer, hispid hare, Bengal florican, white-backed and long-billed vultures.

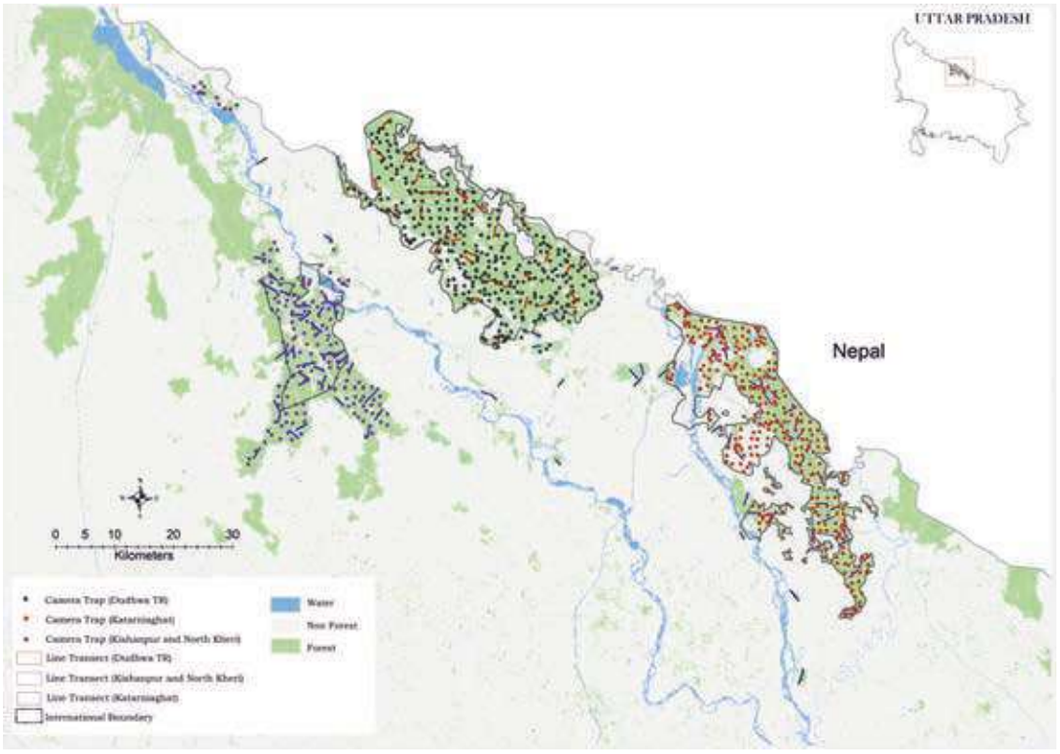


Figure 9.45

Camera trap and transect layout in 1) Dudhwa National Park 2) Kishanpur Wildlife Sanctuary and 3) Katarniaghat Wildlife Sanctuary 2018.

RESULTS

Tiger Density Estimates

A total of 2120 tiger images were obtained from Dudhwa Tiger Reserve from which 82 tigers were identified with a tiger density of 3.70 (SE) tigers per 100 km^2. Tiger population using Dudhwa Tiger Reserve and the surrounding areas was 107 (SE 16), but the number of tigers in the tiger reserve was 82 (SE 3.4). The detection corrected tiger male to female sex ratio was 0.39:0.61 (Table 9.19).

Table 9.19

Sampling details and tiger density parameter estimates using spatially explicit capture mark-recapture analysis using likelihood framework for Dudhwa National Park, Kishanpur and Katarniaghat Wildlife Sanctuary, 2018

Parameters	Dudhwa National Park	Kishanpur Widlife Sanctuary	Katarniaghat Wildlife Sanctuary
Model space (km^2)	1273	1230	1314
Camera Points	343	172	283
Trap Nights (effort)	12544	5086	8891
Unique tigers captured	20	33	29
Model	P_{mix}(sex), g_0(sex),σ(sex)	P_{mix}(sex), g_0(sex),σ(sex)	P_{mix}(sex), g_0(sex),σ(sex)
D̂ SECR (per 100 km^2)	2.30 (0.51)	4.21 (0.74)	4.6 (0.87)
σ Female (SE) km	1.6 (0.12)	3.0 (0.13)	2.1 (0.11)
σ Male (SE) km	5.0 (0.24)	4.2 (0.30)	3.1 (0.13)
g_0 Female (SE)	0.02(0.004)	0.03 (0.002)	0.05 (0.005)
g_0 Male (SE)	0.01(0.001)	0.01(0.002)	0.04 (0.004)
Pmix Female (SE)	0.57(0.11)	0.67 (0.09)	0.58 (0.09)
Pmix Male (SE)	0.43(0.11)	0.33 (0.09)	0.42 (0.09)

SE: Standard error

D̂ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Prey Density Estimates

Chital came out to be the most abundant prey species in both Katarniaghat WLS (41.26±1.76) and North Kheri forest division (42.08±2.04) followed by wild pig.

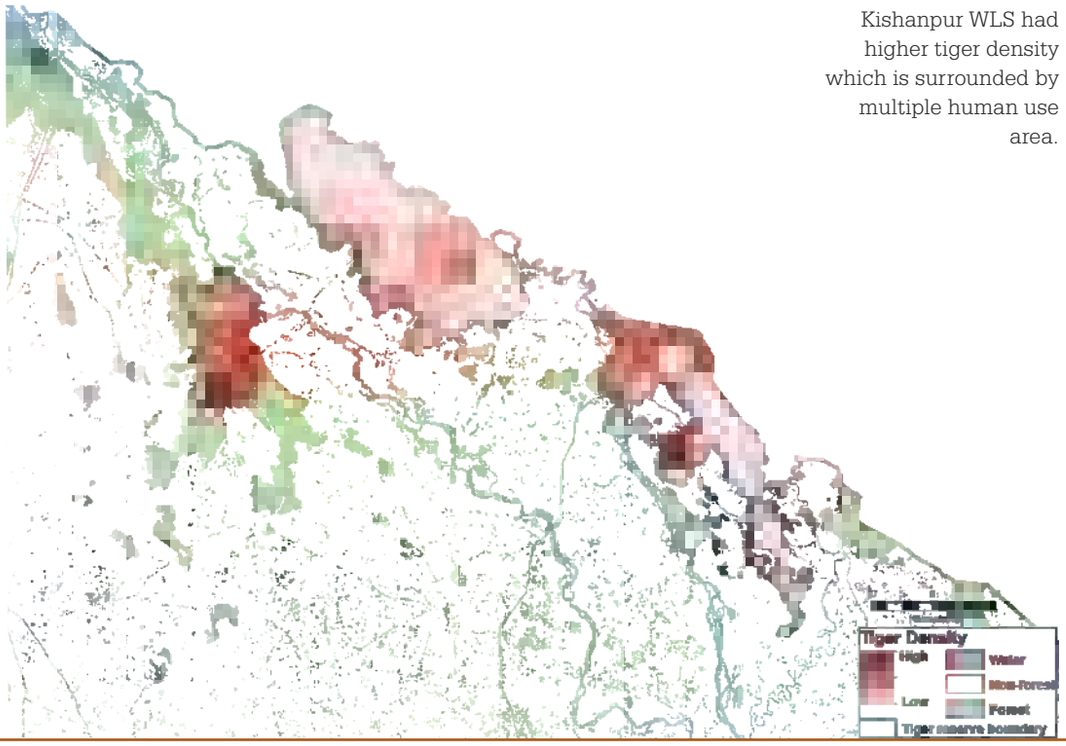
Table 9.20

Model statistics and parameter estimates of line transect in Dudhwa National Park (n=176, Total effort 389 km) Katarniaghat Wildlife Sanctuary (n=120, Total effort 230 km) and North-Kheri (n=103, Total effort 187 km) based distance sampling for prey species, 2018

Site	Species	Effective strip-width (SE)	#groups detected	Mean group-size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Dudhwa National Park	Wild Pig	33.10(1.80)	103	6.51(1.05)	0.57(0.03)	0.26(0.02)	4.00(0.43)	26.03(5.10)
	Hog Deer	37.66(5.2)	29	3.85(0.76)	0.57(0.08)	0.07(0.01)	0.98(0.24)	3.61(1.12)
	Langur	27.38(3.35)	34	17.23(1.79)	0.62(0.07)	0.08(0.01)	1.59(0.35)	27.42(6.73)
	Nilgai	45.21(3.83)	60	5.70(0.51)	0.74(0.06)	0.15(0.02)	1.70(0.26)	9.71(1.72)
	Barking Deer	NA	12	NA	NA	0.03(0.01)	NA	NA
Katarniaghat Wildlife Sanctuary	Chital	41.26(1.76)	99	6.80(0.58)	0.44(0.02)	0.43(0.03)	5.21(0.48)	35.51 (4.50)
	Barking Deer	40.82(4.02)	26	1.32(0.14)	0.65(0.06)	0.11(0.02)	1.38(0.31)	1.82(0.46)
	Wild Pig	33.10(1.80)	68	6.35(0.64)	0.57(0.03)	0.30(0.03)	4.46(0.51)	28.37(4.31)
	Nilgai	45.21(3.83)	49	3.93(0.31)	0.74(0.06)	0.21(0.02)	2.35(0.35)	9.28(1.57)
	Langur	NA	16	NA	NA	0.07(0.01)	NA	NA
	Hog Deer	NA	11	NA	NA	0.04(0.01)	NA	NA
North-Kheri	Chital	42.08(2.04)	24	6.77(1.14)	0.27(0.01)	0.12(0.02)	1.52(0.33)	10.35(2.85)
	Nilgai	NA	13	NA	NA	0.07(0.01)	NA	NA
	Wild Pig	NA	12	NA	NA	0.06(0.01)	NA	NA

Figure 9.46

Spatial density of tiger in Dudhwa Tiger Reserve, 2018



Kishanpur WLS had higher tiger density which is surrounded by multiple human use area.

Distribution of Major Mammalian Species Found in Dudhwa Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates.

Hog deer was photo-captured throughout the tiger reserve with higher concentration of photo-captures in Dudhwa national park in the flat, grassland areas of the park.

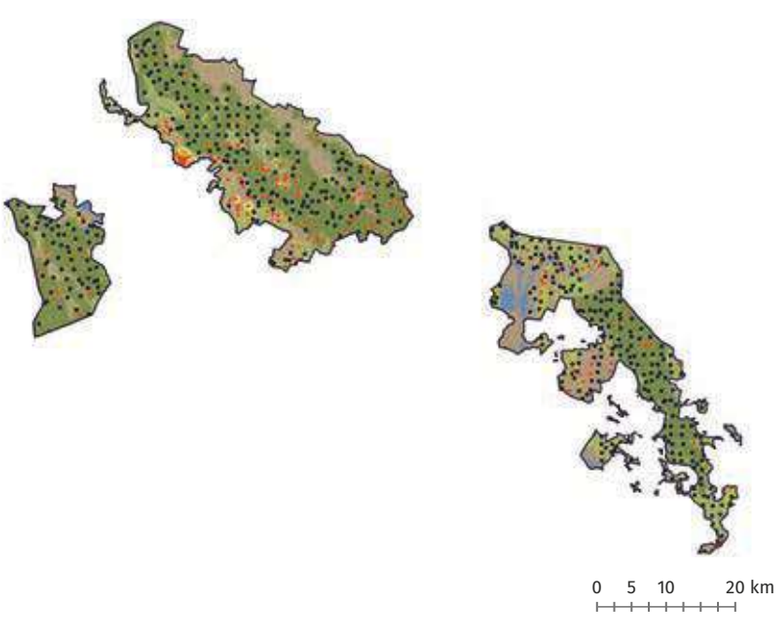


Figure 9.47

Distribution, and relative spatial abundance of hog deer in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Swamp deer photo-captures were concentrated in the flat grasslands of the Dudhwa National Park and some photo-captures in Kishenpur wildlife sanctuary. No swamp deer photos were obtained from Katarniaghat.

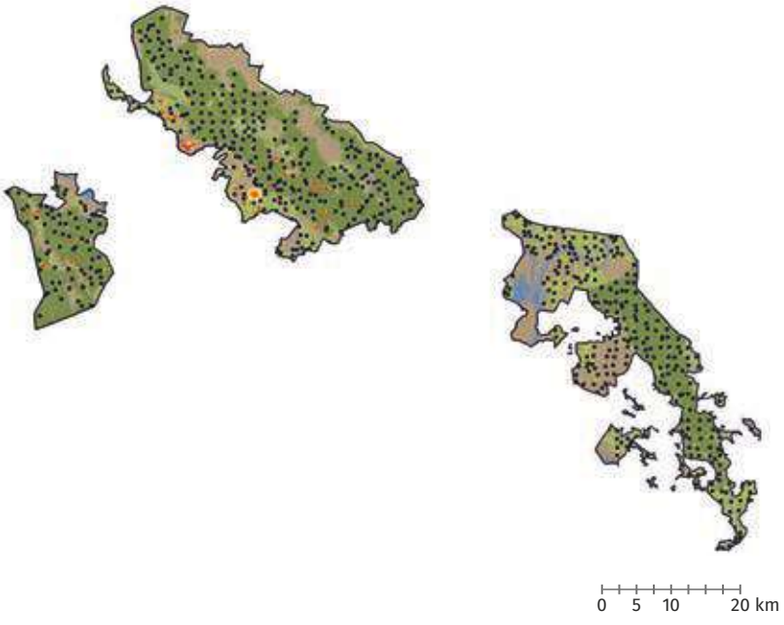


Figure 9.48

Distribution, and relative spatial abundance of swamp deer in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

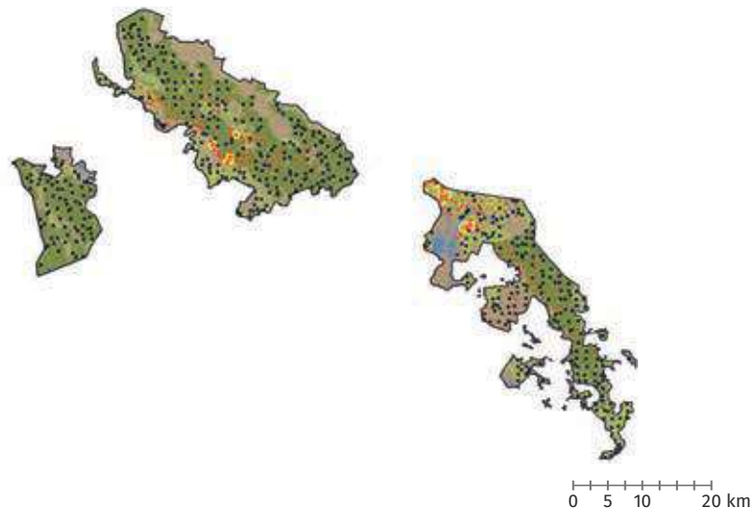


Figure 9.49

Distribution, and relative spatial abundance of elephants in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Elephants were photo-captured in both Dudhwa National park and in Katarniaghat wildlife sanctuary, but not from Kishenpur wildlife sanctuary. The photo-captures were highest in the flat terrain and grasslands of the tiger reserve.

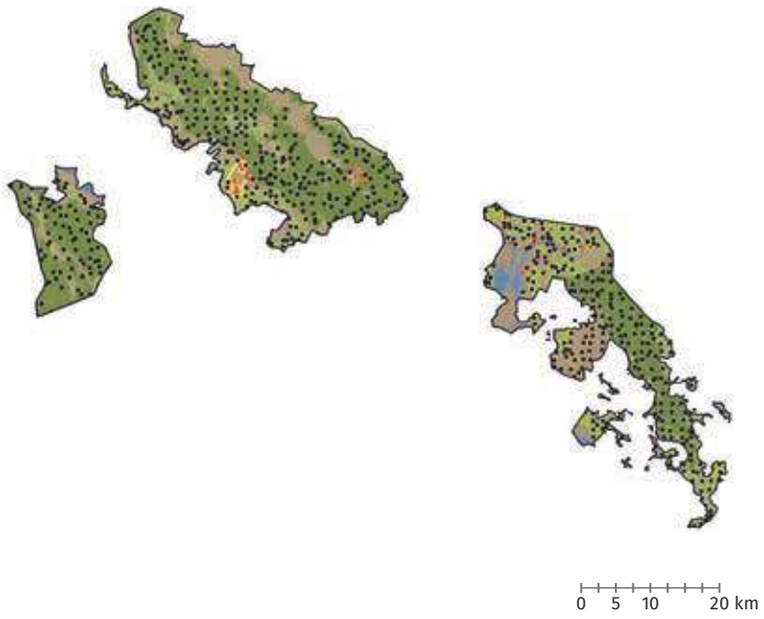


Figure 9.50

Distribution, and relative spatial abundance of greater one horned rhinoceros in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Rhinoceros were re-introduced in Dudhwa National Park in 1984 from Assam. The population is doing well after 34 years of reintroduction. Katarniaghat Widlife Sanctuary, receives dispersing rhinos from Bardia National Park through the Khata corridor. Most of the rhino population is restricted to the flat swampy grasslands of the Dudhwa National Park.

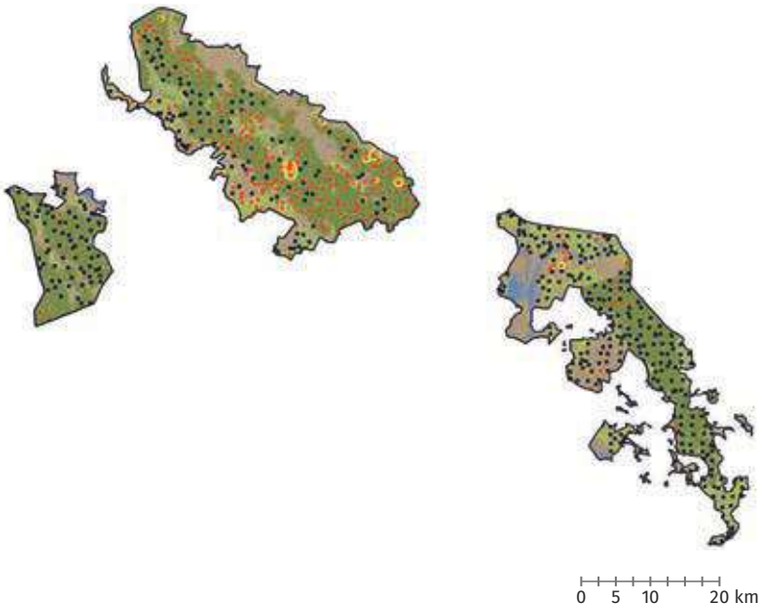


Figure 9.51

Distribution, and relative spatial abundance of golden jackal in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Golden jackal was found throughout the tiger reserve, with higher concentration of photo-captures in dense forest areas of Dudhwa National Park.

Sloth bear was photo-captured in the entire tiger reserve except in Katarniaghat Widlife Sanctuary. Sloth bear photo-captures were concentrated in the forested area of Dudhwa National Park.

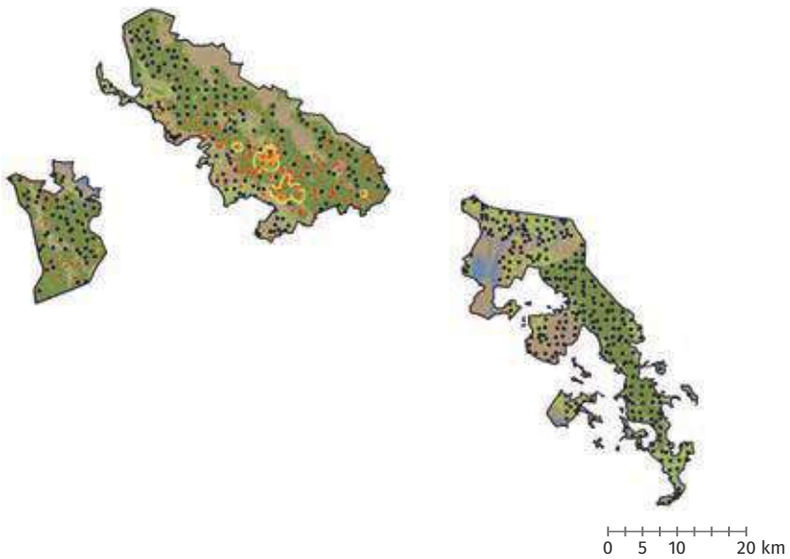


Figure 9.52

Distribution, and relative spatial abundance of sloth bear in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Leopard had photo-captures throughout the tiger reserve with higher concentration of photo-captures in the northern part of Katarniaghat wildlife sanctuary sharing its border with Nepal and connectivity with Bardia National Park through the Khata corridor

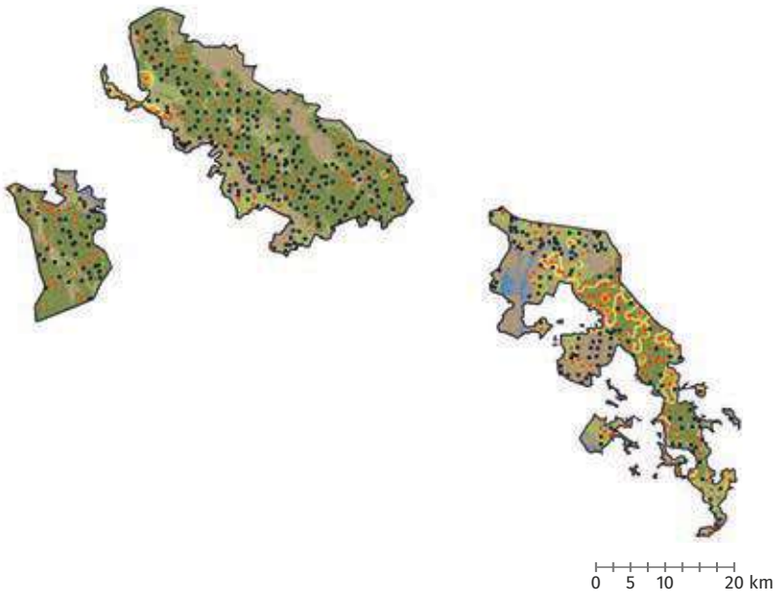


Figure 9.53

Distribution, and relative spatial abundance of leopards in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Photo-captures of jungle cat were distributed throughout the tiger reserve with concentration of photo-captures in the forested areas near the edge of the grasslands of the Dudhwa National Park.

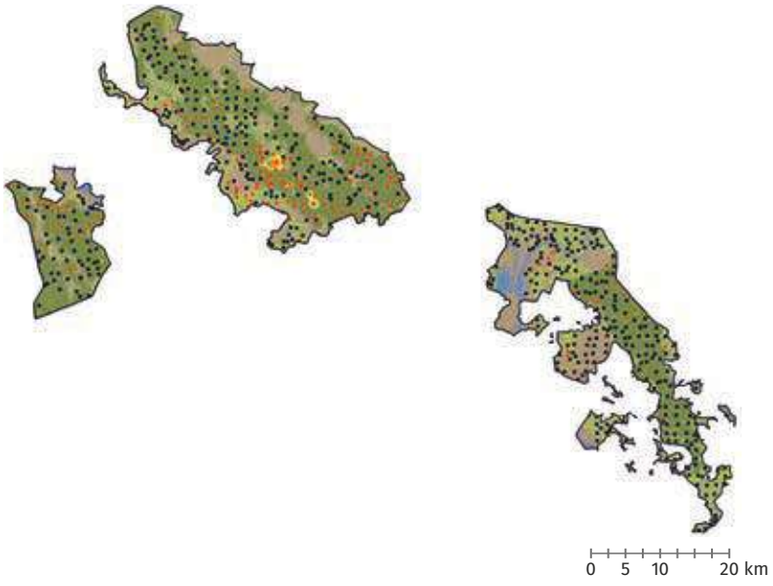


Figure 9.54

Distribution, and relative spatial abundance of jungle cat in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

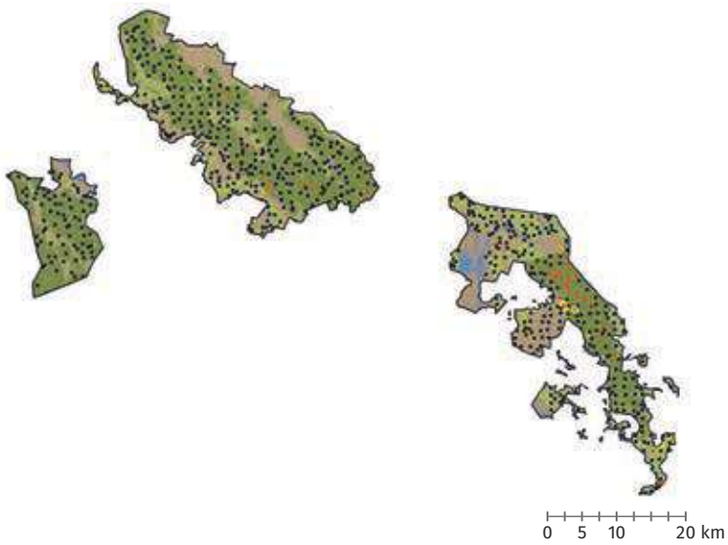


Figure 9.55

Distribution, and relative spatial abundance of leopard cat in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Leopard cat photo-captures were limited to Dudhwa National Park and Katarniaghat Wildlife Sancatury. Higher concentration of photo-captures were obtained in the forested parts of the Katarniaghat Wildlife Sancatury.

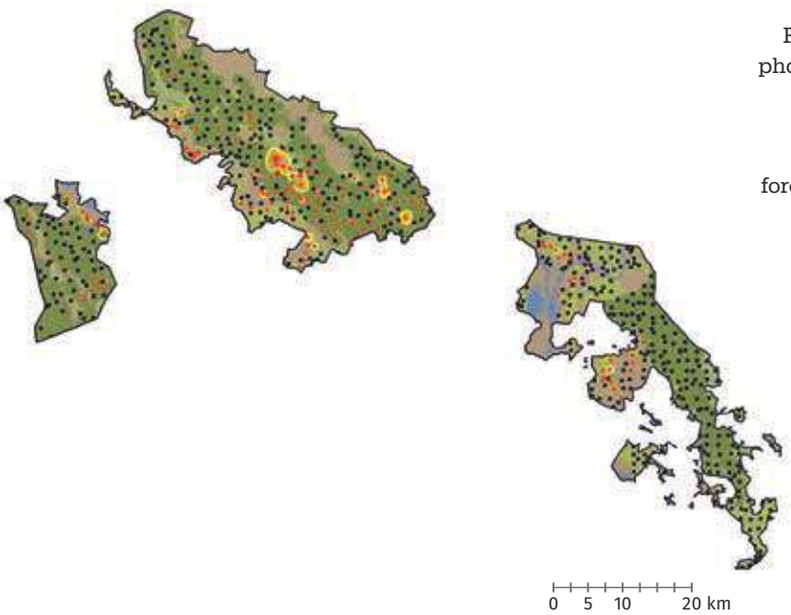


Figure 9.56

Distribution, and relative spatial abundance of fishing cat in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Fishing cat was the most photo-captured small cat in the tiger reserve, with higher concentration of photo-captures in the forests around the swampy grasslands of Dudhwa National Park and the grassland areas of Katarniaghat Wildlife Sanctuary.

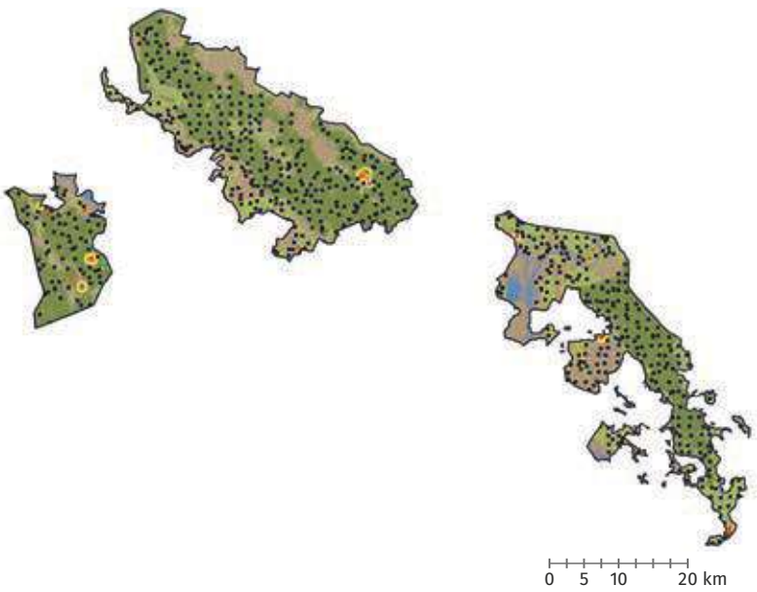


Figure 9.57

Distribution, and relative spatial abundance of rusty-spotted cat in Dudhwa Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Rusty spotted cat was the rarest small cat photo-captured in the tiger reserve, it was found in both forested and grassland areas.

Relative Abundance of all Photocaptured Species in Dudhwa Tiger Reserve

A total of 33 species of ungulates, carnivores, omnivores and galliformes were photo-captured in the tiger reserve. Chital and rhesus macaques were the most common species (Table 9.21) with 4-5 trap nights to obtain one photo-capture per camera. Four horned antelope was the rarest species with just nine photo-captures, followed by pangolin.

Table 9.21

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Dudhwa Tiger Reserve, 2018

Species	No of photos per 100 trap nights	Number of days to get one photo
Barking Deer	2.65	37.67
Black naped hare	2.10	47.70
Chital	21.50	4.65
Domestic cat	0.73	136.71
Domestic dog	1.84	54.46
Elephant	1.99	50.23
Fishing cat	1.50	66.64
Four horned antelope	0.02	4420.17
Golden Jackal	6.77	14.77
Hog Deer	3.55	28.15
Honey badger	0.52	190.80
Indian fox	0.05	1894.36
Indian Pangolin	0.03	3315.13
Indian Rhinoceros	0.40	250.20
Jungle cat	1.28	78.23
Langur	3.10	32.26
Large Indian civet	2.72	36.73
Leopard	2.77	36.13
Leopard cat	0.24	420.97
Livestock	29.91	3.34
Mongoose	1.30	76.87
Monitor lizard	0.04	2411.00
Nilgai	4.22	23.70
Otter	0.05	2040.08
Palm civet	2.54	39.35
Peafowl	8.10	12.34
Porcupine	5.41	18.48
Red Jungle Fowl	2.25	44.50
Rhesus macaque	17.62	5.67
Rusty spotted cat	0.12	828.78
Sambar	1.01	99.33
Sloth Bear	1.64	60.97
Small Indian civet	0.65	153.30
Swamp Deer	0.40	247.86
Tiger	5.35	18.68
Wid Pig	6.41	15.61

DISCUSSION

Both Kishenpur and Katarniaghat wildlife sanctuaries are surrounded by sugarcane fields and rapidly expanding human habitation, thereby bringing tigers into conflict and this has emerged as a major conservation challenge in this region.

SOUTH KHERI FOREST DIVISION

INTRODUCTION

South Kheri forest division is the southern most part of the Kishenpur Wildlife Sanctuaty in the state of Uttar Pradesh. Much like the Kishenpur, this forest division also has patches of sal forest and seasonal streams. The forest division is surrounded by agricultural fields and has very high human usage. Tiger presence was observed only in the forest patch connected with the Kishenpur Wildlife Sanctuary.

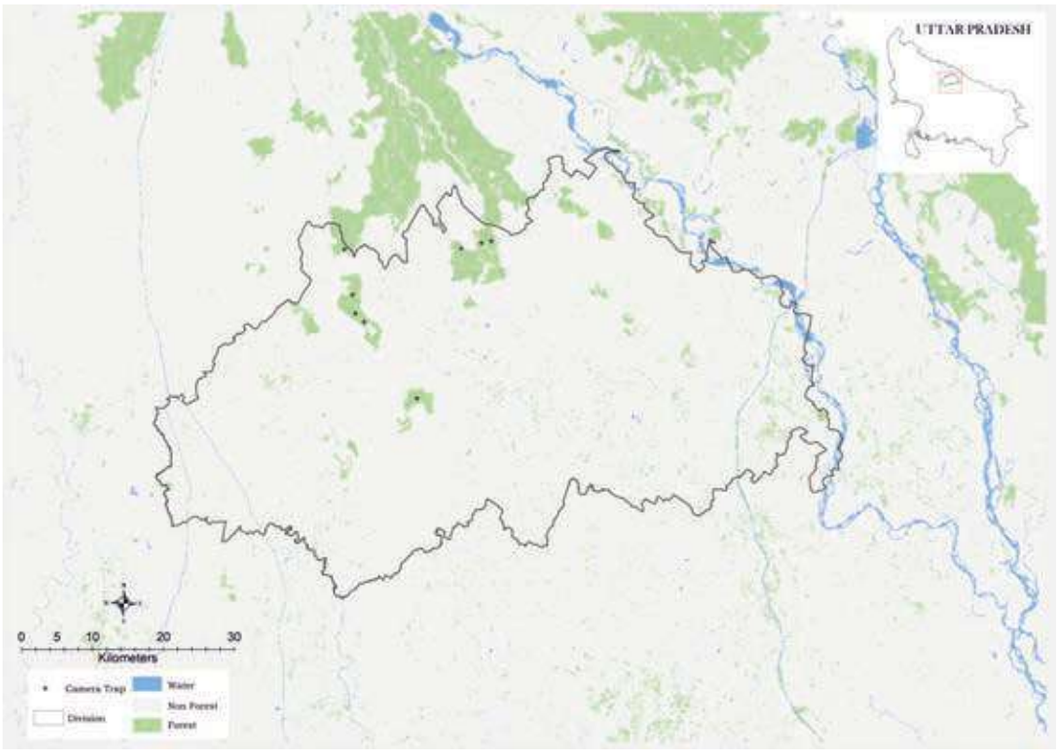


Figure 9.58
Camera trap layout in South Kheri Forest Division, 2018.

RESULTS

Camera Trap Results

Camera trapping was carried out by the forest department, where 4 tiger photos were obtained with an effort of 399 trap-nights (Table 9.22). Two tigers were identified from the four photo-captures.

Table 9.22
Sampling details of camera trapping exercise in South Kheri Forest Division, 2018

Sampling details	Count
Camera points	8
Trap-nights (effort)	399
Number of tiger photos	4
Unique tigers captured	2

SUHELWA WILDLIFE SANCTUARY

INTRODUCTION

Suhelwa was declared a Wildlife Sanctuary in 1988, which spans over Shravasti, Balrampur and Gonda districts of Uttar Pradesh (27°30'1"N to 27°55'42"N and 81°55'36"E to 82°48'33"E). The sanctuary core area comprises of 452 km^2 with a buffer of 220 km^2. The forests and topography is uneven, primarily comprising of rugged mountains and boulder-strewn riverbeds, especially along the northern boundary. This is because there are Shivalik Ranges of Himalaya with dense forest and different water channels in its northern boundary.

The sanctuary is covered with *Shorea robusta, Dalbergia sissoo, Acacia catechu, Tectona grandis, Syzygium cumini, Haldina cordiolia, Terminalia tomentosa* and grass species of *Vetiveria, Themeda, Imperata, Saccharum,* and *Arundo*. It is the habitat of various wild animals. The main mammals of Suhelwa are Bengal tiger (*Panthera tigris*), Indian leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*), fox, small cats, golden Jackal (*Canis aureus*), wild pig (*Sus scrofa*), sambar (*Rusa unicolor*), chital (*Axis axis*), nilgai *(Boselaphus tragocamelus*), barking deer (*Muntiacus vaginalis*), Indian elephant (*Elephas maximus*), grey langur (*Semnopithecus entellus*), Rhesus macaque *(Macaca mulatta*) and various bird species.

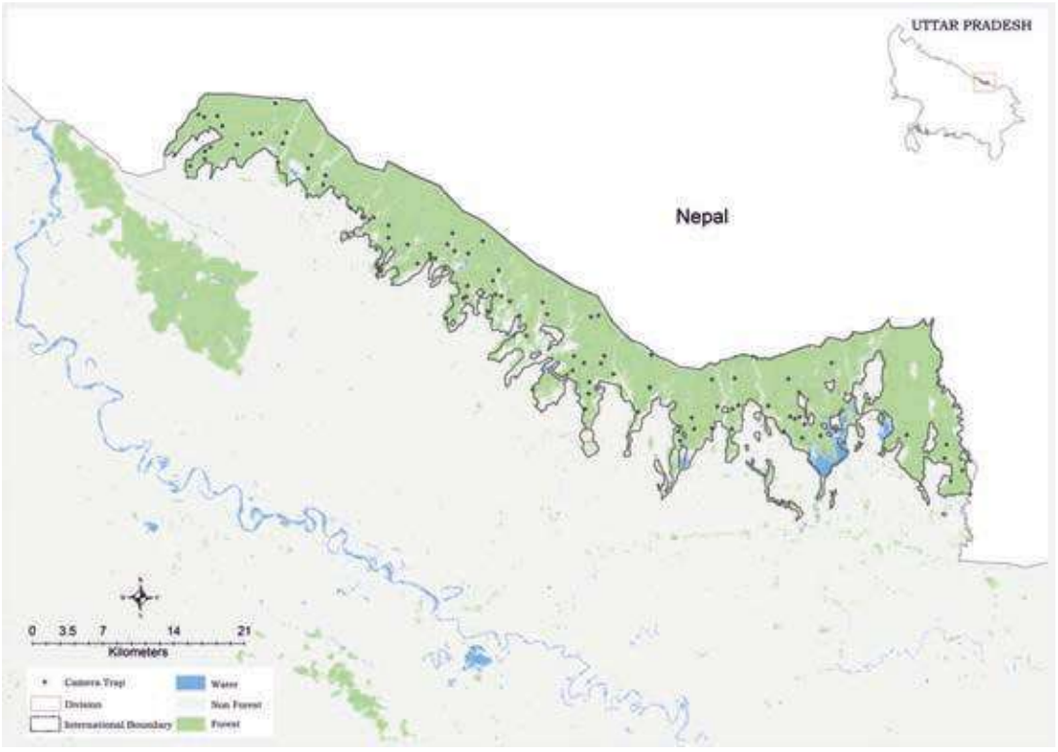


Figure 9.59
Camera trap layout in Suhelwa Wildlife Sanctuary, 2018.

RESULTS

Camera Trap Results

Camera trapping was carried out by the forest department, where no tiger photos were obtained with an effort of 3559 trap-nights (Table 9.23). No tigers were photo-captured during the camera trapping exercise.

Table 9.23

Sampling details and number of tigers photo-captured in Suhelwa Wildlife Sanctuary, 2018

Variables	Estimates
Camera points	91
Trap-nights (effort)	3559
Number of tiger photos	0
Unique tigers captured	0

DISCUSSION

Suhelwa WLS forms a connecting link through the foot hill forests of Nepal as part of the Terai Arc Landscape. The WLS has potential for megaherbivores like buffalo and rhinos along with tigers and dhole. However the WLS requires investments in the form of protection and restoration.

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RANIPUR WILDLIFE SANCTUARY

INTRODUCTION

Ranipur Wildlife Sanctuary, was founded in 1977, it is situated in the Chitrakoot district in Uttar Pradesh. Ranipur covers an area of 230 km^2 and is noted for its diverse wildlife. The flora of the region comprises dense deciduous forest, mostly dominated by sal. Additionally, the forest area of Chauri, Lakhanpur and Rujhawa are known for their grasslands.

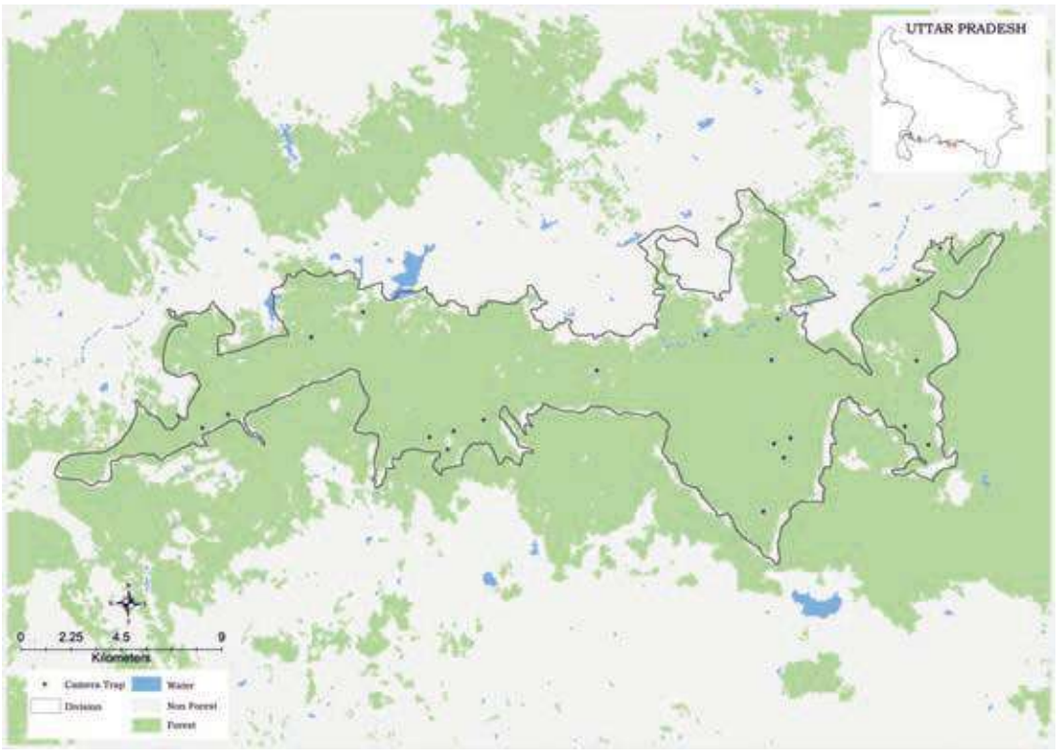

Figure 9.60

Camera trap layout in Ranipur Wildlife Sanctuary, 2018.

RESULTS

Camera trapping was carried out by the forest department, where 12 tiger photo-captures yielded 3 tiger individuals (Table 9.24) of which one was male and two female tigers.

Variables	Estimates
Camera points	21
Trap-nights (effort)	1205
Number of tiger photos	12
Unique tigers captured	3

Table 9.24

Sampling details and number of tigers photo-captured in Ranipur Widlife Sanctuary, 2018-19

DISCUSSION

Ranipur WLS is an extension of forests constituting Panna Tiger Reserve. The area needs to be managed as part of the Panna Landscape.

SOHAGIBARWA WIDLIFE SANCTUARY

Sohagibarwa Wildlife Sanctuary lies in Maharajganj and Kushinagar districts of Uttar Pradesh, between 26° 58' to 27° 25' N and 83° 23' to 84°10' E. The sanctuary is at the border of Uttar Pradesh and Bihar and also shares the international Indo-Nepal border in the North. It also shares its eastern boundary with Valmiki Tiger Reserve in the state of Bihar. Sohagibarwa was declared a Wildlife Sanctuary in June 1987. The total area of the sanctuary is 428.20 km^2 and it is further divided into seven zones - Pakadi, Laxmipur, North Chowk, South Chowk, Madhwalia, Nichlaul and Sheopur.

Sal forest is the dominant forest type with other important tree species being *Terminalia alata, Syzygium cumini, Lagerstroemia parviflora, Semecarpus anacardium, Mallotus phillipensis, Trivea nudiflora, Bombax ceiba, Adina cardifolia, Barringtonia acutangula, Mitragyna parviflora, Schliecher aoleosa, Mallotus phillipensis, Sterospermum suaveotens, Aegle marmelos* and *Streblusa spern. Syzygium cumini*. The forests are interspersed with grasslands and constitute approximately 13% of the area. The major grasslands are located at different parts of the sanctuary. An important feature of the grasslands is their seasonal flooding and water logging. During monsoon most of the grasslands gets covered by very tall grasses such as *Sachrum munjha, Sachrum spontaneum, Sclerostachya fusca, Vetiveria zizimiodes, Typha elephantina* and *Demostachya bipinnata*. Wetlands at Sohagibarwa Wildlife Sanctuary constitute the third major habitat type. They include rivers, streams, wetlands and marshy areas. The sanctuary is has a number of perennial water sources viz, the Gandak, Pyas and Rohin rivers.

Sohagibarwa is home to various wild animals which mainly includes- common leopard (*Panthera pardus*), tiger (*Panthera tigris*), jungle cat (*Felis chaus*), civets, grey langur (*Semnopithecus entellus*), chital (*Axis axis*), hog deer (*Axis porcinus*) and barking deer (*Muntiacus vaginalis*), nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*), porcupine (*Hystrix indica*), many birds species like lesser fish-eagle (*Icthyophaga humillus*) and grey-headed fish-eagle (*Icthyophaga ichthyaetus*) and also supports many aquatic fauna such as the mugger (*Crocodilus palustuis*), rohu (*Labeo rohita*), saur (*Channa marul*), tengur (*Myshesseen chala*), singhi (*Heteropneustes fossifis*) and barari (*Velgo attu*) and turtles.

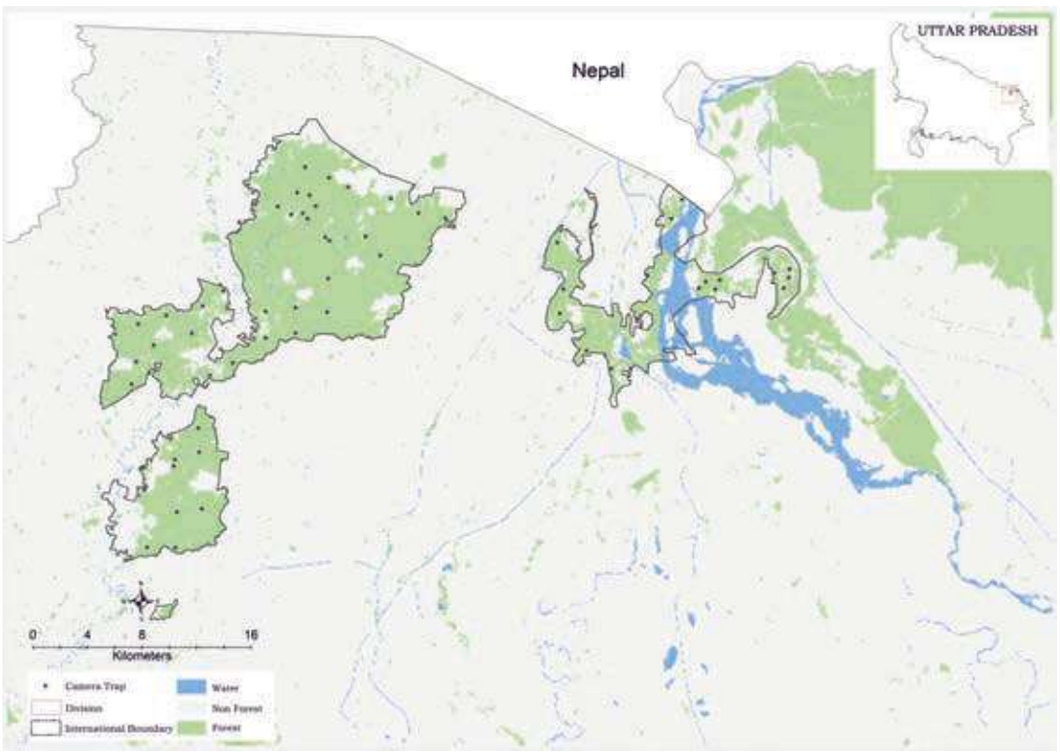

Figure 9.61

Camera trap layout in Sohagibarwa Wildlife Sanctuary, 2018.

RESULTS

Camera Trap Results

Camera trapping was carried out by the forest department, where 10 tiger photo-captures yielded 5 tiger individuals (Table 9.25). Due to insufficient photo-captures, density of tigers for this site was not estimated.

Variables	Estimates
Camera points	59
Trap-nights (effort)	1862
Number of tiger photos	10
Unique tigers captured	5

Table 9.25
Sampling details and number of tigers photo-captured in Sohagibarwa Wildlife Sanctuary, 2018

DISCUSSION

Sohagibarwa was camera trapped by the forest department for the first time and it is an important area for wildlife conservation due to its connectivity to Valmiki Tiger Reserve.

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VALMIKI TIGER RESERVE

Valmiki Tiger Reserve is located at 27° 19' 54" N, 84° 9' 45" E and covers an area of 901 km^2. It is the only tiger reserve in the state of Bihar. Valmiki Tiger Reserve is located in the extreme north-eastern corner along the international border with Nepal in western Champaran district. In the west the reserve is bounded by the Gandak (Narayani in Nepal) River. It is contiguous with Nepal's Chitwan National Park to the north, sharing a forested boundary of approximately 100 km and is also tenuously connected with Sohagibarwa Wildlife Sanctuary in Uttar Pradesh.

The topography of Valmiki Tiger Reserve is characterized by bouldary hills and doon (valleys) drained by numerous rivers and streams which gradually merge with flat alluvial plains in the south. These rivers and streams are the major sources of water for wildlife. Valmiki represents one of the last patches of forests having a unique combination of the terai-bhabar vegetation, which harbour rich fauna of several endemic and globally endangered species such as tiger and greater one-horned rhinoceros. The Asian elephant infrequently migrates from Chitwan National Park, Nepal. The forest of Valmiki Tiger Reserve also harbours other felids, canids, ursids, viverrids such as leopard (*Panthera pardus*), fishing cat (*Prionailurus viverrinus*), jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*), Indian fox (*Vulpes bengalensis*), dhole *(Cuon alpinus*), sloth bear (*Melursus ursinus*), and large Indian civet (*Viverra zibetha*). The important prey species of the reserve include chital (*Axis axis*), sambar (*Rusa unicolor*), hog deer (*Axis porcinus*), nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*), and gaur (*Bos gaurus*).

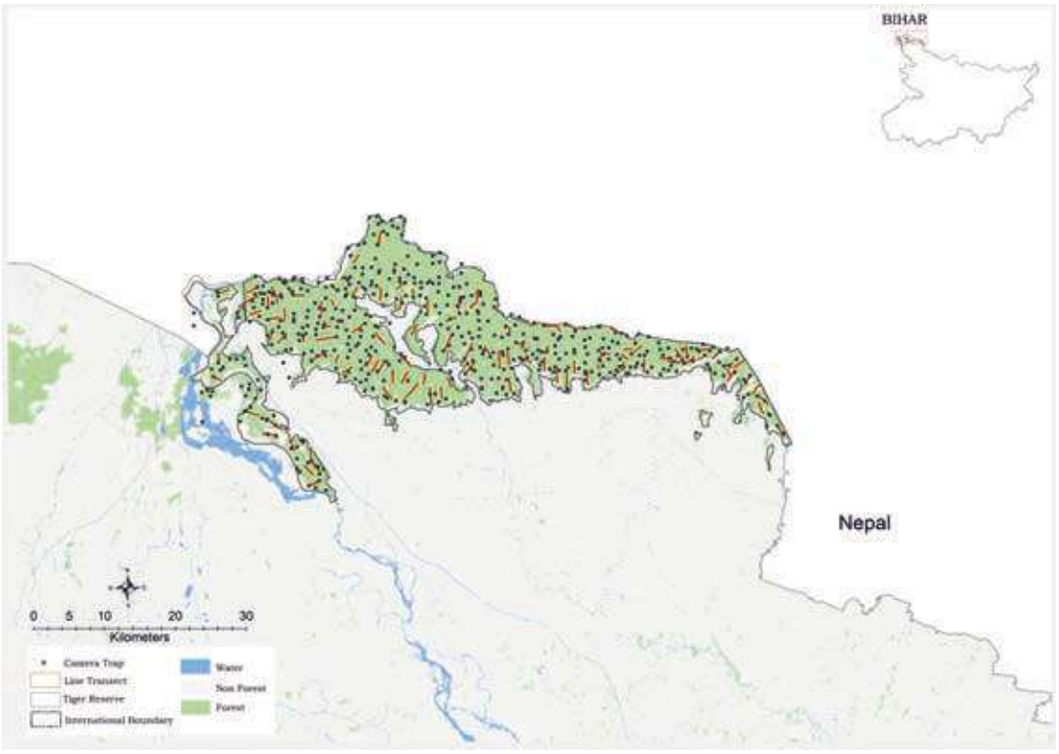


Figure 9.62
Camera trap and line transects layout in Valmiki Tiger Reserve, 2018.

RESULTS

Tiger Density Estimates

A total of 1161 tiger images were obtained from which 33 tigers were identified with a density of 2.5 (SE 0.43) tigers per 100 km^2. Tiger population using the tiger reserve was 33 (SE 1), while the number of tigers present in the tiger reserve was 32 (0.06). The detection corrected tiger male to female sex ratio was 0.38:0.62 (Table 9.26). A total of 6 cubs were photo-captured.

Table 9.26

Sampling details and tiger density parameter estimates using spatially explicit capture mark-recapture analysis in a likelihood framework for Valmiki Tiger Reserve, 2018

Variables	Estimates
Model space (km^2)	1314
Camera Points	492
Trap Nights (effort)	18170
Unique tigers captured	33
Model	P_{mix}(sex), g_0(sex),σ(sex)
$\hat{D}$ SECR (per 100 km^2)	2.5 (0.43)
σ Female (SE) km	3.0 (0.11)
σ Male (SE) km	6.0 (0.24)
g_0 Female (SE)	0.01 (0.001)
g_0 Male (SE)	0.008 (0.0007)
Pmix Female (SE)	0.62 (0.09)
Pmix Male (SE)	0.38 (0.09)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Valmiki Tiger Reserve has shown increase in tiger number over the previous monitoring cycles. It shares tiger with Chitwan National Park in Nepal and Sohagibarwa WLS in Uttar Pradesh.

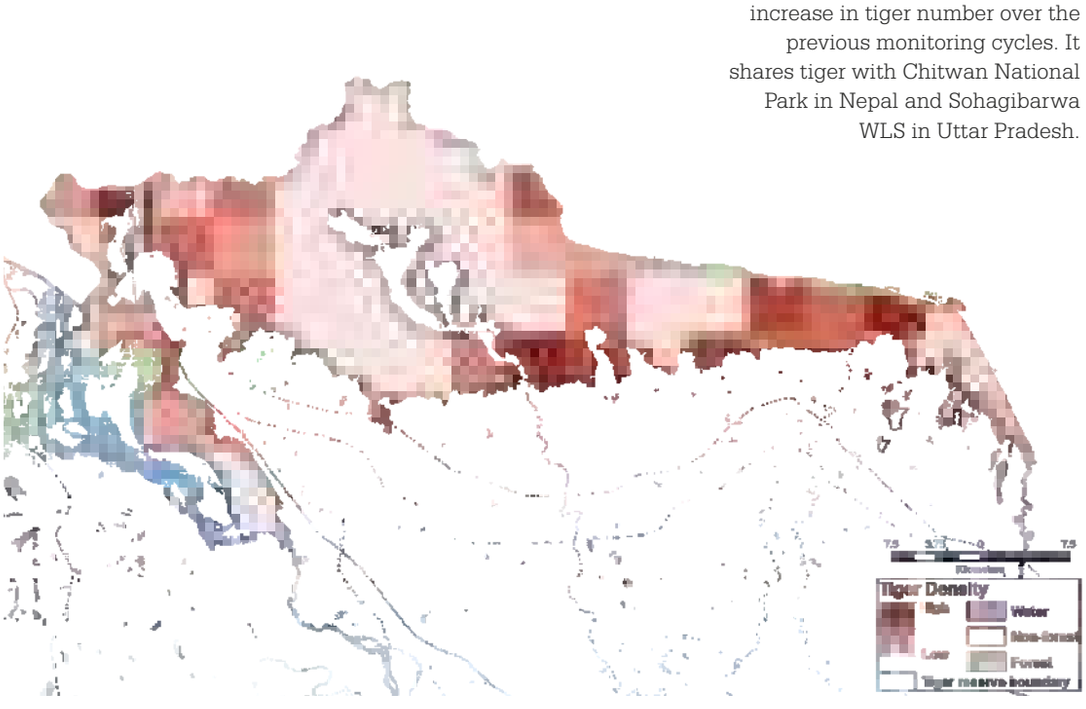


Figure 9.63

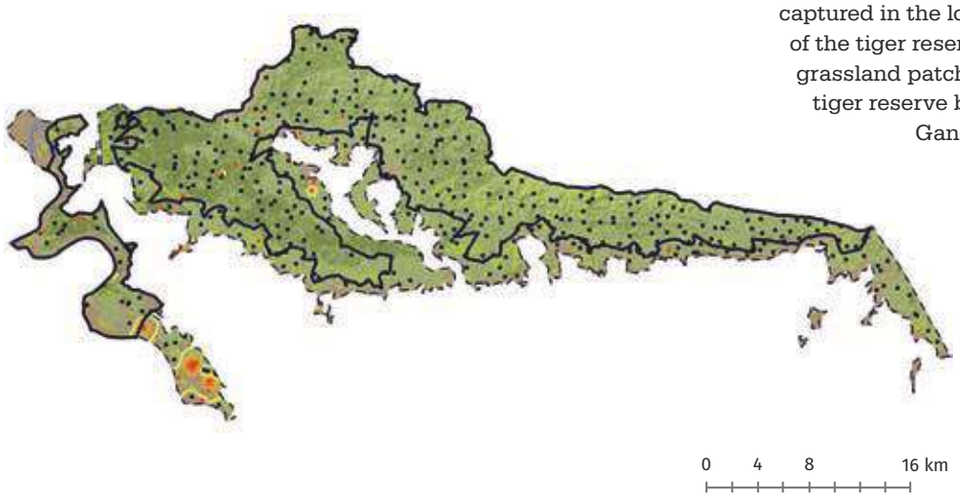
Camera trap and line transects layout in Valmiki Tiger Reserve, 2018.

Distribution of Major Mammalian Species Found in Valmiki Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates.

Figure 9.64

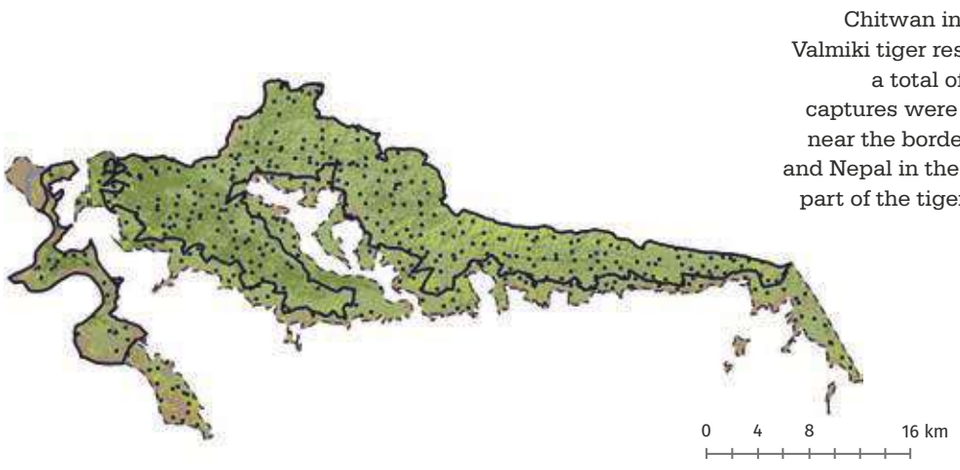
Distribution, and relative spatial abundance of hog deer in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.



Hog deer was photo-captured in the lower part of the tiger reserve in the grassland patches of the tiger reserve bordering Gandak river.

Figure 9.65

Distribution, and relative spatial abundance of greater one horned rhinoceros in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.



Rhinoceros move from Chitwan in Nepal to Valmiki tiger reserve and a total of 4 photo-captures were obtained near the border of India and Nepal in the northern part of the tiger reserve.

Valmiki is the only protected area where gaur is found in the Shivaliks and Gangetic plains landscape. Its photo-captures were concentrated in the flat terrain sal forests of the tiger reserve.

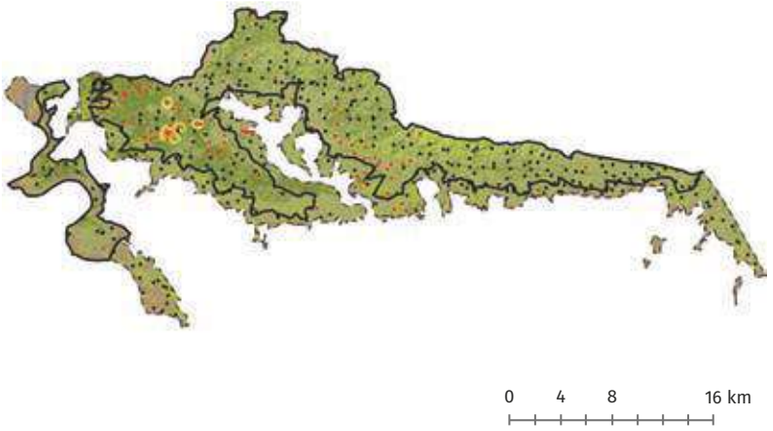


Figure 9.66

Distribution, and relative spatial abundance of gaur in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Water buffalo is only recorded in Valmiki tiger reserve in the entire Shivaliks and Gangetic plains landscape. Most of its photo-captures were in the southern boundary of the tiger reserve.

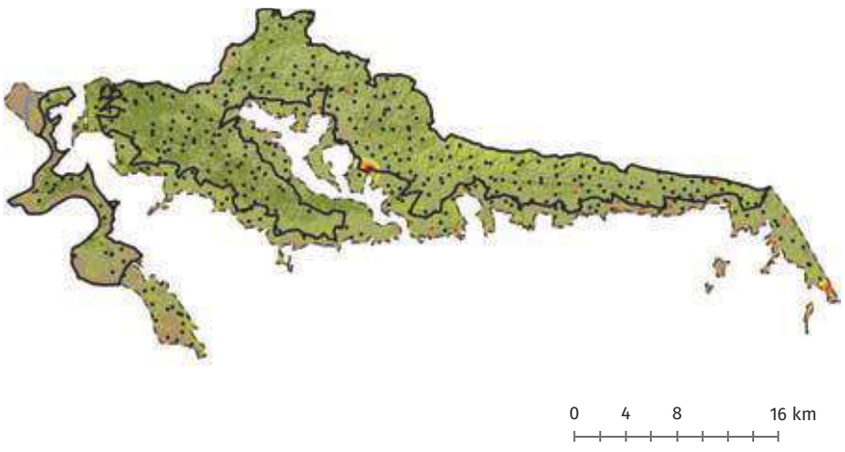


Figure 9.67

Distribution, and relative spatial abundance of water buffalo in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Leopards were photo-captured throughout the tiger reserve. Higher concentration of photo-captures were obtained from the more elevated regions of the tiger reserve.

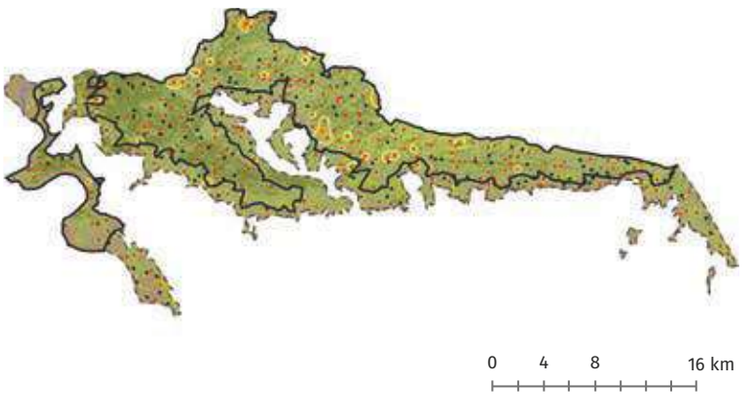


Figure 9.68

Distribution, and relative spatial abundance of leopard in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

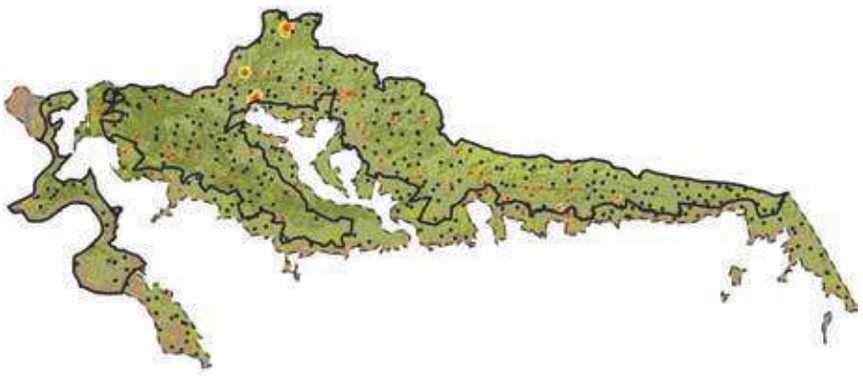


Figure 9.69

Distribution, and relative spatial abundance of dhole in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Valmiki tiger reserve is the only protected area from which wild dog is recorded in the Shivalik hills and Gangetic plains landscape. This high conservation priority species was photo-captured throughout the tiger reserve with higher concentration of photo-captures in the northern hilly terrain of the tiger reserve.

0 4 8 16 km

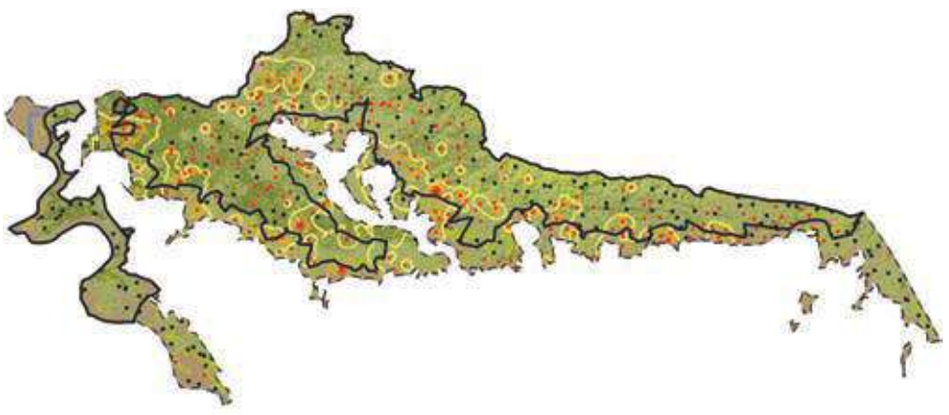


Figure 9.70

Distribution, and relative spatial abundance of sloth bear in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Sloth bear was distributed throughout the tiger reserve with more concentration of photo-captures in the flatter terrain of the tiger reserve.

0 4 8 16 km

Figure 9.71

Distribution, and relative spatial abundance of golden jackal in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Jackal was distributed mostly near the tiger reserve boundary in proximity to human settlements and there were no photo-captures from the core area of the tiger reserve.

0 4 8 16 km

Jungle cat was distributed in pockets within the tiger reserve, with higher concentration of photo-captures near open forest and water bodies.

Figure 9.72

Distribution, and relative spatial abundance of jungle cat in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Leopard cat was distributed throughout the tiger reserve, with higher concentration of photo-captures in sal and mixed forests.

Figure 9.73

Distribution, and relative spatial abundance of leopard cat in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Fishing cat had clumped distribution in the tiger reserve, with most photo-captures restricted near the Gandak river on the south west edge of the park.

Figure 9.74

Distribution, and relative spatial abundance of fishing cat in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

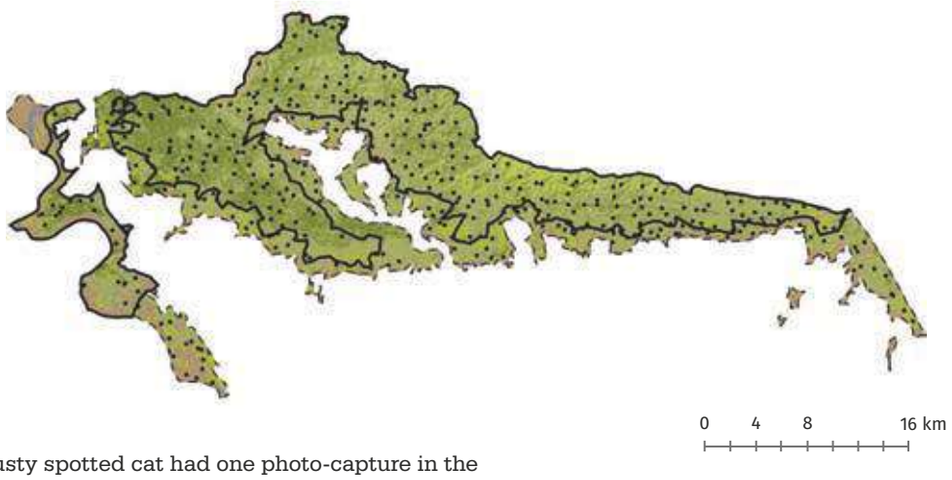


Figure 9.75

Distribution, and relative spatial abundance of rusty spotted cat in Valmiki Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Rusty spotted cat had one photo-capture in the tiger reserve in the Churia hills of Nepal boundary.

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Relative Abundance of all Photocaptured Species in Valmiki Tiger Reserve

A total of 35 species of ungulates, carnivores, omnivores and galliformes were photo-captured in the tiger reserve. Sambar and chital were the most commonly photo-captured species (Table 9.27). Rusty spotted cat was the rarest species photo-captured followed by pangolin.

Table 9.27

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Valmiki Tiger Reserve, 2018

Species	No. of photos per 100 trap nights	No. of days to get one photo
Barking Deer	7.68	13.03
Black naped hare	3.08	32.50
Chital	10.89	9.19
Domestic cat	0.04	2271.25
Domestic dog	1.95	51.33
Fishing cat	0.26	386.60
Four horned antelope	0.05	2018.89
Gaur	3.45	29.03
Golden Jackal	0.42	235.97
Himalyan Thar	0.07	1397.69
Hog Deer	0.42	239.08
Indian fox	0.08	1297.86
Indian Pangolin	0.01	9085.00
Indian Rhinoceros	0.02	4542.50
Jungle cat	0.74	135.60
Khalij	0.44	227.13
Langur	2.57	38.91
Large Indian civet	2.36	42.45
Leopard	5.26	19.03
Leopard cat	0.95	105.64
Livestock	17.86	5.60
Mongoose	2.01	49.64
Monitor lizard	0.02	4542.50
Nilgai	3.41	29.35
Palm civet	3.64	27.45
Peafowl	7.98	12.53
Porcupine	4.06	24.65
Red Jungle Fowl	2.26	44.21
Rhesus macaque	4.36	22.94
Rusty spotted cat	0.01	18170.00
Sambar	13.81	7.24
Sloth Bear	5.45	18.35
Small Indian civet	0.84	118.76
Striped Hyaena	0.16	626.55
Tiger	3.98	25.13
Wid Pig	5.66	17.66
Wild Dog	0.85	117.99
Yellow throated marten	0.14	726.80

DISCUSSION

Valmiki Tiger Reserve population is connected to Chitwan National Park in Nepal and tigers move between these two trans-boundary protected areas. Conservation investments in this park since 2008 has resulted in dramatic increase in the tiger population and the overall health of this ecosystem, where it supports a good population of wild dogs (the only place in Indian Terai to harbor this species), gaur and rhinoceros.

RANTHAMBHORE TIGER RESERVE (Division I)

INTRODUCTION

Ranthambhore Tiger Reserve (Division I, hereafter Ranthambhore, 26°22' N to 25°41' N and 77°14' to 76°16' E) is situated at the junction of two ancient mountain ranges, the Aravalli and the Vindhya, and bounded in the north by river Banas and river Chambal in the east. Ranthambhore is part of the western block of the central Indian landscape that includes Sariska Tiger Reserve, Kuno-Palpur Wildlife Sanctuary and Madhav National Park, Ramgarh Visdhari Wildlife Sanctuary and Mukundara Hills Tiger Reserve (Figure 10.1). The core area of Ranthambhore Tiger Reserve is composed of Ranthambhore National Park (392 km^2), Sawai Mansingh Sanctuary (290 km^2) while Kailadevi Wildlife Sanctuary (630 km^2) has been designated as the buffer zone of Ranthambhore. Within this western block, tigers were present only in Ranthambhore National Park in 2002-2008. Later on, tigers from this population were reintroduced in Sariska Tiger Reserve and Mukundara Hills Tiger Reserve. Tigers have also dispersed from Ranthambhore to other neighbouring forested areas such as Kuno-Palpur Wildlife Sanctuary to the east and forests of Kota and Bundi districts to the south. The terrain of the reserve varies from highly undulating (Aravalli hill range) to flat valleys, with the dominant terrain being hills with steep slopes.

The forest is mainly an edaphic climax and belongs to the subgroup 5B-northern tropical dry deciduous forests and subgroup 6B-DS1-*Ziziphus* shrub (Champion and Seth 1968). The area is representative of dry deciduous *Anogeissus pendula* forests sub type in association with *Acacia, Butea, Capparis, Zizyphus* and *Prosopis* species. The carnivore guild consists of seven felid species tiger (*Panthera tigris*), leopard (*Panthera pardus*), caracal (*Caracal caracal*), jungle cat (*Felis chaus*), desert cat (*Felis silvestris*), fishing cat (*Prionailurus viverrinus*) (Sadhu and Reddy 2013), and rusty spotted cat (*Prionailurus rubiginosus*), and other carnivores such as golden jackal (*Canis aureus*), striped hyaena (*Hyena hyena*), sloth bear (*Melursus ursinus*), ratel (*Mellivera capensis*), Bengal fox (*Vulpes bengalensis*), ruddy mongoose (*Herpestes smithii*), Indian grey mongoose (*Herpestes edwarsi*), small Indian mongoose (*Herpestes auropunctatus*), common palm civet (*Paradoxurus hermaphroditus*) and small Indian civet (*Viverricula indica*). Herbivore species include chital (*Axis axis*), sambar (*Rusa unicolor*), nilgai (*Boselephus tragocamelus*), wild pig (*Sus scrofa*), chinkara (*Gazella bennetti*).

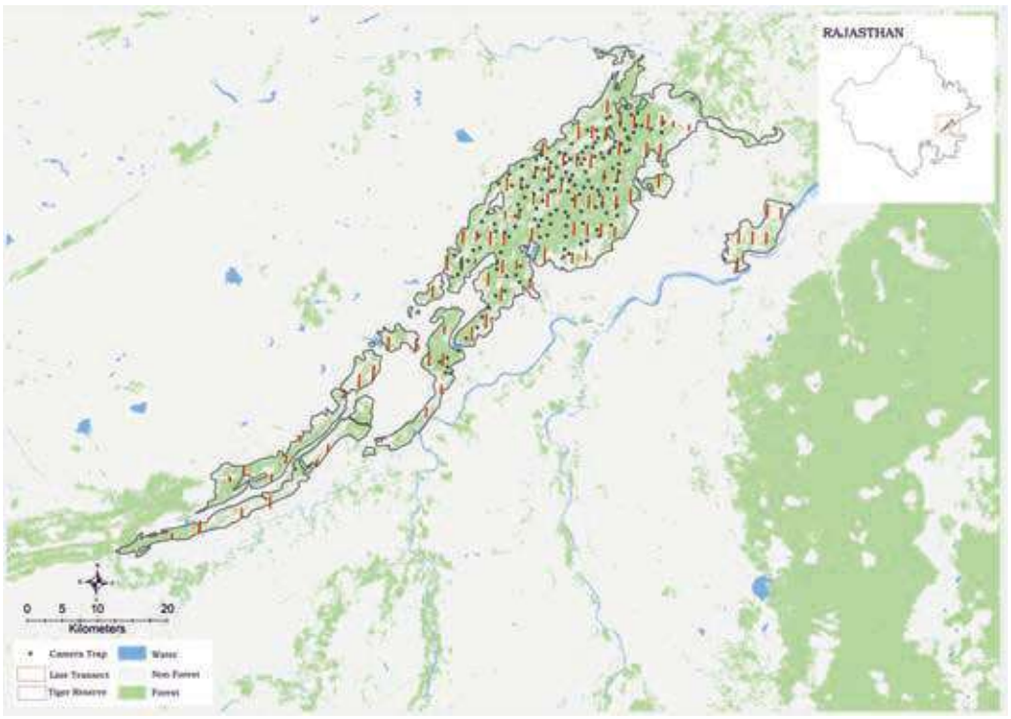

Figure 10.1
Camera trap and line transects layout in Ranthambore Tiger Reserve, 2018.

RESULTS

Tiger Density Estimates

During the camera trapping session a total of 880 tiger detections were obtained from which 53 individual tigers were identified. Tiger density was estimated at 9.6 (SE 1.3) tiger per 100 km^2 (Table 10.1). The detection corrected sex ratio was male biased (Table 10.1).

Variables	Estimates
Model space (km^2)	560
Camera points	150
Trap nights (effort)	5341
Unique tigers captured	53
Model	g_0(sex) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	9.6 (1.33)
σ Female (SE) km	1.48 (0.04)
σ Male (SE) km	2.0 (0.05)
g_0 Female (SE)	0.09 (0.006)
g_0 Male (SE)	0.08 (0.005)
Pmix Female (SE)	0.47 (0.07)
Pmix Male (SE)	0.53 (0.07)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Table 10.1

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Ranthambhore Tiger Reserve (Division - I), 2018-19

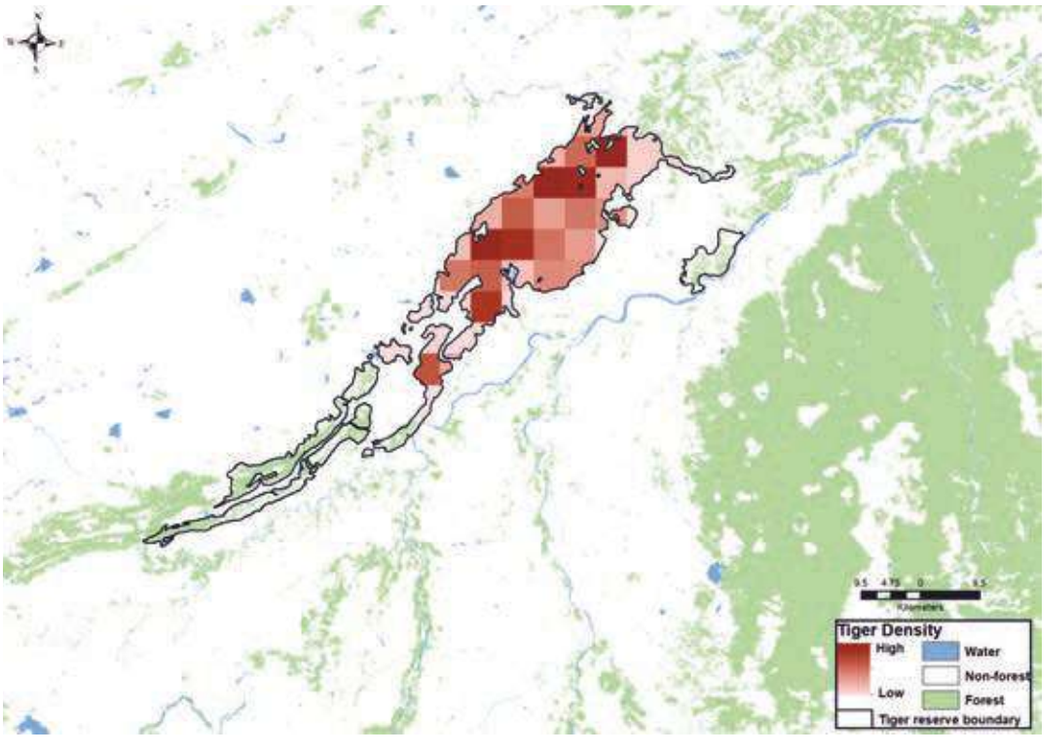

Figure 10.2

Spatial density of tigers in Ranthambhore tiger reserve (Division I) 2018-19.

Ranthambhore harbours one of the highest tiger densities in the central Indian landscape. Tigers were more or less evenly distributed within the Ranthambhore National Park. Some high density pockets were seen along the central ridge line and lakes ares of the National Park.

Prey Density Estimates

A total of 198 transects were walked with an effort of 353 km. Chital were found to be the most abundant ungulate with a density of 21.61(SE 3.34) animals/km^2 followed by sambar (Table 10.2).

Table 10.2

Model statistics and parameter estimates of line transect based distance sampling for prey species in Ranthambhore Tiger Reserve (Division - I), 2018-19.

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group) density/ km^2 (SE	Individual density/ km^2 (SE)
Chital	43.65 (3.3)	97	6.85 (0.45)	0.37 (0.02)	0.27 (0.03)	3.15 (0.44)	21.62 (3.34)
Sambar	42.10 (2.7)	148	2.79 (0.17)	0.26 (0.01)	0.42 (0.04)	4.99 (0.63)	13.95 (1.97)
Nilgai	39.37 (4.1)	102	2.54 (0.21)	0.27 (0.02)	0.29 (0.03)	3.67 (0.55)	9.37 (1.63)
Wild pig		14			0.04 (0.01)		
Chinkara	34.06 (6.6)	21	2.33 (0.24)	0.61 (0.12)	0.06 (0.01)	0.87 (0.25)	2.04 (0.63)

Distribution of Major Mammalian Species Found in Ranthambhore Tiger Reserve (Division I)

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates.

Caracal was photocaptured only in one camera trap from out of 150 camera traps locations for the entire session in Ranthambhore. The location is situated in the north western part of Ranthambhore, this area is dominated with sparse vegetation with thorny scrub.

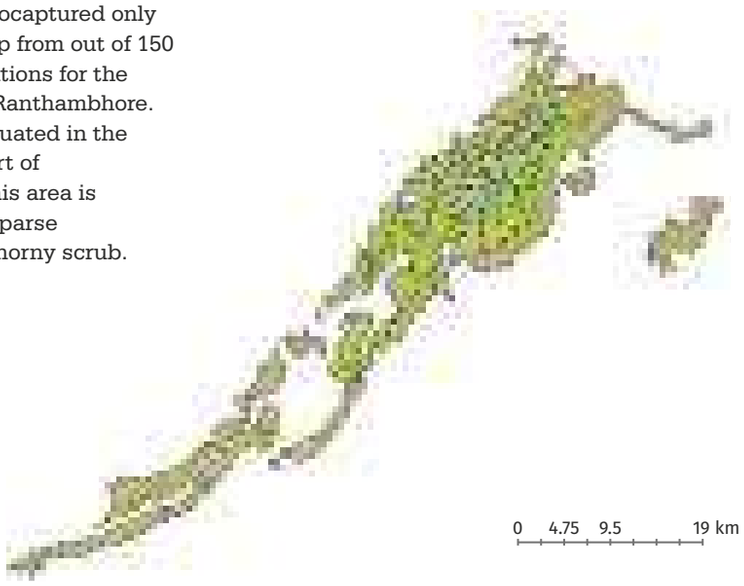

Figure 10.3

Distribution and relative spatial abundance of caracal in Ranthambhore Tiger Reserve (Division I). Red dot represent photo-capture in camera traps (all dots).

Desert cat was photocaptured mostly in the peripheral areas of Ranthambhore, especially near Banas river (in the north). The capture locations were in areas dominated by open forest intermixed with scrublands and close to human settlements.

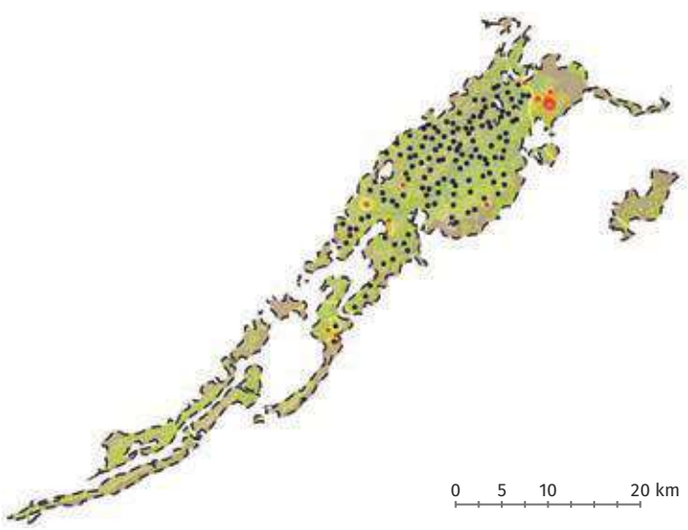

Figure 10.4
Distribution and relative spatial abundance of desert cat in Ranthambhore Tiger Reserve (Divison I). Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Golden jackal was photocaptured mostly in the peripheral areas of Ranthambhore. The capture locations were dominated with open forests on the plateau top and with scanty vegetation. They were often photocaptured in pairs, with the occasional capture of three individuals together.

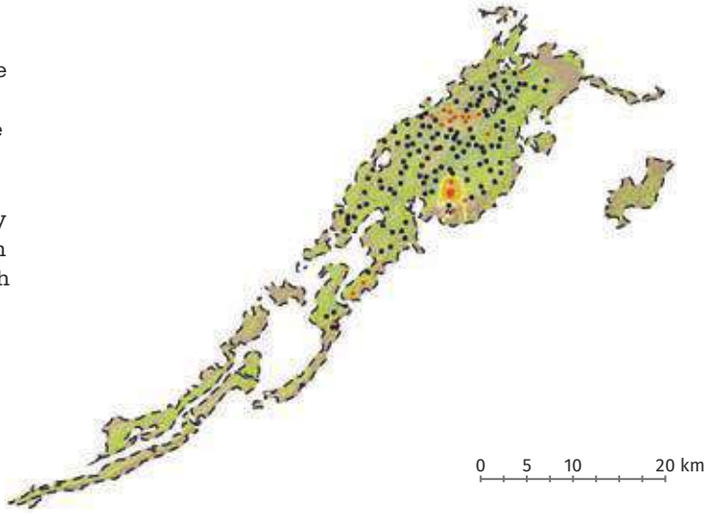

Figure 10.5
Distribution and relative spatial abundance of golden jackal in Ranthambhore Tiger Reserve (Division I). Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was photocaptured throughout Ranthambhore with higher captures on the peripheral region of the park. The capture locations were mostly dominated with open forests on the plateau top.

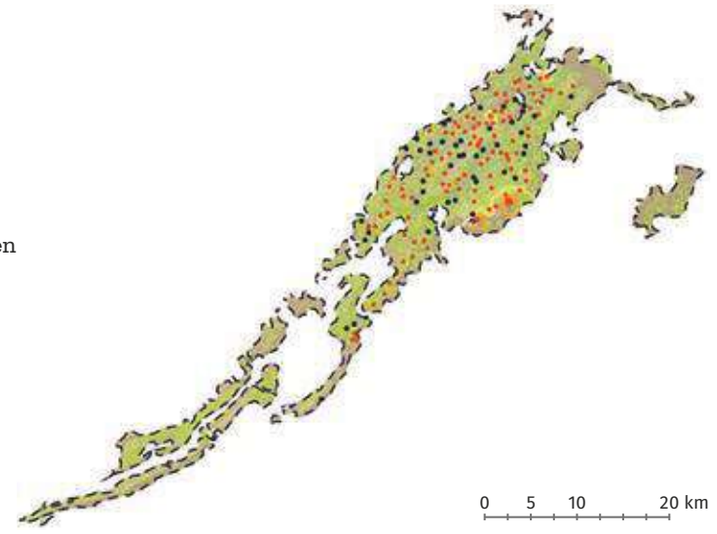

Figure 10.6
Distribution and relative spatial abundance of jungle cat in Ranthambhore Tiger Reserve (Division I). Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

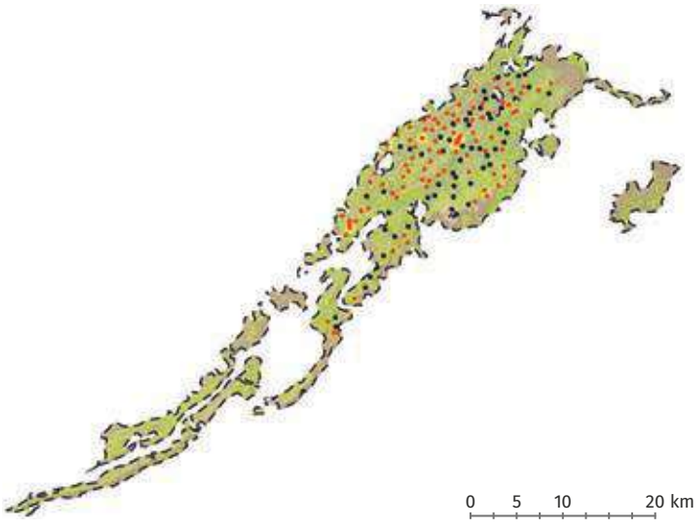

Figure 10.7
Distribution and relative spatial abundance of leopard in Ranthambhore Tiger Reserve (Division I). Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was photocaptured throughout Ranthambhore with higher capture rates obtained from the centre of the park.

Figure 10.8
Distribution and relative spatial abundance of striped hyena in Ranthambhore Tiger Reserve (Division I). Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Striped hyena was photocaptured throughout Ranthambhore, photocapture intensity was higher near the periphery (closer to human habitation).

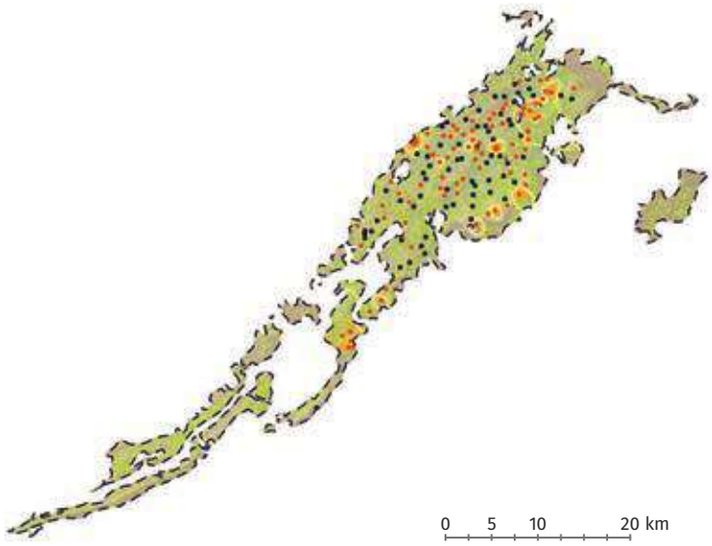

Figure 10.9
Distribution and relative spatial abundance of sloth bear in Ranthambhore Tiger Reserve (Division I). Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear was photocaptured throughout Ranthambhore with higher capture rates in the northern rugged terrain of the park dominated by woodlands.

Rusty spotted cat was photocaptured at very few locations, mostly on the periphery of the Park. This species is the smallest cat of the world and semi-arboreal in nature, hence trail camera photocaptures may not be an ideal for estimating their abundance.

Figure 10.10

Distribution and relative spatial abundance of rusty spotted cat in Ranthambhore Tiger Reserve (Division I). Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Relative Abundance of all Photocaptured Species in Ranthambhore Tiger Reserve (Division I)

A total of 27 species of carnivores, herbivores, and others species (omnivores, galliformes, domestic animals, etc.) were photocaptured, where chital and sambar were the most common ungulates, and tiger and striped hyena were the most common carnivore species. Caracal was captured only once during the camera trapping session (Table 10.3).

Table 10.3

Details of all photocaptured species and their relative abundance index (RAI) in Ranthambhore Tiger Reserve (Division I) 2018-19.

Species name	No. of photos/ 100 trap nights	No. of trap nights to get one photograph
Caracal	0.02	5341
Chinkara	4.25	24
Chital	39.92	3
Common palm civet	4.42	23
Desert cat	0.49	205
Domestic dogs	0.41	243
Golden jackal	1.07	94
Hanuman langur	5.64	18
Honey badger	5.67	18
Indian crested porcupine	19.92	5
Indian fox	0.21	486
Indian grey mongoose	0.84	119
Indian hare	43.59	2
Indian peafowl	57.78	2
Jungle cat	7.26	14
Leopard	4.38	23
Livestock	9.79	10
Nilgai	18.82	5
Painted spur fowl	0.36	281
Ruddy mongoose	3.41	29
Rusty spotted cat	0.11	890
Sambar	29.43	3
Sloth bear	2.98	34
Small Indian civet	1.89	53
Striped hyena	13.03	8
Tiger	18.16	6
Wild pig	6.14	16

DISCUSSION

The tiger abundance and density in Ranthambhore has shown a steady increase compared to previous estimates (Jhala et al. 2015). However, Ranthambhore is an island in an ocean of human-dominated landscape, which reduces the dispersal opportunity for large carnivores in the landscape and make the population of large carnivores vulnerable to environmental and demographic stochasticity. Protecting and restoring the potential dispersal routes to facilitate large carnivore dispersal is required for long-term conservation.

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KAILADEVI WILDLIFE SANCTUARY

INTRODUCTION

Kailadevi Wildlife Sanctuary (26°21' - 26°2' N and 77°13' - 76°37' E) is a part of Ranthambhore Tiger Reserve (Division II, 674 km^2), situated in the northern part of the reserve. The sanctuary is located in the Karauli district of Rajasthan and is made up of the erstwhile Karauli and Sapotra blocks. The Kailadevi Wildlife Sanctuary is separated from the Ranthambhore National Park by the Sawanta-Hadoti road and several villages in this area. These villages along with the road and the sand mining activities on river Banas are a constant threat to the only existing corridor between Keladevi and Ranthambhore National Park. The terrain is characterised by plateau top mountains interspersed with narrow river gorges (locally referred to as khos). The khos are the preferred habitats of wildlife due to their higher moisture retention and comparatively lower temperature.

The vegetation type of Kailadevi is dry deciduous forests with thorny scrubs (dominated with *Anogiesus pendula* and *Zizyphus scrubland*). It is noteworthy to mention that tigers had been locally extinct from Kailadevi, however it was never publicized as much as the extinction incidents from the tiger reserves of Sariska and Panna. Since the last 4-5 years, dispersing individuals from Ranthambhore have started colonizing Kailadevi. Apart from tigers (*Panthera tigris*), the carnivore fauna reported from this area includes leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*), Indian wolves (*Canis lupus*), Caracal (*Caracal caracal*), golden jackal (*Canis aureus*), ratel (*Mellivera capensis*), jungle cat (*Felis chaus*), Indian fox (*Vulpes bengalensis*), common palm civet (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*), ruddy mongoose (*Herpestes smithii*), and Indian grey mongoose (*Herpestes edwarsi*). Herbivore species present here are- nilgai (*Boselaphus tragocamelus*), sambar, (*Rusa unicolor*), chital (*Axis axis*), chinkara (*Gazella bennetti*), wild pig (*Sus scrofa*). High level of human disturbance is the primary cause of the extremely low density of wildlife species. Flattening of ravines in the rivers Banas and Chambal and their tributaries for expanding agriculture has also led to loss of habitat connectivity in the landscape.

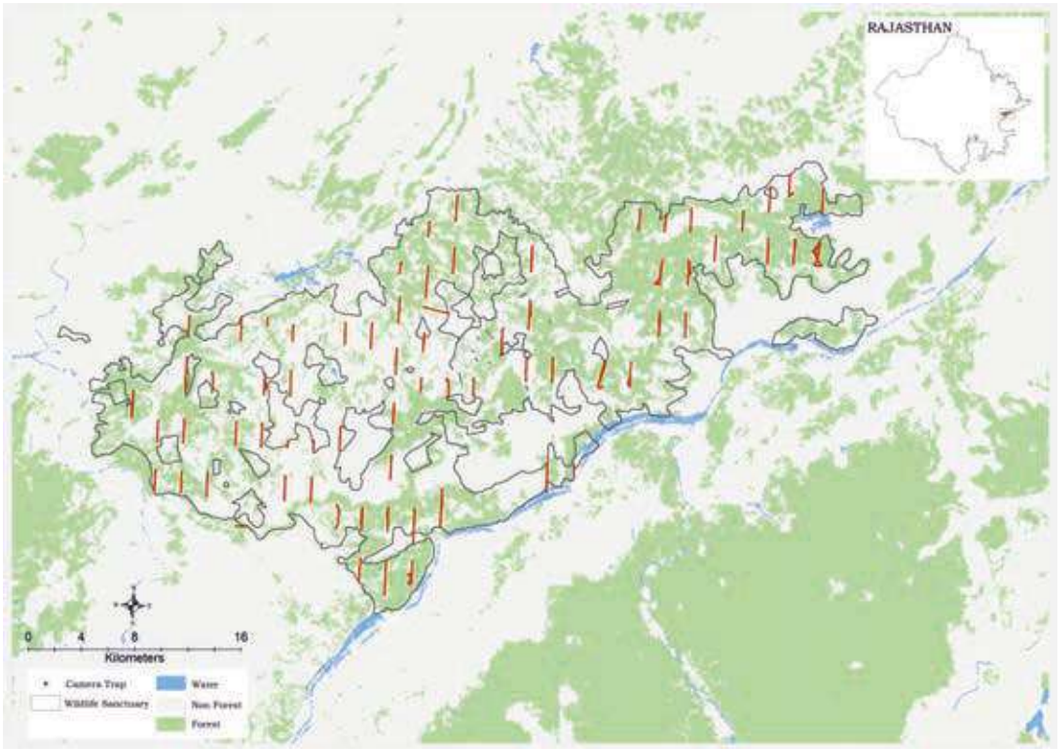


Figure 10.11

Line transect layout in Kailadevi (Ranthambhore Tiger Reserve Division II).

RESULTS

Prey Density Estimates

A total of 270 transect were walked in Kailadevi Wildlife Sanctuary with a total effort of 462 km. Since sightings of wild ungulates were low, distance analysis could not be done; hence encounter rates are mentioned here (Table 10.4).

Table 10.4

Encounter rates obtained from line transect based distance sampling for prey species in Kailadevi WLS, Ranthambhore Tiger Reserve (Division - II), 2018-19.

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital		2			0.004 (0.001)		
Sambar		2			0.004 (0.001)		
Nilgai	50.49 (3.56)	191	3.25 (0.16)	0.30 (0.02)	0.41 (0.07)	4.09 (0.36)	13.33 (1.38)
Wild pig	28.03 (4.04)	30	3.16 (0.42)	0.46 (0.06)	0.06 (0.01)	1.15 (0.26)	3.66 (0.97)

DISCUSSION

Conservation efforts need to be in place for the restoration of Kailadevi landscape through incentivized voluntary village relocation which will create inviolate space for wildlife, and recovery of wild prey populations. Revival of Kailadevi as a good tiger habitat would have the added advantage of providing connectivity to the landscape of Kuno-Sheopur-Madhav which together with Ranthambore Tiger Reserve can be managed as a metapopulation to ensure long term survival of tigers in this semi-arid landscape. Rigorous patrolling, monitoring, law enforcement and involvement of local stake holders for alternative livelihoods is the need of the hour.

SARISKA TIGER RESERVE

INTRODUCTION

Sariska Tiger Reserve (hereafter Sariska, 27° 15' N to 27° 24' N and 76°20' E to 76°32' E) is infamous for losing its tiger in the beginning of this century (Narain et al. 2005). Situated in the Aravalli hills in Alwar district of Rajasthan, the reserve spreads across 881 km^2 and is dotted with human settlements. The reserve has 26 villages in the core zone and 246 villages in the buffer zone, populated by predominantly the 'gujjar' tribe with a high dependency on the reserve for livestock grazing. These pastoral communities live inside the reserve and exert enormous pressure on the biodiversity. Two state highways, viz., Sariska-Kalighati-Tela and Alwar-Thanagazhi-Jaipur also traverse the reserve covering a length of 44 kilometres within the reserve precincts. A number of small settlements have emerged along the highway, many of which are encroachments. The presence of a religious site within the park adds further challenges to the park management. After the local extinction of tigers in 2004, three tigers (two females and one male) were reintroduced from Ranthambhore Tiger Reserve to Sariska with the aim of re-establishing the population. After additional supplementations and breeding of reintroduced tigers, currently 11 adult tigers are resident in Sariska. Paucity of undisturbed areas and increasing anthropogenic pressure have likely delayed reproduction and rapid growth of the tiger population in the reserve.

The vegetation class comprises of northern tropical dry deciduous forests and northern tropical thorn forest (Champion and Seth 1968). The major vegetation types are *Anogeissus* dominated forest, *Boswellia* dominated forest, *Acacia* mixed forest, *Zizyphus* mixed forest, *Butea* mixed forest, scrubland and forest and nallah. Due to prolonged exposure to human disturbance, the native vegetation has been degraded and wide spread weed invasion has occurred in Sariska. Apart from tiger (*Panthera tigris*), other carnivores present are leopard (*Panthera pardus*), striped hyena (*Hyena hyena*), honey badger (*Mellivera capensis*), golden jackal (*Canis aureus*), jungle cat (*Felis chaus*), desert cat (*Felis silvestris*), small Indian civet (*Viverricula indica*), common palm civet (*Paradoxurus hermaphroditus*), ruddy mongoose (*Herpestes smithii*), and Indian grey mongoose (*Herpestes edwarsi*). The wild ungulates found in Sariska are chital (*Axis axis*), sambar (*Rusa unicolor*), nilgai (*Boselephus tragocamelus*) and wild pig (*Sus scrofa*). In the current camera trapping survey, desert fox (*Vulpes vulpes*), black francolin (*Francolinus francolinus*) and four-horned antelope (*Tetracerus quadricornis*) were photocaptured inside the reserve after many years.

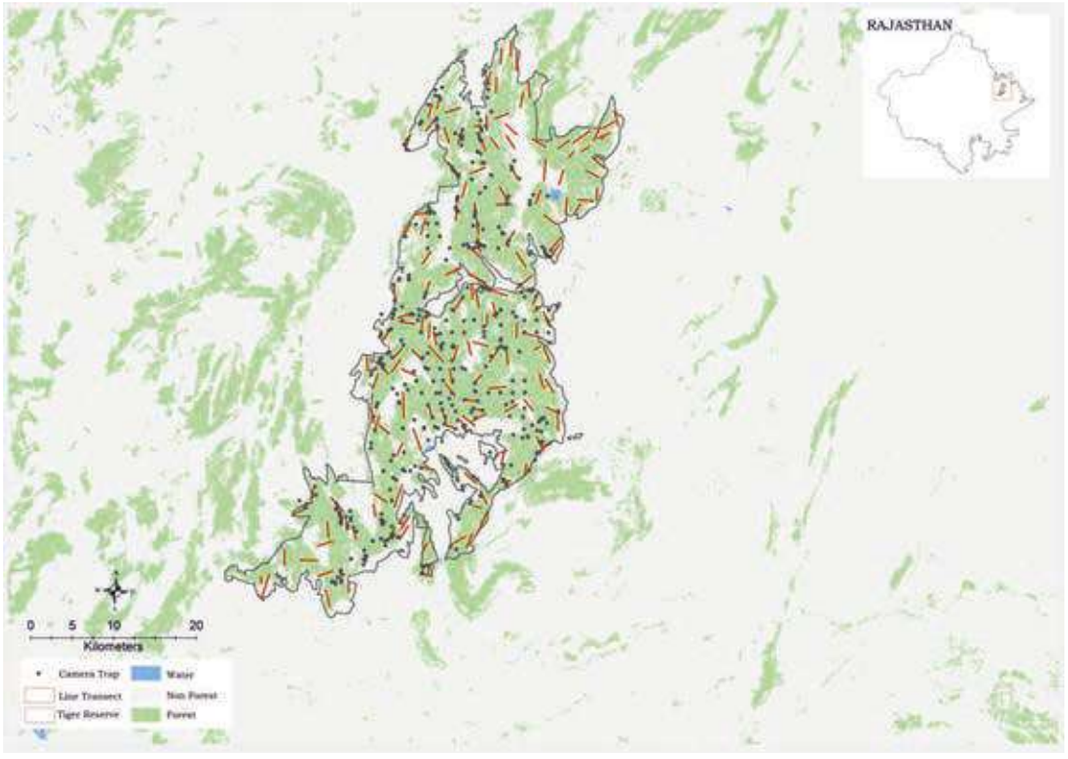


Figure 10.12
Camera trap and transect layout in Sariska Tiger Reserve

RESULTS

Camera Trap Results

Four-hundred and twenty six camera traps were deployed in two blocks and a total of 451 tiger images were obtained from which 11 tiger individuals were identified. We did not estimate the spatially explicit density for Sariska as the reintroduced tiger population abundance was known (absolute abundance). Out of these 11 individuals, 3 were male (1 old adult, 2 young adults) and 8 were females (2 old adults, 4 prime adults, 2 young adults) (Table 10.5); 5 cubs (<1 year) were also recorded during the survey.

Table 10.5

Sampling details for Sariska Tiger Reserve, 2019.

Variables	Estimates
Camera points	426
Trap nights (effort)	11820
Unique tigers captured	11
Tiger male	3
Tiger female	8

Prey Density Estimates

A total of 673 foot transects were walked in Sariska Tiger Reserve with a total effort was of 1346 km. Nilgai was found to be the most abundant ungulate with a density of 25.54 (SE 1.45) individuals/km^2 followed by sambar (Table 10.6).

Table 10.6

Model statistics and parameter estimates of line transect based distance sampling for prey species in Sariska Tiger Reserve, 2018-19.

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital	36.65 (2.94)	206	6.87 (0.32)	0.23 (0.01)	0.15 (0.01)	2.08 (0.25)	14.35 (1.84)
Sambar	31.42 (1.31)	473	3.38 (0.11)	0.19 (0.01)	0.351 (0.01)	5.59 (0.36)	18.95 (1.39)
Nilgai	37.461 (1.4)	897	2.87 (0.09)	0.15 (0.01)	0.666 (0.01)	8.89 (0.41)	25.54 (1.45)
Wild pig	35.72 (3.08)	361	4.82 (0.25)	0.14 (0.01)	0.268 (0.01)	3.75 (0.36)	18.11 (2.09)

Distribution of Major Fauna Found in Sariska Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Sariska Tiger reserve.

Tiger were photocaptured in the northern part of the reserve with higher number of photographs obtained from Sariska, Akbarpur & Talvriksh region of the park. Highly rugged areas in the northern and the southern parts were not frequented by tigers.

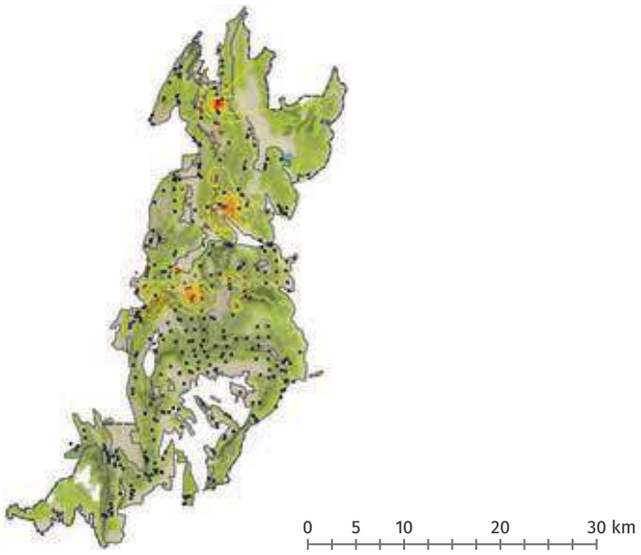


Figure 10.13

Distribution and relative spatial abundance of tiger in Sariska Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Golden jackal were photocaptured across the reserve with higher number of photographs obtained from the central portion of the park near the human dominated areas (settlements inside the reserve). Highly rugged areas in the northern and the southern parts were not frequented by jackals.

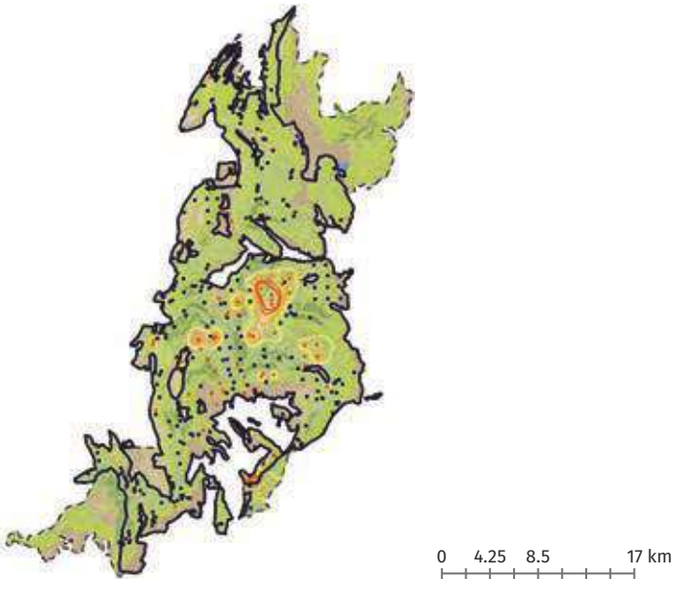


Figure 10.14

Distribution and relative spatial abundance of golden jackal in Sariska Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was photocaptured across the reserve with higher photocaptures on the periphery of the park.

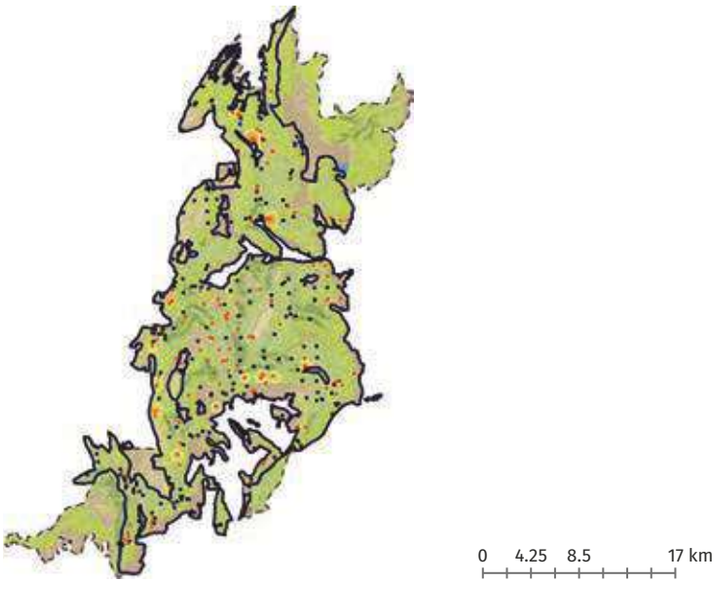


Figure 10.15

Distribution and relative spatial abundance of jungle cat in Sariska Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

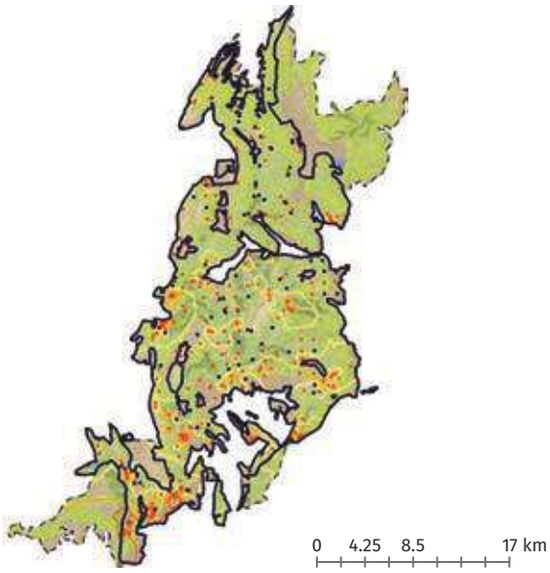


Figure 10.16

Distribution and relative spatial abundance of leopard in Sariska Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was photocaptured across the reserve with higher number of photographs obtained from the central and southern portion of the park, especially from the areas where tiger captures were less. Leopard showed preference mostly to rugged terrain with moderately dense vegetation.

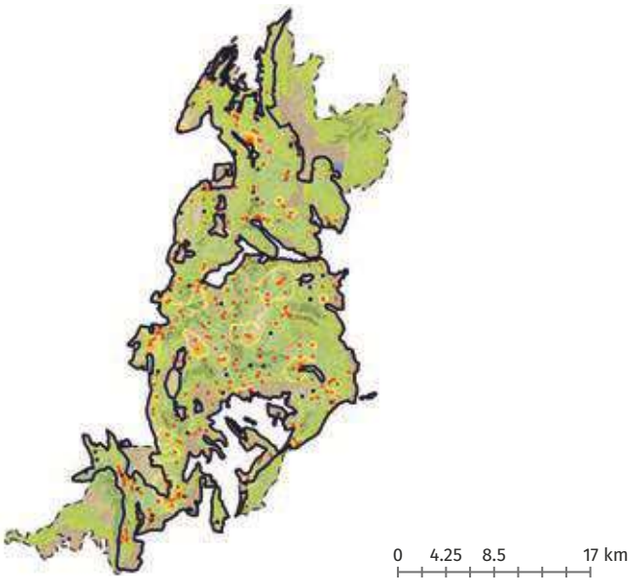


Figure 10.17

Distribution and relative spatial abundance of Striped hyena in Sariska Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Striped hyena was photocaptured across the reserve, however highly rugged areas and densely vegetated areas were used more by the species. Several settlements (inside the park) has resulted in the availability of livestock carcasses, on which striped hyena are known to thrive.

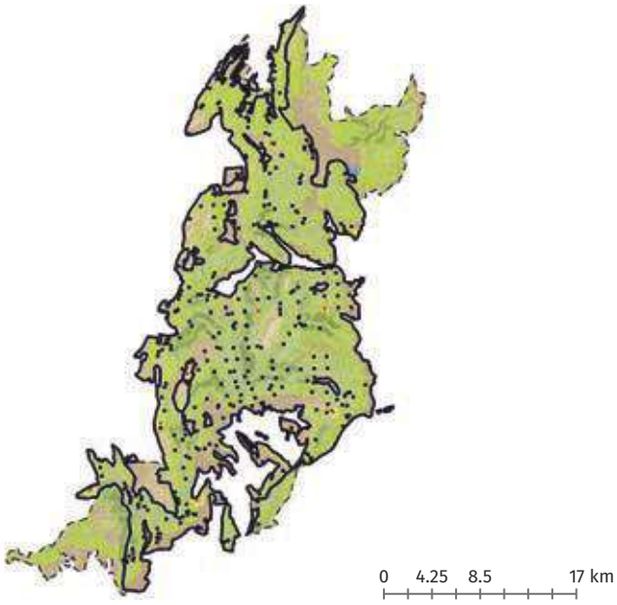


Figure 10.18

Distribution and relative spatial abundance of Rusty-spotted cat in Sariska Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Rusty-spotted cat was photocaptured only in a few locations.

Desert fox was photocaptured at three locations inside the park. Despite the historical distributional records, this species was photographed for the first time in Sariska Tiger Reserve.

Figure 10.19

Distribution and relative spatial abundance of desert fox in Sariska Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Four-horned antelope was photocaptured at two locations near the Kiraska plateau top. This forest antelope was reported earlier in Sariska, however photographic evidence was not available.

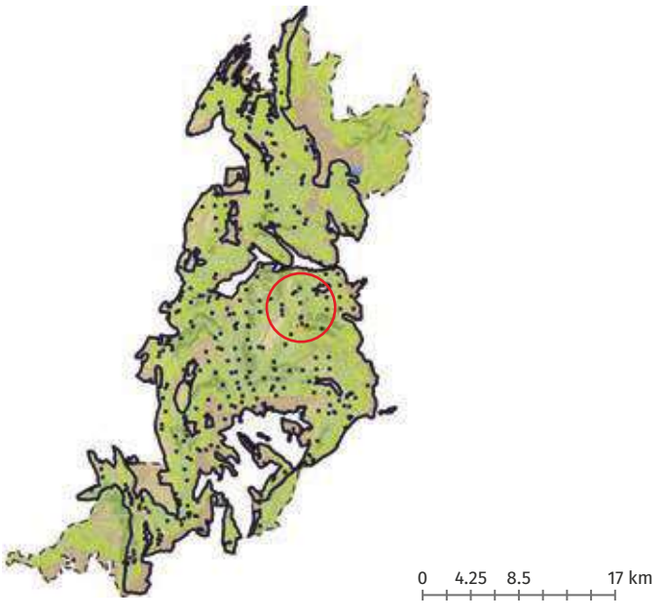


Figure 10.20

Distribution and relative spatial abundance of four-horned antelope in Sariska Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

The rare black francolin was photocaptured in the north-western part of Sariska Tiger Reserve (Talvriksh range). The species was last reported (confirm record) in 1993.

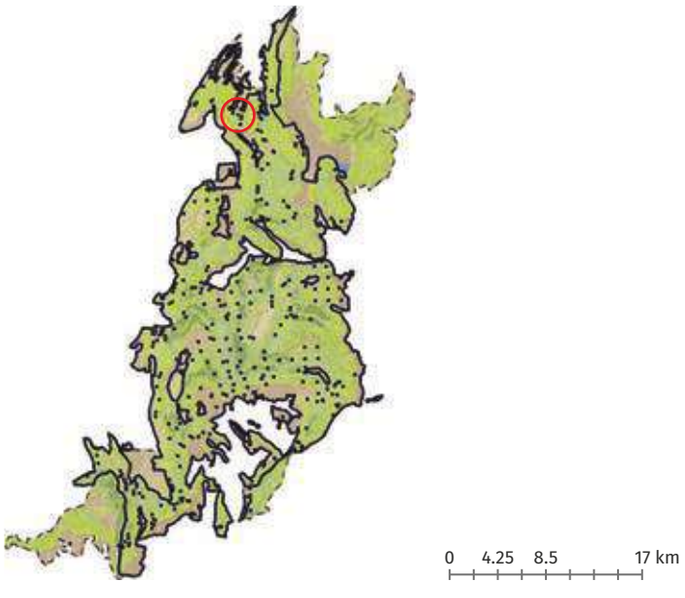


Figure 10.21

Distribution and relative spatial abundance of black francolin in Sariska Tiger Reserve. Red dot represents photo-capture in camera traps (all dots) while contour lines depict intensity of photo-captures.

Table 10.7

Details of all photocaptured species and their relative abundance index (RAI) in Sariska Tiger Reserve 2018-19.

Species name	No. of photos/ 100 trap nights	No. of trap nights to get one photograph
Black francolin	0.01	11820
Black naped hare	35.35	3
Chital	10.40	10
Chowsingha	0.02	5910
Desert cat	0.58	171
Desert fox	0.26	381
Domestic cats	0.22	455
Domestic dogs	7.02	14
Golden Jackal	1.43	70
Hanuman langur	6.08	16
Honey Badger	1.57	64
Indian fox	0.24	422
Indian grey mongoose	1.82	55
Jungle cat	1.90	53
Leopard	10.01	10
Livestock	37.50	3
Nilgai	25.19	4
Painted spur fowl	0.30	338
Palm civet	1.18	85
Pangolin	0.06	1689
Peafowl	83.89	1
Porcupine	11.01	9
Ruddy mongoose	0.97	103
Rusty spotted cat	0.14	739
Sambar	44.72	2
Small Indian civet	3.92	26
Striped Hyena	21.77	5
Tiger	2.39	42
Wild pig	15.48	6

Relative Abundance of all Photocaptured Species in Sariska Tiger Reserve

A total of 29 species of carnivores, herbivores, and others species (omnivores, birds, domestic animals) were photocaptured in Sariska Tiger Reserve. Sambar and Nilgai were the most common ungulate species, while striped hyena and leopard were the most common carnivore species (Table 10.7). Desert fox, four-horned antelope, and black francolin were photocaptured for the first time in the camera traps.

DISCUSSION

Human disturbance inside the reserve is a major setback to wildlife conservation. Biotic pressure (especially livestock grazing) on the forest reduces resource availability in Sariska, therefore ungulate population density in the park was comparatively low. A few inviolate pockets harbor rich faunal diversity and can be the key to wildlife recovery in this landscape. The present camera trapping survey recorded higher photocapture rates of large carnivores from the relocated village areas (inviolate areas). As a part of the tiger reintroduction program, tigers from Ranthambhore need to be translocated at regular intervals as per the original reintroduction plan (Sankar et al. 2010). Anthropogenic pressure inside Sariska TR is the major concern for the long-term.

MUKUNDARA HILLS TIGER RESERVE

INTRODUCTION

Mukundara Hills Tiger Reserve spreads across the districts of Kota, Bundi, Chittorgarh and Jhalawar in Rajasthan covering an area of 759 km^2 (core 417 km^2, buffer 342.82 km^2). It was declared as a tiger reserve in the year 2013 and the first tiger was translocated from Ranthambhore in April 2018. In December 2018, one female from Ranthambhore was translocated in Mukundara. In February 2019, a dispersing male from Ranthambhore reached Mukundara using the ravines of Kali Sindh river (one of the tributaries of Chambal). In April 2019, another female from Ranthambhore was translocated in Mukundara. Along with Bhainsrodgarh Wildlife Sanctuary, Mukundara has the potential to serve as a natural extension of Ranthambhore Tiger Reserve within the larger landscape to accommodate dispersing large tigers from Ranthambhore. It is also connected to the Gandhi Sagar Wildlife Sanctuary in Madhya Pradesh.

The forest type of Mukundara is of northern tropical dry deciduous forest (Champion and Seth 1968), and is dominated by *Anogeissus pendula, Anogeissus latifolia, Acacia catechu, Zizyphus mauratiana, Flacouritia indica,* and *Acacia leucofloea.* The carnivore guild comprises of tiger (*Panthera tigris*), leopard (*Panthera pardus*), grey wolf (*Canis lupus*), honey badger (*Mellivera capensis*), golden jackal (*Canis aureus*), Indian fox (*Vulpes bengalensis*), sloth bear (*Melursus ursinus*), striped hyena (*Hyena hyena*), jungle cat (*Felis chaus*), desert cat (*Felis silvestris*), rusty-spotted cat (*Prionailurus rubiginosus*), common palm civet (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*), ruddy mongoose (*Herpestes smithii*), and Indian grey mongoose (*Herpestes edwarsi*). Indian pangolin (*Manis crassicaudata*), which is threatened by habitat loss and poaching is reported from Mukundara (Latafat and Sadhu 2016). The ungulate prey base mostly comprises of nilgai (*Boselaphus tragocamelus*) and chinkara (*Gazella bennettii*) while chital (*Axis axis*) and sambar (*Rusa unicolor*) populations are found in pockets. Large number of domestic livestock (from the nearby villages) compete with wild ungulates in much of the Tiger Reserve. Due to the linear nature of Mukundhara, there is a large interface with human dominated landscape creating conditions of human-wildlife conflict as well as livestock grazing. Therefore, a large fenced area of 80 km^2 on the southern part has been created within which a pair of tigers is kept.

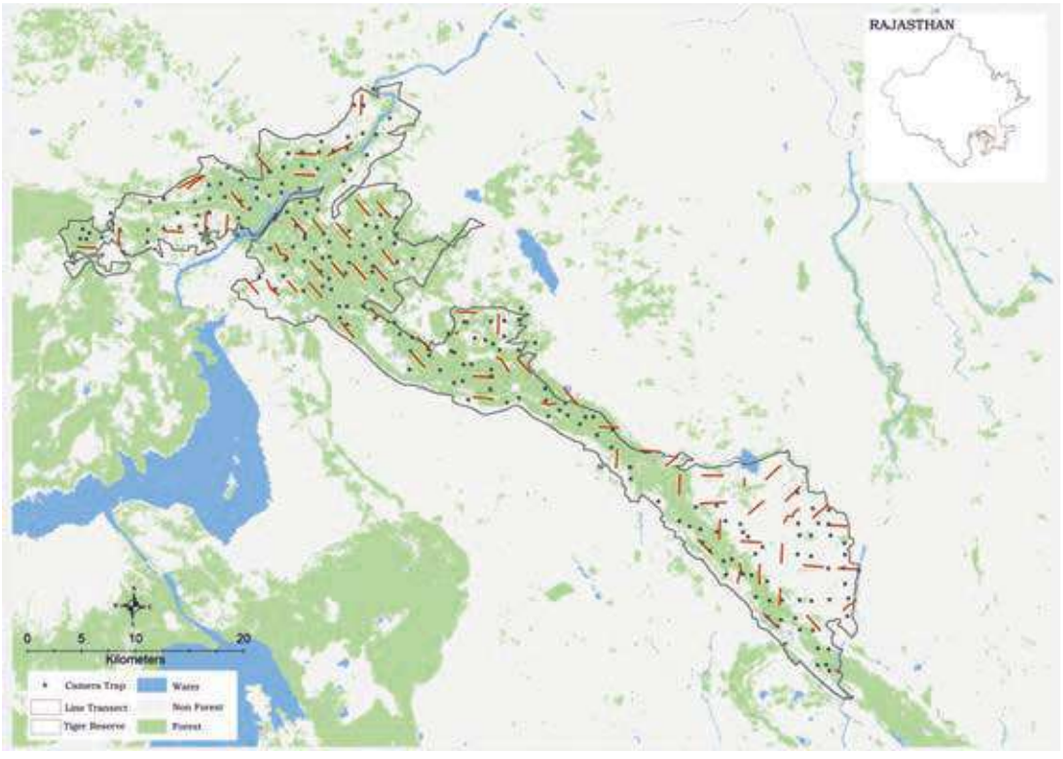


Figure 10.22

Camera trap and transect layout in Mukundara Hills Tiger Reserve

RESULTS

Camera Trap Results

A total of 236 camera traps were deployed which resulted in total effort of 8316 trap nights and a total of 23 tiger images of 1 individual male tiger were obtained. We have not estimated spatially explicit density for Mukundara as reintroduced tiger population abundance was known (absolute abundance). After completion of the camera trapping survey, 1 female and 2 males were added to the Mukundara tiger population and presently there are 4 adult tigers.

Prey Density Estimates

A total of 227 transect were walked in Mukundara Hills Tiger Reserve with a total effort of 426 km. Nilgai was found to be the most abundant ungulate with a density of 3.59 (SE 0.76) individuals/km^2 followed by chinkara (Table 10.8).

Table 10.8

Model statistics and parameter estimates of line transect based distance sampling for prey species in Mukundara Hills Tiger Reserve, 2018-19.

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital		11			0.02 (0.0)		
Nilgai	48.62 (7.21)	66	2.25 (0.2)	0.32 (0.04)	0.15 (0.01)	1.59 (0.3)	3.59 (0.76)
Wild pig		8			0.01 (0.01)		
Chinkara	47.41 (6.37)	31	2.67 (0.34)	0.36 (0.04)	0.07 (0.01)	0.76(0.18)	2.05 (0.57)

Distribution of Major Mammalian Species in Mukundara Hills Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Mukundara Hills Tiger reserve.

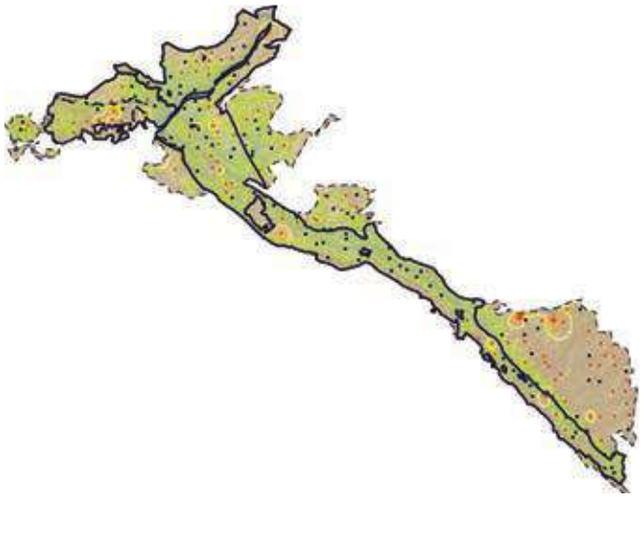


Figure 10.23

Distribution and relative spatial abundance of golden jackal in Mukundara Hills Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Golden jackal was photocaptured across the reserve with higher number of photographs obtained from the periphery, near to human settlements inside and outside the reserve.

Jungle cat was photocaptured across the reserve with higher number of photographs obtained from narrow valleys or on plateau tops.

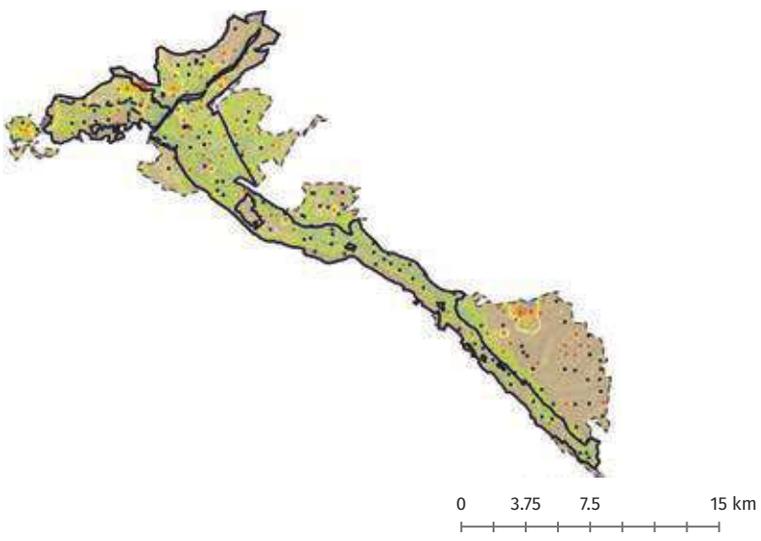


Figure 10.24
Distribution and relative spatial abundance of jungle cat in Mukundara Hills Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Desert cat was photocaptured across the reserve with higher number of photographs obtained from the southern Jawahar Sagar and Masalpura regions.

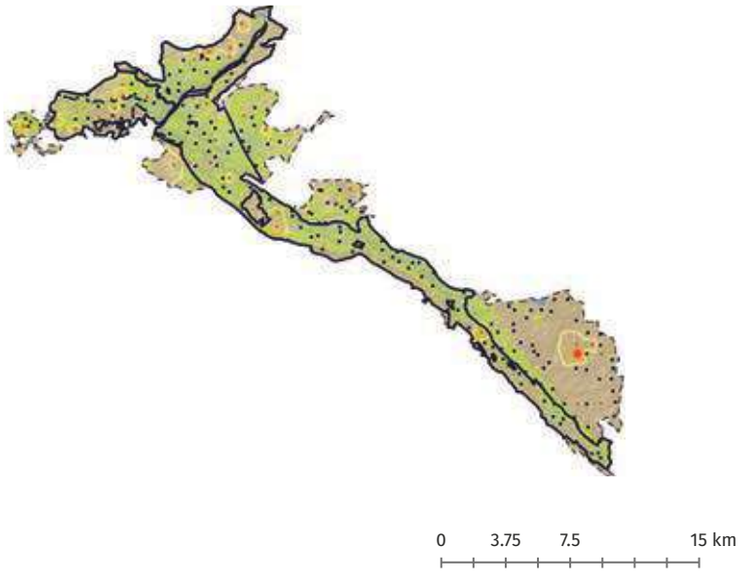


Figure 10.25
Distribution and relative spatial abundance of desert cat in Mukundara Hills Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Grey wolf was photocaptured in the northern and southern part of the reserve. Woodland savannahs of the Borawas region and the Massalpura region had highest number of photocaptures.

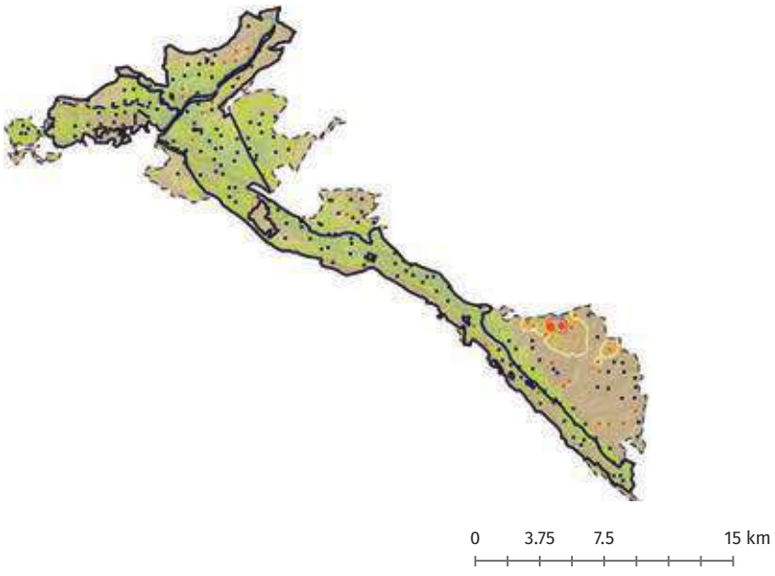


Figure 10.26
Distribution and relative spatial abundance of grey wolf in Mukundara Hills Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

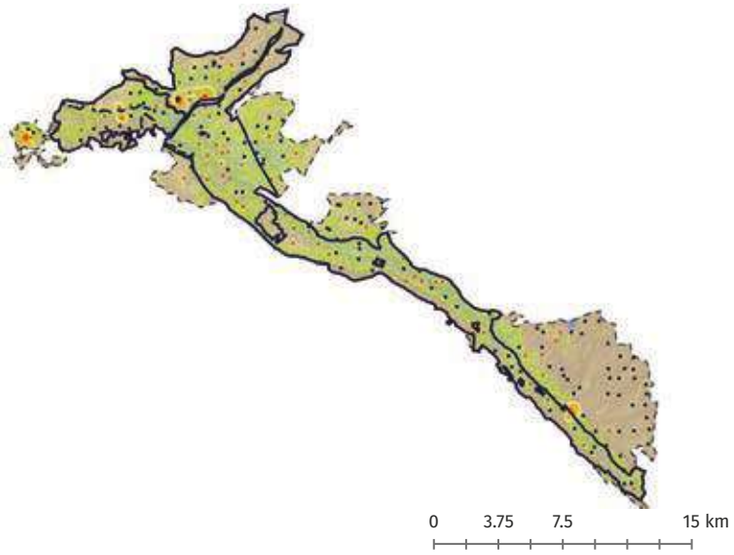


Figure 10.27

Distribution and relative spatial abundance of leopard in Mukundara Hills Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was photocaptured across the reserve, however, northern part of the reserve (Jawahar Sagar and Seljar ranges/regions) had higher number of photocaptures. The comparatively undisturbed parts of the reserve act as a refuge for this large carnivore.

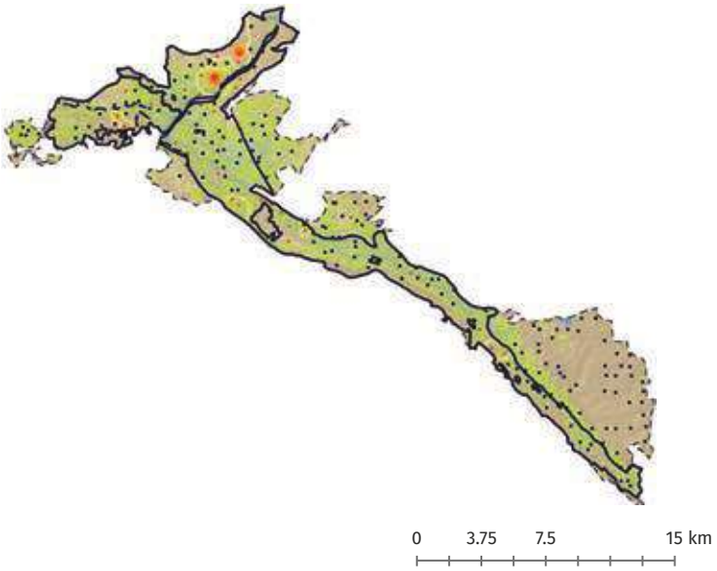


Figure 10.28

Distribution and relative spatial abundance of sloth bear in Mukundara Hills Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear was photocaptured mostly in the norther part of the reserve (Jawahar Sagar) where rugged terrain with open forests on the plateau tops (near the river Chambal) was frequented most by the species.

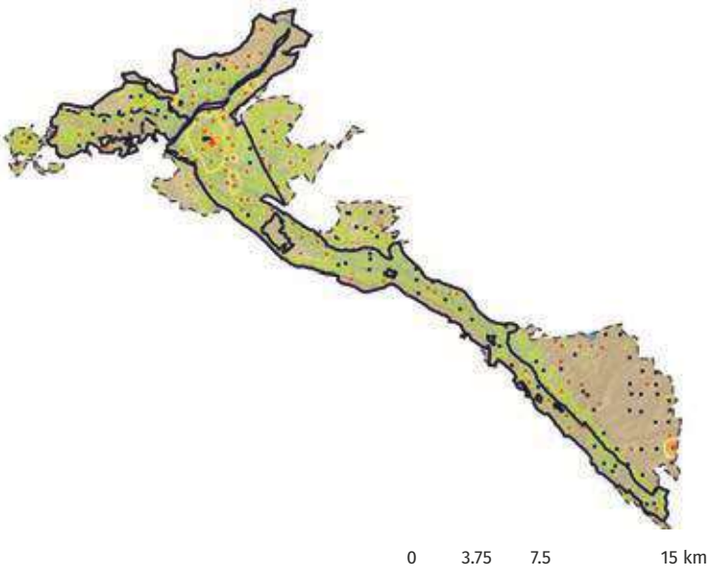


Figure 10.29

Distribution and relative spatial abundance of Striped hyena in Mukundara Hills Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Striped hyena was photocaptured across the reserve with higher number of photographs obtained from the northern part (Seljar-Kolipura area) of the reserve. These forests with few tiger provide a refuge to striped hyanas in this predominantly human dominated landscape.

Rusty spotted cat was photocaptured in a few pockets of the reserve (in the north western and southern part).

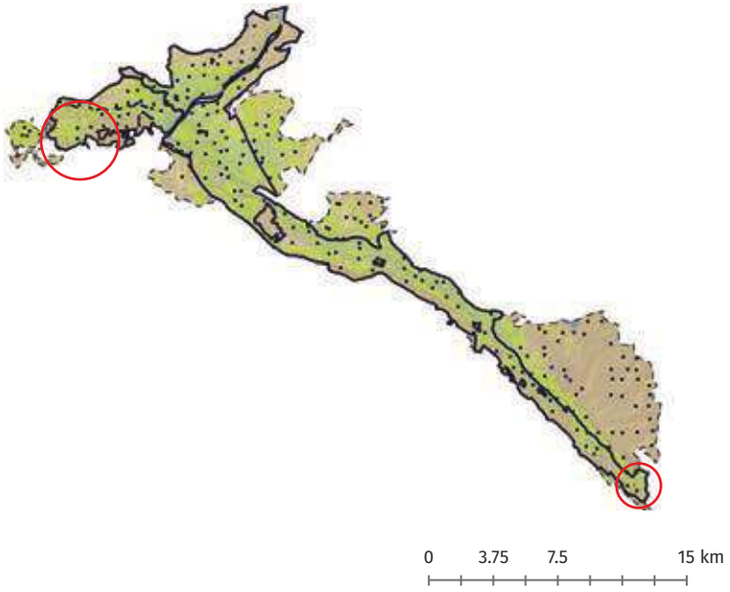


Figure 10.30

Distribution and relative spatial abundance of rusty spotted cat in Mukundara Hills Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Relative Abundance of all Photocaptured Species in Mukundara Hills Tiger Reserve

A total of 32 species of carnivores, herbivores, and others species (omnivores, birds, domestic animals) were photocaptured in Mukundara Hills Tiger Reserve. Nilgai and chinkara were the most common ungulate species, while striped hyena and golden jackal were the most common carnivore species (Table 10.9).

Table 10.9

Details of all photocaptured species and their relative abundance index (RAI) in Mukundara Hills Tiger Reserve 2018-19.

Species name	No. of photos/ 100 trap nights	No. of trap nights to get one photograph
Chinkara	6.17	16
Chital	1.30	77
Common palm civet	1.31	76
Desert cat	0.60	166
Domestic cat	0.10	1040
Domestic dog	2.18	46
Golden Jackal	5.86	17
Grey francolin	0.11	924
Hanuman langur	4.00	25
Honey badger	0.14	693
Indian crested porcupine	5.69	18
Indian fox	4.80	21
Indian grey mongoose	0.82	122
Indian hare	11.17	9
Indian pangolin	0.02	4158
Indian wolf	1.70	59
Jungle cat	3.45	29
Leopard	2.43	41
Livestock	76.54	1
Mugger	0.01	8316
Nilgai	17.91	6
Peafowl	7.26	14
Rhesus macaque	0.06	1663

Species name	No. of photos/ 100 trap nights	No. of trap nights to get one photograph
Ruddy mongoose	0.37	268
Rusty spotted cat	0.06	1663
Sambar	0.97	103
Sloth bear	0.73	136
Small Indian civet	3.12	37
Small Indian mongoose	0.63	157
Striped hyena	8.34	12
Tiger	0.26	378
Wild pig	5.65	18

DISCUSSION

Mukundara has the potential to sustain tiger populations with restorative management and enhancement of prey base. However, due to its small size, liner shape and being surrounded by a predominantly human-dominated landscape, a sizable tiger population is likely to cause severe human-tiger conflict in the region. Therefore, prior to increasing the tiger occupied area any further, villages from the core of the reserve need to be relocated along with stringent law enforcement.

BANDHAVGARH TIGER RESERVE

INTRODUCTION

Bandhavgarh Tiger Reserve is situated in the central Indian highlands between the Vindhya mountain hill range and the eastern flank of Satpura hill range. BTR lies between 80°43'15" to 81°15'45" E longitudes and 23°27'00" to 23°59'50" N latitudes, spread across the districts of Umaria and Katani on the north-eastern border of Madhya Pradesh. The total area of the reserve is 1536.938 km^2 that includes the Bandhavgarh National Park and Panapata Wildlife Sanctuary as the core area (716.903 km^2) and its adjoining area of 820.035 km^2 as the buffer zone. BTR falls within the biogeographic province 6E Deccan Peninsula of central Indian highlands (Rodgers et al. 2002) and topographically, Bandhavgarh is extremely rugged with small hillocks interspersed with grassy swamps in the foothills (Manjrekar et al. 2017, Gopal 1991).

The vegetation of Bandhavgarh Tiger Reserve is mainly moist peninsular low-level Sal (3C/C2e), northern dry mixed deciduous forest (5B/C2), dry deciduous scrub (DS1), dry grassland (5/DS4) and west Gangetic moist mixed deciduous forest (3C/C3a) (Champion and Seth, 1968). Bandhavgarh Tiger Reserve is enriched with numerous species of birds, butterflies and a variety of reptiles. The major carnivore species include tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), wild dog (*Cuon alpinus*), grey wolf (*Canis lupus*), striped hyena (*Hyaena hyaena*), Indian fox (*Vulpes bengalensis*), golden jackal (*Canis aureus*) while chital (*Axis axis*), sambar (*Rusa unicolor*), gaur (*Bos gaurus*), barking deer (*Muntiacus vaginalis*), nilgai (*Boselaphus tragocamelus*), four-horned antelope (*Tetracerus quadricornis*), and chinkara (*Gazella bennettii*) are the major prey species found in Bandhavgarh Tiger Reserve. Bandhavgarh also harbours good populations of four species of vultures viz. long-billed vulture (*Gyps indicus*), white-rumped vulture (*Gyps bengalensis*), red-headed vulture (*Sarcogyps calvus*) and Egyptian vulture (*Neophron percnopterus*) (Navaneethan 2015). Gaur had became locally extinct by 1955 from Bandhavgarh, and was reintroduced from Kanha Tiger Reserve in the year 2011 to maintain long-term survival of the species and the natural biodiversity of the park (Sankar et al. 2013). Bandhavgarh is one of the major source populations of tigers in this landscape and the forest corridor connectivity of Bandhavgarh with other protected areas like Sanjay-Dubri Tiger Reserve, Achanakmar Tiger Reserve and Kanha Tiger Reserve is of vital importance for the movement and maintenance of the meta-populations of tigers in this landscape (Jhala et al. 2011).

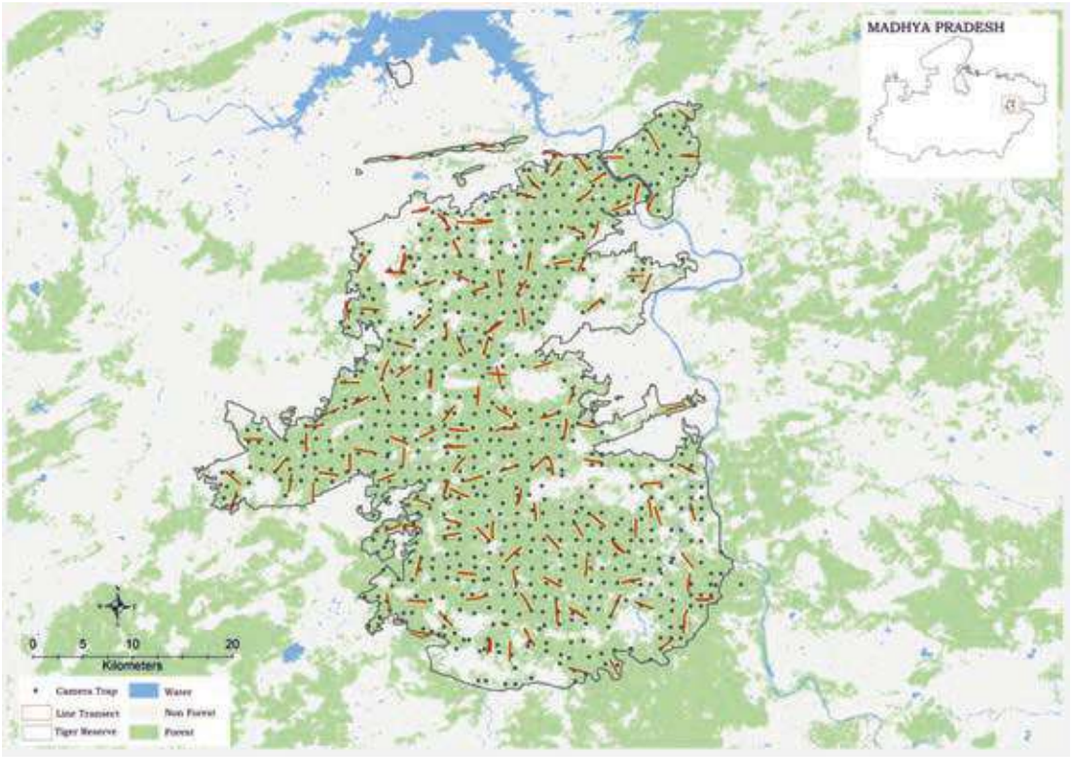


Figure 10.31
Camera trap and line transect layout in Bandhavgarh Tiger Reserve, 2018.

RESULTS

Tiger Density Estimates

A total of 1316 detections of tigers have been obtained during the sampling period from which 104 adult individual tigers were identified giving a density estimate of 5.83 (SE 0.57) tiger per 100 km^2. The detection corrected sex ratio was female biased (Table 10.10).

Table 10.10

Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Bandhavgarh Tiger Reserve, 2018.

Variables	Estimates
Model space (km^2)	2127.5
Camera locations	680
Trap nights (effort)	23607
Unique tigers captured	104
Model	g_0 (sex) σ (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	5.83 (0.57)
σ Female (SE) km	1.99 (0.04)
σ Male (SE) km	2.95 (0.07)
g_0 Female (SE)	0.02 (0.001)
g_0 Male (SE)	0.01 (0.001)
Pmix Female (SE)	0.60 (0.05)
Pmix Male (SE)	0.40 (0.05)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

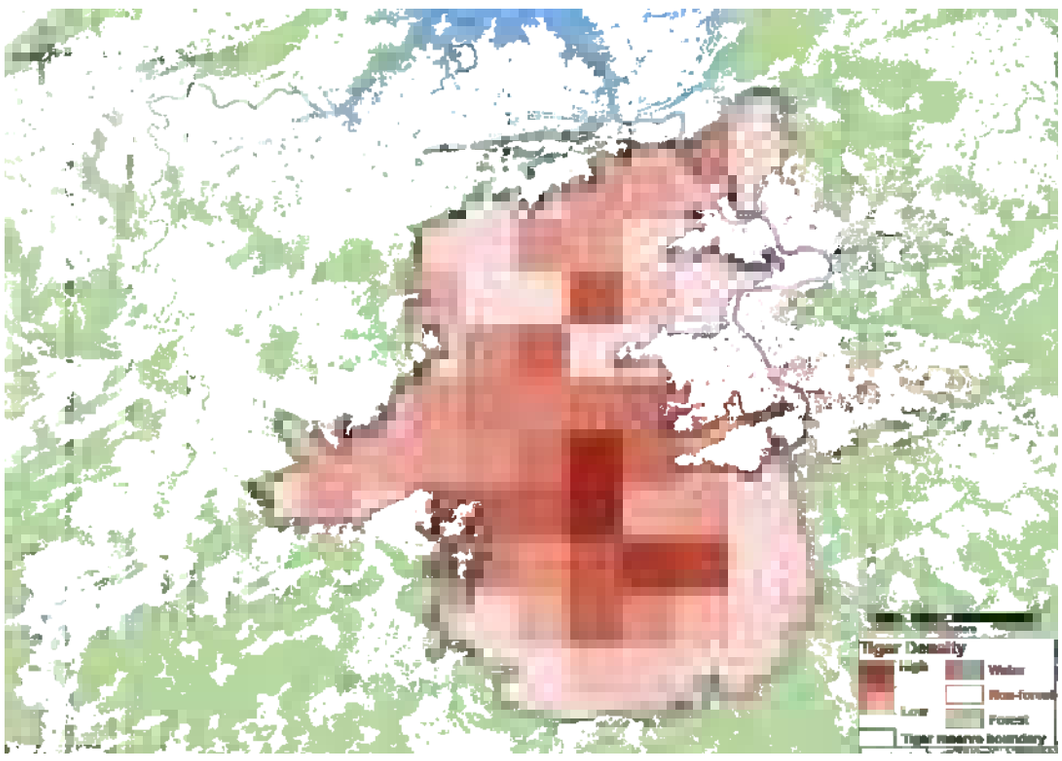
σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Figure 10.32

Spatial density of tigers in Bandhavgarh Tiger Reserve, 2018.



Bandhavgarh Tiger Reserve has one of the highest tiger densities in Central India and within the tiger reserve, forests of Tala and Magdhi ranges had the highest density of tigers.

Prey Density Estimates

A total of 406 line transects were walked in Bandhavgarh Tiger Reserve with a cumulative effort of 792.36 km. Chital was found to be the most abundant ungulate with a density of 41.36 (SE 4.09) per km^2 (Table 10.11).

Table 10.11

Model statistics and parameter estimates of line transect (n= 406, Total effort 792.36 km) based distance sampling for prey species in Bandhavgarh Tiger Reserve, 2018.

Species	Effective strip-width (SE)	#groups detected	Mean group-size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital	47.27 (2.08)	510	6.08 (0.34)	0.18 (0.01)	0.64 (0.04)	6.81 (0.56)	41.36 (4.09)
Sambar	42.96 (4.96)	90	2.91 (0.26)	0.15 (0.02)	0.11 (0.01)	1.32 (0.21)	3.85 (0.71)
Nilgai	72.88 (7.78)	75	2.95 (0.25)	0.28 (0.03)	0.10 (0.01)	0.65 (0.11)	1.91 (0.35)
Wild Pig	60.85 (4.19)	109	5.26 (0.41)	0.32 (0.02)	0.14 (0.01)	1.13 (0.13)	5.94 (0.82)
Chinkara	54.43 (8.77)	48	2.29 (0.17)	0.20 (0.03)	0.06 (0.009)	0.56 (0.12)	1.28 (0.29)
Barking Deer	39.78 (9.00)	28	1.07 (0.05)	0.35 (0.08)	0.04 (0.006)	0.44 (0.13)	0.48 (0.14)

Distribution of Major Mammalian Species Found in Bandhavgarh Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Bandhavgarh Tiger Reserve.

Golden jackal was distributed throughout the tiger reserve with higher concentration of photo-captures towards south-western periphery of the core zone in moderately dense forest.

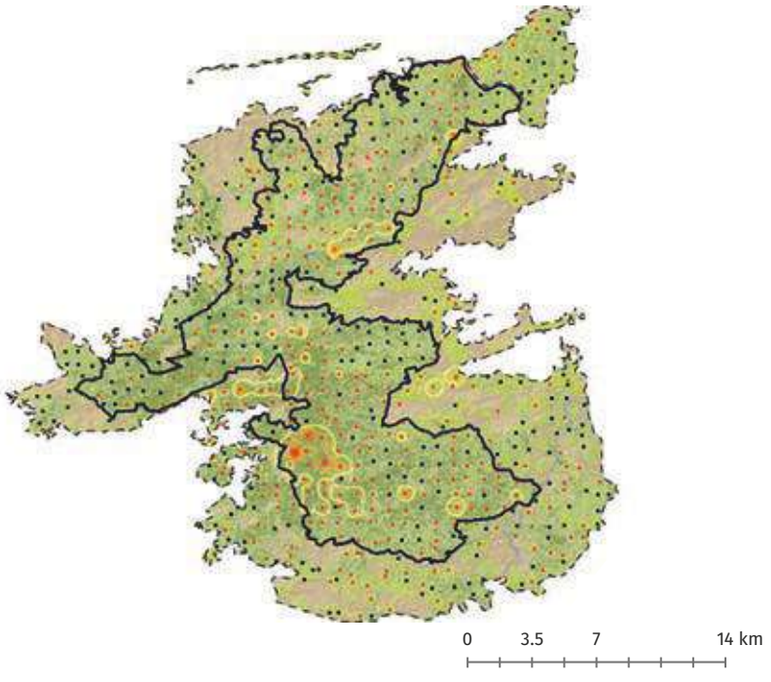


Figure 10.33

Distribution and relative spatial abundance of golden jackal in Bandhavgarh Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

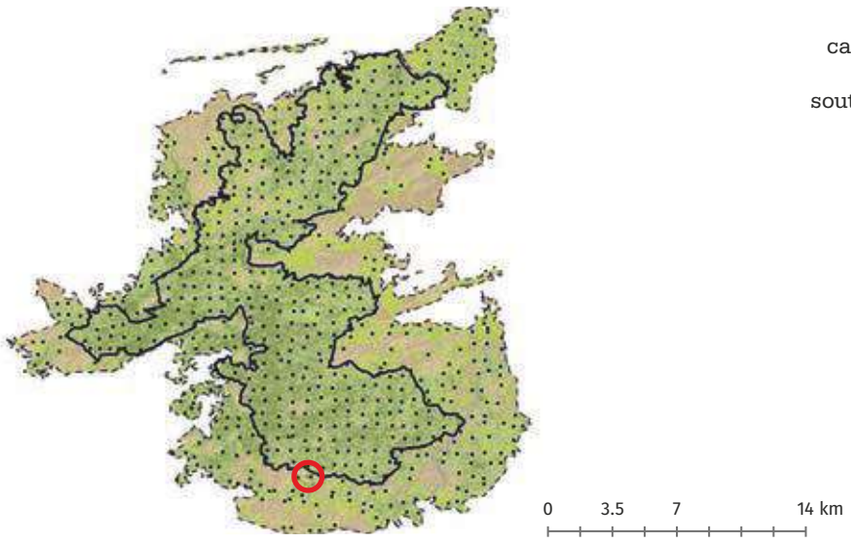


Figure 10.34

Distribution and relative spatial abundance of grey wolf in Bandhavgarh Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Grey wolf was captured at a single location on the southern boundary of core zone.

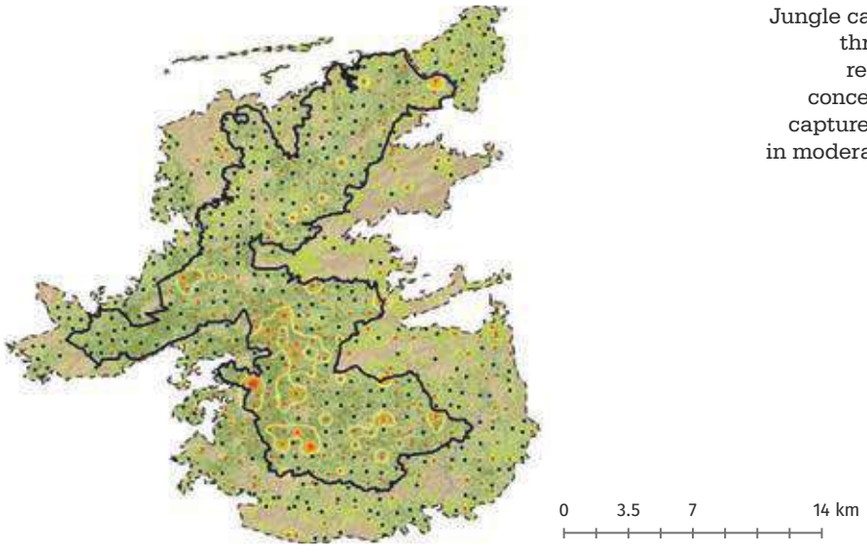


Figure 10.35

Distribution and relative spatial abundance of jungle cat in Bandhavgarh Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was distributed throughout the tiger reserve with higher concentration of photo-captures in the core zone in moderately dense forest.

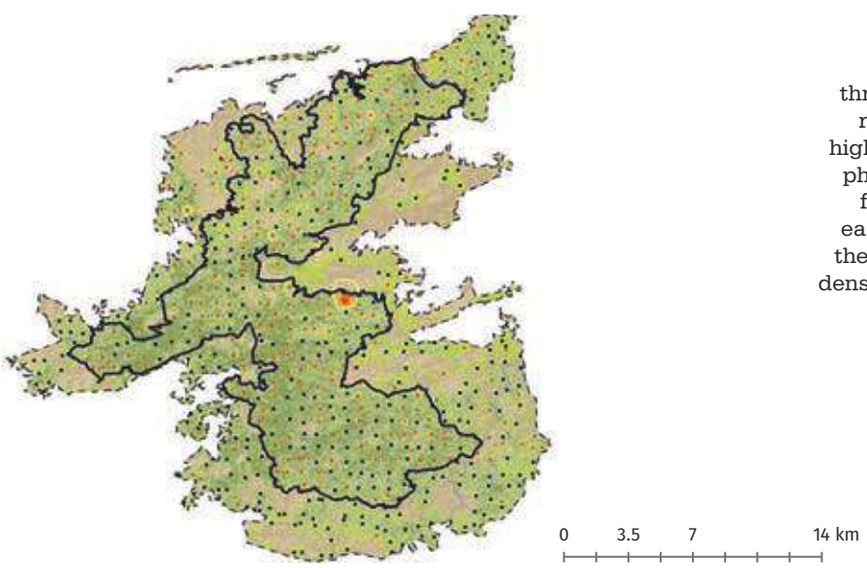


Figure 10.36

Distribution and relative spatial abundance of leopard in Bandhavgarh Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was distributed throughout the tiger reserve. Relatively high concentration of photo-captures was found towards the eastern boundary of the core zone in very dense and moderately dense forest.

Rusty-spotted cat was sparsely distributed in tiger reserve with higher photo-captures on the periphery of the core zone in moderately dense forest.

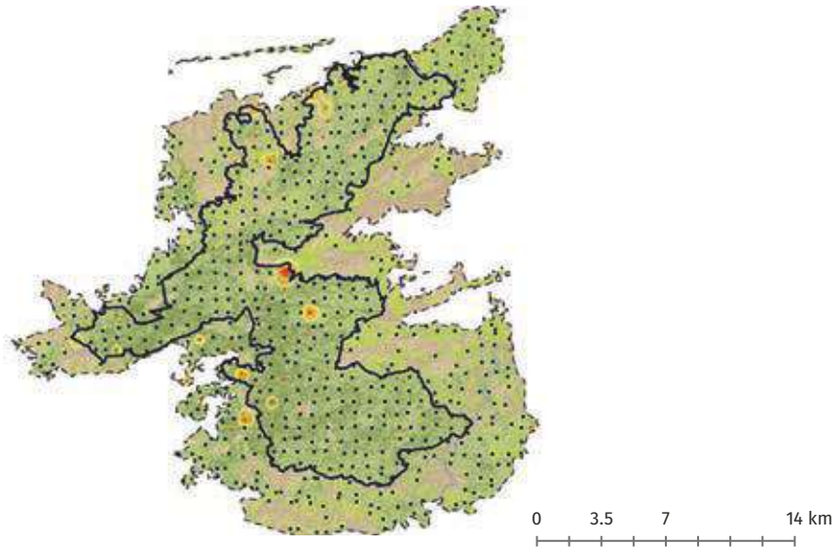


Figure 10.37

Distribution and relative spatial abundance of rusty-spotted cat in Bandhavgarh Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

Sloth bear was distributed throughout the tiger reserve with higher concentration of photo-captures towards the western side of the core zone in moderately dense forest.

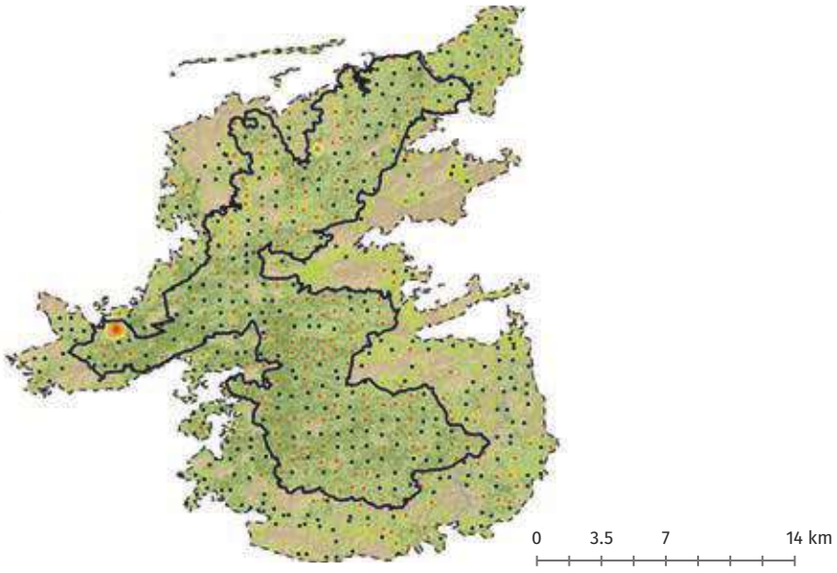


Figure 10.38

Distribution and relative spatial abundance of sloth bear in Bandhavgarh Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Striped hyena was exclusively distributed and photo-captured at the south-eastern extent of the tiger reserve in the buffer zone in moderately dense forest.

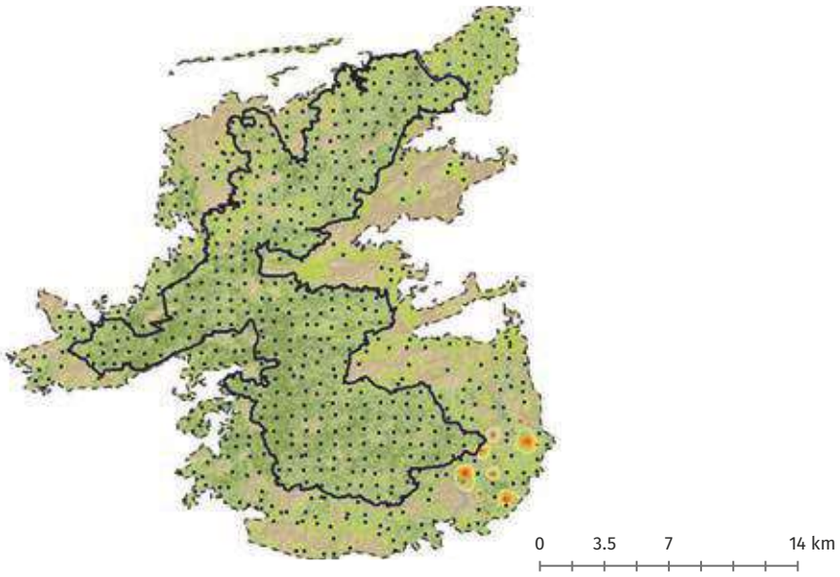


Figure 10.39

Distribution and relative spatial abundance of striped hyena in Bandhavgarh Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

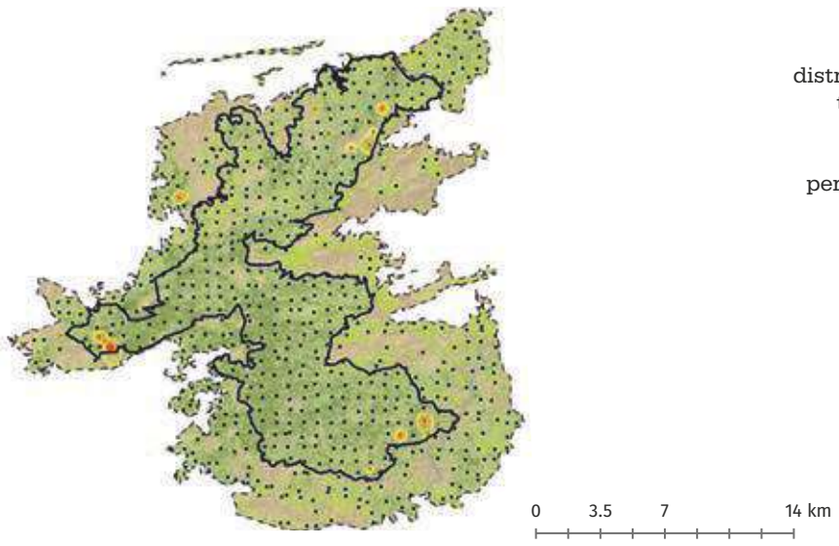


Figure 10.40

Distribution and relative spatial abundance of wild dog in Bandhavgarh Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Wild dog was sporadically distributed within the tiger reserve with higher photo-captures at the periphery of the core and buffer zones.

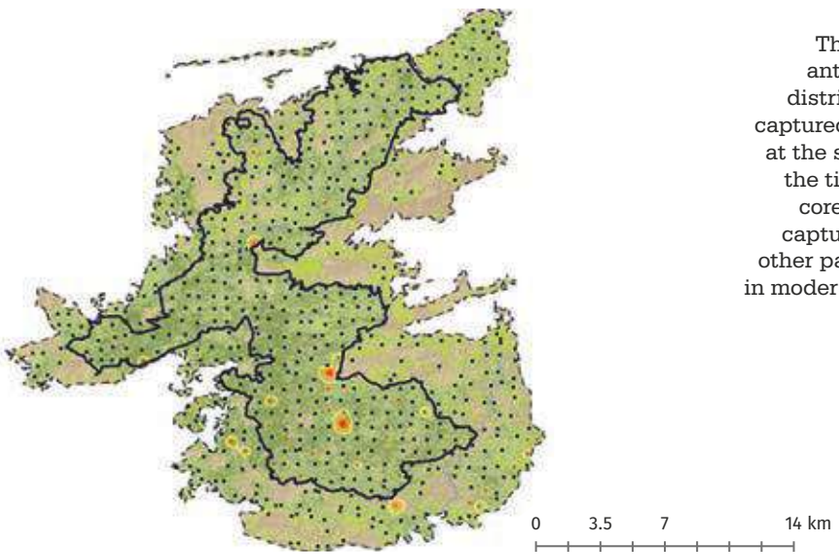


Figure 10.41

Distribution and relative spatial abundance of four-horned antelope in Bandhavgarh Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Though four-horned antelope was mostly distributed and photo-captured at the periphery at the southern extent of the tiger reserve in the core zone, few photo-captures were found in other parts of the reserve in moderately dense forest and open forest.

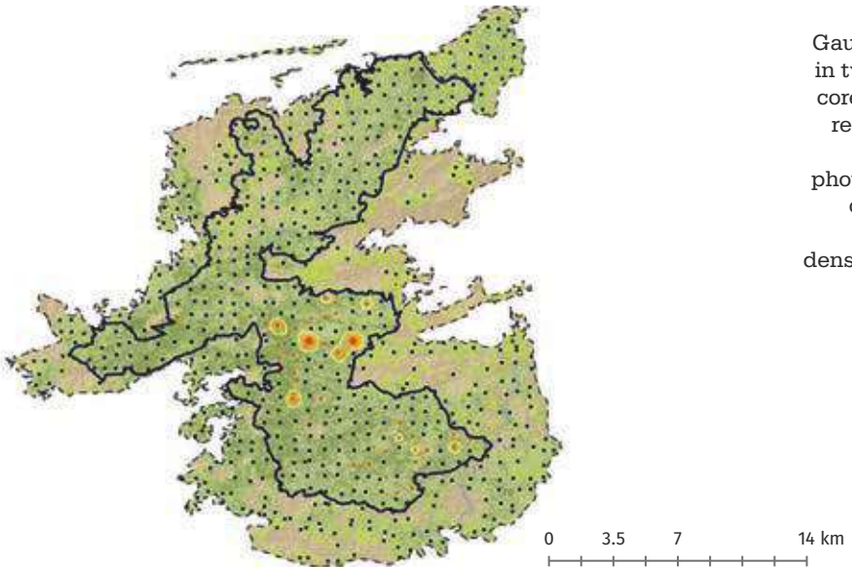


Figure 10.42

Distribution and relative spatial abundance of gaur in Bandhavgarh Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Gaur was distributed in two patches in the core zone of the tiger reserve with higher concentration of photo-captures in the central part of the core zone in very dense and moderately dense forest.

Relative Abundance of all Photocaptured Species in Bandhavgarh Tiger Reserve

A total of 34 wild species of ungulates, carnivores, primates, birds, and reptiles were photo-captured in Bandhavgarh Tiger Reserve. Chital followed by Hare were the most common species, whereas, grey wolf and Indian pangolin were the rarest mammals camera trapped (Table 10.12).

Table 10.12

Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Bandhavgarh Tiger Reserve, 2018.

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Barking deer	3.12	32
Chinkara	1.57	64
Chital	57.39	2
Common grey mongoose	0.90	111
Common palm civet	5.04	20
Desert cat	0.45	221
Domestic dog	4.20	24
Four-horned antelope	0.30	332
Gaur	0.42	236
Golden jackal	12.26	8
Indian wolf	<0.01	23607
Hanuman langur	17.52	6
Honey badger	0.73	137
Indian fox	4.89	20
Indian hare	19.83	5
Indian pangolin	0.03	3935
Indian porcupine	4.69	21
Jungle cat	4.24	24
Leopard	2.92	34
Lesser adjutant stork	0.08	1180
Livestock	28.72	3
Monitor lizard	0.07	1475
Nilgai	5.76	17
Peafowl	4.82	21
Red jungle fowl	0.52	194
Rhesus macaque	5.75	17
Ruddy mongoose	0.93	107
Rusty-spotted cat	0.27	369
Sambar	10.89	9
Sloth bear	2.08	48
Small Indian civet	3.07	33
Striped hyena	0.08	1180
Tiger	5.84	17
Wild dog	0.12	814
Wild pig	11.50	9

DISCUSSION

With a high ungulate biomass the Bandhavgarh tiger reserve, it maintains a high tiger density acting as a source of dispersing tigers to neighbouring protected areas such as Achanakmar, Sanjay-Dubri, and potentially to Palamau tiger reserves and is crucial for their recovery, hence, it has great importance for tiger conservation in this landscape. Wild elephants were not found in Bandhavgarh earlier but since the last few months, about 45 wild elephants including breeding females and a calfs became resident in Bandhavgarh and it is believed that these elephants have moved here from the adjoining forests of Chhattisgarh. Hence, apart from the tiger, it is crucial to implement conservation strategies for the protection of the wild elephants that have entered the reserve in the last few months.

KANHA TIGER RESERVE

INTRODUCTION

Kanha Tiger Reserve is located in Mandla and Balaghat districts of Madhya Pradesh between 80°26' E to 81°07' E longitudes and 22°02' N to 22°27' N latitudes in the Maikal hills of Satpura range. It lies in the Deccan peninsula central highland zone 6E of biogeographic classification of India (Rodgers and Panwar, 1988). The reserve has an excellent interspersion of the Dadars (flat hill tops), grassy expenses, dense forests and riverine forests. Kanha Tiger Reserve is divided into the three zones, the core (Kanha National Park) having an area of 917.43 km^2, the buffer having an area of 1134.39 km^2 and the microsatellite core (Phen Wildlife Sanctuary) having an area of 110.740 km^2. Kanha encompasses the catchments of two rivers- Banjar and Halon.

The vegetation of Kanha Tiger Reserve falls under two types (Champion and Seth, 1968): moist sal forests (3C/C2), with subgroups high level sal (3C/C2 ci) and low level sal (3C/C2 cii); and miscellaneous forests (3A/C2), with subgroups southern tropical moist deciduous forest, southern tropical dry mixed deciduous forest and grassland. The floral diversity comprises of 609 species, 10 varieties of angiosperms belonging to 386 genera and 104 families and 17 species of pteridophytes belonging to 11 genera and 9 families (Lal et al. 1986). The flora of the reserve also includes around 50 species of aquatic plants and 18 species of rare plants. The major tree species are *Shorea robusta, Terminalia elliptica, Lagerstroemia parviflora, Anogeissus latifolia, Diospyros melanoxylon, Butea monosperma, Pterocarpus marsupium, Madhuca longifolia, Phyllanthus emblica, Buchnania lanjan* and *Dendrocalamus strictus* etc. Besides these, there are many species of climbers, forbs and grasses.

There are 36 species of mammals and several species of reptiles found in Kanha. The reserve is also rich in avifauna and over 260 species of birds have been reported. Amongst the carnivores, apart from tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), jackal (*Canis aureus*), fox (*Vulpes bengalensis*), wolf (*Canis lupus*) etc. are found. Amongst the ungulates, chital (*Axis axis*), sambar (*Rusa unicolor*), hard ground Barasingha (*Rucervus duvaucelli branderi*), barking deer (*Muntiacus vaginalis*), chausingha (*Tetracerus quadricornis*), gaur (*Bos gaurus*), wild pig (*Sus scrofa*) etc. are commonly found. Small mammals like rusty spotted cat (*Prionailurus rubiginosus*), Indian creasted porcupine (*Hystrix indica*), mouse deer (*Moschiola indica*), and small Indian civet (*Viverricula indica*) are also found.

Kanha has been long recognized as an important tiger reserve for long-term conservation of tigers (Wikramanayake et al. 1998; Jhala et al. 2008). Kanha Tiger Reserve is one of the most renowned wildlife protected areas and has achieved tremendous success in providing a sound ecological haven to the rich floral and faunal assemblages through the concerted efforts under Project Tiger.

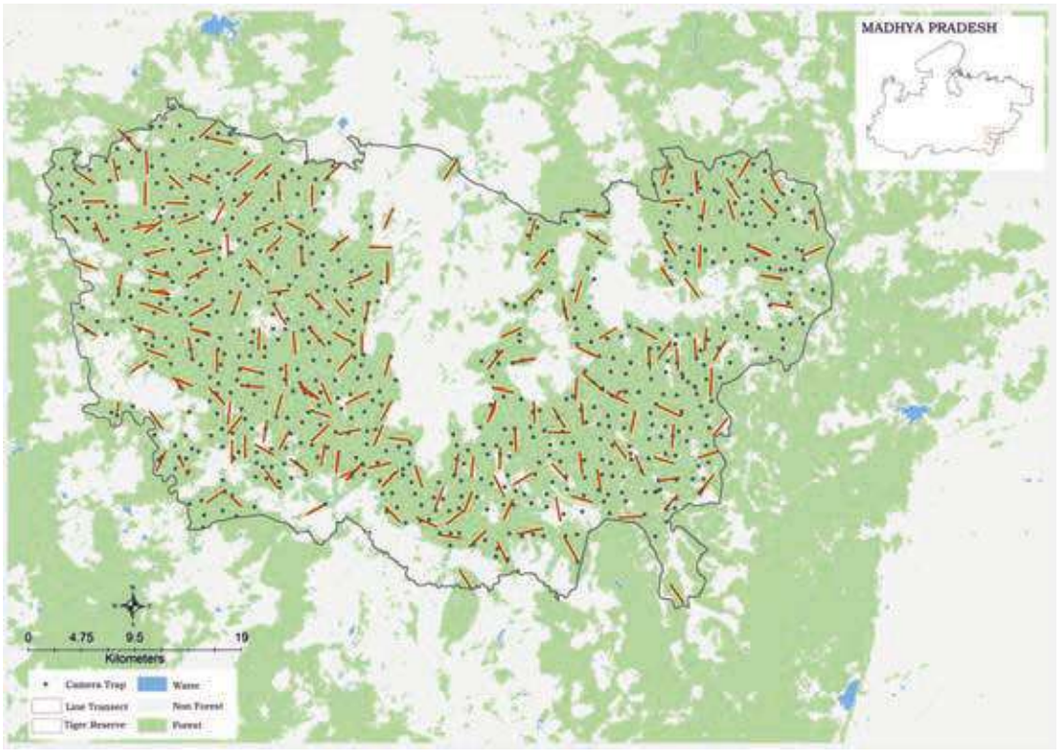


Figure 10.43
Camera trap and line transect layout in Kanha Tiger Reserve, 2018.

RESULTS

Tiger Density Estimates

A total of 1732 detections of tigers were obtained during the sampling period from which 88 adult individual tigers were identified. Tiger density was estimated as of 4.40 (SE 0.40) tiger per 100 km^2. The detection corrected sex ratio was male biased (Table 10.13).

Table 10.13
Sampling details and tiger density parameter estimates using spatially explicit Capture-Recapture in likelihood framework for Kanha Tiger Reserve, 2018.

Variables	Estimates
Model Space (km^2)	2421.5
Camera points	648
Trap nights (effort)	21091
Unique tigers captured	88
Model	g_0 (sex)σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	4.40 (0.40)
σ Female (SE) km	1.75 (0.04)
σ Male (SE) km	3.32 (0.07)
g_0 Female (SE)	0.060 (0.003)
g_0 Male (SE)	0.020 (0.001)
Pmix Female (SE)	0.48 (0.05)
Pmix Male (SE)	0.52 (0.05)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
σ (Sigma): Spatial scale of detection function,
g_0: Magnitude (intercept) of detection function
Pmix: Detection corrected estimate of proportion of males and females

Prey Density Estimates

A total of 222 line transects were walked in KTR with a cumulative effort of 1332 km. Chital was found to be the most abundant ungulate with a density of 38.14 (SE 5.04) per km^2 followed by sambar 6.95 (SE 0.94) (Table 10.14).

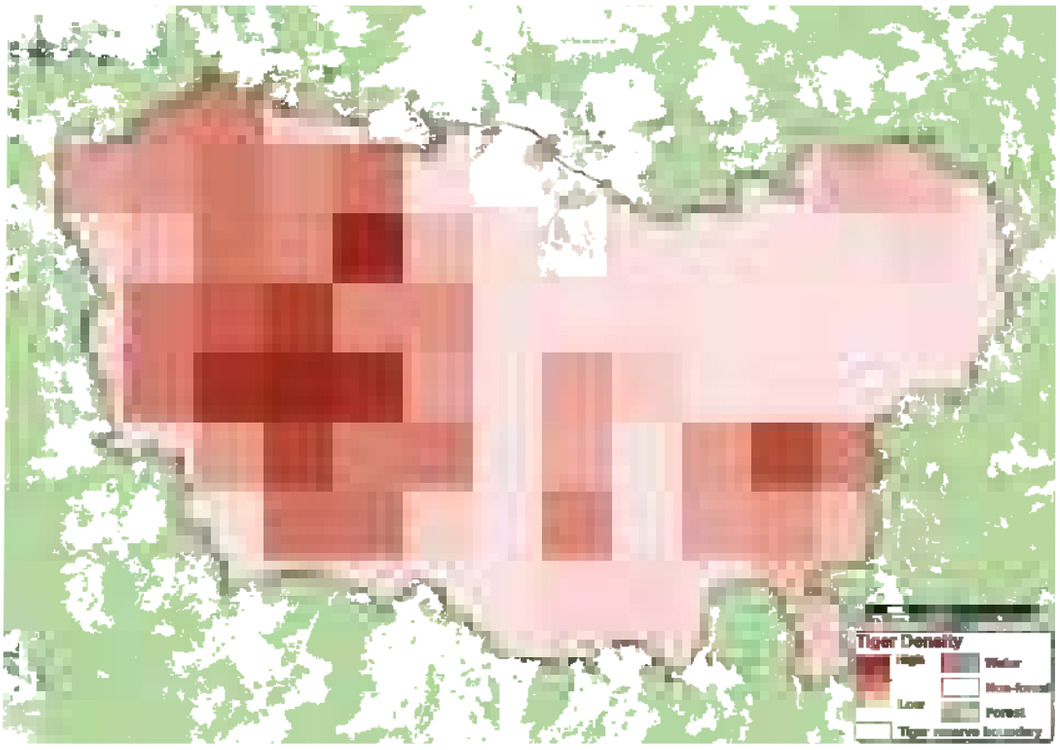
Table 10.14

Model statistics and parameter estimates of line transect (n= 222, Total effort 1332 km) based distance sampling for prey species in Kanha Tiger Reserve, 2018.

Species	Effective strip width (SE)	#groups detected	Mean group-size (SE)	Detection Probability (SE)	Encounter rate (SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital	46.52 (1.78)	352	10.10 (0.71)	0.18 (0.007)	0.35 (0.05)	3.77 (0.42)	38.14 (5.04)
Sambar	38.88 (3.25)	205	2.64 (0.13)	0.20 (0.01)	0.20 (0.03)	2.63 (0.33)	6.95 (0.94)
Wild Pig	45.48 (4.11)	102	4.36 (0.51)	0.22 (0.02)	0.10 (0.02)	1.11 (0.16)	4.88 (0.91)
Gaur	46.94 (5.14)	82	4.44 (0.54)	0.15 (0.01)	0.08 (0.02)	0.87 (0.15)	3.87 (0.82)
Barking Deer	28.50 (1.42)	137	1.07 (0.01)	0.23 (0.01)	0.13 (0.01)	2.39 (0.26)	2.57 (0.28)

Figure 10.44

Spatial density of tigers in Kanha Tiger Reserve, 2018



Kanha Tiger Reserve is home to one of the largest Tiger population in the Central India and within the tiger reserve, grasslands and mixed forests of Banjar catchment had the highest density of tigers.

Distribution of Major Mammalian Species Found in Kanha Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Kanha Tiger Reserve.

Golden jackal was photo-captured across the tiger reserve with higher concentration of photo-captures in the Banjar valley, while fewer photo-captures were obtained in the Halon valley in woodland and meadows.

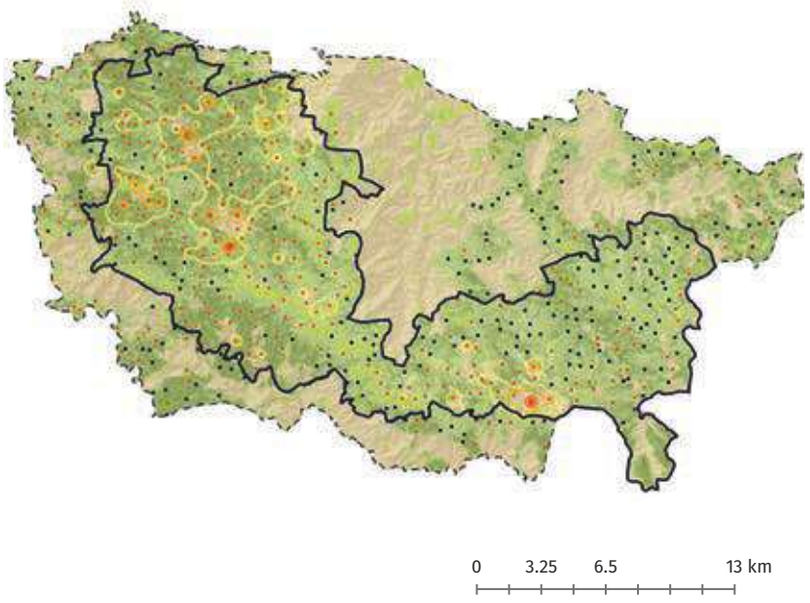


Figure 10.45
Distribution and relative spatial abundance of golden jackal in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Grey wolf had very few photo-captures, primarily in the buffer zone of the tiger reserve.

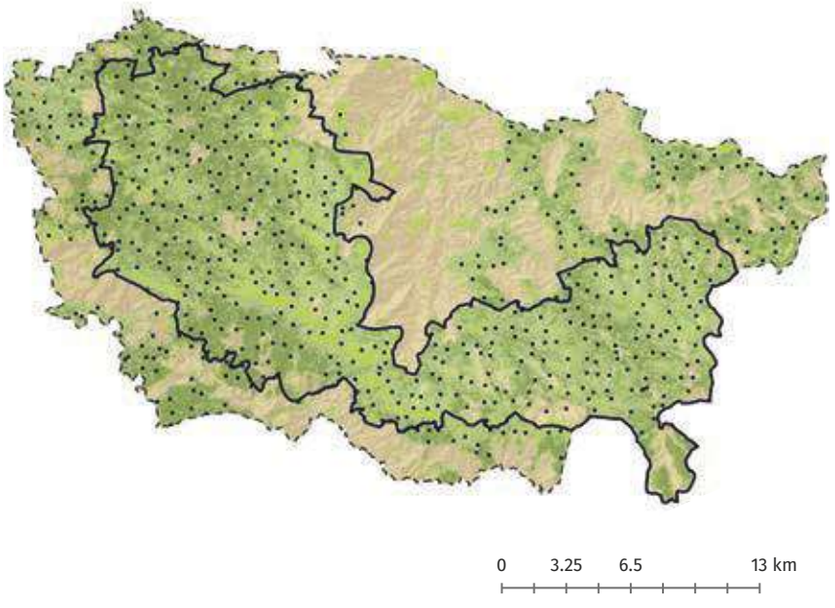


Figure 10.46
Distribution and relative spatial abundance of grey wolf in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

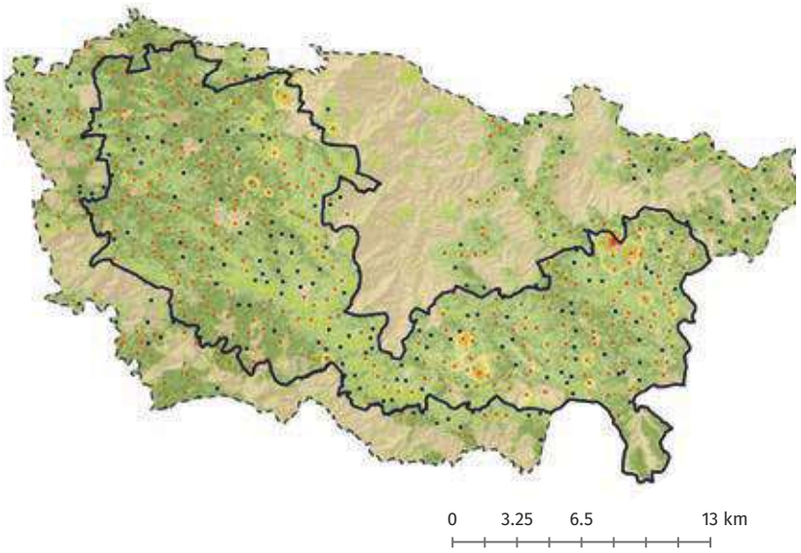


Figure 10.47

Distribution and relative spatial abundance of jungle cat in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was photo-captured across the tiger reserve with higher concentration of photo-captures in the Halon valley, and fewer photo-captures in the Banjar valley in woodland and meadows in the periphery of the tiger reserve.

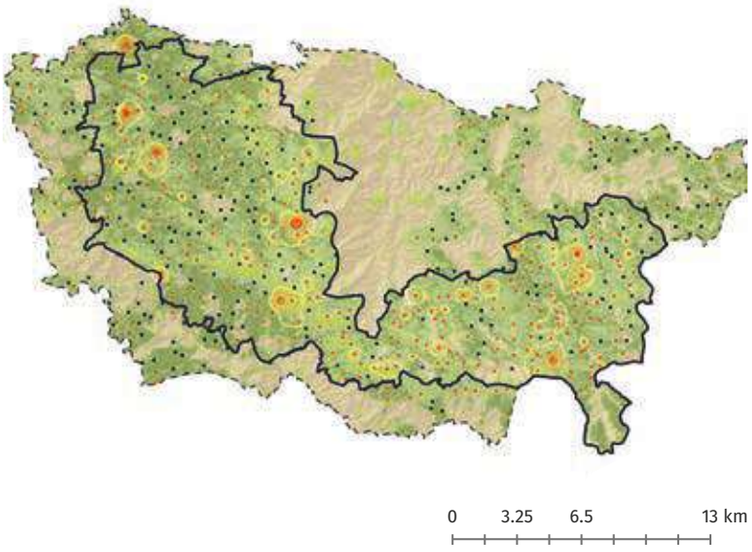


Figure 10.48

Distribution and relative spatial abundance of leopard in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was distributed throughout the tiger reserve with higher concentration of photo-captures in the core zone in woodland and meadow.

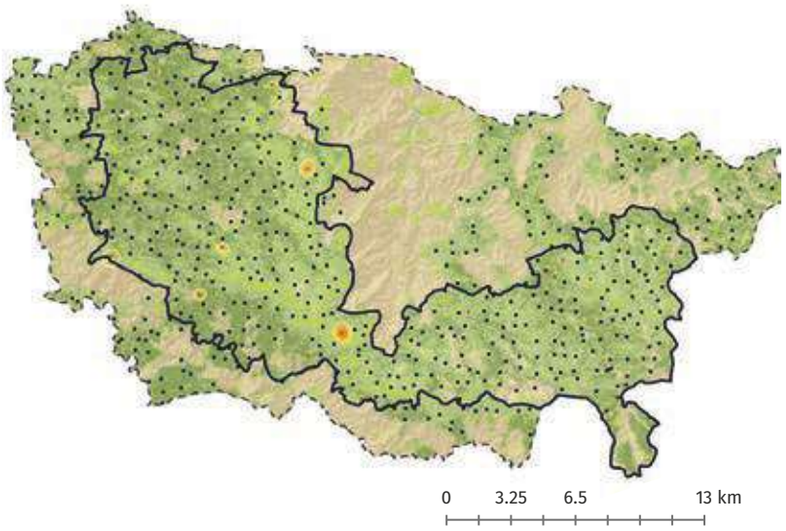


Figure 10.49

Distribution and relative spatial abundance of rusty-spotted cat in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Rusty-spotted cat had an erratic distribution in the tiger reserve with photo-captures mostly in sal and miscellaneous forest in the Banjar valley.

Sloth bear was spread across the tiger reserve with higher concentration of photo-captures in the core zone in woodland and meadows.

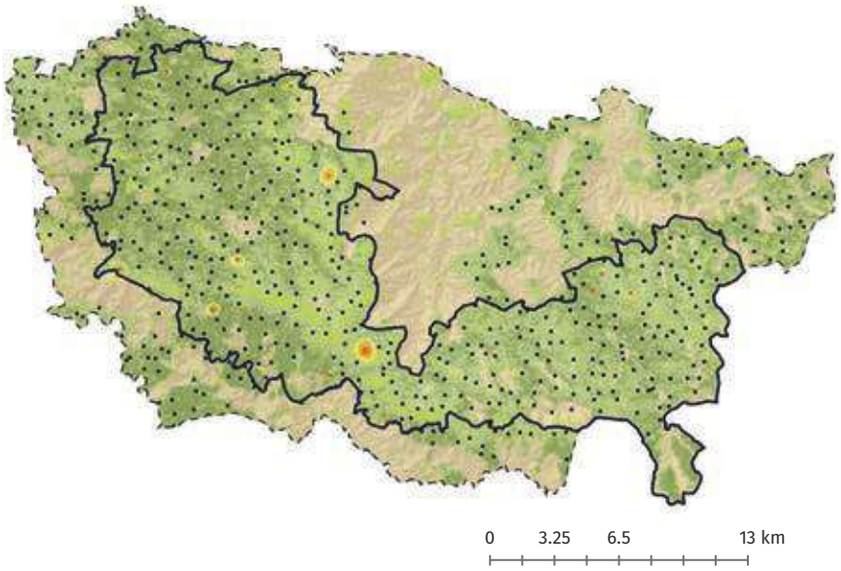


Figure 10.50

Distribution and relative spatial abundance of sloth bear in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Wild dog was spread across the tiger reserve with higher concentration of photo-captures in Banjar valley in woodland. However, few captures were also found in the buffer zone in Khatiya and Khapa range.

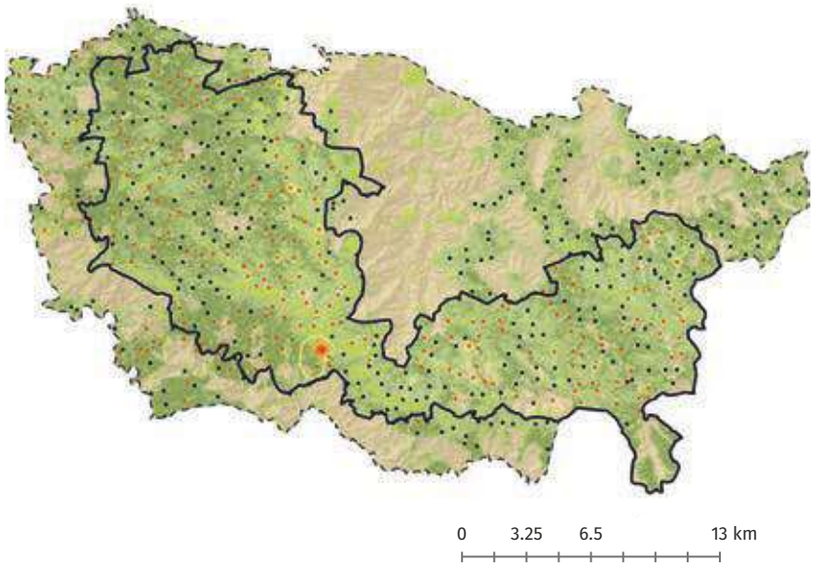


Figure 10.51

Distribution and relative spatial abundance of wild dog in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Four-horned antelope was distributed throughout the tiger reserve with higher concentration of photo-captures in the core zone of Halon valley. In the Banjar valley it was captured mostly in the buffer zone.

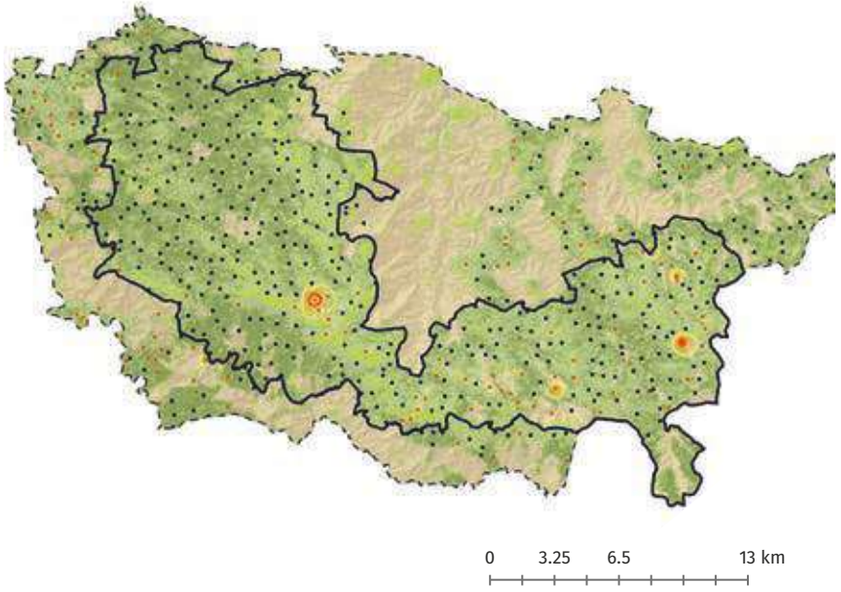


Figure 10.52

Distribution and relative spatial abundance of four-horned antelope in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

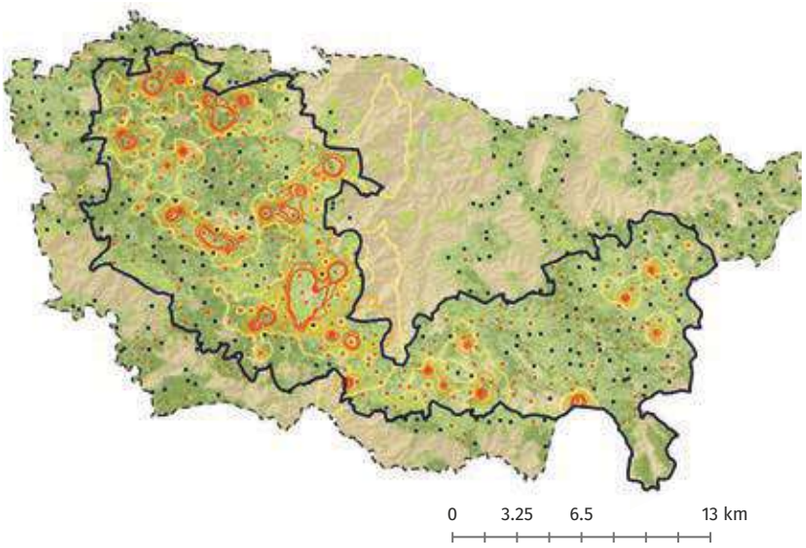


Figure 10.53

Distribution and relative spatial abundance of gaur in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Gaur was distributed throughout the tiger reserve with relatively higher concentration of photo-captures in the core zone of Banjar valley, while, fewer photo-captures were also found in the Halon valley in woodland and meadows.

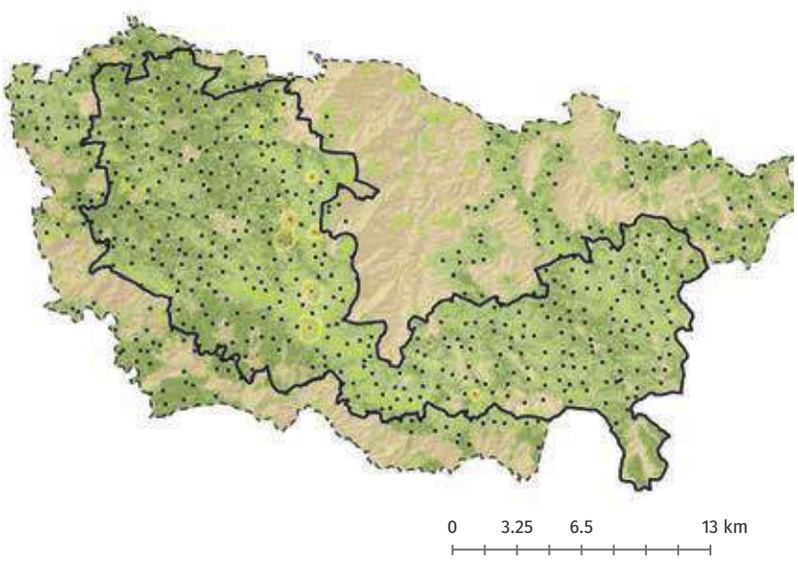


Figure 10.54

Distribution and relative spatial abundance of mouse deer in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Mouse deer was only photo captured in the core zone of tiger reserve with higher concentration of photo-captures in Banjar valley in miscellaneous forest.

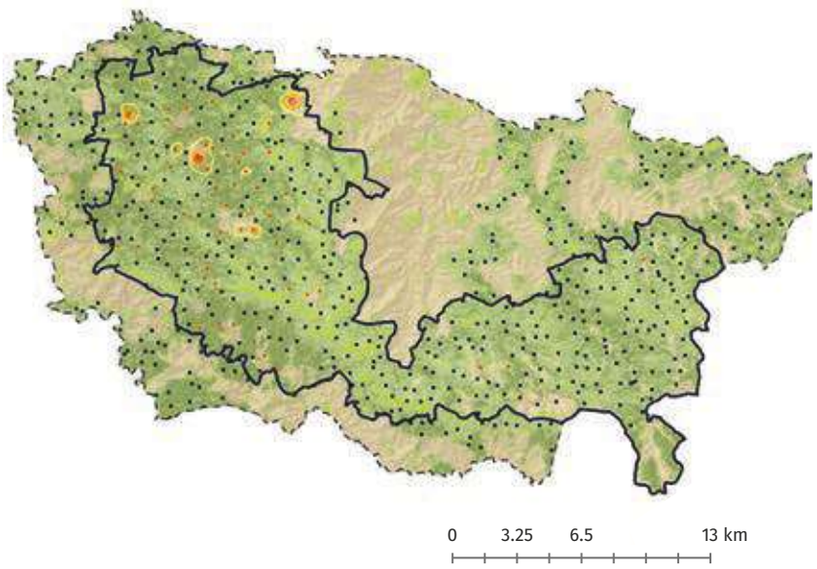


Figure 10.55

Distribution and relative spatial abundance of swamp deer in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Swamp deer was mostly distributed in the core zone of Banjar valley with higher concentration of photo-captures in grassland.

Smooth coated otter had a very restricted distribution in the tiger reserve and was mainly photocaptured in Kisli range. However, few captures were also obtained from Bhaisanghat range.

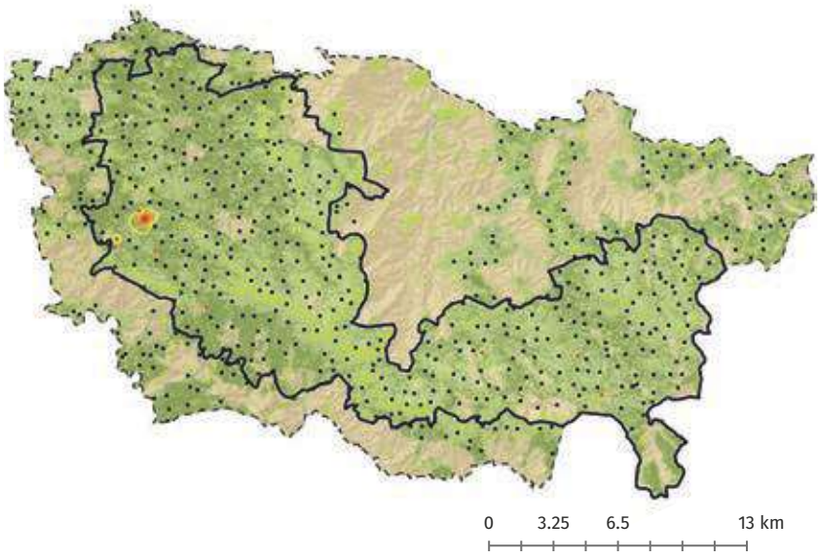


Figure 10.56

Distribution and relative spatial abundance of smooth coated otter in Kanha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Relative Abundance of all Photocaptured Species in Kanha Tiger Reserve

A total of 31 wild species of ungulates, carnivores, primates, and birds were photo-captured in Kanha Tiger Reserve. Chital followed by Indian hare were the most common species, whereas, honey badger and grey wolf followed by Indian pangolin were the rarest mammalian camera trapped species. (Table 10.15).

Table 10.15

Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Kanha Tiger Reserve, 2018.

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Barking deer	12.97	8
Chital	43.46	2
Common grey mongoose	0.24	414
Common palm civet	4.17	24
Domestic dog	3.23	31
Four-horned antelope	1.38	72
Gaur	8.12	12
Golden jackal	16.04	6
Grey wolf	0.03	3515
Hanuman langur	20.48	5
Honey badger	0.01	10546
Indian fox	0.18	570
Indian hare	25.25	4
Indian pangolin	0.03	3013
Indian porcupine	5.87	17
Jungle cat	10.82	9
Leopard	4.32	23
Livestock	8.42	12
Mouse deer	0.12	844
Nilgai	0.8	125
Peafowl	5.46	18
Red jungle fowl	0.36	278
Rhesus macaque	1.1	91
Ruddy mongoose	1.61	62
Rusty-spotted cat	0.11	917
Sambar	17.14	6

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Sloth bear	2.67	37
Small Indian civet	2.82	36
Smooth-coated otter	0.08	1241
Swamp deer	0.7	143
Tiger	9.23	11
Wild dog	2.88	35
Wild pig	12.47	8

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DISCUSSION

Kanha tiger reserve has one of the highest diverse prey base as well one of the highest ungulate biomass density in the tiger landscapes of the world. It is a source population for many species and helps to populate neighbouring sink habitats such as Bhoramdeo wildlife sanctuary and neighbouring territorial forest divisions also it is the one main source population for tigers in the Achanakmar-Kanha-Pench meta population. Evidence of tiger dispersal from Kanha to Bandhavgarh, Kanha to Navegaon Nagzira, and Kanha to Satpuda are documented by camera trap images from the all India tiger estimation exercise.

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PANNA TIGER RESERVE

INTRODUCTION

Panna Tiger Reserve (PTR) is situated in the Vindhyan mountain range in northern Madhya Pradesh and spans across the Panna and Chhatarpur districts. The geography of PTR is broadly divided into the upper Talgaon plateau (Panna Range), the middle Hinnauta plateau (Hinnauta Range) and the Ken river valley (Mandla and Chandranagar Ranges). PTR lies within the biogeographic zone of 6A Deccan Peninsula central- Highlands (Rodgers et al. 2002), between 79^0 45' to 80^0 09' E longitudes and 24^0 27' to 24^0 46' N latitudes. It comprises of a core area of 542.66 km^2 and a buffer area of 1002.42 km^2, with the total area of the reserve being 1545.08 km^2. The landscape is characterized by extensive plateaus and gorges.

Vegetation type of the reserve comprises of southern tropical dry deciduous teak mixed forest, northern tropical dry deciduous mixed forest, dry deciduous scrub forest, anogeissus pendula forest, Boswellia forest, and dry bamboo brakes (Champion and Seth 1968). This area is the northernmost tip of the natural teak (*Tectona grandis*) forests and the easternmost tip of the natural kardhai (*Anogeissus pendula*) forest. Other than tiger (*Panthera tigris*), Panna Tiger Reserve has a wide array of faunal species including leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*), wild dog (*Cuon alpinus*), jungle cat (*Felis chaus*), golden jackal (*Canis aureus*), sambar (*Rusa unicolor*), chital (*Axis axis*), nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella bennettii*), four-horned antelope (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), hanuman langur (*Semnopithecus entellus*), and numerous bird species. The tiger population of Panna had been successfully reintroduced after the local extinction due to poaching (WII 2009). Besides its rich wildlife values, the reserve is dotted with ancient rock paintings, which are believed to be around two thousand years old.

Panna Tiger Reserve along with surrounding territorial forest division of north Panna and south Panna is the only large chunk of wildlife habitat remaining in the fragmented forested landscape of north Madhya Pradesh. It represents one of the important tiger habitats of central Indian highlands along with its associated species.

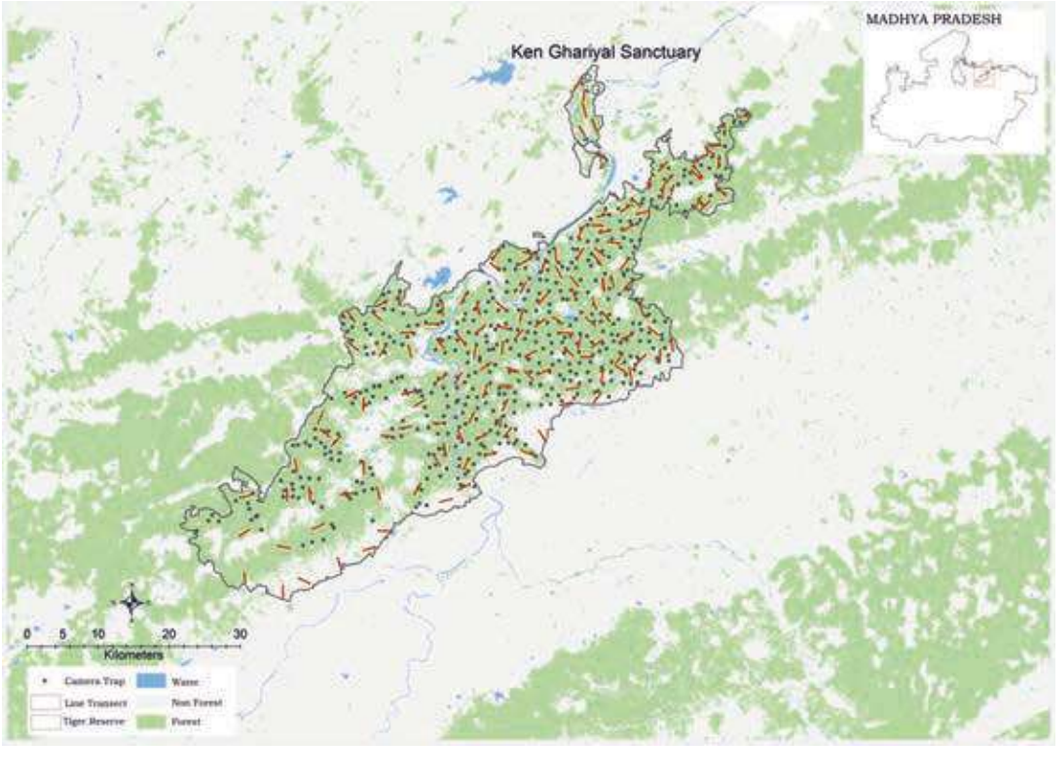


Figure 10.57
Camera trap and line transect layout in Panna Tiger Reserve, 2018.

RESULT

Tiger Density Estimates

A total of 332 detections of tigers were obtained during the sampling period from which 25 adult individual tigers were identified and density was estimated as of 1.41 (SE 0.28) tigers per km^2. The detection corrected sex ratio was female biased (Table 10.16).

Table 10.16

Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Panna Tiger Reserve, 2018.

Variables	Estimates
Model Mask (km^2)	2222.8
Camera points	531
Trap nights (effort)	15900
Unique tigers captured	25
Model	g_0 (.) σ (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.41 (0.28)
σ Female (SE) km	2.39 (0.09)
σ Male (SE) km	3.82 (0.14)
g_0 (SE)	0.020 (0.001)
Pmix Female (SE)	0.67 (0.09)
Pmix Male (SE)	0.33 (0.09)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
σ (Sigma): Spatial scale of detection function,
g_0: Magnitude (intercept) of detection function
Pmix: Detection corrected estimate of proportion of males and females

Prey Density Estimates

A total of 428 line transects were walked in Panna Tiger Reserve which amounted to a walk effort of 837.22 km. Chital was found to be the most abundant ungulate with a density of 13.78 (SE 2.77) per km^2 followed by nilgai with a density of 11.96 (SE 1.10) (Table 10.17).

Table 10.17

Model statistics and parameter estimates of line transect (n= 428, Total effort 837.22 km) based distance sampling for prey species in Panna Tiger Reserve, 2018.

Species	Effective strip-width (SE)	#groups detected	Mean group-size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital	40.79 (2.53)	147	6.40 (1.04)	0.52 (0.03)	0.18 (0.018)	2.15 (0.25)	13.78 (2.77)
Sambar	44.25 (3.43)	155	2.37 (0.12)	0.22 (0.02)	0.19 (0.016)	2.09 (0.25)	4.97 (0.63)
Nilgai	60.97 (2.83)	272	3.75 (0.18)	0.20 (0.01)	0.33 (0.019)	3.19 (0.25)	11.96 (1.10)
Wild Pig	43.28 (5.75)	79	5.68 (0.53)	0.24 (0.03)	0.09 (0.01)	1.09 (0.19)	6.20 (1.21)
Chinkara	50.10 (6.04)	56	1.18 (0.13)	0.44 (0.05)	0.07 (0.009)	0.67 (0.12)	1.45 (0.27)

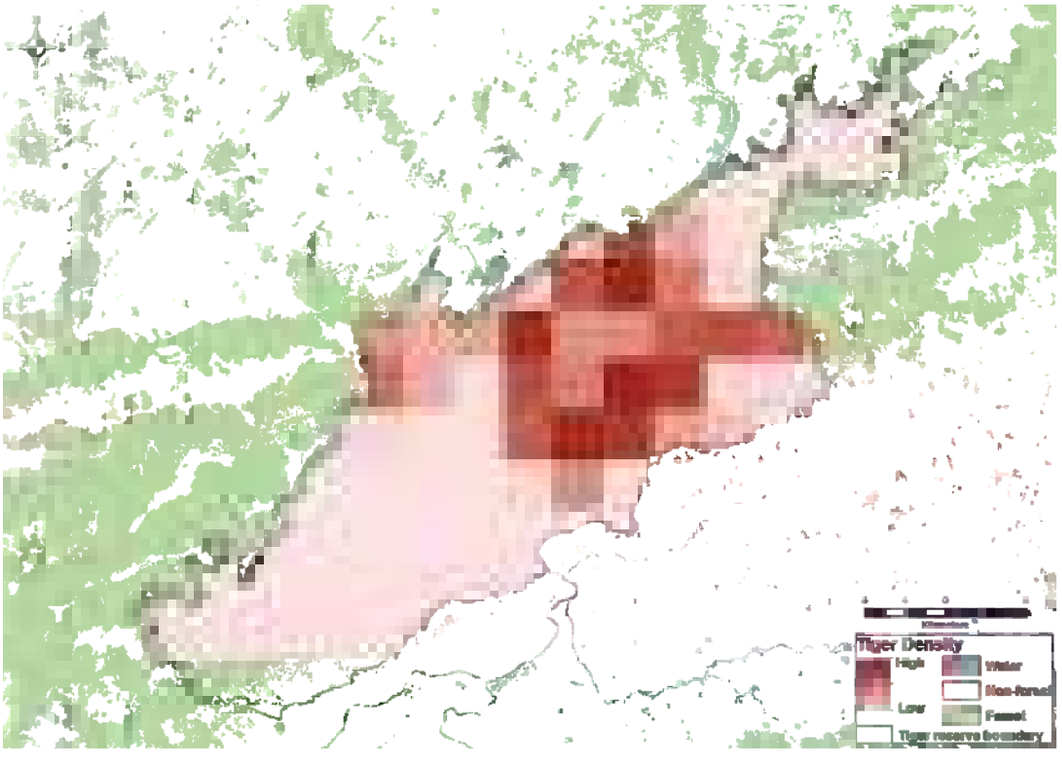


Figure 10.58
Spatial density of tigers in Panna Tiger Reserve, 2018

Panna Tiger Reserve is the best example of tiger recovery due to proactive management after reintroduction. The population is increasing within the tiger reserve, mixed forests of Hinnauta and Panna ranges had the highest density of tigers.

Distribution of Major Mammalian Species Found in Panna Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Panna Tiger Reserve.

Golden jackal was distributed throughout the tiger reserve with a concentration of photo-captures within moderately dense forests and grasslands of the core area.

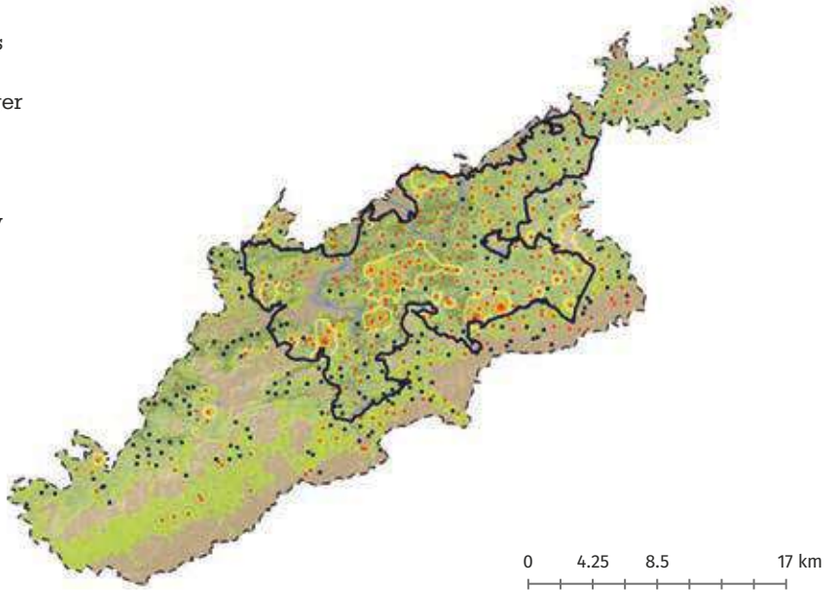


Figure 10.59
Distribution and relative spatial abundance of golden jackal in Panna Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

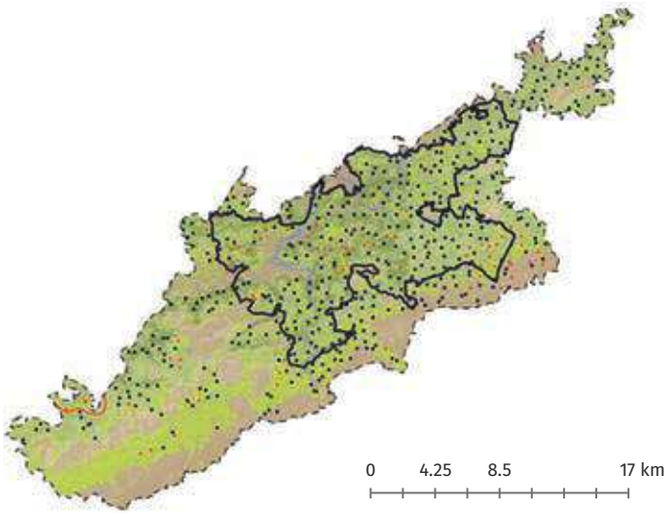


Figure 10.60

Distribution and relative spatial abundance of grey wolf in Panna Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Grey wolf showed patchy distribution within the tiger reserve with higher concentration of photo-captures within the moderately dense forest and open forest within the buffer area.

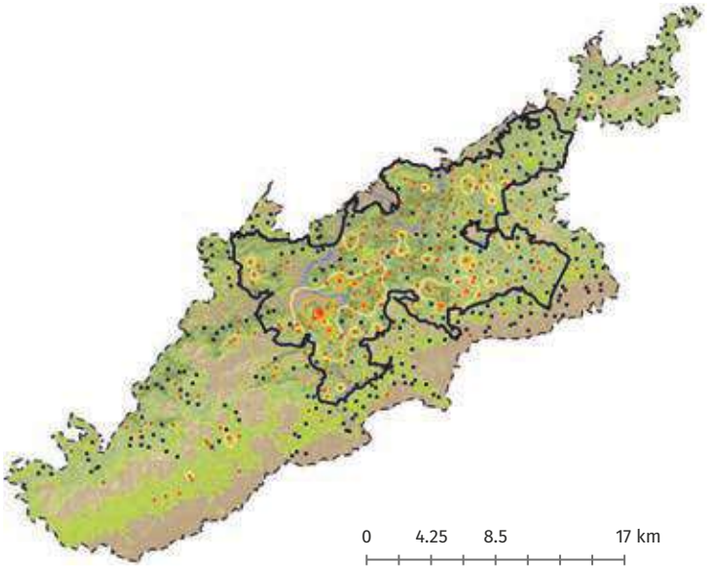


Figure 10.61

Distribution and relative spatial abundance of jungle cat in Panna Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was distributed throughout the tiger reserve. Higher concentration of photo-captures were recorded within moderately dense forests and the open forests of the core zone. Apart from this, few captures were also found in the very dense forests.

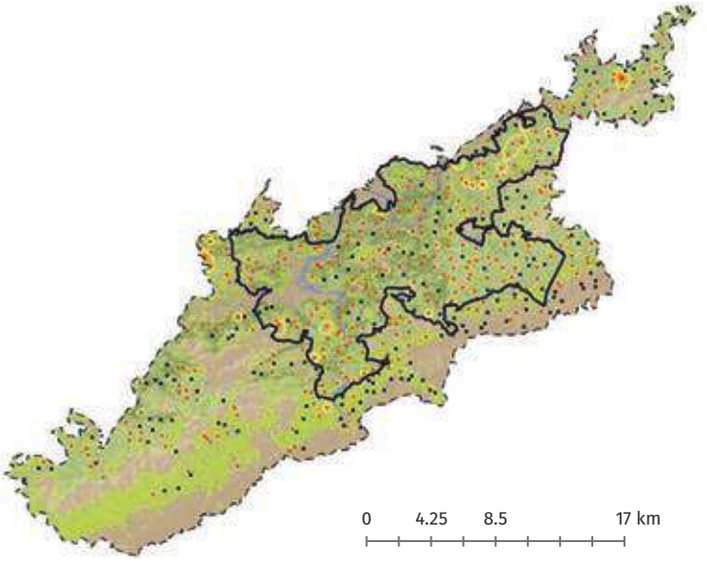


Figure 10.62

Distribution and relative spatial abundance of leopard in Panna Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was distributed throughout the tiger reserve with a higher concentration of photo-captures in the core area of the reserve in very dense and moderately dense forests.

Rusty-spotted cat had very few captures in the tiger reserve. Higher concentration of photo-captures was found at the periphery of the core as well as buffer zone in moderately dense forests and open forests.

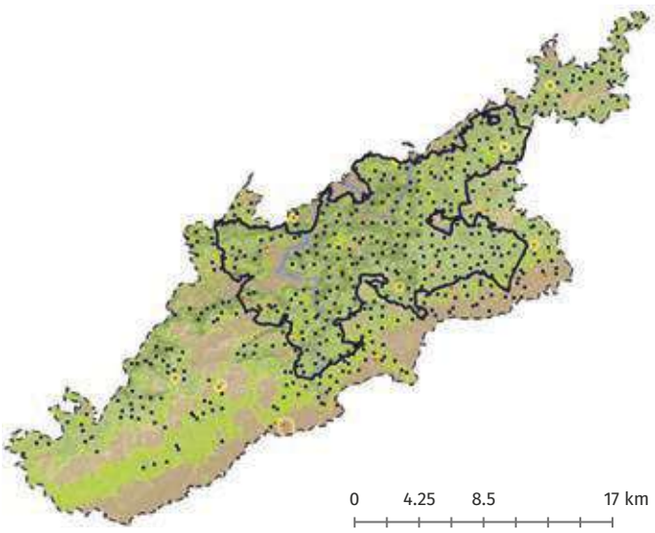


Figure 10.63

Distribution and relative spatial abundance of rusty-spotted cat in Panna Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear was distributed throughout the tiger reserve with higher concentration of photo-captures towards the north and north-western boundary of the core and in moderately dense forests of the buffer zone.

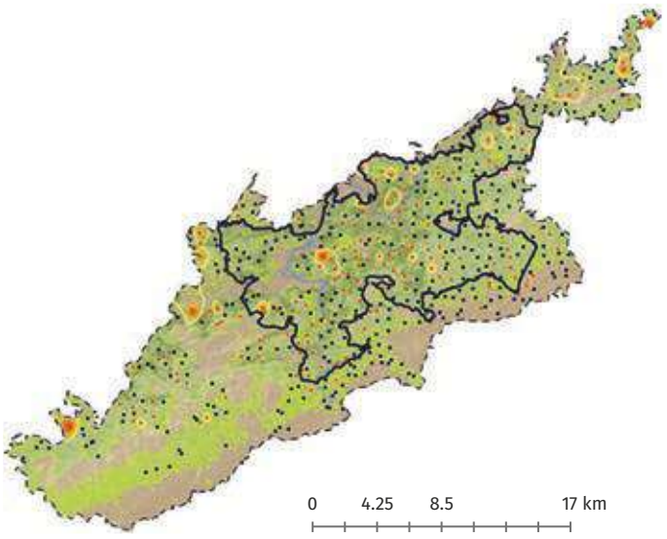


Figure 10.64

Distribution and relative spatial abundance of sloth bear in Panna Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Wild dog was mainly distributed in the core zone with very few captures in the buffer area. Higher concentration of photo-captures were obtained along the Ken river in moderately dense forests.

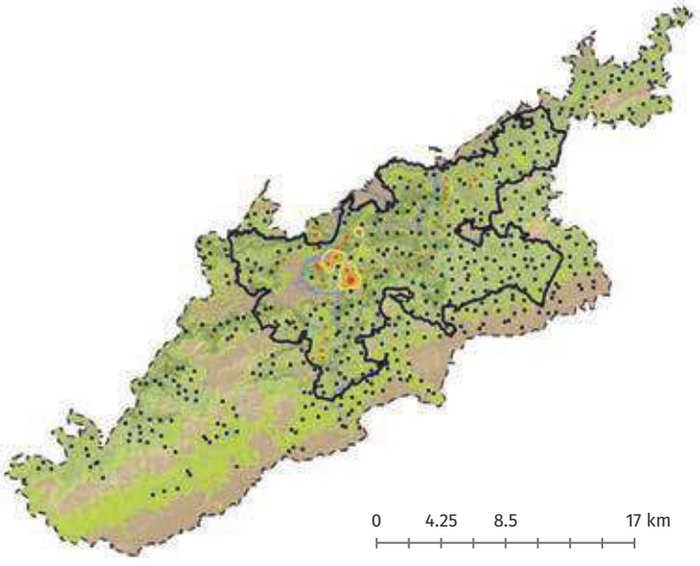


Figure 10.65

Distribution and relative spatial abundance of wild dog in Panna Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

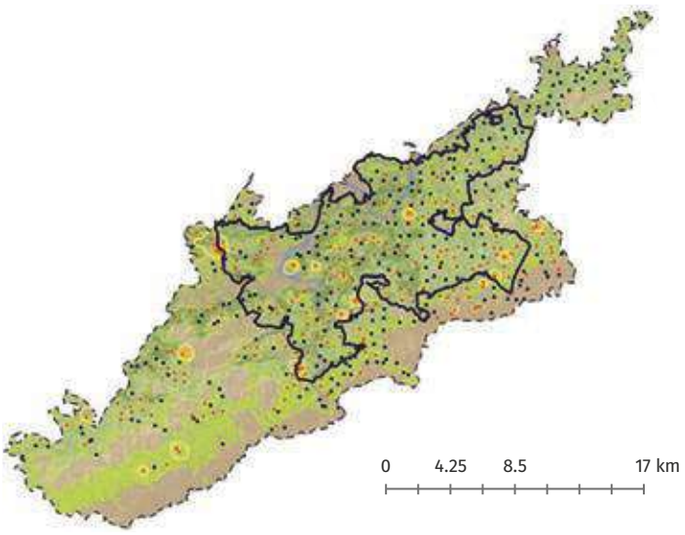


Figure 10.66

Distribution and relative spatial abundance of four-horned antelope in Panna Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Four-horned antelope was distributed throughout the tiger reserve with higher concentration of photo-captures at the boundary of core zone, in the grassland and moderately dense forest.

Table 10.18

Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Panna Tiger Reserve, 2018.

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Asiatic wild cat	1.33	75
Barking deer	0.04	2271
Chinkara	3.87	26
Chital	20.89	5
Common grey mongoose	0.94	107
Common palm civet	4.17	24
Domestic Dog	4.92	20
Four-horned antelope	3.45	29
Golden jackal	18.31	5
Grey wolf	0.8	125
Hanuman langur	11.72	9
Honey badger	0.64	156
Indian fox	2.76	36
Indian hare	23.72	4
Indian pangolin	0.07	1445
Indian porcupine	4.32	23
Jungle cat	6.2	16
Leopard	7.5	13
Lesser adjutant stork	0.01	15900
Livestock	46.61	2
Monitor lizard	0.01	15900
Nilgai	31.84	3

Relative Abundance of all Photocaptured Species in Panna Tiger Reserve

A total of 32 wild species of ungulates, carnivores, primates, birds and reptiles were photo-captured in Panna Tiger Reserve. Nilgai and sambar were the most common species, whereas barking deer and Indian pangolin were the rarest mammals photo-captured. Apart from this, lesser adjutant stork, red-headed vulture and monitor lizard were also the rarest photo-captured species in the camera traps. (Table 10.18).

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Peafowl	6.92	14
Red-headed vulture	0.01	7950
Rhesus macaque	2	50
Ruddy mongoose	0.69	145
Rusty-spotted cat	0.2	497
Sambar	26.58	4
Sloth bear	2.35	43
Small Indian civet	5.79	17
Striped hyena	17.99	6
Tiger	2.25	44
Wild dog	0.47	212
Wild pig	17.69	6

DISCUSSION

The tiger population of Panna Tiger Reserve has shown a good recovery after reintroduction in 2009. The pro-active management by forest department had played a major role in the recovery of tigers. The major threat to Panna is due to upcoming Ken Betwa river linking where diversion of around 500 km^2 of forests is proposed from Panna tiger reserve.

PENCH TIGER RESERVE, MADHYA PRADESH

INTRODUCTION

Pench Tiger Reserve and the surrounding area is the forest that was referred to in Rudyard Kipling's famous "The Jungle Book" and is popularly known as Mowgli land. Nestled in the southern slope of the Satpura-Maikal landscape in the biogeographic province (6E) Deccan peninsular central highlands (Rodgers and Panwar 1988), Pench Tiger Reserve derived its name from the Pench river, which originates from Mahadeo hills and flows from north to south, through reserve covering a length of 24 km. The reserve is located in Seoni and Chhindwara district in southern Madhya Pradesh and spreads across 79°08' to 79°31' E longitudes and 21°38' to 21°53' N latitudes. The total area of the reserve is 1179.632 km^2 that comprises of Pench Priyadarshini National park (292.86 km^2) and Pench Mowgli Wildlife Sanctuary (118.47 km^2) as the core zone and an additional buffer zone with an area of 768.302 km^2. The reserve belongs to the Indo-Malayan phytogeographical realm while zoo-geographically, it is a member of the Oriental region.

The major forest type of the reserve is classified as southern Indian tropical moist deciduous (3B/C1c), southern tropical dry deciduous (5A/C1b), and southern dry mixed deciduous forest (5A/C3) (Champion and Seth 1968). Pench Tiger Reserve is an ideal representative of teak (*Tectona grandis*) dominated forest, overlapping with bamboo and miscellaneous species with considerable shrub cover and open grassy patches. This high habitat heterogeneity supports a large number of species such as gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), wild pig (*Sus scrofa*), barking deer (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*), chinkara (*Gazella bennettii*), tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), wild dog (*Cuon alpinus*), grey wolf (*Canis lupus*), striped hyena (*Hyaena hyaena*), and golden jackal (*Canis aureus*).

Pench Tiger Reserve of Madhya Pradesh is contiguous with Pench Tiger Reserve of Maharashtra, and is also connected to Kanha Tiger Reserve through the forests in Seoni, Balaghat and Mandla districts. Along the eastern boundary of the reserve, around 10 km stretch of the national highway, NH7 connecting Nagpur and Jabalpur acts as a barrier for habitat connectivity with Kanha Tiger Reserve. The area of Kanha-Pench corridor spread over 16000 km^2 is one of the most crucial forest corridors in the central Indian landscape that act as a refuge for dispersing tigers and several other animals.

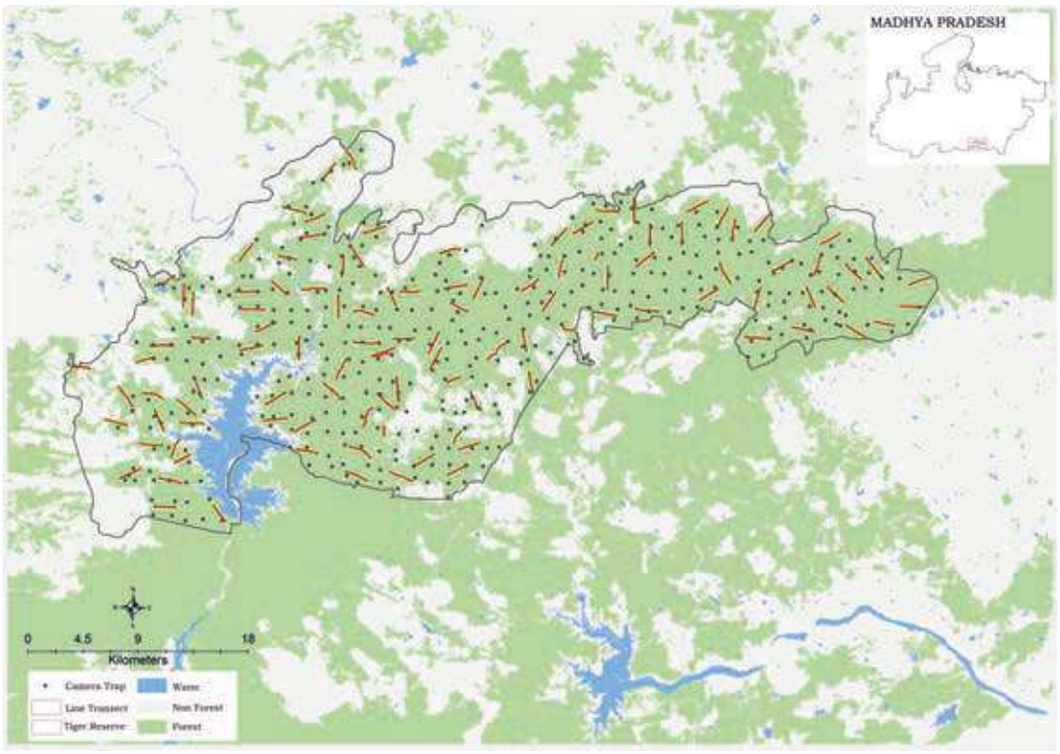


Figure 10.67
Camera trap and line transect layout in Pench Tiger Reserve, 2018.

RESULT

Tiger Density Estimates

A total of 875 detections of tigers were obtained during the sampling period from which 56 adult individual tigers were identified with and density was estimated as of 5.50 (SE 0.85) tiger per 100 km^2. The detection corrected sex ratio was female biased (Table 10.19).

Table 10.19

Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Pench Tiger Reserve, Madhya Pradesh, 2018.

Variables	Estimates
Model mask (Km^2)	1599.5
Camera points	421
Trap nights (effort)	15291
Unique tigers captured	56
Model	σ (sex) g_0 (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	5.50 (0.85)
σ Female (SE) km	1.54 (0.16)
σ Male (SE) km	4.43 (0.30)
g_0 Female (SE)	0.19 (0.07)
g_0 Male (SE)	0.21 (0.03)
Pmix Female (SE)	0.73 (0.05)
Pmix Male (SE)	0.27 (0.05)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Prey Density Estimates

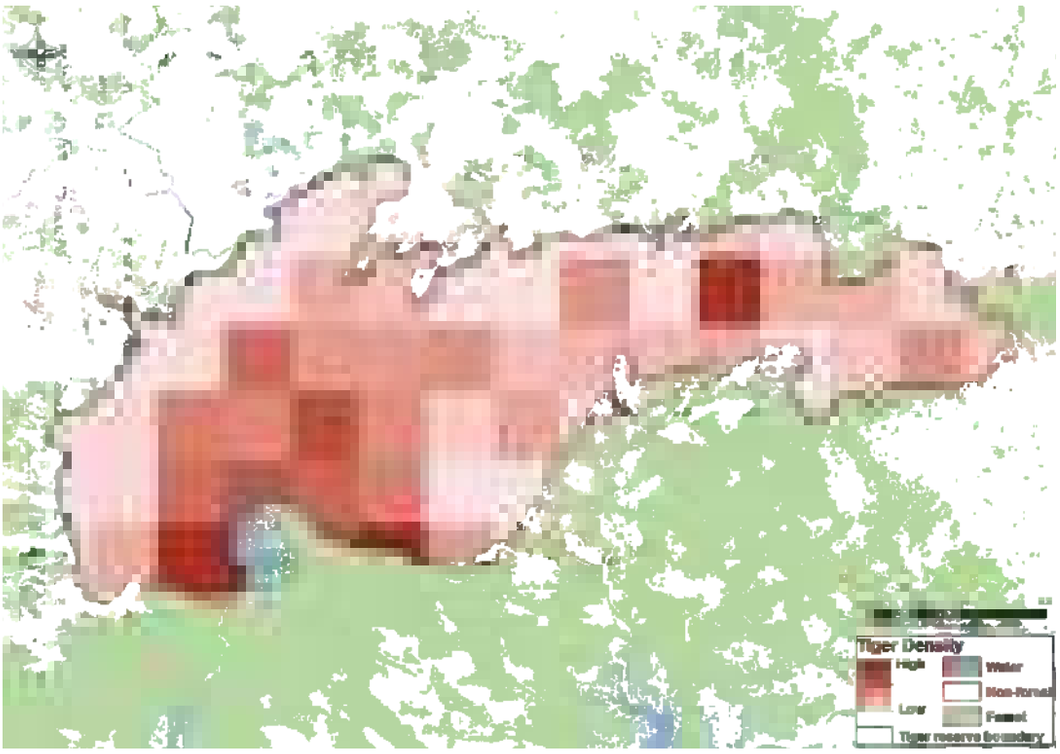
A total of 324 line transects were walked in Pench Tiger Reserve with a cumulative effort of 624.41 km. Chital was found to be the most abundant ungulate with a density of 65.75 (SE 8.35) followed by wild pig 12.34 (SE 2.30) per km^2 (Table 10.20).

Table 10.20

Model statistics and parameter estimates of line transect (n= 324, Total effort 626.41 km) based distance sampling for prey species in Pench Tiger Reserve, Madhya Pradesh, 2018.

Species	Effective strip-width (SE)	#groups detected	Mean group-size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital	50.83 (2.26)	430	9.74 (0.74)	0.18 (0.01)	0.69 (0.06)	6.75 (0.69)	65.75 (8.35)
Sambar	45.21 (3.11)	185	2.40 (0.11)	0.55 (0.04)	0.29 (0.02)	3.21 (0.36)	7.68 (0.92)
Nilgai	51.66 (5.60)	106	2.60 (0.16)	0.25 (0.03)	0.17 (0.01)	1.61 (0.25)	4.19 (0.69)
Wild Pig	36.45 (4.21)	82	7.00 (0.64)	0.10 (0.01)	0.13 (0.02)	1.76 (0.29)	12.34 (2.30)
Gaur	48.59 (5.18)	49	5.51 (0.67)	0.52 (0.06)	0.08 (0.01)	0.79 (0.15)	4.35 (0.99)
Barking Deer	34.66 (4.21)	22	1.18 (0.08)	0.29 (0.07)	0.03 (0.007)	0.50 (0.16)	0.59 (0.19)

Figure 10.68
Spatial density of tigers in Pench Tiger Reserve (M.P.), 2018

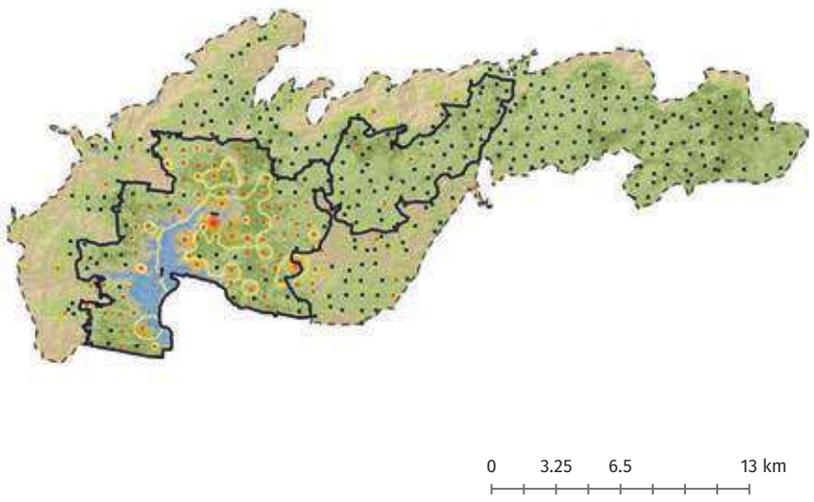


Pench Tiger Reserve (MP) has a moderately high density of tigers within the Central Indian landscape. Within the tiger reserve, the grassland and mixed forests of Karmajhiri range had the highest density of tigers.

Distribution of Major Mammalian Species Found in Pench Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Pench Tiger Reserve.

Figure 10.69
Distribution and relative spatial abundance of golden jackal in Pench Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.



Golden jackal was distributed throughout the western part of the core zone in PTR with relatively higher concentration of photo-captures on the bank of Pench river and the adjoining dam in moderately dense forest and open forest. Few capture were obtained in the eastern part of the core zone.

Grey wolf was photo-captured in the buffer zone of tiger reserve mainly in the open forest or near the villages.

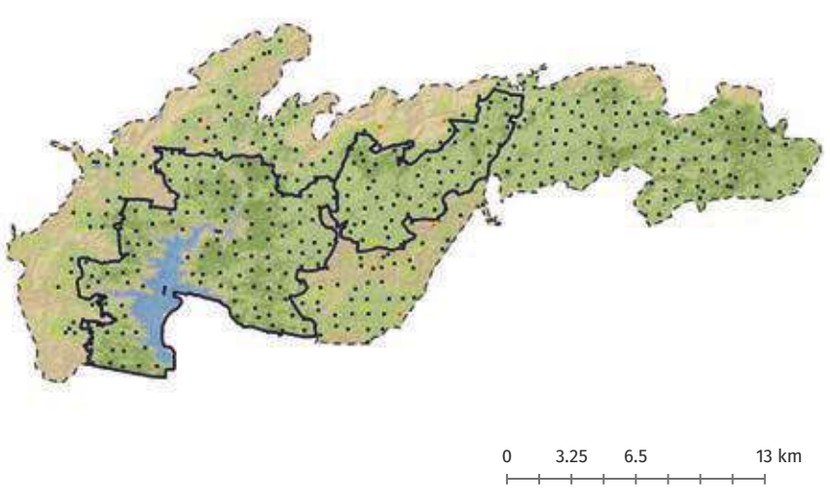


Figure 10.70

Distribution and relative spatial abundance of grey wolf in Pench Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was distributed throughout the tiger reserve with relatively higher concentration of photo-captures in the buffer zone towards eastern side of the park.

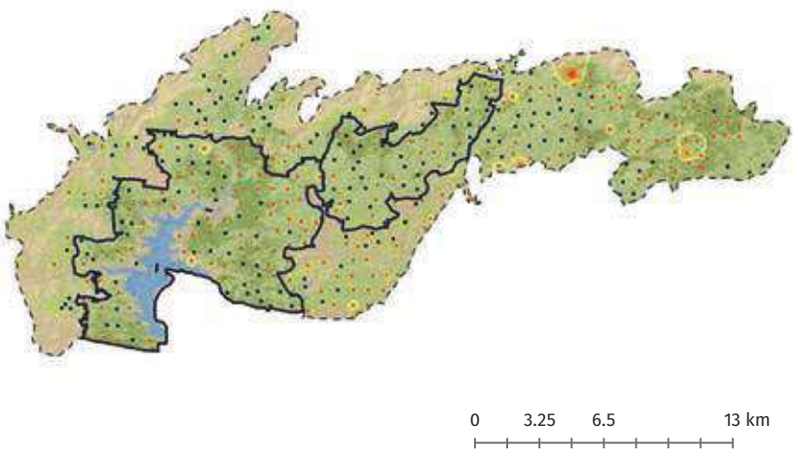


Figure 10.71

Distribution and relative spatial abundance of jungle cat in Pench Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was distributed throughout the tiger reserve with relatively higher concentration of photo-captures on the periphery of the core zone in moderately dense forests. However, few captures were also obtained towards the eastern side of the tiger reserve in the buffer zone.

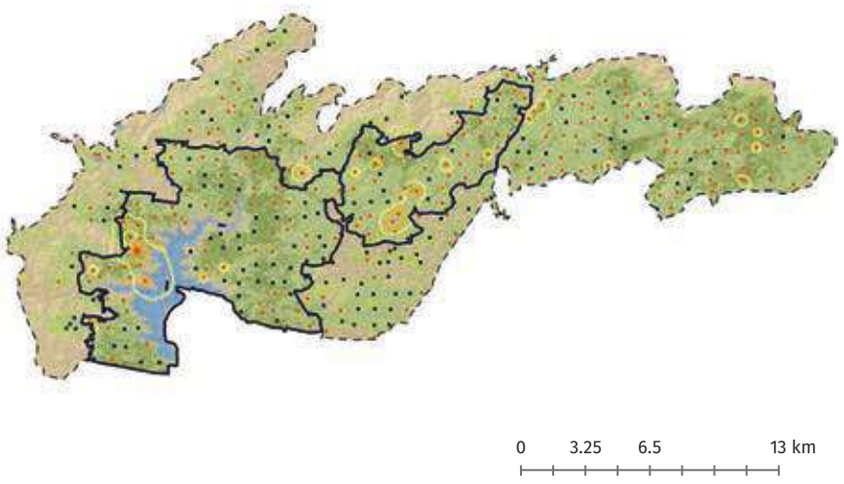


Figure 10.72

Distribution and relative spatial abundance of leopard in Pench Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

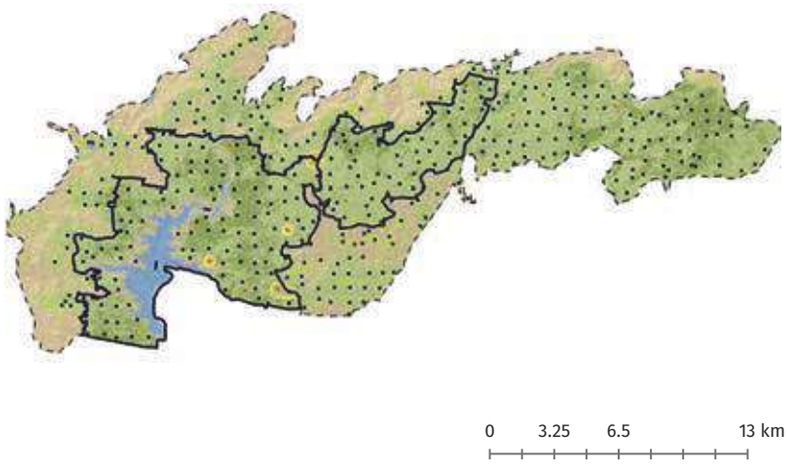


Figure 10.73

Distribution and relative spatial abundance of rusty-spotted cat in Pench Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Rusty-spotted cat had sporadic distribution and was mainly photo-captured in Karmajhiri range in moderately dense forests. Few captures were also obtained in the buffer zone of the tiger reserve.

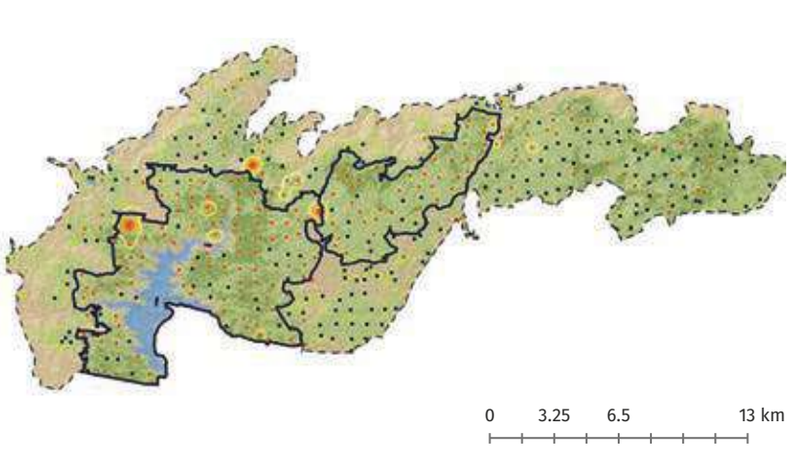


Figure 10.74

Distribution and relative spatial abundance of wild dog in Pench Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Wild dog was distributed throughout the tiger reserve with relatively higher concentration of photo-captures on the periphery of the northern boundary of the core zone.

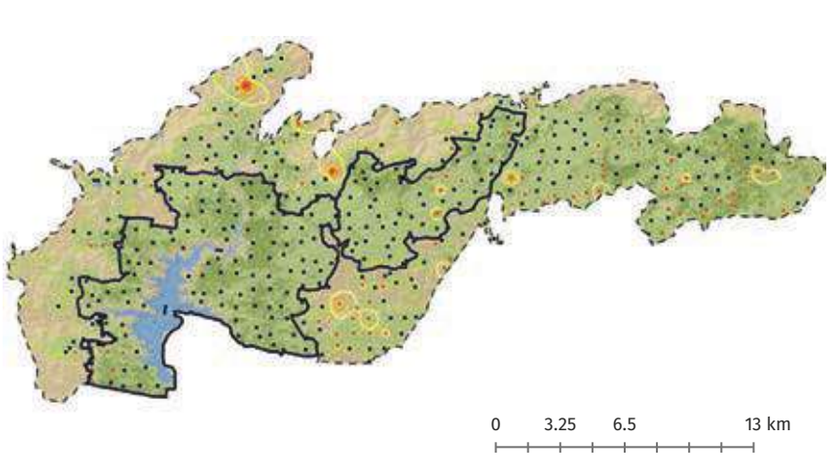


Figure 10.75

Distribution and relative spatial abundance of four-horned antelope in Pench Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Four-horned antelope was mainly distributed in the buffer zone, however, few captures were also found in Kurai range of the tiger reserve. Higher concentration of photo-captures were found on the periphery of the tiger reserve and in the buffer zone in moderately dense to open forests.

Gaur was distributed throughout the tiger reserve. Higher concentration of photo-captures were obtained in moderately dense forests.

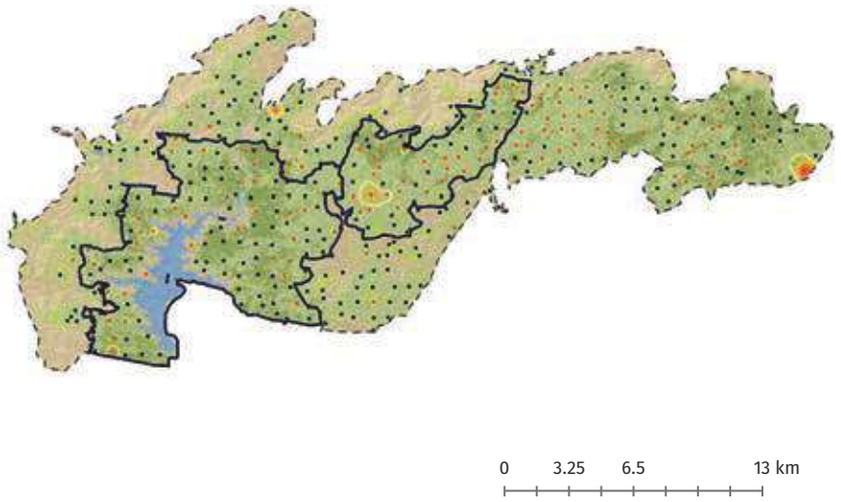


Figure 10.76

Distribution and relative spatial abundance of gaur in Pench Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Relative Abundance of all Photocaptured Species in Pench Tiger Reserve

A total of 30 wild species of ungulates, carnivores, primates and birds were photo-captured in Pench Tiger Reserve. Chital followed by Indian hare were the most common species, while blackbuck, grey wolf followed by chinkara were the rarest mammalian camera trapped species. (Table 10.21).

DISCUSSION

Pench tiger reserve has one of the highest prey biomass in the central India. The tiger population of Pench tiger reserve is connected to Kanha Tiger reserve through the forests of territorial divisions and it is contiguous to Pench tiger reserve Maharashtra. It is one of the major source populations in the Achanakmar-Kanha-Pench landscape. The tiger population at Pench tiger reserve is increasing.

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Barking deer	1.94	52
Blackbuck	0.02	5097
Chinkara	0.10	956
Chital	46.03	2
Common grey mongoose	0.69	144
Common palm civet	6.56	15
Domestic dog	6.25	16
Four-horned antelope	1.35	74
Gaur	2.44	41
Golden jackal	8.76	11
Grey wolf	0.04	2549
Hanuman langur	23.03	4
Honey badger	1.09	92
Indian fox	0.30	332
Indian hare	32.28	3
Indian pangolin	0.12	850
Indian porcupine	6.13	16
Jungle cat	7.57	13
Leopard	5.00	20
Livestock	9.36	11
Nilgai	6.78	15
Peafowl	6.39	16
Red jungle fowl	0.45	222
Rhesus macaque	4.55	22
Ruddy mongoose	2.22	45
Rusty-spotted cat	0.12	805
Sambar	15.51	6
Sloth bear	0.90	111
Small Indian civet	3.11	32
Tiger	5.65	18
Wild dog	4.70	21
Wild pig	11.37	9

Table 10.21

Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Pench Tiger Reserve, 2018.

SANJAY-DUBRI TIGER RESERVE

INTRODUCTION

Sanjay-Dubri Tiger Reserve is situated in the northeastern part of Madhya Pradesh in Siddhi district and is bordered by Guru Ghasidas National Park in Chhattisgarh. The reserve is lies between 81°28'30" to 82°14'38" E longitudes and 23°48'24" to 24°7'38" N latitudes. The tiger reserve has an area of 1674.511 km^2. This includes the Sanjay National Park and Dubri Wildlife Sanctuary as the core or critical tiger habitat zone (812.581 km^2) and the forested areas of Siddhi and Shahdol districts as the buffer zone (861.930 km^2). The topography of the park is mainly plain towards in the Dubri Wildlife Sanctuary while it is gently undulating in Sanjay National Park with an altitude range of 200-500m. Various perennial rivers flow through the reserve viz. Gopad, Banas, Mawai, Mahan, Kodmar, Umrari etc. This reserve's unique phytogeographical position, topography, and physiography are responsible for its high degree of diversity.

The forest vegetation type is mainly north Indian moist deciduous peninsular sal (3C/C2e) and north Indian dry deciduous peninsular sal (5B/C1c) (Champion and Seth 1968) with the predominance of *Shorea robusta, Terminalia elliptic, Madhuca longifolia,* and *Diospyros melanoxylon* with thick Bamboo clumps. Few patches of montane subtropical forests are also found in the southern-most part of the reserve. Tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*) and wild dog (*Cuon alpinus*) are the major predators found here while chital (*Axis axis*), sambar (*Rusa unicolor*), nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella bennettii*), barking deer (*Muntiacus vaginalis*) and wild pig (*Sus scrofa*) form the major prey species. Due to the connectivity of the sal habitat with the adjoining states of Chhattisgarh, Jharkhand, and Odisha, herds of wild elephants occasionally venture into the tiger reserve for temporary shelter.

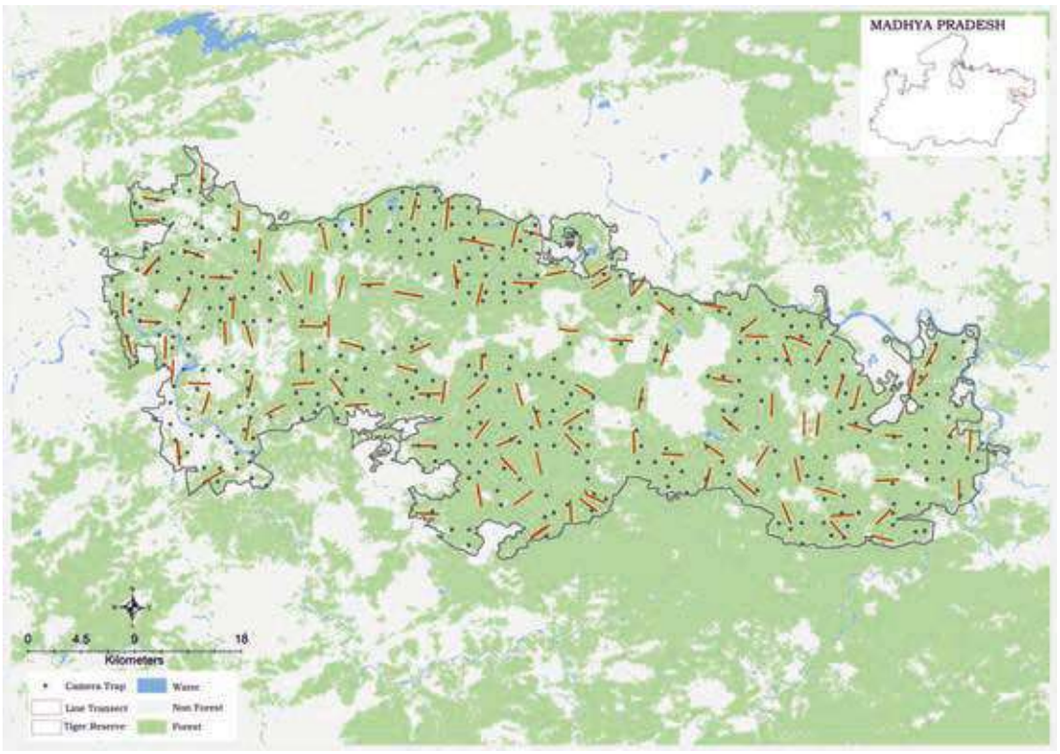


Figure 10.77
Camera trap and line transect layout in Sanjay-Dubri Tiger Reserve, 2018.

RESULT

Tiger Density Estimates

A total of 98 detections of tigers were obtained during the sampling period from which 5 adult individual tigers were identified giving a density estimate of 0.23 (SE 0.10) tiger per 100 km^2. The detection corrected sex ratio was female biased (Table 10.22).

Table 10.22

Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Sanjay-Dubri Tiger Reserve, 2018.

Variables	Estimates
Model mask (km^2)	2242.25
Camera points	375
Trap nights (effort)	13853
Unique tigers captured	5
Model	g_0 (.) σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.23 (0.10)
σ (SE) km	8.0 (0.61)
g_0 Female SE	0.004 (0.00)
Pmix Female (SE)	0.67 (0.27)
Pmix Male (SE)	0.33 (0.27)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Prey Density Estimates

A total of 375 line transects were walked in Sanjay-Dubri Tiger Reserve with a cumulative effort of 718.63 km. Nilgai was found to be the most abundant ungulates with a density of 10.08 (SE 2.96) per km^2 followed by chital with a density of 9.67 (SE 2.61) (Table 10.23). Density of sambar and barking deer were not estimated due to few observations.

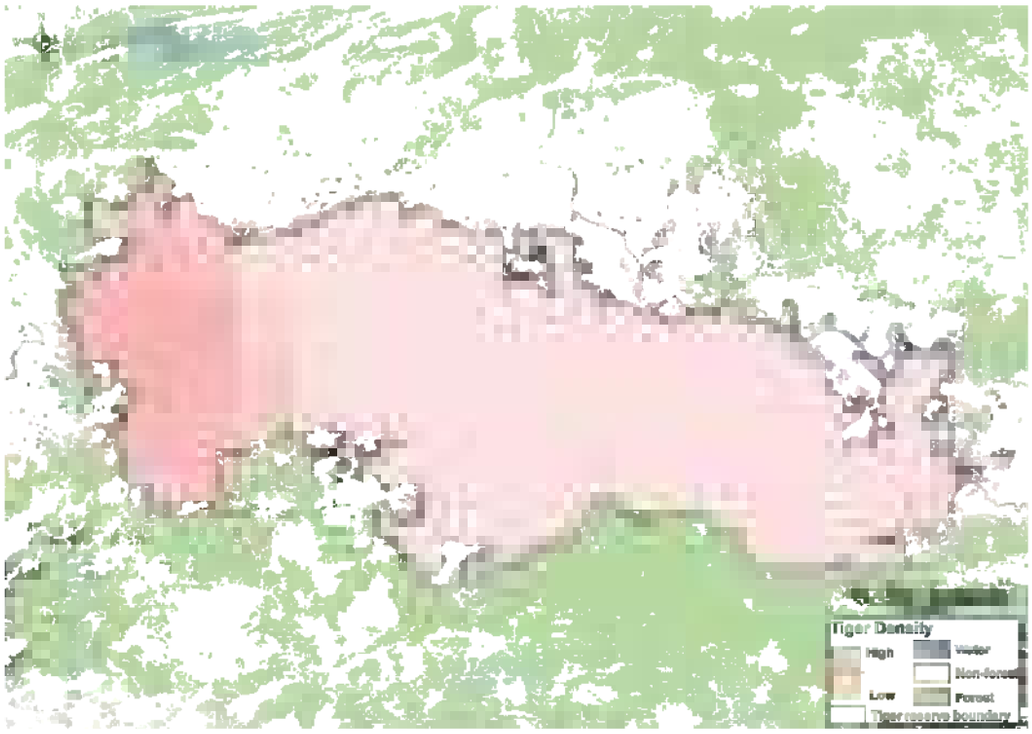
Table 10.23

Model statistics and parameter estimates of line transect (n= 375, Total effort 718.63 km) based distance sampling for prey species in Sanjay-Dubri Tiger Reserve, 2018.

Species	Effective strip-width (SE)	#groups detected	Mean group-size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital	30.51 (3.50)	45	9.42 (1.75)	0.28 (0.03)	0.06 (0.01)	1.03 (0.20)	9.67 (2.61)
Sambar	-	6	-	-	0.01 (0.003)	-	-
Nilgai	36.93 (10.01)	110	4.86 (0.35)	0.31 (0.08)	0.15 (0.013)	2.07 (0.59)	10.08 (2.96)
Wild Pig	39.67 (6.17)	37	4.89 (0.56)	0.31 (0.05)	0.05 (0.009)	0.65 (0.16)	3.17 (0.84)
Chinkara	24.58 (2.73)	78	3.10 (0.29)	0.35 (0.04)	0.11 (0.012)	2.21 (0.34)	6.85 (1.23)
Barking Deer	-	15	-	-	0.02 (0.005)	-	-

Figure 10.78

Spatial density of tigers in Sanjay-Dubri Tiger Reserve, 2018



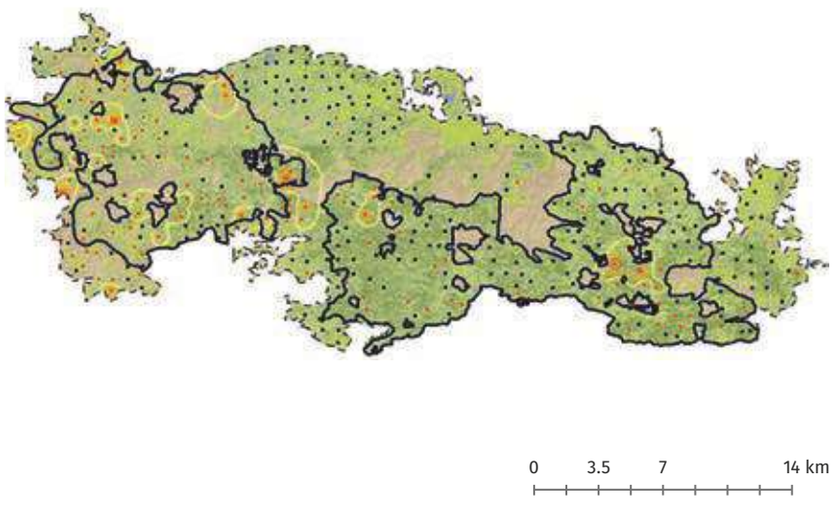
Sanjay-Dubri Tiger Reserve is one of the low-density tiger populations in the Central Indian landscape. Within the tiger reserve, the sal- mixed forests of Dubri range had the highest density of tigers.

Distribution of Major Mammalian Species Found in Sanjay Dubri Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Sanjay Dubri Tiger Reserve.

Figure 10.79

Distribution and relative spatial abundance of golden jackal in Sanjay-Dubri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.



Golden jackal was distributed throughout the tiger reserve. Higher concentration of photo-captures were obtained from the periphery of villages, in the moderately dense and very dense forests of the core area.

Grey wolf presence was recorded only in the core zone towards the western side of the tiger reserve in moderately dense forest.

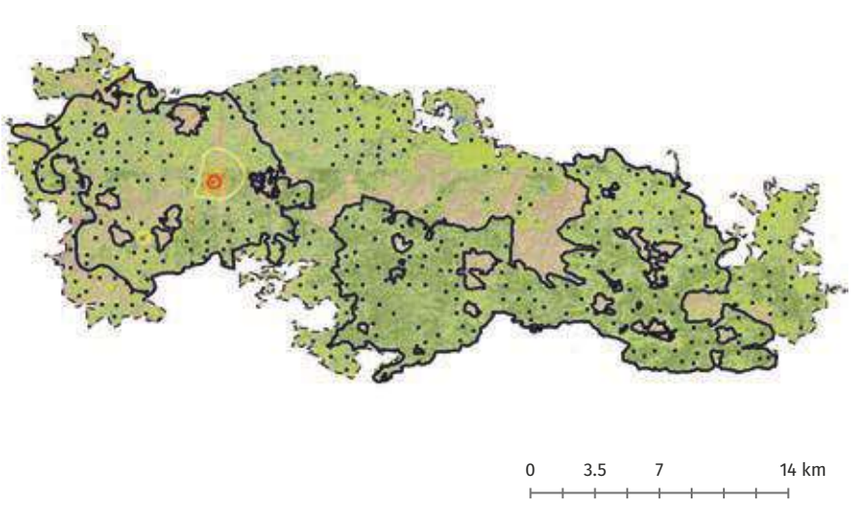


Figure 10.80

Distribution and relative spatial abundance of grey wolf in Sanjay-Dubri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Striped hyena had high photo-captures on the fringes within the core area in very dense and the moderately dense forests. However, very few to single captures were also obtained in buffer zone.

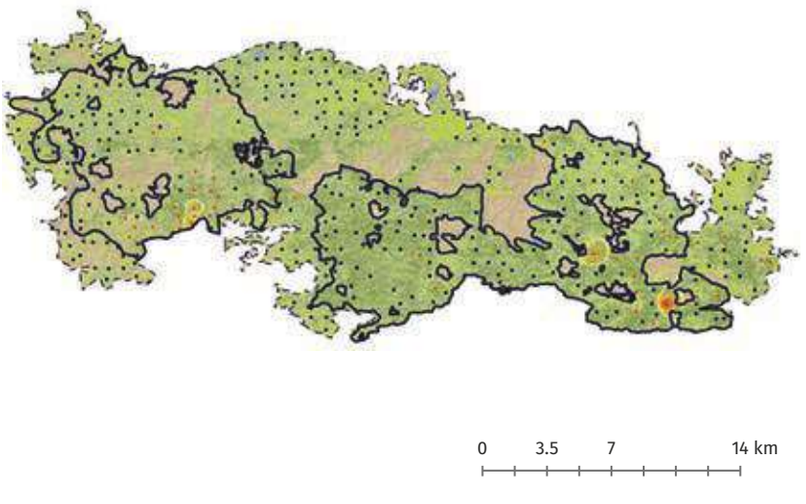


Figure 10.81

Distribution and relative spatial abundance of striped hyena in Sanjay-Dubri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was distributed throughout the tiger reserve with higher concentration of photo-captures in the core zone in moderately dense to very dense forests. However, some photo-captures were also obtained from open forests.

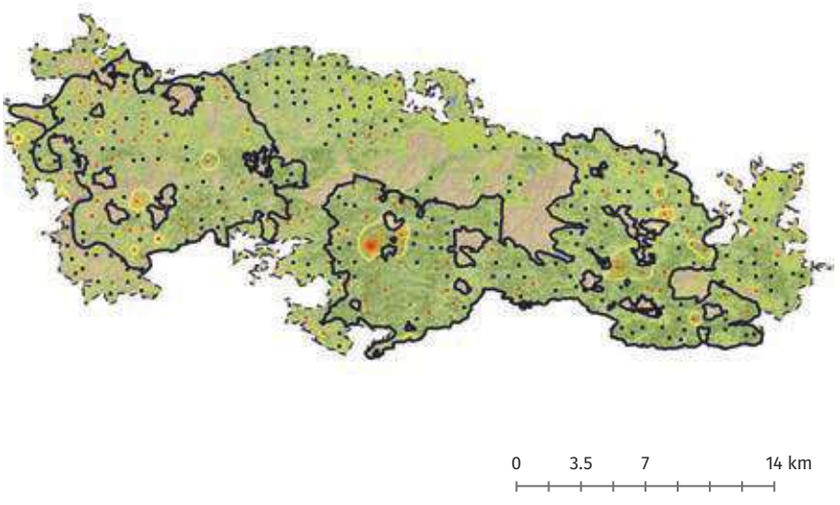


Figure 10.82

Distribution and relative spatial abundance of jungle cat in Sanjay-Dubri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

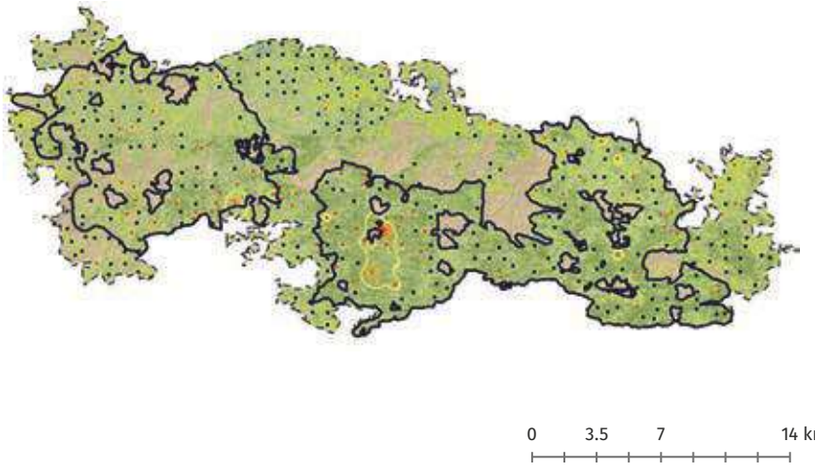


Figure 10.83

Distribution and relative spatial abundance of leopard in Sanjay-Dubri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was distributed throughout the tiger reserve with higher concentration of photo-captures near villages or from periphery of the core zone in moderately dense and very dense forests.

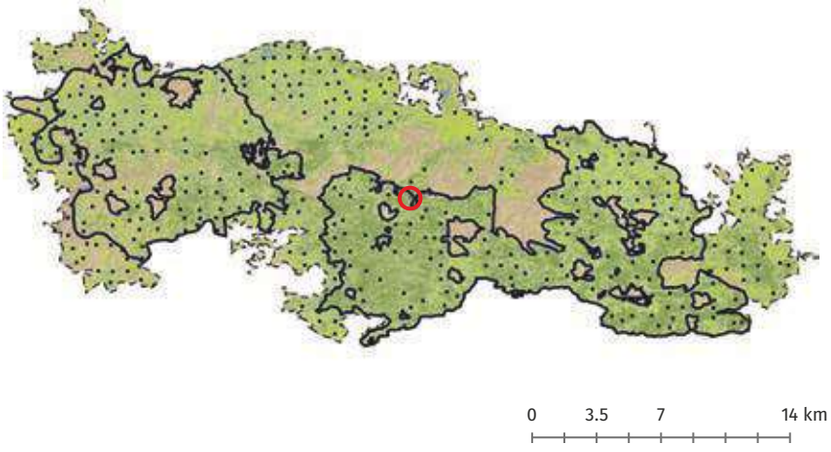


Figure 10.84

Distribution and relative spatial abundance of rusty-spotted cat in Sanjay-Dubri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Rusty-spotted cat had a single capture in the northern boundary of Pondi range in the moderately dense forest.

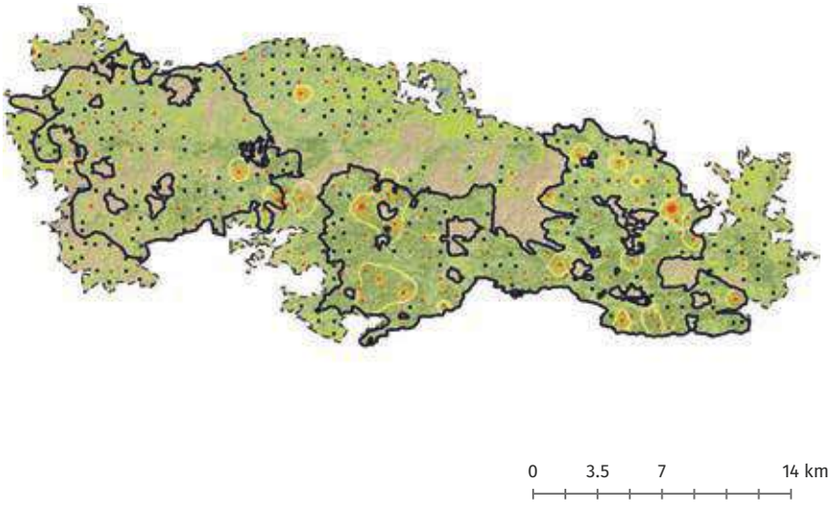


Figure 10.85

Distribution and relative spatial abundance of sloth bear in Sanjay-Dubri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear was distributed throughout the tiger reserve with higher concentration of photo-capture towards the central and eastern side of the park in the core area. Though most of the captures were in moderately dense and very dense forests, few captures were also obtained from open forest near the village.

Wild dogs were captured only in the western side of tiger reserve in the Dubri range in moderately dense forests.

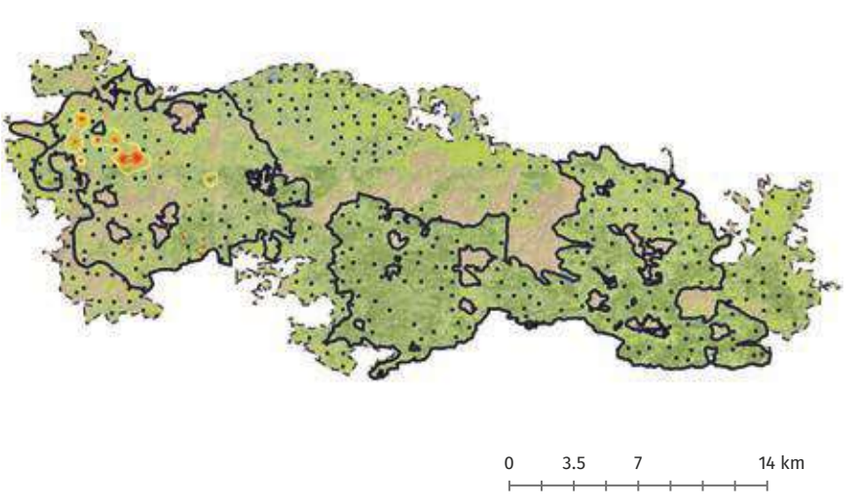


Figure 10.86
Distribution and relative spatial abundance of wild dog in Sanjay-Dubri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Four-horned antelope was distributed throughout the tiger reserve with higher concentration of photo-captures in the western side of the park in Dubri range from open and moderately dense forests.

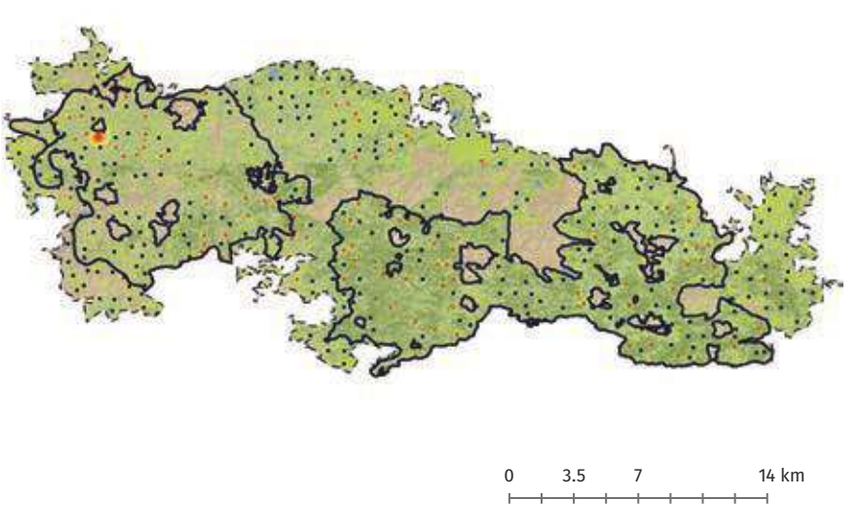


Figure 10.87
Distribution and relative spatial abundance of four-horned antelope in Sanjay-Dubri Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Relative Abundance of all Photocaptured Species in Sanjay Dubri Tiger Reserve

A total of 30 wild species of ungulates, carnivores, primates, birds and reptiles were photo-captured in Sanjay-Dubri Tiger Reserve. Hanuman langur followed by golden jackal were the most common species, whereas, rusty-spotted cat followed by grey wolf were the rarest mammalian species to camera trapped. Apart from this, monitor lizard was the rarest photo-captured species in camera traps. (Table 10.24).

Table 10.24
Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Sanjay-Dubri Tiger Reserve, 2018.

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Asiatic wild cat	0.16	630
Barking deer	0.66	152
Chinkara	5.04	20
Chital	8.96	11
Common palm civet	1.41	71
Domestic dog	5.35	19
Four-horned antelope	2.35	42
Golden jackal	10.56	9
Grey mongoose	0.92	108
Grey wolf	0.07	1385

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Hanuman langur	14.34	7
Honey badger	0.51	198
Indian fox	5.96	17
Indian hare	8.27	12
Indian porcupine	1.36	73
Jungle cat	3.63	28
Leopard	1.75	57
Livestock	33.73	3
Monitor lizard	0.01	13853
Nilgai	6.19	16
Peafowl	2.11	47
Red jungle fowl	0.16	630
Rhesus macaque	6.26	16
Ruddy mongoose	0.17	602
Rusty-spotted cat	0.01	13853
Sambar	0.41	243
Sloth bear	3.21	31
Small Indian civet	0.38	266
Striped hyena	0.86	116
Tiger	0.79	126
Wild dog	0.39	257
Wild pig	9.58	10

DISCUSSION

The tiger population of Sanjay-Dubri Tiger Reserve is very low and required intensive management input in terms of habitat management and law enforcement to build up a good prey base. This reserve is connected with Bandhavgarh Tiger Reserve on the west, Palamau Tiger Reserve on the east in Jharkhand through habitat linkages and contiguous with Guru Ghasidas National Park on the south in Chhattisgarh. Hence, this landscape has been identified as a potential tiger meta-population landscape and require intensive conservation efforts. Further supplementation of tigers should only be done after substantial prey recovery.

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SATPURA TIGER RESERVE

INTRODUCTION

Satpura Tiger Reserve (STR) is located in the Satpura landscape in the Deccan peninsular biogeographic zone of central Indian highlands, south of river Narmada between 77°53'48" to 78°34'0" E longitudes and 22°19'28" to 22°45'30" N latitudes in the Hoshangabad district of Madhya Pradesh. STR has a total area of 2133.30 km^2 that includes the 1339.26 km^2 of Satpura National Park, Bori Wildlife Sanctuary and Panchmarhi Wildlife Sanctuary as the core habitat and the peripheral area of 794.04 km^2 of Hoshangabad Division, Rampur Bhatodi Project Division and west Chhindwara Division as the buffer zone. The terrain of the national park is extremely rugged and consists of deep valleys, sandstone peaks, narrow gorges, rivulets, dense forests, and reservoirs. A combination of various climate and edaphic factors at different altitudinal levels has given rise to rich and luxuriant tropical flora in this protected area.

Vegetation type of the reserve includes southern moist mixed deciduous, southern dry mixed deciduous, and dry peninsular sal (Champion and Seth 1968). The high ranges of the Panchmarhi plateau are covered with sal (*Shorea robusta*) forests on Gondwana sandstone, whereas dense teak (*Tectona grandis*) forests are spread over its lower hill ranges on basaltic traps. The major mammal species found are tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), wild dog (*Cuon alpinus*), striped hyena (*Hyaena hyaena*), golden jackal (*Canis aureus*), chital (*Axis axis*), sambar (*Rusa unicolor*), gaur (*Bos gaurus*), barking deer (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*), blackbuck (*Antilope cervicapra*), chinkara (*Gazella bennettii*), and wild pig (*Sus scrofa*). The only record of the wooly horseshoe bat (*Rhinolophus luctus*) in the central Indian landscape is found in the Panchmarhi plateau. The endangered central Indian hard ground swamp deer (*Rucervus duvauceli branderi*) has been recently reintroduced in the Satpura Tiger Reserve from Kanha Tiger Reserve in the year 2015-2016 to establish a new and separate population.

The corridor connectivity between the tiger reserves of Satpura and Melghat is a contiguous intact forest, whereas the Pench-Satpura Corridor is a fragmented forest patch.

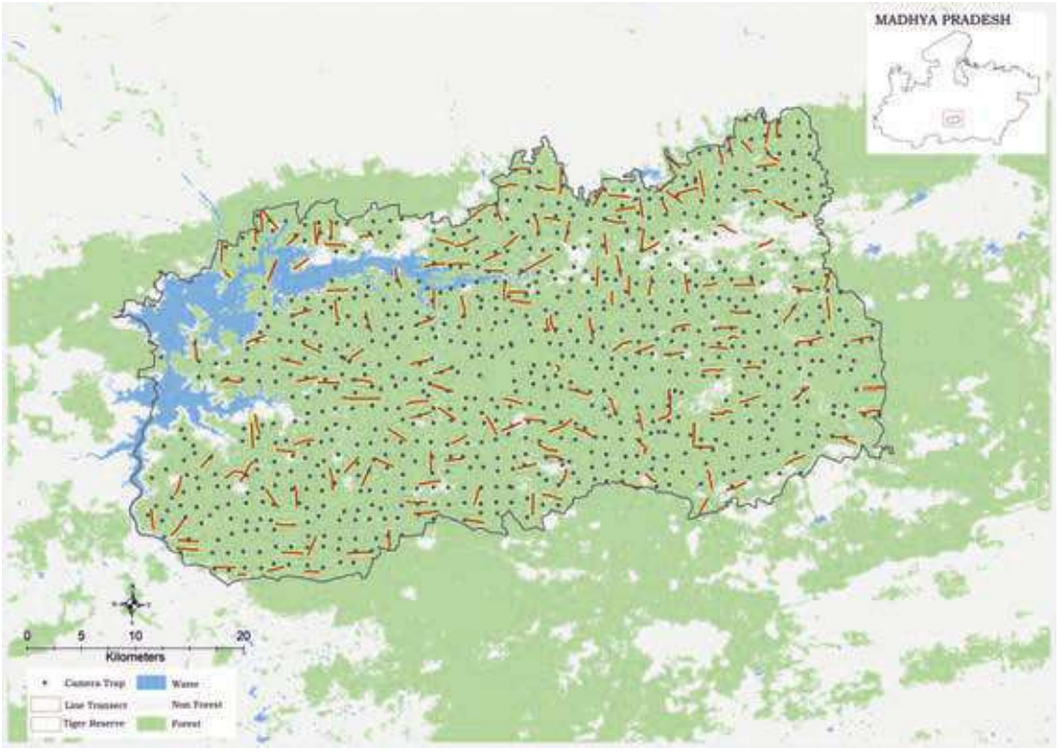


Figure 10.88
Camera trap and line transect layout in Satpura Tiger Reserve, 2018.

RESULT

Tiger Density Estimates

A total of 911 detections of tigers were obtained during the sampling period from which 40 adult individual tigers were identified. Tiger density was estimated 1.39 (SE 0.20) tiger per 100 km^2. The detection corrected sex ratio was female biased (Table 10.25).

Table 10.25

Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Satpura Tiger Reserve, 2018.

Variables	Estimates
Models mask (km^2)	2948.5
Camera points	794
Trap nights (effort)	31972
Unique tigers captured	40
Model	σ (sex) g_0 (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.39 (0.20)
σ Female (SE) km	7.30 (0.24)
σ Male (SE) km	10.39 (0.39)
g_0 Female (SE)	0.002 (0.000)
g_0 Male (SE)	0.003 (0.000)
Pmix Female (SE)	0.68 (0.07)
Pmix Male (SE)	0.32 (0.07)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Prey Density Estimates

A total of 627 line transects were walked in Satpura Tiger Reserve with a cumulative effort of 1197.6 km. Wild pig was found to be the most abundant ungulate with a density of 11.41 (SE 1.30) per km^2 followed by gaur 6.84 (SE 1.06) and sambar 6.48 (SE 0.55) (Table 10.26).

Table 10.26

Model statistics and parameter estimates of line transect (n= 627, Total effort 1197.6 km) based distance sampling for prey species in Satpura Tiger Reserve, 2018.

Species	Effective strip-width (SE)	#groups detected	Mean group-size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ km^2 (SE)	Individual density/km^2 (SE)
Chital	38.99 (4.20)	62	6.39 (0.86)	0.56 (0.06)	0.05 (0.007)	0.66 (0.11)	4.24 (0.91)
Sambar	40.75 (2.12)	276	2.29 (0.09)	0.26 (0.01)	0.23 (0.013)	2.83 (0.22)	6.48 (0.55)
Nilgai	45.92 (3.30)	114	2.47 (0.17)	0.38 (0.03)	0.10 (0.009)	1.04 (0.12)	2.56 (0.35)
Wild Pig	34.37 (2.16)	144	6.52 (0.36)	0.34 (0.02)	0.12 (0.009)	1.75 (0.17)	11.41 (1.30)
Gaur	36.30 (2.44)	106	5.61 (0.56)	0.26 (0.02)	0.09 (0.009)	1.22 (0.14)	6.84 (1.06)
Barking Deer	34.20 (2.01)	163	1.25 (0.04)	0.38 (0.02)	0.14 (0.010)	1.99 (0.19)	2.49 (0.25)

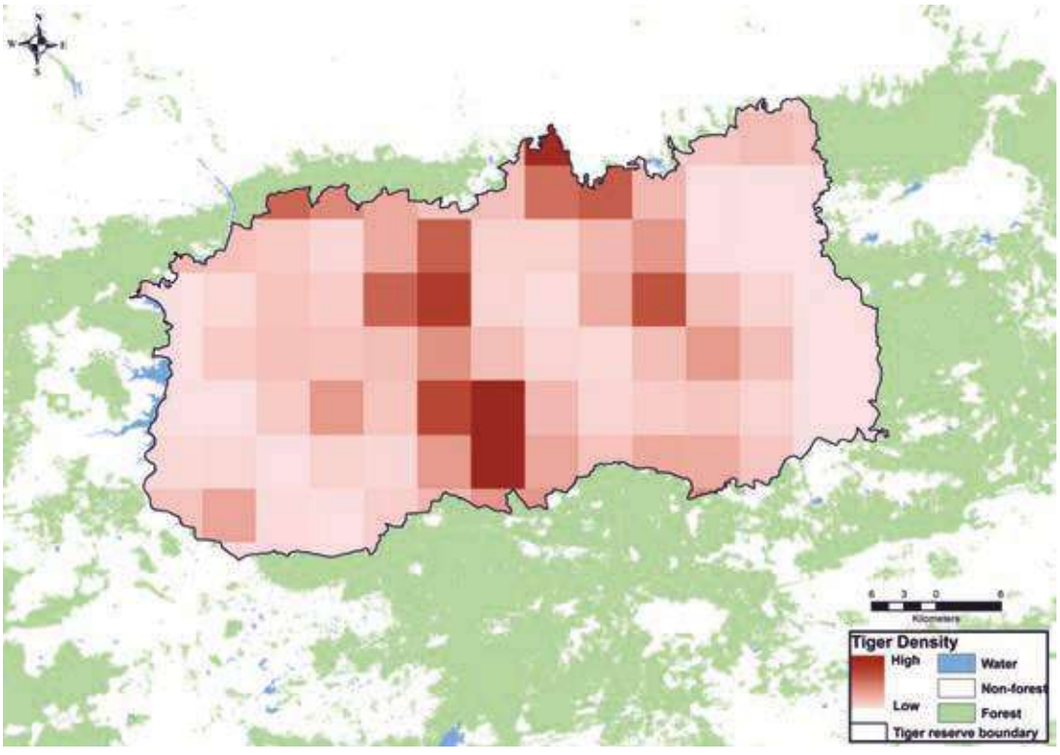


Figure 10.40
Spatial density of tigers in Satpura Tiger Reserve, 2018

Satpura Tiger Reserve is one of the low density tiger populations in the Central India and within the tiger reserve, the grassland and mixed forests of Bori, and Kamti range had the highest density of tigers.

Distribution of Major Mammalian Species Found in Satpura Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Satpura Tiger Reserve.

Asiatic wild cat had very few photo-captures in moderately dense forest towards the south-western side of the park in the core zone.

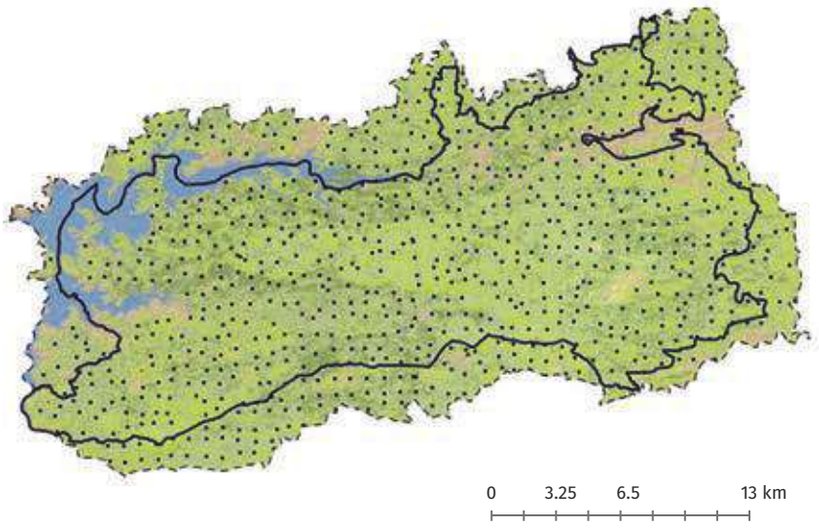


Figure 10.90
Distribution and relative spatial abundance of Asiatic wild cat in Satpura Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

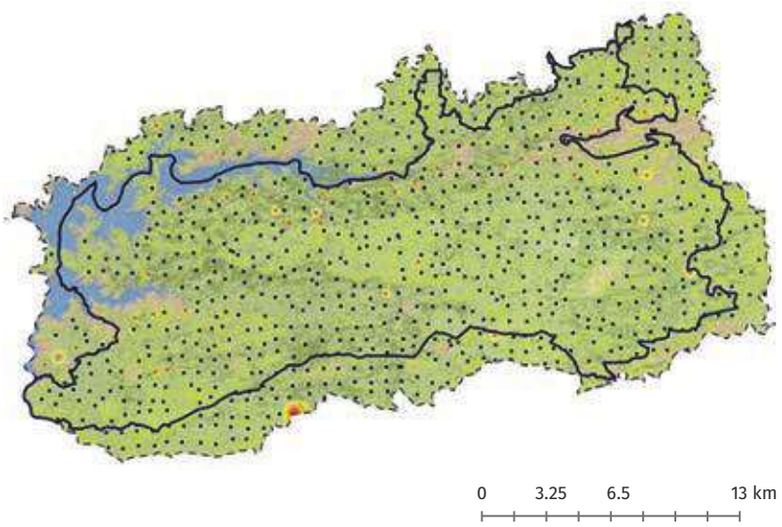


Figure 10.91

Distribution and relative spatial abundance of golden jackal in Satpura Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Golden jackal had sporadic distribution and was mostly photo-captured on the periphery of the tiger reserve in moderately dense forest and open forest.

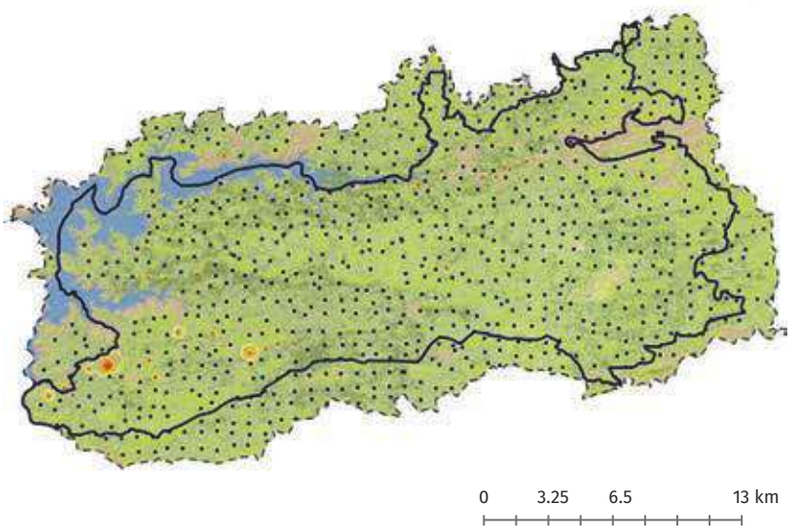


Figure 10.92

Distribution and relative spatial abundance of grey wolf in Satpura Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Grey wolf had sporadic distribution within the tiger reserve. Higher concentration of photo-captures were found towards the south-western side, however, few captures were also found towards the northern side of tiger reserve.

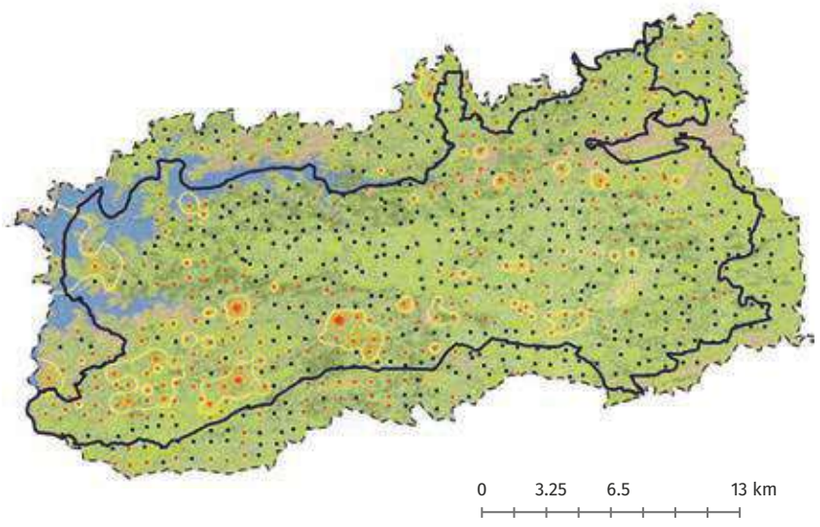


Figure 10.93

Distribution and relative spatial abundance of jungle cat in Satpura Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat distribution was well spread across the tiger reserve with relatively higher concentration of photo-captures near the southern boundary of the park.

Leopard distribution was well spread across the tiger reserve with higher concentration of photo-captures near the eastern boundary of the park.

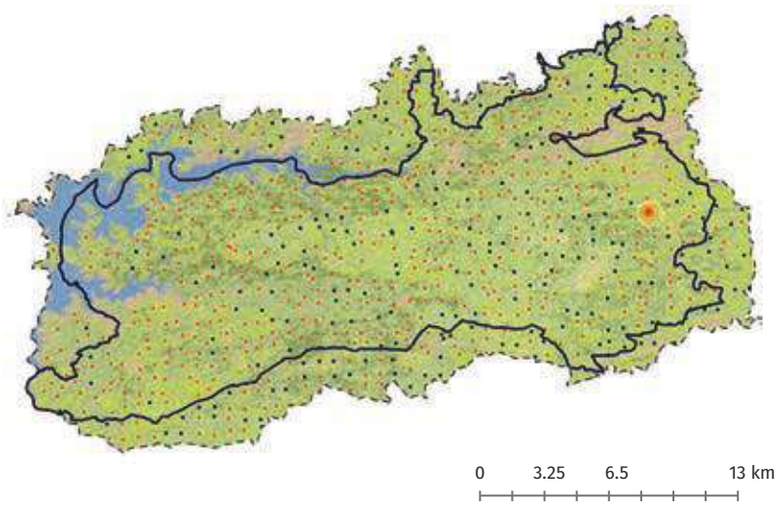


Figure 10.94

Distribution and relative spatial abundance of leopard in Satpura Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Rusty-spotted cat showed erratic distribution in the tiger reserve with relatively higher concentration of photo-captures on the periphery of the park.

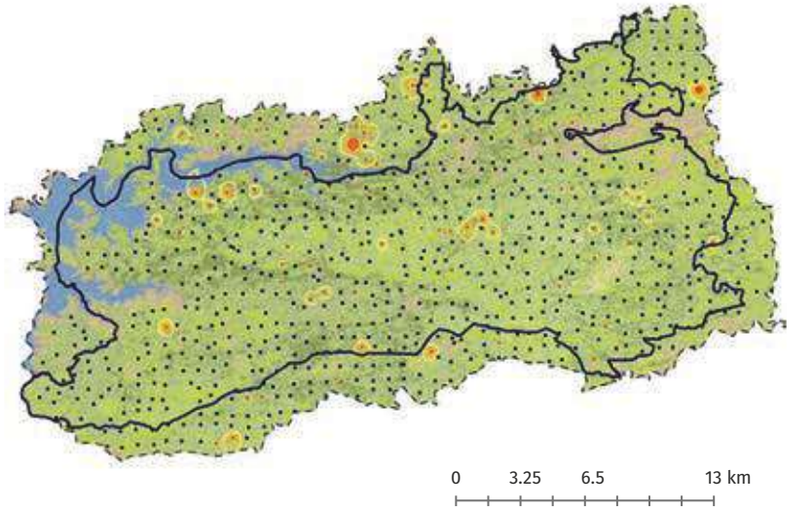


Figure 10.95

Distribution and relative spatial abundance of rusty-spotted cat in Satpura Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear was distributed across the tiger reserve with relatively higher concentration of photo-captures on the northern periphery of the core zone.

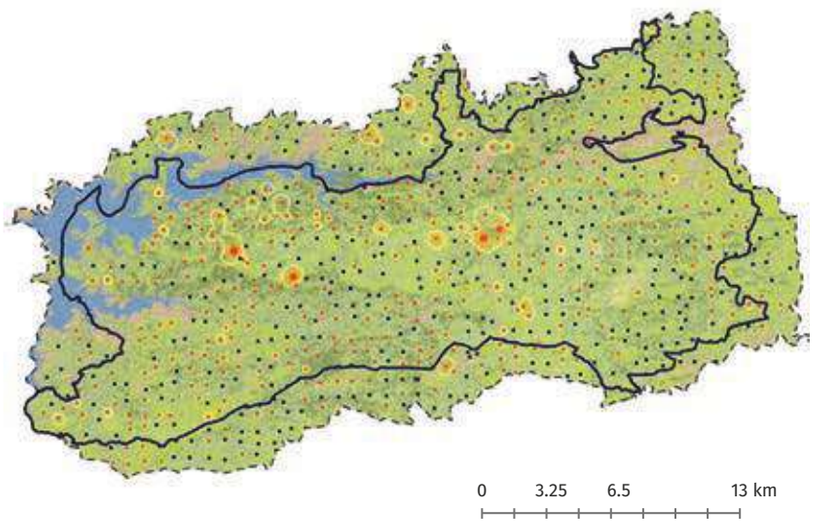


Figure 10.96

Distribution and relative spatial abundance of sloth bear in Satpura Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

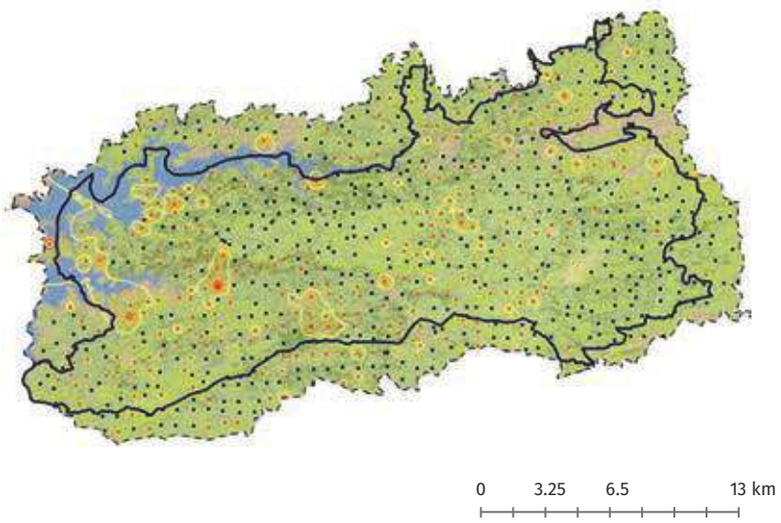


Figure 10.97

Distribution and relative spatial abundance of wild dog in Satpura Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Wild dog was distributed across the tiger reserve with higher concentration of photo-captures near the periphery of the core zone.

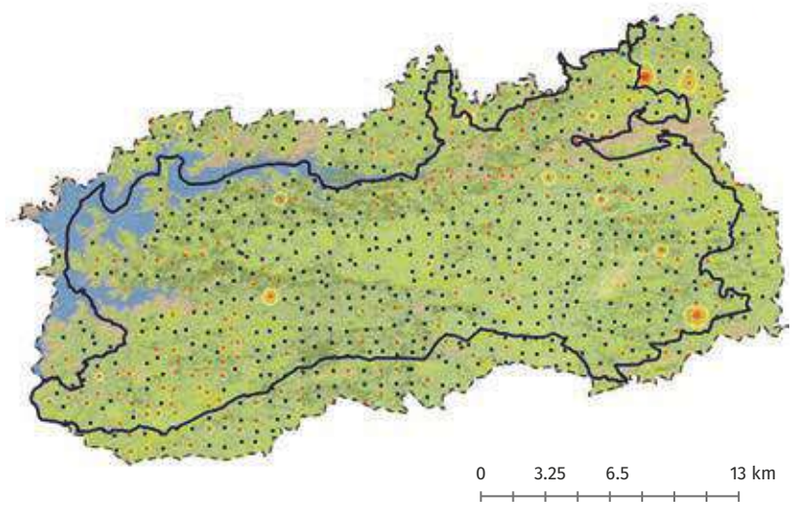


Figure 10.98

Distribution and relative spatial abundance of four-horned antelope in Satpura Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Four-horned antelope was distributed throughout the tiger reserve with relatively higher concentration of photo-capture near the eastern boundary of the core zone in moderately dense forest.

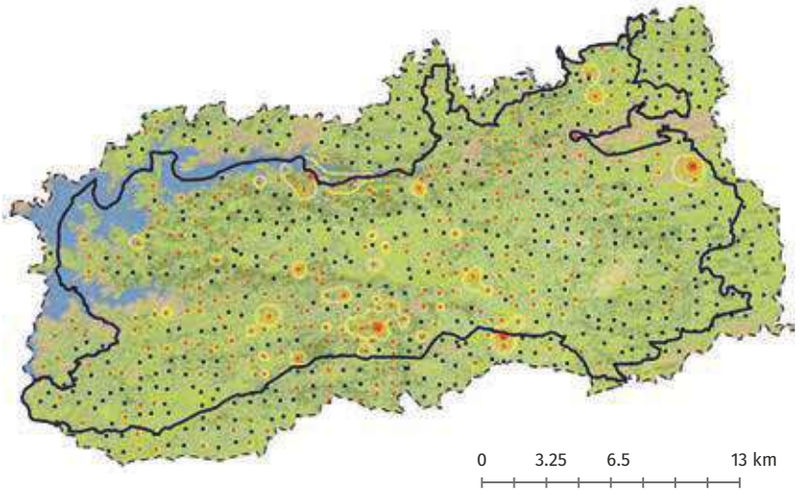


Figure 10.99

Distribution and relative spatial abundance of gaur in Satpura Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Gaur was distributed throughout the tiger reserve with relatively higher concentration of photo-capture in the central part of the core zone in moderately dense forest and very dense forest.

Relative Abundance of all Photocaptured Species in Satpura Tiger Reserve

A total of 31 wild species of ungulates, carnivores, primates, and birds were photo-captured in Satpura Tiger Reserve. Indian hare followed by sambar were the most common species, whereas, Asiatic wild cat and Indian pangolin were the rarest camera trapped species (Table 10.27).

Table 10.27

Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Satpura Tiger Reserve, 2018.

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Asiatic wild cat	0.01	15986
Blackbuck	0.05	1998
Barking deer	2.71	37
Chinkara	0.78	129
Chital	2.62	38
Common palm civet	4.08	25
Domestic dog	2.34	43
Four-horned antelope	2.15	47
Gaur	3.93	25
Golden jackal	0.17	592
Grey mongoose	0.18	542
Grey wolf	0.25	395
Hanuman langur	12.05	8
Honey badger	0.49	205
Indian fox	0.08	1279
Indian hare	19.03	5
Indian pangolin	0.02	6394
Indian porcupine	8.25	12
Jungle cat	5.63	18
Leopard	6.34	16
Livestock	8.31	12
Nilgai	3.53	28
Peafowl	6.88	15
Red jungle fowl	1.11	90
Rhesus macaque	2.93	34
Ruddy mongoose	1.23	82
Rusty-spotted cat	0.34	293
Sambar	13.74	7
Sloth bear	2.71	37
Small Indian civet	1.06	94
Tiger	3.16	32
Wild dog	2.44	41
Wild pig	13.40	7

DISCUSSION

The tiger population of Satpura tiger reserve has shown recovery after village relocation in 2014-2016. Prey base also had increased due to management intervention like restocking of chital and barasingha in the relocated sites for fast recovery. Satpura tiger reserve is one of largest intact forest of tiger habitat in India. More importantly it is a biodiversity hotspot in central India owing to its elevation gradient and varid habitats with good rainfall.

BALAGHAT FOREST DIVISION

INTRODUCTION

Balaghat district is located in the southeastern part of the Satpura hills and the upper valley of the Wainganga river in Madhya Pradesh. The district extends between 21° 19' to 22° 24'N latitudes and 79°30' to 81°5' E longitudes. The total geographical area of the district is 9229 km^2 out of which 4823 km^2 is forested area. Balaghat district is bounded by Mandla district on the north, Dindori district in northwest, Seoni district in the west, Rajnandgaon district of Chhattisgarh in the east and Gondia and Bhandara district of Maharashtra in the south. Balaghat district lies in southern lowlands, with mild undulations and is comparatively well cultivated and drained by the Wainganga, Bagh, Deo, Ghisri, and Son rivers. Balaghat district is famous for its copper and manganese mines and about 52% of the area is covered with forests. By merging the North and South Balaghat territorial divisions, the Lamta and Mohgaon project divisions, the forest of Balaghat forms an important tiger landscape.

The forest of Balaghat division is mainly mixed forest and according to the forest classification, it belongs to southern tropical dry mixed deciduous forest class (5A/C3) (Champion and Seth 1968). Balaghat is known for its bamboo forest and is the biggest bamboo-producing district in Madhya Pradesh. Three types of bamboo namely desi bamboo (*Dendrocalamus strictus*), katang bamboo (*Bamboosa arundinaceae*) and balan bamboo (*Cephalastachym bergraile munro*) are found in the division (Green India Mission, 2018-19). The other prominent tree species are *Shorea robusta, Terminalia elliptica, Diospyros melanoxylon, Pterocarpus marsupium, Anogeissus latifolia, Lagerstroemia parviflora, Butea monosperma, Madhuca longifolia,* etc. The forest is rich in biodiversity and includes tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*), gaur (*Bos gaurus*), chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*), as major mammalian species. In the recent past few months, few wild elephants (*Elephas maximus*) have moved in the Lamta area of Balaghat forest division and it is speculated that these elephants have come from the adjoining forests of Chhattisgarh.

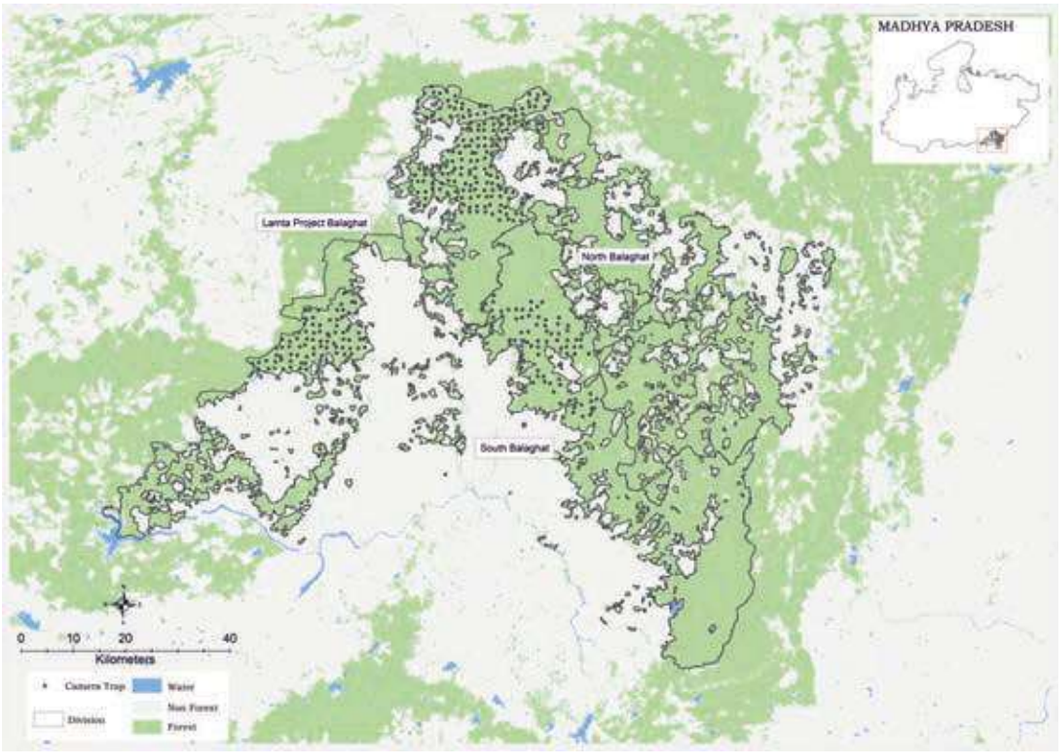


Figure 10.100
Camera trap layout in Balaghat Forest Division, 2018.

RESULT

Tiger Density Estimates

A total of 154 detections of tigers were obtained during the sampling period from which 21 adult individual tigers were identified. Tiger density was estimated as of 1.25 (SE 0.28) tiger per 100 km^2. The detection corrected sex ratio was female biased (Table 10.28).

DISCUSSION

The tiger density in Balaghat was low but higher compare to many tiger reserves. The intact forest of Balaghat can harbor a good population of tigers and other threatened carnivores like dhole and leopard, if it is declared as a Protected Area. Due to its non-protected area status, this area is under severe pressure from grazing, mining and other anthropogenic activities and prone to degradation and habitat fragmentation. This landscape has high biodiversity and is connected with three protected areas namely Kanha, Pench, and Navegaon-Nagzira tiger reserves. As parts of this division fall under the important Kanha-Pench corridor in central Indian landscape, facilitating tiger dispersal, this area holds high conservation value. This area of Madhya Pradesh (Kanha-Pench-Balaghat) currently holdsabout 300 Tigers has the potential to become one of the top five largest tiger populations in the world if Balaghat Forests Divisions were to be given a Protected Area status and managed for Wildlife conservation as the priority objective.

Table 10.28
Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Balaghat forest division, 2018.

Variables	Estimates
Model mask (km^2)	2259.75
Camera points	327
Trap nights (effort)	12316
Unique tigers captured	21
Model	g_0 (sex) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.25 (0.28)
σ Female (SE) km	2.30 (0.14)
σ Male (SE) km	5.13 (0.93)
g_0 Female (SE)	0.008 (0.001)
g_0 Male (SE)	0.002 (0.001)
Pmix Female (SE)	0.79 (0.08)
Pmix Male (SE)	0.21 (0.08)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
σ (Sigma): Spatial scale of detection function,
g_0: Magnitude (intercept) of detection function
Pmix: Detection corrected estimate of proportion of males and females

BARGHAT

INTRODUCTION

Barghat Project Division (Van Vikash Nigam) is situated in Seoni district of Madhya Pradesh between Kanha-Pench corridors. The buffer zone of Pench Tiger Reserve, Madhya Pradesh is contiguous with Barghat block of Barghat Project Division. It lies between 21°51' N to 22°10' N latitudes and 79°45'E to 79°55'E longitudes. Barghat Project Division covers an area of 503 km^2 forest. The administrative control of this project division lies with Madhya Pradesh Rajya Van Vikas Nigam Ltd. This forest division is primarily managed with the aim of accelerating and increasing forestry production by growing species with higher economic value.

The forests of Barghat Project Division are classified into two major forest types viz. southern tropical dry deciduous teak forest and southern dry mixed deciduous forests (Champion and Seth 1968). Tectona grandis is the dominant tree species growing gregariously in the division. However, as this division is a commercial forestry division, hence *Dendrocalamaus strictus* along with other commercial timber valued trees are grown by the department. This division supports felids like tiger (*Panthera tigris*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*), and rusty spotted cat (*Prionailurus rubiginosus*). Other carnivores include golden jackal (*Canis aureus*), sloth bear (*Melursus ursinus*), wild dog (*Cuon alpinus*) and wolf (*Canis lupus*). Herbivores include gaur (*Bos gaurus*), chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*) and wild pig (*Sus scrofa*). Nilgai (*Boselaphus tragocamelus*) is seen only in the fringes of the forest. Small Indian civet (*Viverricula indica*) and common palm civet (*Paradoxurus hermaphroditus*) are also found here. Black napped hare (*Lepus nigricollis*) and Indian porcupine (*Hystrix indica*) are of common occurrence.

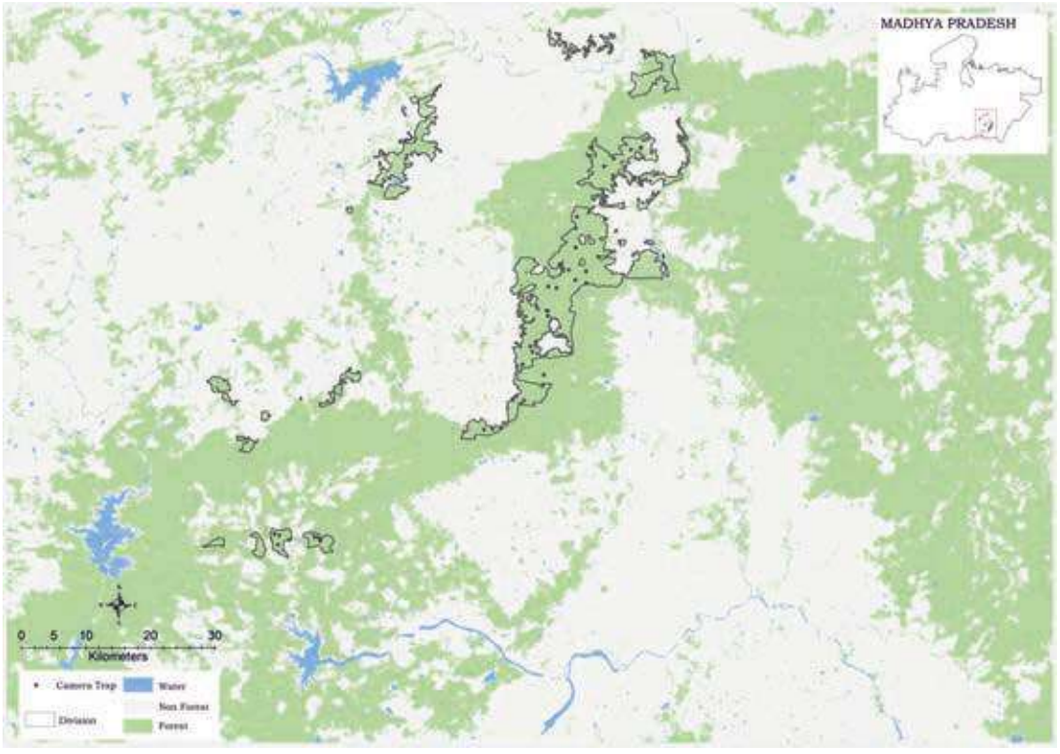


Figure 10.101
Camera trap layout in Barghat Project Division, 2018.

RESULT

Camera Trap Results

A total of 7 detections of tigers were obtained during the sampling period from which 6 adult individual tigers were identified (Table 10.29). Due to low detections, tiger density could not be estimated.

Variables	Counts
Camera points	38
Trap nights (effort)	1004
Unique tigers captured	6

Table 10.29
Sampling details in Barghat Project division, 2018.

DISCUSSION

Barghat Project Division is connected to Pench Tiger Reserve and lies in Kanha-Pench corridor. As it is primarily a commercial forest housing at the same time many endangered species, hence effort should be made to provide adequate staff and support for wildlife management.

BHOPAL FOREST DIVISION

INTRODUCTION

Known as the city of lakes, Bhopal is the capital city of Madhya Pradesh and is located on the Malwa plateau just north of the upper limit of the Vindhyan mountain ranges in the central Indian landscape. Early history of this district is somewhat unknown and there is a legend that Bhopal was part of "Mahakautar", a barrier of dense forests and hills, outlined by the river Narmada, separating northern India from southern India. The division lies between latitudes 23°05' to 23°54' N and longitudes 77°10' to 77°40' E. The total forested area of the division is about 366 km^2. The forest division has uneven terrain and has small hills within its boundaries with an average elevation of 500m above mean sea level. The major hills in Bhopal are Idgah hills and Shyamala hills in the northern region and Arera hills and Katara hills in the central and the southern region. The division covers parts of two river sub-basins - the Betwa river sub-basin and the lower Chambal basin. Bhopal territorial division comprises of two forest ranges namely Berasia forest range and the Samardha forest range.

The forests type is mainly southern tropical dry deciduous with dry deciduous shrub forests (Champion and Seth 1968) and divided into (i) dry deciduous teak forest, (ii) fort hill teak forests, (iii) mixed forest. The trees species found in these forests include *Tectona grandis, Anogeissus latifolia, Boswellia serrata, Terminalia elliptica, Pterocarpus marsupium, Madhuca longifolia, Bombax ceiba, Adina cardifolia, Diospyros melanoxylon, Buchanania lanzan,* etc. Bamboos are also found in small measure in mixed forests. The common mammalian species found in this area are chital (*Axis axis*), sambar (*Rusa unicolor*), blackbuck (*Antilope cervicapra*), nilgai (*Boselaphus tragocamelus*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), golden jackal (*Canis aureus*), and grey wolf (*Canis lupus*).

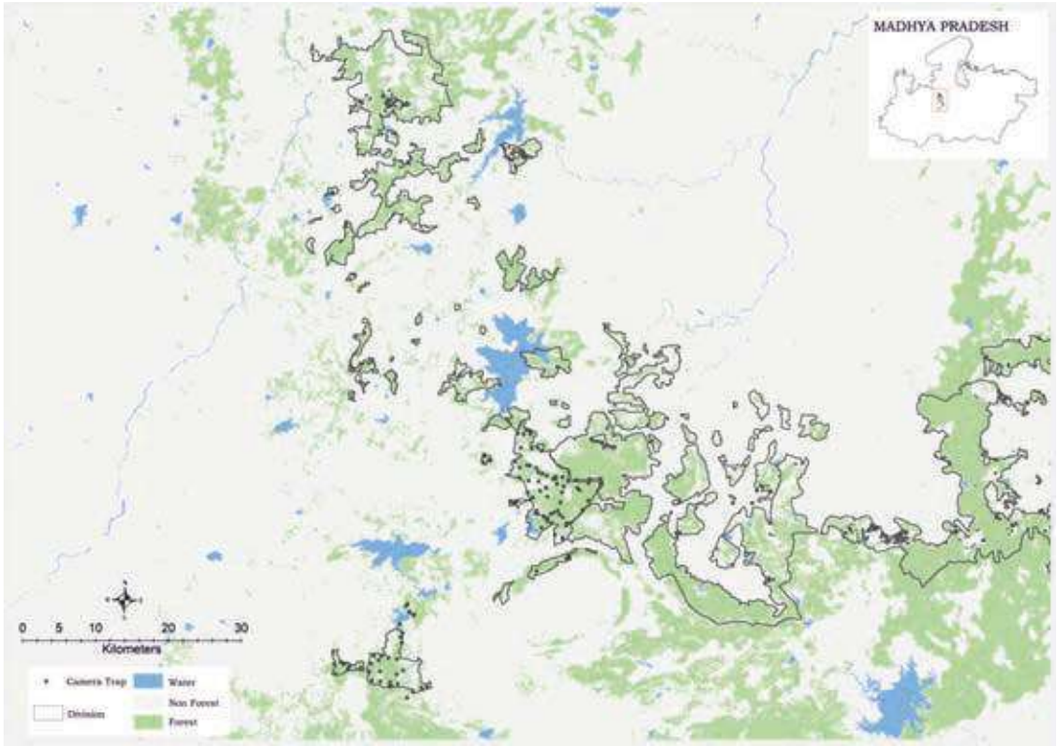


Figure 10.102
Camera trap layout in Bhopal Territorial Forest Division, 2018.

RESULT

Tiger Density Estimates

A total of 37 detections of tigers were obtained during the sampling period from which 6 adult individual tigers were identified. The estimated density was of 1.47 (SE 0.64) tiger per 100 km^2. The detection corrected sex ratio was female biased (Table 10.30).

Table 10.30
Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Bhopal forest division, 2018.

Variables	Estimates
Model space (km^2)	553.75
Camera points	119
Trap nights (effort)	2500
Unique tigers captured	6
Model	g_0 (sex) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.47 (0.64)
σ Female (SE) km	4.02 (0.69)
σ Male (SE) km	4.07 (2.23)
g_0 Female (SE)	0.014 (0.004)
g_0 Male (SE)	0.02 (0.01)
Pmix Female (SE)	0.82 (0.19)
Pmix Male (SE)	0.18 (0.19)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
σ (Sigma): Spatial scale of detection function,
g_0: Magnitude (intercept) of detection function
Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Bhopal being a capital city and tiger population near the capital urban landscape may imperil the co-existence approach of tiger conservation if appropriate management is not done. Forest patches of Bhopal act as corridors with adjoining forest divisions and frequent movement of tigers have been observed in the vicinity of human settlements. Hence, it is crucial to implement adequate precautionary measures in order to minimize human-wildlife conflict. In the last four of years, Berasia and Samardha forest ranges of Bhopal forest block along with the forest adjoining Kerwa dam and Kaliasot dam on the outskirts of Bhopal have emerged as a prominent wildlife corridor connecting Ratapani Wildlife Sanctuary (recently proposed as a Tiger reserve).

CHHATARPUR FOREST DIVISION

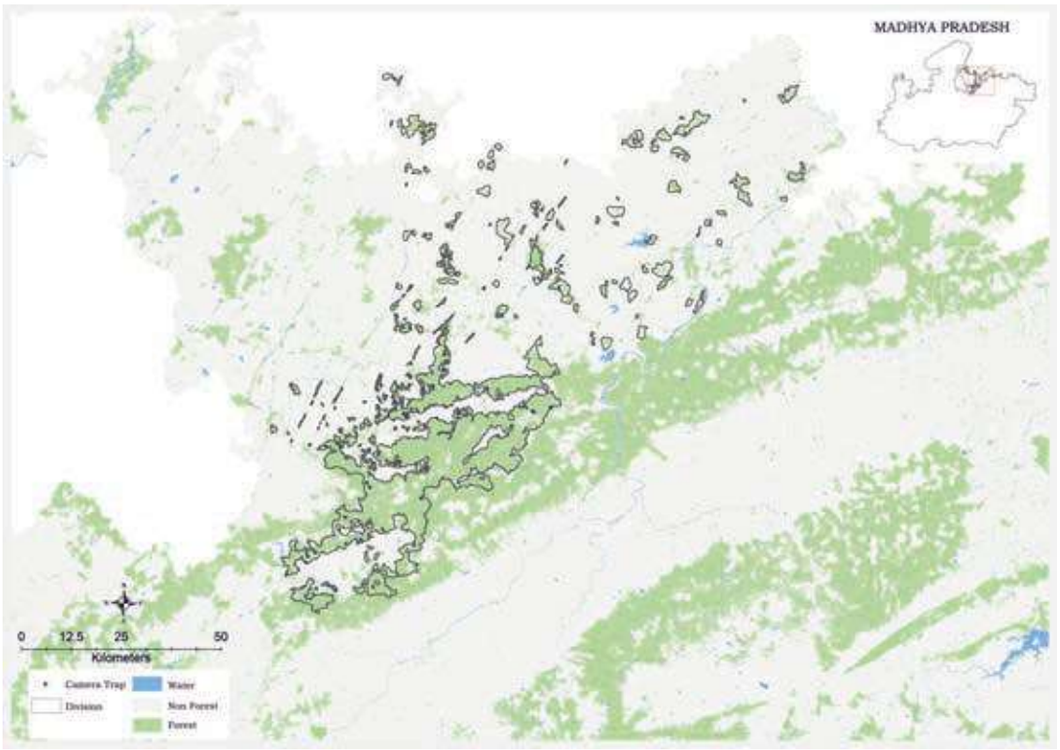
INTRODUCTION

Chhatarpur Forest Division is situated in the central portion of the plateau of Bundelkhand lying between latitudes 24°06' and 25°20' N and longitudes 79°59' and 80°26' E. This forest division is the part of greater Panna tiger landscape. Chhatarpur Forest Division covers an area of about 1400 km^2. This forest division shares it boundary with Panna tiger reserve in eastern side and Damoh Forest Division in the western side.

The forests of Chhatarpur Forest Division are classified into two major forest types viz. southern tropical dry deciduous teak forest and southern dry mixed deciduous forests (Champion and Seth 1968). *Tectona grandis, Boswellia serrata, Acacia catechu* and *Dendrocalamus strictus* are the dominant tree species growing in the division. The mixed forests of this division is further represented by *Terminalia elliptica, Anogeissus latifolia, Lagerstromia parviflora, Phyllanthus emblica, Buchanania lanzan, Madhuca longifolia* etc. There are occasional movement of tiger (*Panthera tigris*) from Panna Tiger Reserve to this division however this division has good occupancy of leopard (*Panthera pardus*) and jackal (*Canis aureus*). Among other carnivores, this division has jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*), sloth bear (*Melursus ursinus*) and wolf (*Canis lupus*). Herbivores includes nilgai (*Boselaphus tragocamelus*), sambar (*Rusa unicolor*), chital (*Axis axis*), and chausingha (*Tetracerus quadricornis*) and wild pig (*Sus scrofa*). Small Indian civet (*Viverricula indica*) and common palm civet (*Paradoxurus Hermaphroditus*) are also found. Black napped hare (*Lepus nigricollis*) and Indian porcupine (*Hystrix indica*) are of common occurrence.

Figure 10.103

Camera trap layout in Chhatarpur Territorial Forest Division, 2018.



RESULT

Camera Trap Results

Only 1 photograph of a tiger was captured during the sampling period hence the density could not be estimated (Table 10.31).

Variables	Count
Camera points	9
Trap nights (effort)	234
Unique tigers captured	1

Table 10.31
Sampling details for Chhatarpur Forest Division, 2018.

DISCUSSION

The Chhatarpur Forest Division acts as the buffer zone for Panna Tiger Reserve. The presence of tiger in this division reflects the potential of this area to act as corridor or sink habitat for dispersing tigers.

DEWAS FOREST DIVISION

INTRODUCTION

Dewas Forest Division is situated in the district of Dewas in Madhya Pradesh. Dewas Forest Division lies between 76°14' to 77°03' E longitudes and 22°04' to 22°19' N latitudes and has an area of about 2000 km^2. There are 11 forest ranges in this division; one of these ranges constitute Kheoni Wildlife Sanctuary. The forest division is situated in the Vindhya range, between Malwa plateau in the north and Narmada river valley in south. The division is connected in the east to Sehore Forest Division, which connects it through Ratapani Wildlife Sanctuary in Obedullaganj. In the south, it is connected to the forest divisons of Harda and Khandwa while in the west it is connected to the forest divisons of Indore and Khargone.

The vegetation of the forest division is teak dominated and mixed southern tropical dry deciduous forest. Important tree species are T*ectona grandis, Boswellia serrate, Diospyros melanoxylon, Madhuca indica, Buchanania lanzan, Butea monosperma, Acacia catechu* etc. Dewas Forest Division is rich in avifauna and mammalian fauna. Some important mammalian species are tiger (*Panthera tigris*), leopard (*Panthera pardus*), wolf (*Canis lupus*), jackal (*Canis aureus*), jungle cat (*Felis chaus*), chital (*Axis axis*), sambar (*Rusa unicolor*), chausingha (*Tetracerus quadricornis*), barking deer (*Muntiacus vaginalis*) and wild pig (*Sus scrofa*).

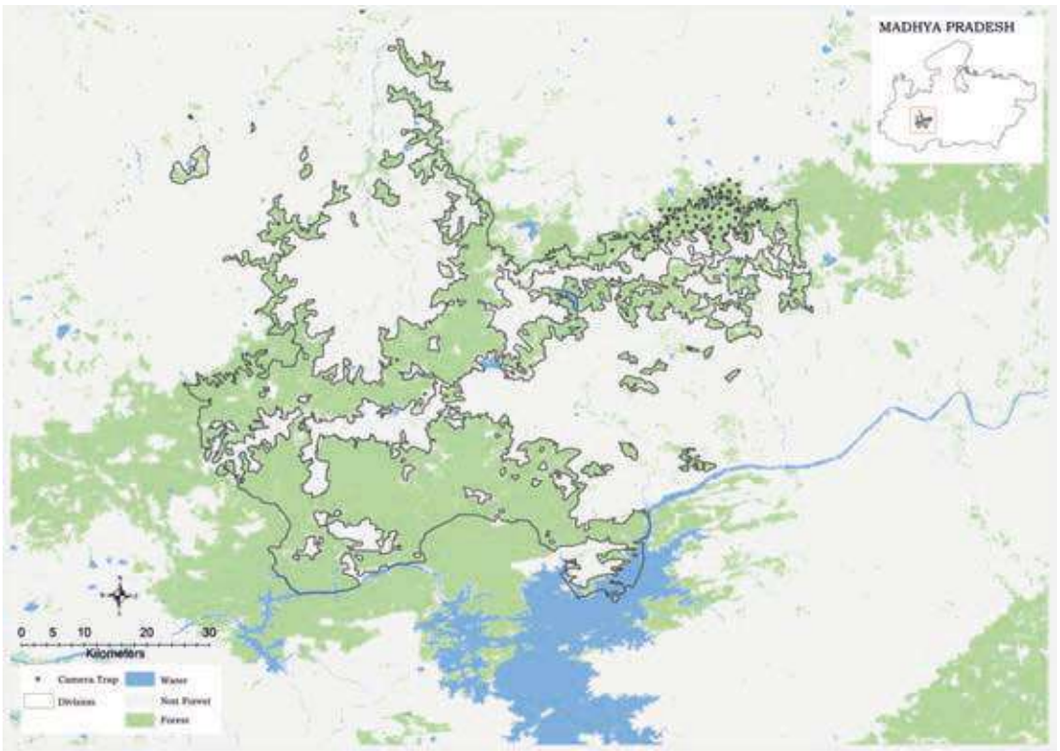


Figure 10.104
Camera trap layout in Dewas Forest Division, 2018.

RESULT

Camera Trap Results

A total of 21 detections of tigers were obtained during the sampling period from which 3 adult individual tigers were identified (Table 10.32). However, the density could not be estimated due to the small sample size.

Variables	Counts
Camera points	79
Trap nights (effort)	1256
Unique tigers captured	3

Table 10.32
Sampling details for Dewas Forest Division, 2018.

DISCUSSION

Dewas Forest Division and particularly Kheoni Wildlife Sanctuary is home to the western most tiger population of Madhya Pradesh. Due to a sufficient prey base this area has the potential to become a source to populate the historic ranges of tiger in Madhya Pradesh and westward into Gujarat. In the recent past one tiger had moved from Dewas Forest Division to forests of Santrampur Gujarat.

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KUNO NATIONAL PARK

INTRODUCTION

Kuno National Park is part of the Sheopur-Shivpuri forested landscape (6800 km^2), located in the northern part of the Vindhyanchal mountain range in the district of Sheopur in Madhya Pradesh. Kuno National Park lies between 77°07' to 77°26' E longitudes and 25°30' to 25°53' N latitudes having an area of 344.686 km^2. In December 2018, the state government declared Kuno WLS as Kuno National Park with the inclusion of 404.0758 km^2 area spread over the periphery of the Kuno Wildlife Division. The area is classified under the semi-arid Gujarat Rajputana (4B) biogeographic province (Rodgers et al. 2002). The Kuno River, which is the main tributary of Chambal river, runs through the sanctuary and is the main source of water.

The vegetation of Kuno National Park represents the northern tropical dry deciduous forest, northern tropical mixed deciduous, southern tropical dry deciduous, tropical riverine forest (Champion and Seth 1968) and is dominated by kardhai (*Anogeissus pendula*), dhawda (*Anogeissus latifolia*), salai (*Boswellia serrata*) and khair (*Acacia catechu*) with extensive savannah woodlands. The major herbivore species found in the National Park are chital (*Axis axis*), chinkara (*Gazella bennettii*), sambar (*Rusa unicolor*), nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*), blackbuck (*Antilope cervicapra*), four-horned antelope (*Tetracerus quadricornis*), hanuman langur (*Semnopithecus entellus*) and feral cattle that were left behind during village relocation. Leopard (*Panthera pardus*), grey wolf (*Canis lupus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*), golden jackal (*Canis aureus*), and jungle cat (*Felis chaus*) are the main carnivores found in the area, apart from occasional reports of one tiger (*Panthera tigris*) that had migrated from Ranthambore Tiger Reserve in December 2010. Based on sociological and ecological parameters, the government of India has considered Kuno-Palpur wildlife sanctuary (Kuno National Park) as a suitable habitat for the relocation of Asiatic lion (*Panthera leo persica*) from Gujarat and reintroduction of cheetah (*Acinonyx jubatus*) in India. The Government of India and Madhya Pradesh have invested significantly in habitat management, protection and village relocation to make Kuno suitable to receive lions. Prey recovery has been explenary in Kuno National Park.

Kuno is connected to Ranthambore Tiger Reserve and Kailadevi National Park with remnant linkages on the northwestern side. On its southeastern side, Kuno has patchy connectivity to Madhav National Park through the territorial Shivpuri Forest Division.

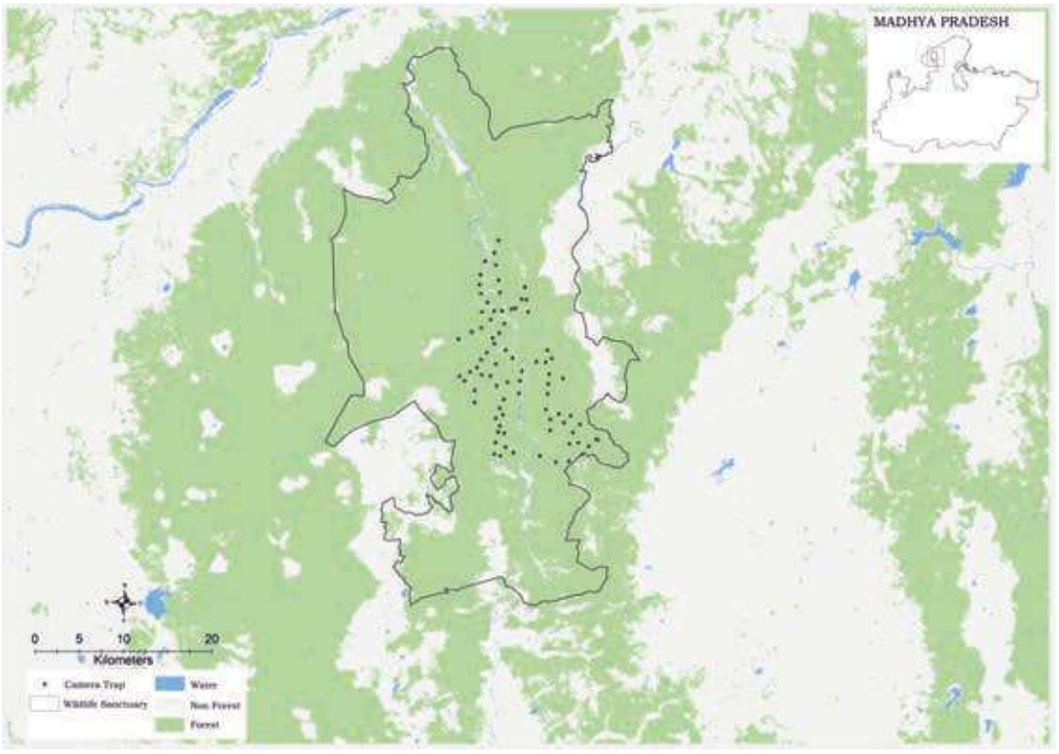


Figure 10.105
Camera trap layout in Kuno National Park, 2018.

RESULT

Camera Trap Results

A total of 10 detections of a tiger were obtained during the sampling period from which only one individual tigers was identified (Table 10.33). Tiger density could not be estimated due to small sample size.

Table 10.33
Sampling details for Kuno National Park, 2018.

Variables	Counts
Camera points	85
Trap nights (effort)	1792
Unique tigers captured	1

DISCUSSION

The adult male tiger captured in the camera traps had dispersed from Ranthambore Tiger Reserve and has now settled in the sanctuary. Kuno is ecologically ready for receiving lions as well as cheetah. If reintroduction of cheetah is to be considered here it should preceed that of lions so that cheetah become established within their new habitat before a larger carnivore is introduced here.

MANDLA FOREST DIVISION

INTRODUCTION

Mandla is thought to have originated from the Sanskrit word "Mandal" meaning circle and is thus named as the river Narmada almost girdles the town from three sides (Captain HCE Ward, Dist. Gazetteer, 2000). Mandla is a south-eastern district of Madhya Pradesh lying between 22^0 2' to $23^0$22 " N latitudes and $80^0$18' to $81^0$50" E longitudes. The district forms a part of the Satpura hills, which separates the cotton-growing regions of the south from the wheat-growing extensions of the Malwa Plateau on the north. The district is bound on the north-west by Jabalpur district, on the north and north-east by Dindori district, on the west by Seoni, on the south by Balaghat, and on the south-east by Kawardha district of Chhattisgarh. The total area of the district is 5800 km^2, out of which 2577.71 km^2 area is forest (FSI State forest report 2019). Forest of Mandla is divided into East Mandla Forest Division and West Mandla Forest Division. Most of the forest is classified as reserved forest while a small portion of the forest is categorized as protected forest and revenue forest (Management plan of East and West Mandla divisions). The area belongs to the 'Indo-Malayan Realm' floristically and zoo-geographically, it is a member of the 'Oriental region'. The district has undulating plains, numerous small valleys intersected by seasonal streams and rivers with flat hilltops locally known as "Dadar". These Dadar are prominent topographical features which offer unique setting and ecotones for diverse species of plants and animals.

As per the forest classification (Champion and Seth 1968), major forest type of Mandla are categorized as i) moist peninsular sal forest (3C/C2e), ii) south Indian sub-tropical moist deciduous forest (3B), iii) southern dry mixed deciduous forest (3C/C3), and iv) southern tropical dry deciduous forest (5A). The vegetation type of Mandla reflects two different climax species- teak (*Tectona grandis*) and sal (*Shorea robusta*). The prominent tree species are Tectona grandis, *Shorea robusta, Terminalia elliptica, Lagerstroemia parviflora, Madhuca longifolia, Diospyros melanoxylon, Terminalia chebula, Anogeissus latifolia, Pterocarpus marsupium, Buchanania lanzan, bamboo*, etc. The common animal species found in the area are tiger (*Panthera tigris*), leopard (*Panthera pardus*), golden jackal (*Canis aureus*), Indian fox (*Vulpes bengalensis*), wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*), grey wolf (*Canis lupus*), chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*), nilgai (*Boselaphus tragocamelus*), four-horned antelope (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), etc.

Mandla is one of the forest-rich districts in the central Indian landscape. However, due to over-exploitation of forest resources, low regeneration, forest fires, this area faces severe habitat degradation.

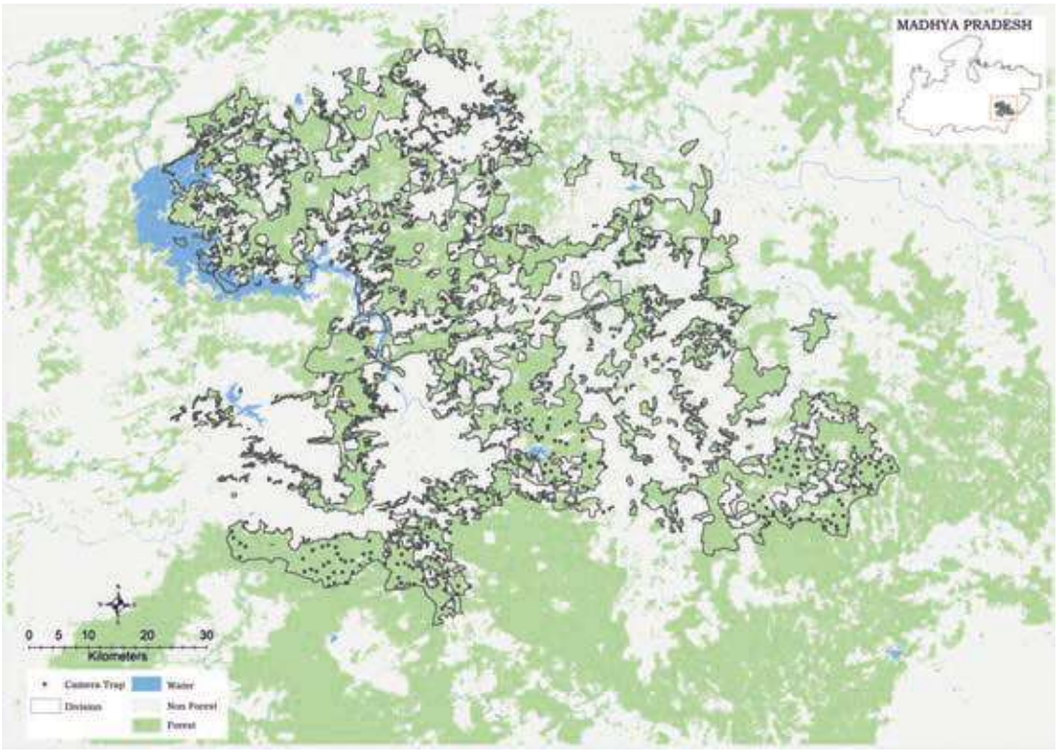


Figure 10.106
Camera trap layout in Mandla Forest Divisions, 2018.

RESULT

Tiger Density Estimates

A total of 31 detections of tigers had been obtained during the sampling period from which 9 adult individual tigers were identified giving a density estimate of 0.57 (SE 0.20) tiger per 100 km^2. The sex ration was equal for male and female (Table 10.34).

Table 10.34
Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Mandla forest division, 2018.

Variables	Estimate
Model space (km^2)	2482.5
Camera points	191
Trap nights (effort)	5379
Unique tigers captured	9
Model	g_0 (.) σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.57 (0.20)
σ (SE) km	4.52 (0.64)
g_0 (SE)	0.01 (0.003)
Pmix Female (SE)	0.5 (0.17)
Pmix Male (SE)	0.5 (0.17)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
σ (Sigma): Spatial scale of detection function,
g_0: Magnitude (intercept) of detection function
Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Mandla forest division was camera trapped for the first time for the All India Tiger monitoring exercise. Forests of Mandla divisions are crucial link infor the Kanha Pench habitat corridor. These forests also acts as buffer to Kanha tiger reserve. Movement of tigers have been regularely observed between Kanha Tiger Reserve and Mandla Forest Division. Hence, protection of this area becomes crucial for dispersing tigers. The Government of Madhya Pradesh may consider enhancing the legal status of these crucial corridor forests for conserving their long term wildlife values.

NORTH PANNA FOREST DIVISION

INTRODUCTION

North Panna Territorial Forest Division is situated in the central portion of the plateau of Bundelkhand lying between latitudes 24°28' to 25°12' N and longitudes 79°45' to 80°40' E. This forest division is the part of greater Panna tiger landscape and covers an area of about 2155.76 km^2. It shares its boundaries with Panna Tiger Reserve in the western side and Satna Forest Division in the eastern side.

The forests of North Panna Territorial Forest Division are classified into two major forest types viz. southern tropical dry deciduous teak forest and southern dry mixed deciduous forests (Champion and Seth 1968). Tectona grandis is the dominant tree species growing gregariously in the division. The mixed forests are represented by *Terminalia elliptica, Anogeissus latifolia, Lagerstromia parviflora, Phyllanthus emblica, Buchanania lanzan, Madhuca latifolia* etc. Tigers (*Panthera tigris*) occasionally move from Panna Tiger Reserve into this division, however, this division harbours leopard (*Panthera pardus*) and jackal (*Canis aureus*). Among other carnivores, jungle cat (*Felis chaus*), rusty-spotted cat (*Prionailurus rubiginosus*), sloth bear (*Melursus ursinus*) and wolf (*Canis lupus*) are found here. Herbivores include nilgai (*Boselaphus tragocamelus*), sambar (*Rusa unicolor*), chital (*Axis axis*), and four-horned antelope (*Tetracerus quadricornis*). Small Indian civet (*Viverricula indica*) and common palm civet (*Paradoxurus hermaphroditus*) are also found. Indian hare (*Lepus nigricollis*) and Indian porcupine (*Hystrix indica*) are of common occurrence.

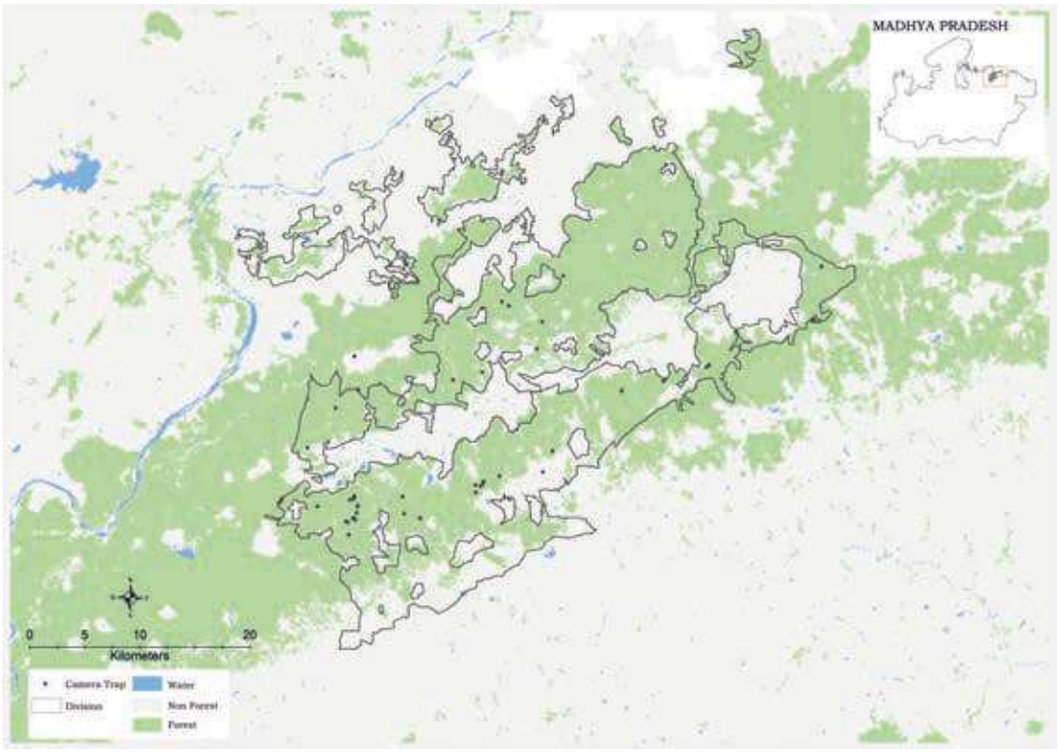


Figure 10.107
Camera trap layout in North Panna Territorial Forest Division, 2018.

RESULT

Camera Trap Results

A total of 2 images of tigers were captured during the sampling period. One adult male tiger was identified and due to low detections the density could not be estimated (Table 10.35).

Variables	Counts
Camera points	55
Trap nights (effort)	1628
Unique tigers captured	1

Table 10.35
Sampling details for North Panna Territorial Forest Division, 2018.

DISCUSSION

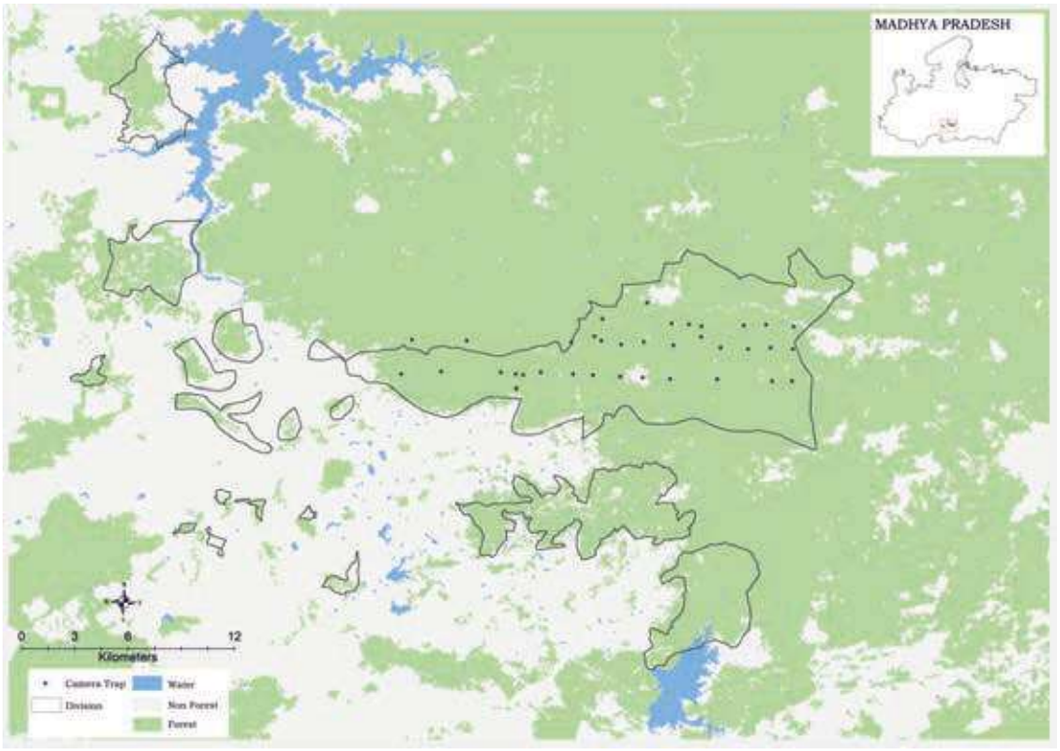
The forests of North Panna Territorial Forest Division are a crucial link between Ranipur Wildlife Sanctuary and Panna Tiger Reserve, thereby necessitating adequate protection and management.

RAMPUR BHATODI

INTRODUCTION

Rampur Bhatodi Project Division (Van Vikash Nigam) is situated in Betul district of Madhya Pradesh between Satpura-Melghat-Pench corridors. The buffer zone of Satpura Tiger Reserve lie adjacent to Rampur Bhatodi Project division. It lies between 22° 22' N to 22° 16' N latitudes and 77° 59'E to 78° 16'E longitudes. Rampur Bhatodi Project Division covers an area of 300 km^2. The administrative control of this project division lies with Madhya Pradesh Rajya Van Vikas Nigam Ltd. This forest division is primarily managed with the aim of accelerating and increasing forestry production by growing species with higher economic value. The forests of Rampur Bhatodi Project Division are classified into two major forest types viz. southern tropical moist deciduous forest and southern dry mixed deciduous forests (Champion and Seth 1968). *Dendrocalamaus strictus* is the major commercial forest crop growing gregariously in the division. This division supports felids like tiger (*Panthera tigris*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*), and rusty-spotted cat (*Prionailurus rubiginosus*). Other carnivores include golden jackal (*Canis aureus*), sloth bear (*Melursus ursinus*), wild dog (*Cuon alpinus*) and wolf (*Canis lupus*). Herbivores include sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), gaur (*Bos gaurus*), and wild pig (*Sus scrofa*). Nilgai (*Boselaphus tragocamelus*) is seen only in the fringes of the forest. Small Indian civet (*Viverricula indica*) and common palm civet (*Paradoxurus hermaphroditus*) are also found. Black napped hare (*Lepus nigricollis*) and Indian porcupine (*Hystrix indica*) are of common occurrence.

Figure 10.108
Camera trap layout in Rampur Bhatodi Project Division, 2018.



RESULT

Camera Trap Results

No tiger was photo-captured during the sampling period (Table 10.36).

Table 10.36
Sampling details at Rampur Bhatodi FDC division, 2018.

Variables	Counts
Camera points	36
Trap nights (effort)	729

DISCUSSION

This forest division had previous records of tiger presence and acts as a refuge to dispersing tigers as they move across the Satpura-Melghat-Pench corridor.

RATAPANI WILDLIFE SANCTUARY (OBEDULLAGANJ FOREST DIVISION)

INTRODUCTION

Cradled in the Vindhyan mountain ranges in the central Indian landscape, Ratapani Wildlife Sanctuary (RWLS) is spread over the area of Raisen and Sehore districts of Madhya Pradesh under the administrative control of Obedullaganj Forest Division. The sanctuary runs parallel on the northern side of the Narmada river, while the Kolar river forms the western boundary of the sanctuary. Ratapani WLS lies between 20°49' to 23°06' N latitudes and 77°31' to 78°04' E longitudes. RWLS is spread across an area of 823.065 km^2, out of which 763.812 km^2 has been proposed as the core area and the remaining 59.253 km^2 as the buffer area. The state government has earmarked 3500 km^2 of the adjoining forested areas of Raisen, Sehore and Bhopal districts for up-gradation of Ratapani WLS to a tiger reserve. The landscape is undulating, with hills, plateaux, valleys, and plains. A number of seasonal streams irrigate the site in the monsoon, and water is retained in some pools along these streams even in the summer. Two large reservoirs, namely Barna reservoir and Ratapani dam (Barrusot lake) are the major waterbodies adjacent to and inside the sanctuary, respectively. The area is classified under the semi-arid Gujarat Rajputana (4B) biogeographic province (Rodgers et al. 2002).

According to the forest classification (Champion and Seth 1968), the forest of this region is classified as i) southern tropical dry deciduous dry teak forest (5A/C-1b), ii) southern tropical dry deciduous mixed forest (5A/C-3), iii) tropical dry deciduous scrub (5D/S-1), iv) dry grasslands (5D/S-4). About 55% of the area is mainly covered by *Tectona grandis* and the remaining mixed forest consist of various dry deciduous species. *Dendrocalamus strictus* is found in the understorey of *Tectona grandis* and mixed forest and covers about one-quarter of the forest in hilly areas and in slopes. The sanctuary is inhabited by the common animals of the region, such as tiger (*Panthera tigris*), leopard (*Panthera pardus*), grey wolf (*Canis lupus*), golden jackal (*Canis aureus*), Indian fox (*Vulpes bengalensis*), striped hyena (*Hyaena hyaena*), sloth bear (*Melursus ursinus*) amongst carnivores, and chital (*Axis axis*), sambar (*Rusa unicolor*), nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella bennettii*), wild pig (*Sus scrofa*), four-horned antelope (*Tetracerus quadricornis*) and blackbuck (*Antilope cervicapra*), amongst herbivores. Apart from these, crocodiles are also found in Ratapani Wildlife Sanctuary.

Bhimbetka, a group of rock shelters and rock paintings of the Stone Age, which is designated as a World Heritage Site, is located within the protected area and thus Ratapani Wildlife Sanctuary assumes international importance. Railway tracks passing through Ratapani Wildlife Sanctuary endangers the movement of wild animals while poaching of wild animals, illegal mining, and extensive grazing by cattle threaten the biodiversity of this landscape. With the declaration of the sanctuary as a tiger reserve, one can hope for effective conservation of tigers and other wild animals in the area.

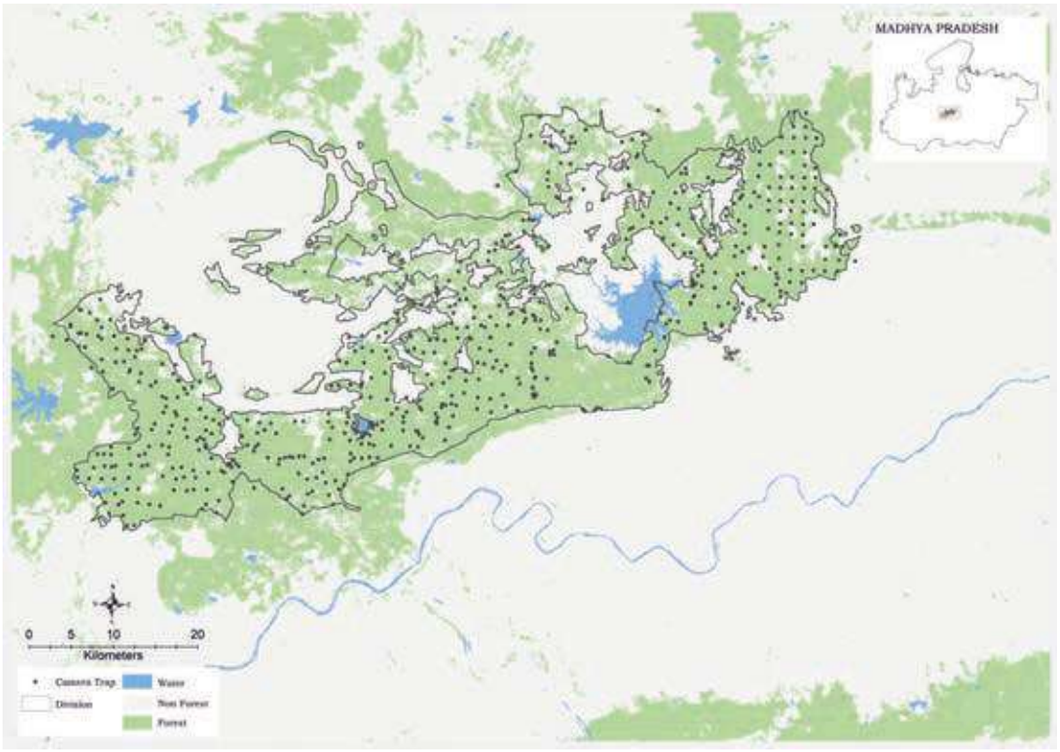


Figure 10.109
Camera trap layout in Ratapani Wildlife Sanctuary (Obedullaganj Forest Division), 2018.

RESULT

Tiger Density Estimates

A total of 89 detections of tigers were obtained during the sampling period from which 27 adult individual tigers were identified giving a density estimate of 1.67 (SE 0.36) tiger per 100 km^2. The detection corrected tiger male to female sex ratio was 0.71:0.29 (Table 10.37).

Table 10.37
Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Ratapani Wildlife Sanctuary (Obedullaganj Forest Division), 2018.

Variables	Estimates
Model space (km^2)	2596.5
Camera points	582
Trap nights (effort)	12618
Unique tigers captured	27
Model	g_0 (sex) σ (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.67 (0.36)
σ Female (SE) km	3.32 (0.29)
σ Male (SE) km	3.93 (0.60)
g_0 Female (SE)	0.009 (0.002)
g_0 Male (SE)	0.002 (0.001)
Pmix Female (SE)	0.29 (0.09)
Pmix Male (SE)	0.71 (0.09)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
σ (Sigma): Spatial scale of detection function,
g_0: Magnitude (intercept) of detection function
Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Ratapani wildlife sanctuary has the potential to develop as a tiger reserve. Due to high contribution of sub-adult males the tiger population has high male biased sex ratio. Together with the forests of Sehore, Bhopal and Dewas this landscape has a high potential to sustain source tiger population in the long run.

SEHORE FOREST DIVISION

INTRODUCTION

Sehore Forest Division is situated in Sehore district (22°33' to 23°38' N and 76°26' to 77°59' E) and spreads over an area of 1520 km^2. The forest division is connected to Dewas Forest Division in the west and Obedullaganj forest division in the east. The forest division is geographically spread over Malwa plateau, lower Vindhya hills, Narmada plains, and the watershed of Narmada and Parvati rivers. The terrain of the forest division is mostly undulating.

Vegetation of the forest division is primarily tropical dry deciduous forest and can further be classified into southern tropical dry deciduous teak and southern tropical dry deciduous mixed forests. Important tree species are *Tectona grandis, Terminalia elliptica, Terminalia arjuna, Diospyros melanoxylon, Madhuca indica, Buchanania lanzan, Pterocarpus marsupium, Butea monosperma* etc. The forest division is refuge to several mammalian species such as tiger (*Panthera tigris*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*), wolf (*Canis lupus*), jackal (*Canis aureus*), chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*) etc.

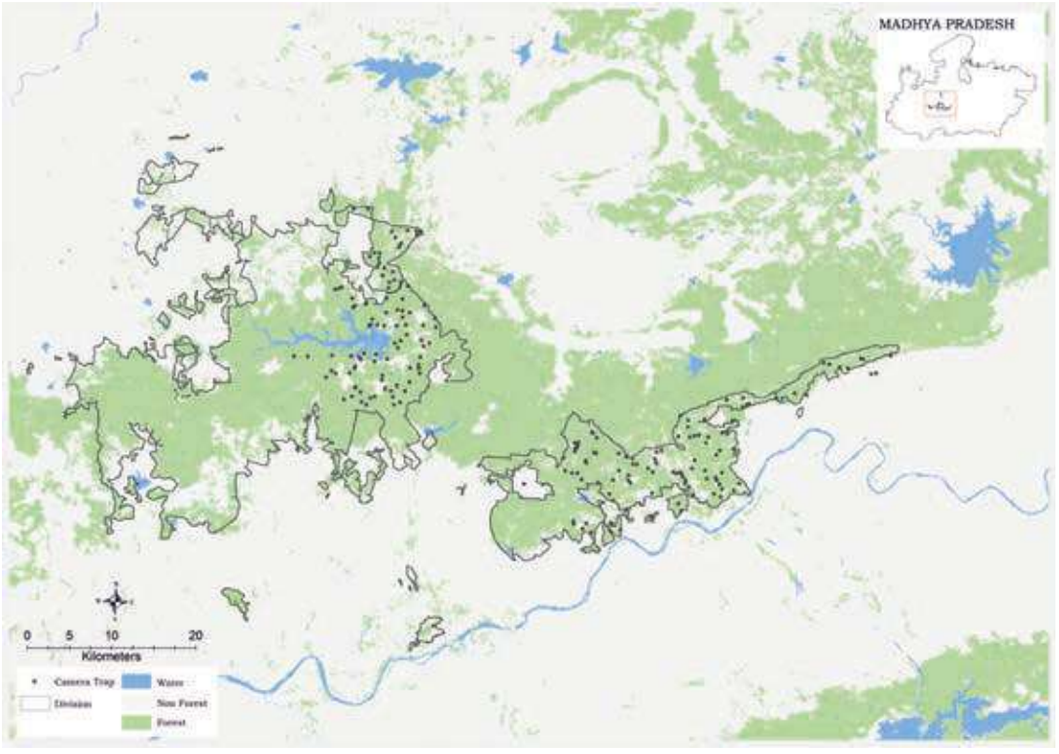


Figure 10.110
Camera trap layout in Sehore Forest Division, 2018.

RESULT

Tiger Density Estimates

A total of 30 detections of tiger were obtained during the sampling period from which 7 individual tigers were identified giving a density estimate of 0.54 (SE 0.23) tiger per 100 km^2. The detection corrected sex ratio was female biased. (Table 10.38).

Table 10.38

Sampling details and tiger density parameter estimates using spatially explicit Capture-Recapture in likelihood framework for Sehore Forest Division, 2018.

Variables	Estimates
Model space (km^2)	1549.75
Camera points	202
Trap nights (effort)	4570
Unique tigers captured	7
Model	σ(.) g_0 (.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.54 (0.23)
σ (SE) km	4.50 (0.90)
g_0 (SE)	0.014 (0.004)
Pmix Female (SE)	0.60 (0.21)
Pmix Male (SE)	0.40 (0.21)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Sehore Forest Division is the part of Ratapani tiger landscape and connects Ratapani Wildlife Sanctuary with Kheoni Wildlife Sanctuary of Dewas Forest Division. The presence of 7 tigers highlights its importance as a sink habitat in this landscape.

SHAHDOL FOREST DIVISION

INTRODUCTION

Shahdol District is situated in the north-eastern part of the Deccan plateau in Madhya Pradesh. It is surrounded by districts Sidhi in the northeast, Korea in the east, Anuppur in east-south, Umaria in the west and Satna in the north-west. This district is situated between 22°38' to 24°20' N latitudes and 80°28' to 82°12' E longitudes. It lies at the tri-junction of Maikal range of Satpura hills, Kymore range of Vindhya hills and the hills extending over Chhota Nagpur plateau in Jharkhand (MSME, Shahdol DIPS). Physiographically the district is divided into i) Maikal Range, ii) Hills of Eastern Plateau and iii) Upper Son Valley divisions. Shahdol is a predominantly hilly district with elevation ranging from 450m to 1123m above mean sea level. The total geographical area of the district is 6205 km^2, out of which 1970.71 km^2 area is forested area (FSI State forest report 2019). The forests of Shahdol are divided into North Shahdol Forest Division and South Shahdol Forest Division. Most of the forests are reserved forests while a small portion of the forests are categorized as protected forest and unclassified forest land.

The vegetation of the region is characterized by tropical moist deciduous Sal forests and northern dry mixed deciduous forest (Champion and Seth 1968) of which Shorea robusta is the dominant species. *Terminalia elliptica, Madhuca longifolia, Lagerstroemia parviflora, Adina cardifolia, Terminalia arjuna, Anogeissus latifolia,* etc. are the other common species found in these forests. The common animal species found in the area are tiger (*Panthera tigris*), leopard (*Panthera pardus*), golden jackal (*Canis aureus*), Indian fox (*Vulpes bengalensis*), wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*), chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), chinkara (*Gazella bennettii*), nilgai (*Boselaphus tragocamelus*), four-horned antelope (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), etc.

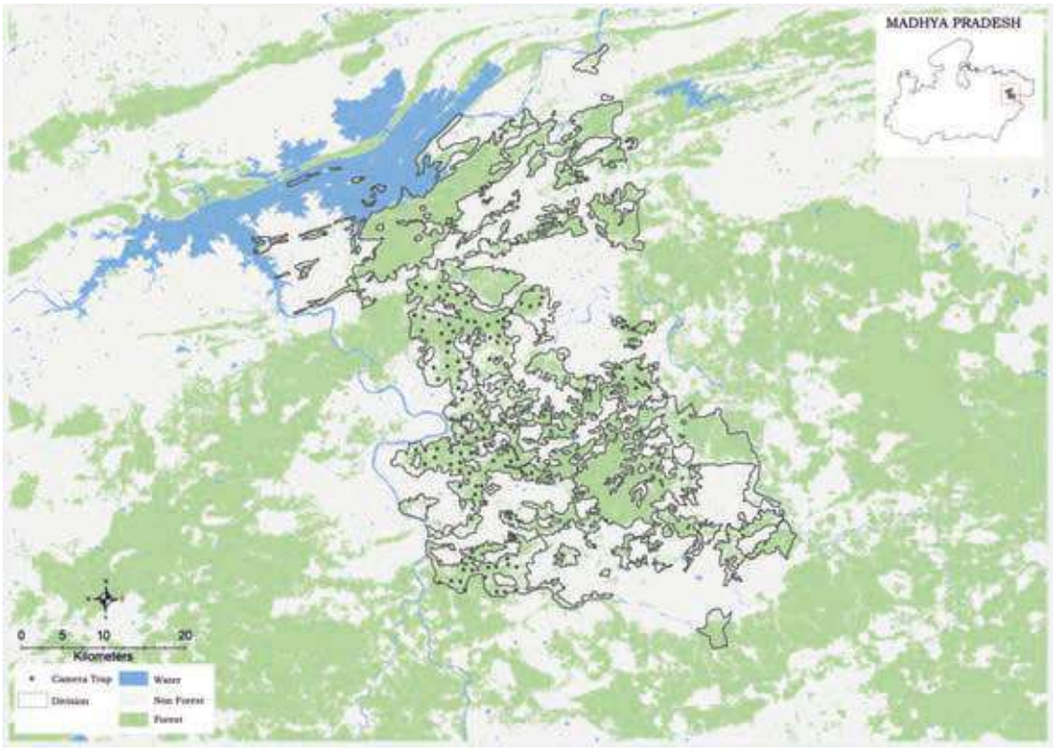


Figure 10.111
Camera trap layout in Shahdol Forest Divisions, 2018.

RESULT

Tiger Density Estimates

A total of 69 detections of tiger was obtained during the sampling period from which 9 individual tigers were identified giving a density estimate of 0.70 (SE 0.24) tiger per 100 km^2. The detection corrected sex ratio was male biased. (Table 10.39).

Table 10.39
Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Shahdol forest divisions, 2018.

Variables	Estimates
Model space (km^2)	1516.25
Camera points	98
Trap nights (effort)	3245
Unique tigers captured	9
Model	g_0 (.) σ (.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.70 (0.24)
σ (SE) km	6.40 (0.06)
g_0 (SE)	0.020 (0.004)
Pmix Female (SE)	0.43 (0.18)
Pmix Male (SE)	0.57 (0.18)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
σ (Sigma): Spatial scale of detection function,
g_0: Magnitude (intercept) of detection function
Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Shahdol forest division is connected to Sanjay Dubri Tiger Reserve and serves as an important wildlife corridor. It has been observed that tigers are moving across nearby protected areas via the forests of Shahdol division. Similarly, elephants (*Elephas maximus*) are also using this forest for temporary shelter and movement from Chhattisgarh.

SOUTH PANNA FOREST DIVISION

INTRODUCTION

South Panna Territorial Forest Division is situated in the central portion of the plateau of Bundelkhand lying between latitude 23°45' to 24°30' N and longitudes 79° 45' to 80°40' E. This forest division is the part of greater Panna tiger landscape. South Panna Territorial Forest Division covers an area of about 4521.91km^2. This forest division in connected to Damoh Forest Division in the west and Satna Forest Division in the east.

The forests of South Panna Territorial Forest Division are classified into two major forest types viz. southern tropical dry deciduous teak forest and southern dry mixed deciduous forests (Champion and Seth 1968). *Tectona grandis* is the dominant tree species growing gregariously in the division. Mixed forests are represented by *Terminalia elliptica, Anogeissus latifolia, Lagerstromia parviflora, Phyllanthus emblica, Buchanania lanzan,* and *Madhuca latifolia* amongst others. Tiger (*Panthera tigris*) occasionally move from Panna Tiger Reserve to this division, however, this division is home to leopard (*Panthera pardus*) and jackal (*Canis aureus*). Among other carnivores, jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*), sloth bear (*Melursus ursinus*) and wolf (*Canis lupus*) are also found here. Herbivores include nilgai (*Boselaphus tragocamelus*), sambar (*Rusa unicolor*), chital (*Axis axis*), and four-horned antelope (*Tetracerus quadricornis*).

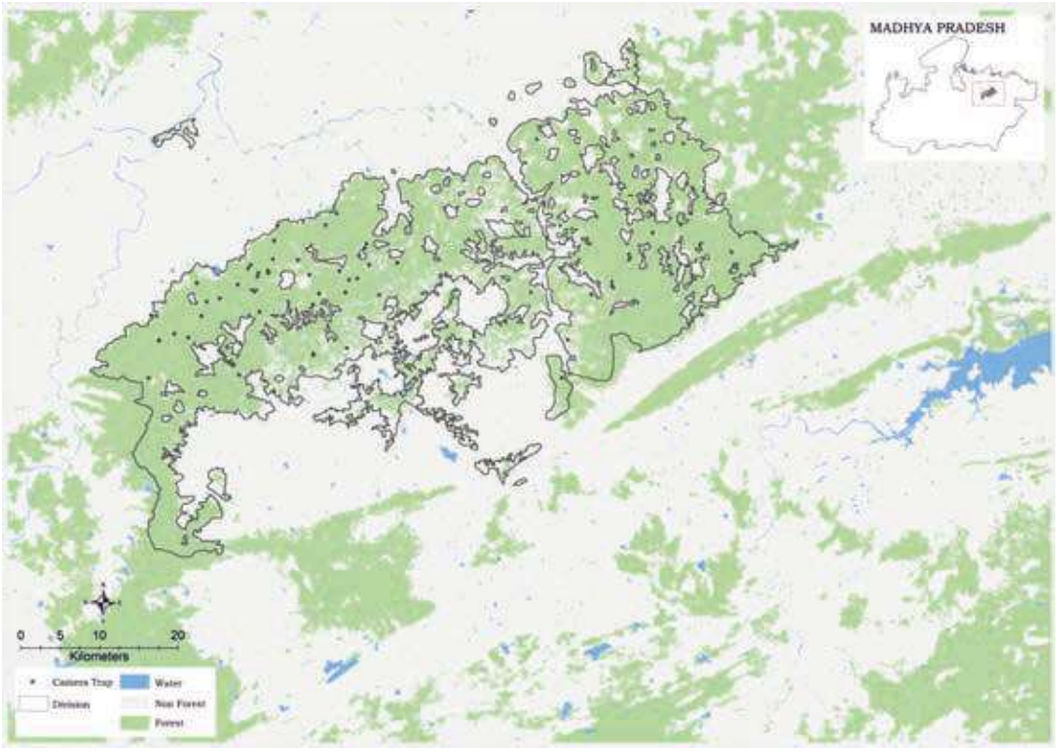


Figure 10.112
Camera trap layout in South Panna Territorial Forest Division, 2018.

RESULT

Camera Trap Results

A total of 4 detections of tigers were obtained during the sampling period. Only 1 adult male tiger was captured and hence the density could not be estimated (Table 10.40).

Table 10.40

Sampling details and tiger density parameter estimates using spatially explicit Capture-Recapture in likelihood framework for South Panna Territorial Forest Division, 2018.

Variables	Counts
Camera points	49
Trap nights (effort)	1412
Unique tigers captured	1

DISCUSSION

South Panna Territorial Forest Division is located south to Panna Tiger Reserve, separated by the intervening agro pastoral landscape and Betwa river. This forest acts as refuge to dispersing tigers of Panna Tiger Reserve.

UMARIA FOREST DIVISION

INTRODUCTION

Umaria district is situated in the eastern part of Madhya Pradesh in the Vindhyan region. It is bounded by Satna district in north, Dindori district in south, Shahdol district in east and Katni district in west. The district lies between 23° 05' to 24° 20' N latitudes and 80° 40' to 81° 17' E longitudes. The geographical area of the district is 4076 km^2 out of which 2022.58 km^2 is forested area (FSI State forest report, 2019). The entire Umaria district located within Son sub-basin area of the Ganga basin. Son river flows from southwest to northeast direction and forms the district boundary between Shahdol and Umaria districts. Rivers Johila and Chhoti Mahanadi are the main tributaries of Son river in the Umaria district.

The forest of the district comprises of Umaria territorial forest division, Bandhavgarh Tiger Reserve (BTR) and Forest Development Corporation Division. The vegetation of the Umaria territorial forest division is mainly categorised as tropical mixed dry deciduous and tropical dry teak forest (Champion and Seth, 1968). The main tree species are *Tectona grandis, Shorea robusta, Terminalia elliptica, Diospyros melanoxylon, Terminalia bellirica, Anogeissus latifolia, Madhuca longifolia, Buchanania lanzan, Butea monosperma,* and *Dendrocalamus strictus.* The main animal species are tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyaena hyaena*), golden jackal (*Canis aureus*), chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), nilgai (*Boselaphus tragocamelus*), and chinkara (*Gazella bennettii*).

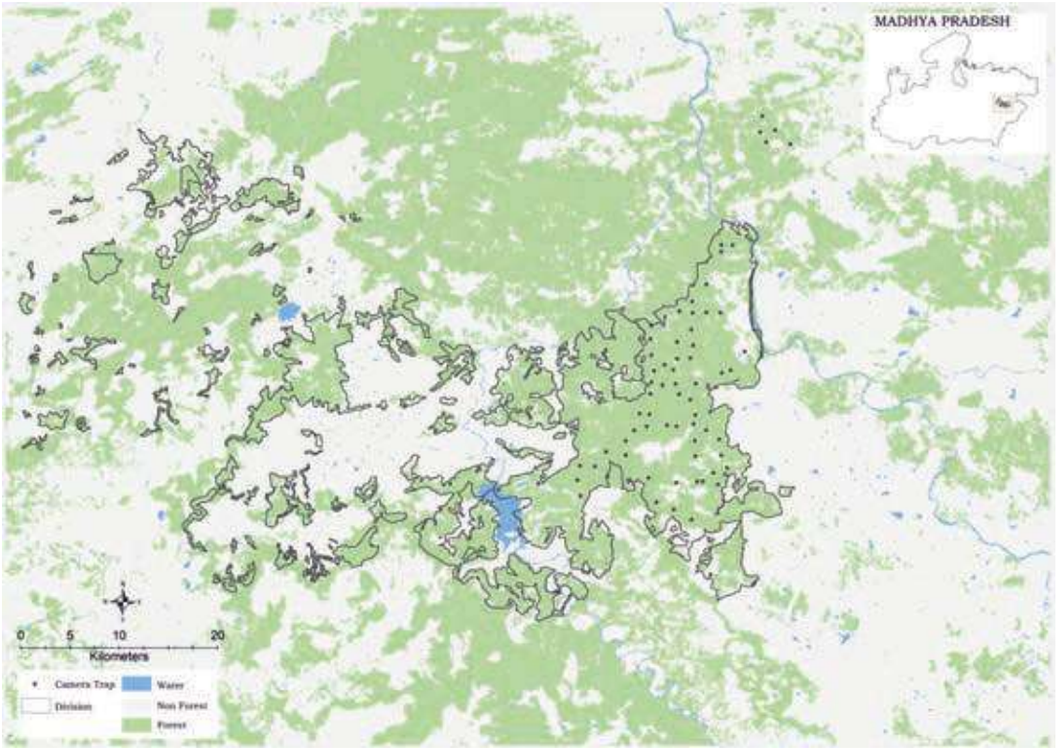


Figure 10.113
Camera trap layout in Umaria Forest Division, 2018.

RESULT

Tiger Density Estimates

A total of 36 detections of tigers had been obtained during the sampling period from which 12 adult individual tigers were identified giving a density estimate of 1.82 (SE 0.59) tiger per 100 km^2. Gender of most of the tigers could not be ascertained from camera trap images, hence, sex ratio was not estimated (Table 10.41).

Table 10.41

Sampling details and tiger density parameter estimates using spatially explicit capture-recapture in likelihood framework for Umaria forest division, 2018.

Variables	Estimates
Model space (km^2)	1094.25
Camera points	67
Trap nights (effort)	1674
Unique tigers captured	12
Model	σ (.) g_0 (.)
$\hat{D}$ SECR (per 100 km^2)	1.82 (0.59)
σ(SE) (km)	5.77 (0.98)
g_0 (SE)	0.004 (0.001)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Umaria is sink habitat of Bandhavgarh tiger reserve. Large scale mining of coal has caused extensive deforestation in this district. As the area forms an important wildlife corridor between Kanha and Bandhavgarh tiger reserves, it needs to be protected from the increasing anthropogenic pressures.

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BOR TIGER RESERVE

INTRODUCTION

Located in the Wardha district of eastern Maharashtra, Bor Tiger Reserve (20°55'7" N to 21° 3'32" N and 78°34'3" E to 78°47'51" E) is spread over 126.7 km^2 and fragmented into two parts by the Bor dam reservoir.

Primarily covered with dry savannahs and dry deciduous forests dominated by *Tectona grandis, Diospyros melanoxylon* and Bamboo thickets, the tiger reserve holds a varied mammalian diversity including dhole (*Cuon alpinus*), leopard (*Panthera pardus*), gaur (*Bos gaurus*), sloth bear (*Melursus ursinus*), chital (*Axis axis*) and sambar (*Rusa unicolor*).

In 2014, five tigers were recorded in the area. Presently, being the second smallest tiger reserve its potential tiger carrying capacity is relatively small, however it serves an important position in maintaining the tiger meta-population in the eastern Maharashtra-Madhya Pradesh landscape. In this landscape, the proximity of Bor Tiger Reserve with the surrounding tiger reserves (Tadoba Andhari, Pench, Nawegaon Nagzira and Melghat) establishes a tiger meta-population connected through forested corridors. These corridors are fragmented by linear infrastructure and used for multiple purposes by the local populace, thus bringing the dispersing tigers in close interaction with humans. As a consequence of the shared space, there have been tiger roadkill's (NH-6) or electrocution around the farms.

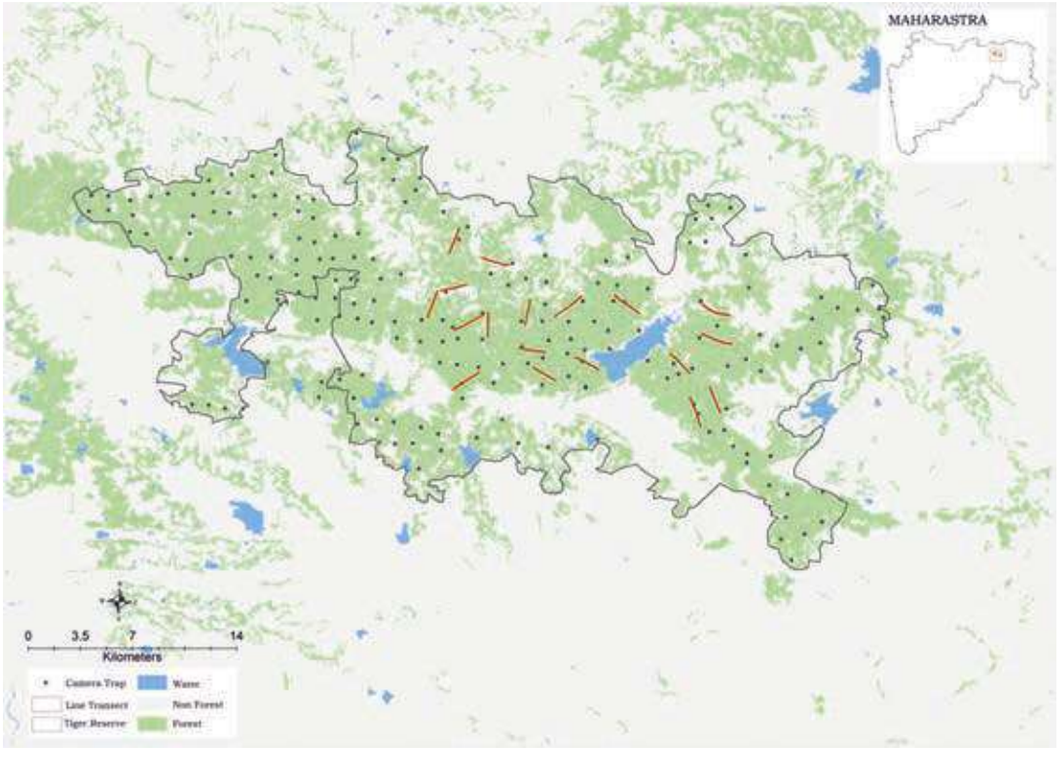


Figure 10.114
Camera trap and transect layout in Bor Tiger Reserve, 2018

RESULT

Tiger Density Estimates

A total of 107 detections of tigers were obtained during the sampling period from which 6 adult individual tigers were identified. Tiger density was estimated at 0.6 (SE 0.29) tiger per 100 km^2 (Table 10.42). The detection corrected sex ratio was female biased.

Table 10.42

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Bor Tiger Reserve, 2018.

Variables	Estimates
Model space (km^2)	872.5
Camera points	193
Trap nights (effort)	8368
Unique tigers captured	6
Model	g_0(.) σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.6(0.29)
σ (SE) km	7.20(0.47)
g_0 (SE)	0.012 (0.001)
Pmix Female (SE)	0.60 (0.21)
Pmix Male (SE)	0.40 (0.21)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

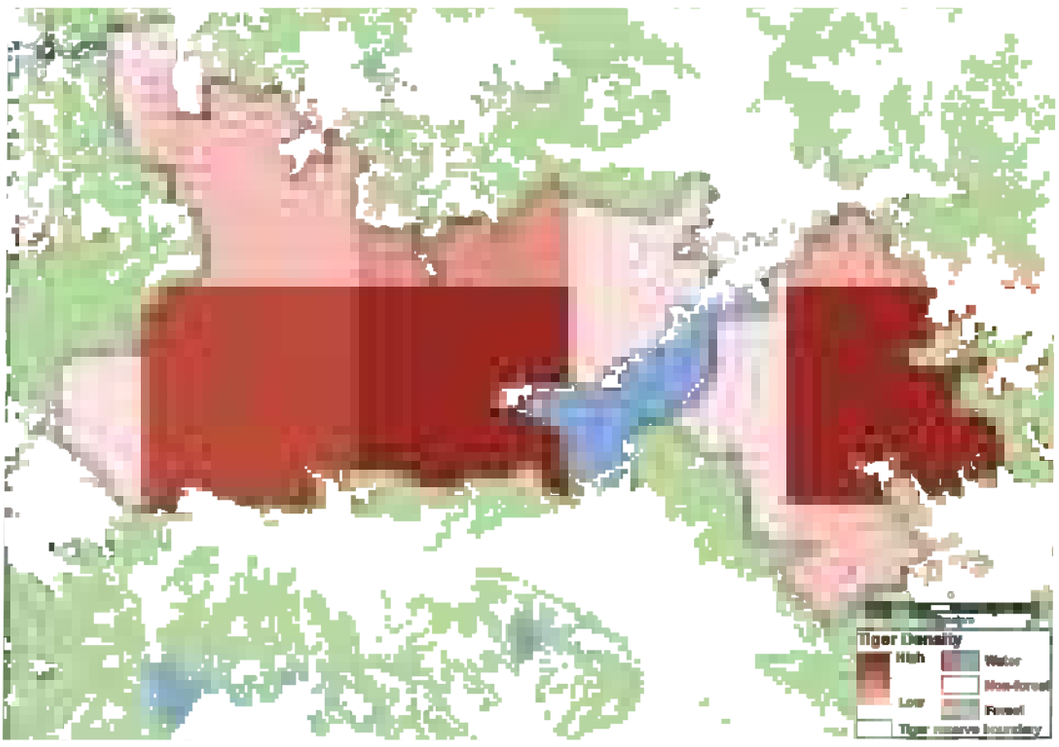
σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Figure 10.115

Spatial density of tigers in Bor Tiger Reserve, 2018



Owing to the small area of the tiger reserve most of the tigers use the available habitat in the reserve. However, relatively higher tiger densities were observed in the central and eastern parts of the tiger reserve.

Prey Density Estimates

A total of 54 transects were sampled in Bor Tiger Reserve, which amounted to an effort of 109 km. Due to low sighting animal densities were not estimated. However, the encounter rate of nilgai and sambar were higher, followed by wild pig and chital (Table 10.43).

Species	Encounter rate (SE)
Chital	0.119 (0.037)
Sambar	0.412 (0.066)
Nilgai	0.412 (0.052)
Wild pig	0.164 (0.035)

Table 10.43
Encounter rate of prey species from line transect (n=54, Total effort 109 km) in Bor Tiger Reserve, 2018-19

Distribution of Major Mammalian Species Found in Bor Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Bor Tiger Reserve.

Leopard presence was recorded in most of the camera traps in the tiger reserve. The capture hotspot was observed in the undulating dry forests and savanna on the western part. Another hotspot was observed in the eastern fringe of the forests with similar habitat.

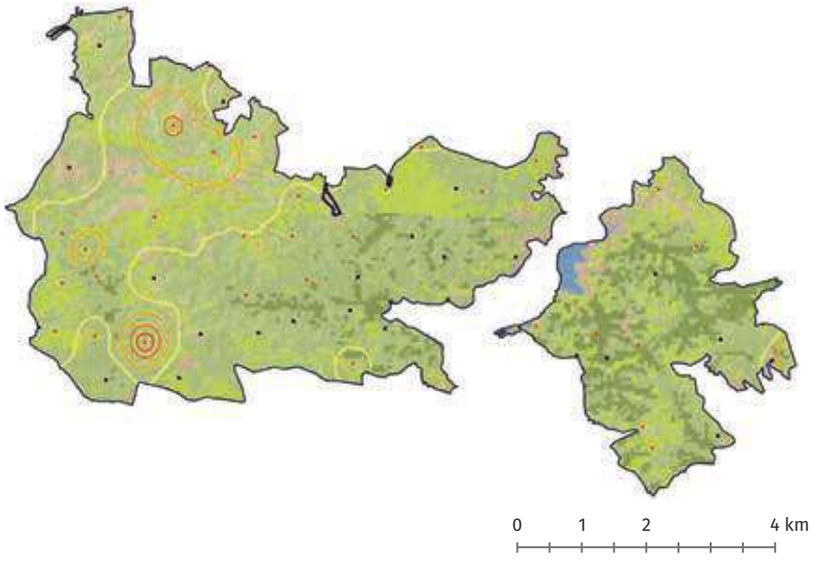


Figure 10.116
Distribution and relative spatial abundance of leopard in Bor Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Dhole was recorded across most of the camera traps in the park, with hotspots in the central part of the park in dry deciduous forests surrounded by dry savanna and scrub patches. The hotspots of dhole captures were spatially distinct from the leopard higher concentration of photo-captures, hinting towards the spatial segregation in these sympatric carnivores.

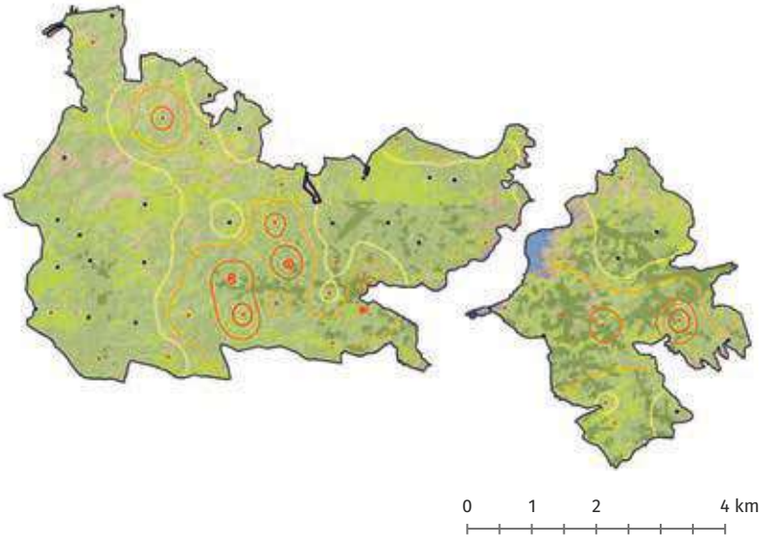


Figure 10.117
Distribution and relative spatial abundance of dhole in Bor Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

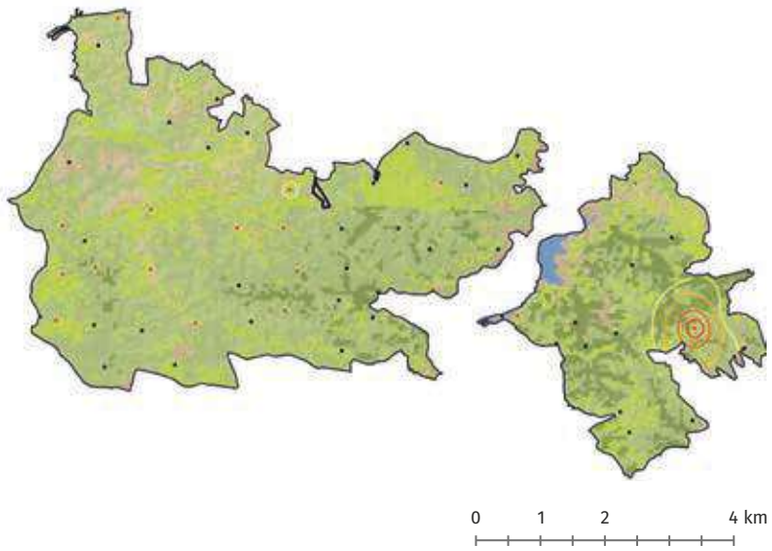


Figure 10.118

Distribution and relative spatial abundance of sloth bear in Bor Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Sloth bear was recorded across the tiger reserve with higher concentration of photo-captures in the rugged terrain of the eastern block. The hotspots were mostly in the scrub patches surrounded by dry deciduous forests and savannas.

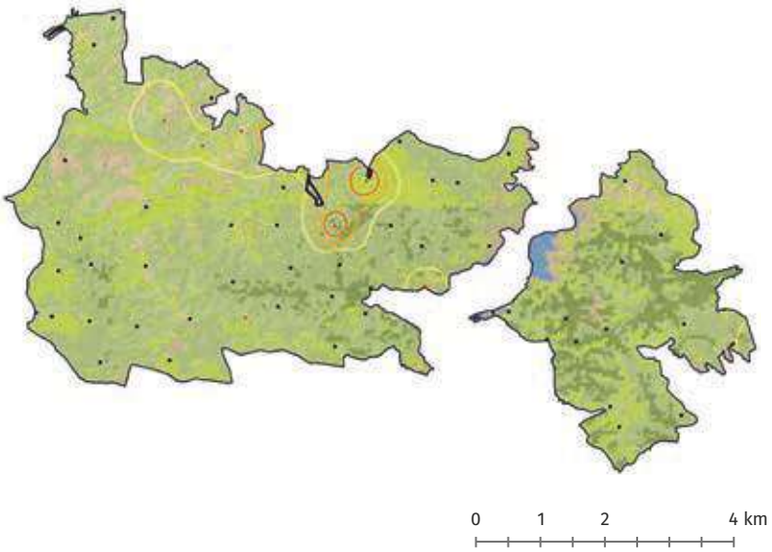


Figure 10.119

Distribution and relative spatial abundance of grey wolf in Bor Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Grey wolf was recorded on the fringes of the tiger reserve. The higher concentration of photo-captures were around rugged terrain with dry grasslands and savannas that are buffered by agricultural farms outside the tiger reserve. The hotspots of grey wolf captures were spatially distinct from that of leopard and dhole.

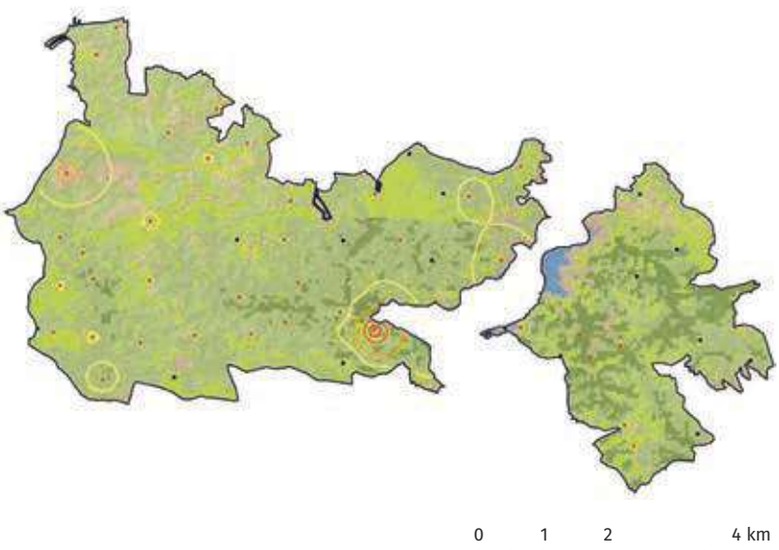


Figure 10.120

Distribution and relative spatial abundance of jungle cat in Bor Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Jungle cat was captured in most of the camera traps of the tiger reserve. The higher concentration of photo-captures were around rugged terrain with patches of dry deciduous forests and scrub savanna.

Four-horned antelope had patchy distribution in the park, with higher concentration of photo-captures on the relatively plain terrain in grasslands or savannas. It also coincided with the nearness to the seasonal water streams.

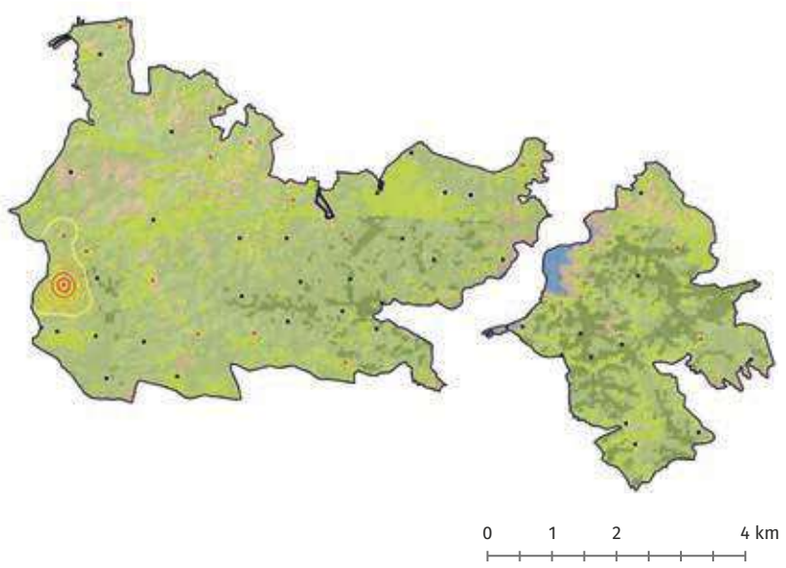


Figure 10.121

Distribution and relative spatial abundance of four-horned antelope in Bor Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Relative Abundance of all Photocaptured Species in Bor Tiger Reserve

A total of 24 wild species of ungulates, carnivores, primates, omnivores, and galliformes were photo-captured in Bor Tiger Reserve. Livestock and nilgai were the most common, while common palm civet and rhesus macaque were the rarest photo-captured species (Table 10.44).

DISCUSSION

Tiger population has remained stable compared to 2014 where 5 (3-6) tigers were estimated.

Table 10.44

Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Bor Tiger Reserve, 2018

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Chinkara	3.38	30
Chital	1.83	55
Common palm civet	0.11	930
Domestic dog	4.95	20
Four-horned antelope	1.12	89
Golden jackal	0.12	837
Grey mongoose	0.31	322
Grey wolf	0.47	215
Hanuman langur	5.49	18
Indian fox	0.30	335
Indian hare	2.51	40
Indian porcupine	5.33	19
Jungle cat	6.63	15
Leopard	2.27	44
Livestock	23.60	4
Nilgai	13.53	7
Peafowl	2.23	45
Red jungle fowl	0.29	349
Rhesus macaque	0.02	4184
Ruddy mongoose	0.14	697
Sambar	9.73	10
Sloth bear	1.53	65
Small Indian civet	0.23	440
Tiger	1.42	70
Wild dog	2.98	34
Wild pig	4.62	22

MELGHAT TIGER RESERVE

INTRODUCTION

Situated in Satpura hill ranges of central India, Melghat Tiger Reserve is located from 21° 6'20" N to 21°45'37" N and 76°37'10" E to 77°31'22" E, in the Amravati district of Maharashtra. Melghat, which means 'meeting of the ghats', is a large area of unending hills and ravines scarred by sharp cliffs and steep climbs. It has an area of 2029 km^2 consisting of three protected areas namely, Sipna Wildlife Division (839 km^2), Gugamal Wildlife Division (639 km^2), and Akot Wildlife Division (550 km^2). It was established as a wildlife sanctuary in 1967 and was subsequently declared a tiger reserve in 1974. The forests of Melghat are chiefly inhabited by the Korku tribes. Melghat Tiger Reserve is a typical representative of the central Indian Highlands forming a part of the biogeographic zone '6 E-Deccan Peninsula'- Central Highlands (Rodgers and Panwar 1988). The forest is classified as southern tropical dry deciduous (5A) (Champion and Seth 1968). The landscape is at the juncture of *Shorea robusta* forests and *Tectona grandis* forests. The major carnivores and herbivores include tiger (*Panthera tigris*), leopard (*Panthera pardus*), gaur (*Bos gaurus*), wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), wolf (*Canis lupus*), wild pig (*Sus scrofa*), sambar (*Rusa unicolor*), chital (*Axis Axis*), and chaushinga (*Tetracerus quadricornis*). Melghat Tiger Reserve forms an important population of tigers that is connected with Satpura Tiger Reserve, through the forested corridor of Betul.

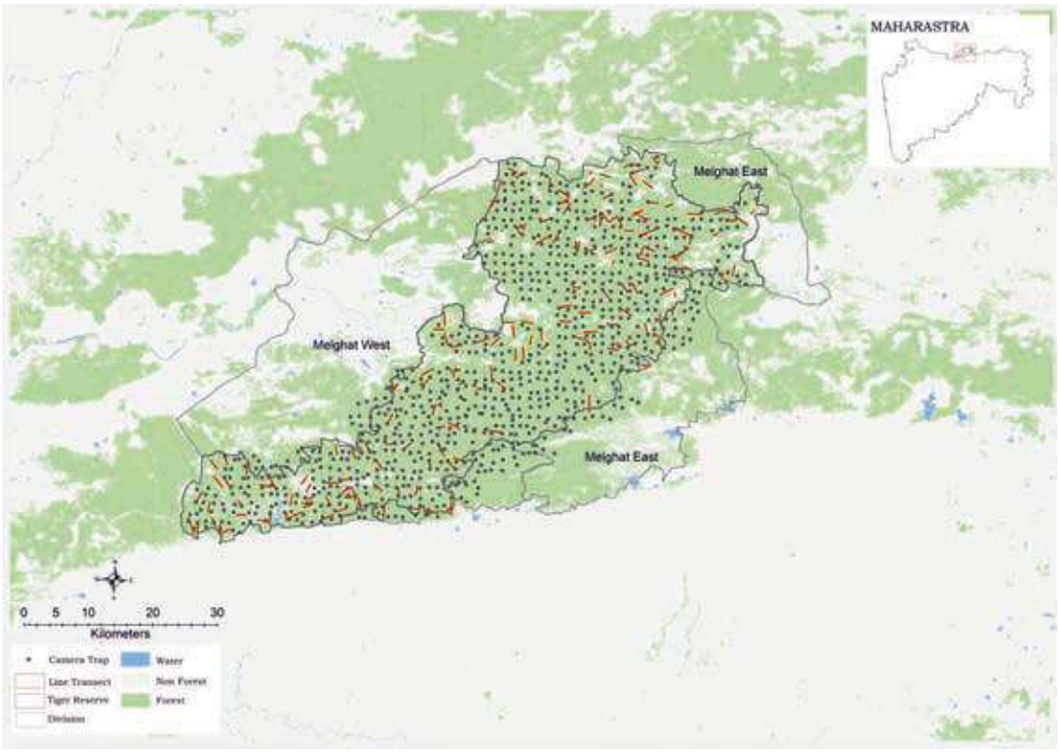


Figure 10.122
Camera trap and transect layout in Melghat Tiger Reserve, 2018

RESULT

Tiger Density Estimates

A total of 1159 detections of tigers were obtained during the sampling period from which 46 individual adult tigers were identified. SECR models estimated tiger density of 1.49 (SE 0.22) tigers per 100 km^2 (Table 10.45). The detection corrected sex ratio was female biased (Table 10.45).

Variables	Estimates
Model space (km^2)	3285.5
Camera points	888
Trap nights (effort)	46784
Unique tigers captured	46
Model	g_0(sex) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.49(0.22)
σ Female (SE) km	3.22(0.07)
σ Male (SE) km	7.62(0.23)
g_0 Female (SE)	0.010(0.001)
g_0 Male (SE)	0.003(0.000)
Pmix Female (SE)	0.62 (0.07)
Pmix Male (SE)	0.38(0.07)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Table 10.45

Sampling details and tiger density parameter estimates in spatially explicit capture-recapture analysis in a likelihood framework for Melghat Tiger Reserve, 2018.

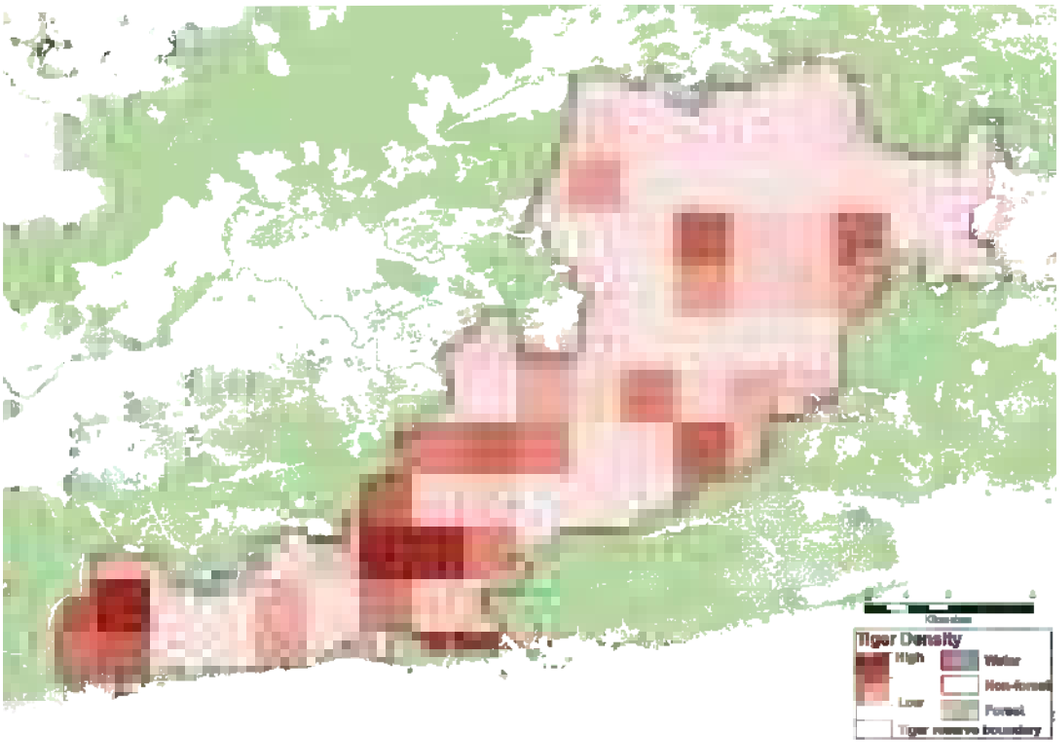


Figure 10.123

Spatial density of tigers in Melghat Tiger Reserve, 2018

Higher tiger densities were observed in the deciduous forests of Gugamal National Park and Amba Barwa Wildlife Sanctuary.

Prey Density Estimates

A total of 812 transects were sampled in Melghat Tiger Reserve, which amounted to an effort of 1415.59 km. Sambar was found to be the most abundant ungulate with a density of 2.55 (SE 0.57) sambar per km^2 (Table 10.46).

Table 10.46

Model statistics and parameter estimates of line transect (n=812, Total effort 1415.59 km) based distance sampling for prey species in Melghat Tiger Reserve, 2018

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Sambar	29.41 (5.07)	97	2.19 (0.2)	0.25 (0.04)	0.07 (0.007)	1.165 (0.23)	2.55 (0.57)
Gaur	31.79 (4.45)	56	3.27 (0.46)	0.26 (0.04)	0.04 (0.005)	0.622 (0.11)	2.03 (0.48)
Nilgai	39.82 (6.63)	72	2.71 (0.31)	0.31 (0.05)	0.05 (0.006)	0.639 (0.12)	1.73 (0.40)
Barking deer	34.59 (2.78)	129	1.34 (0.06)	0.29 (0.02)	0.09 (0.010)	1.317 (0.15)	1.76 (0.21)
Chital		06			0.004 (0.002)		

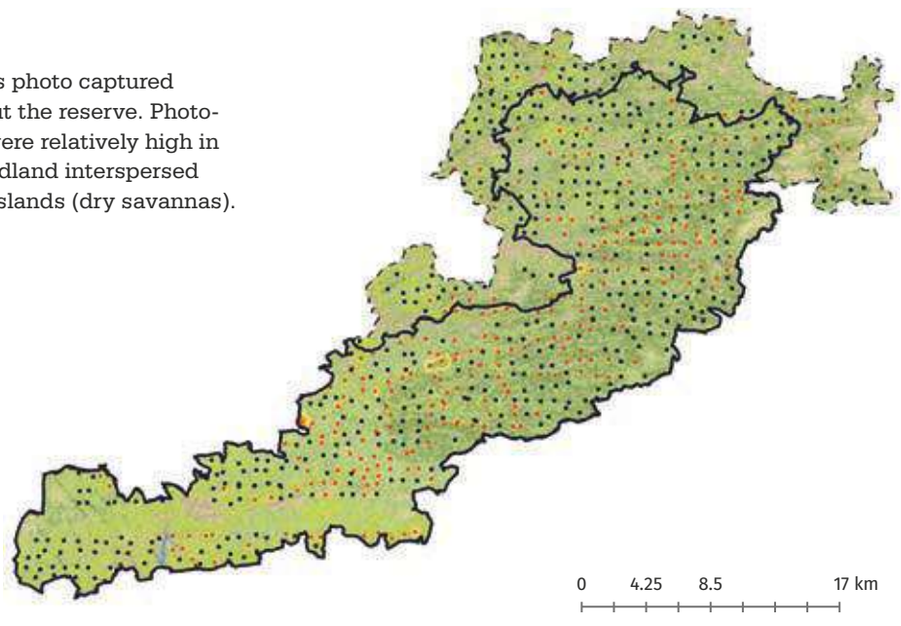
Distribution of Major Mammalian Species Found in Melghat Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of the Tiger Reserve.

Figure 10.124

Distribution and relative spatial abundance of dhole in Melghat Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict the intensity of photo-captures.

Dhole was photo captured throughout the reserve. Photo-capture were relatively high in open woodland interspersed with grasslands (dry savannas).



Four-horned antelope was distributed throughout the reserve. Photo-captures of four-horned antelope were relatively high in dry deciduous forest and scrubland on the undulating terrain.

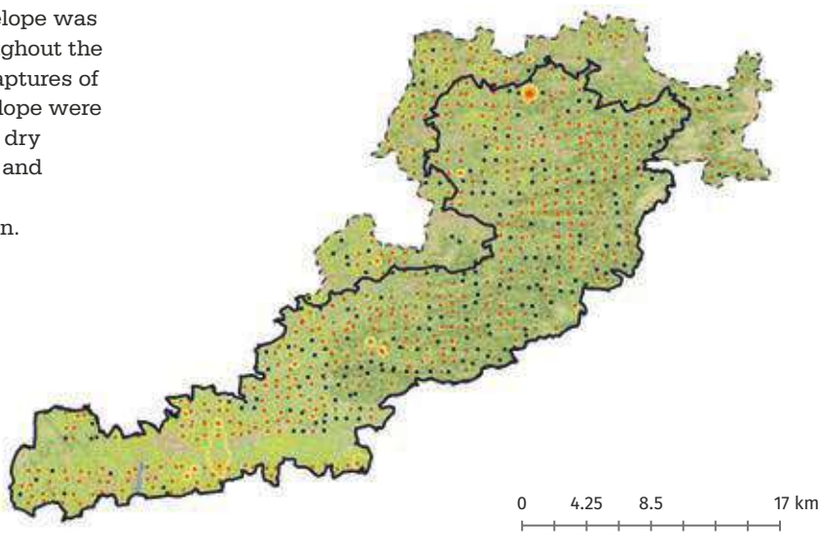


Figure 10.125
Distribution and relative spatial abundance of four-horned antelope in Melghat Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Gaur was photo-captured throughout the reserve.

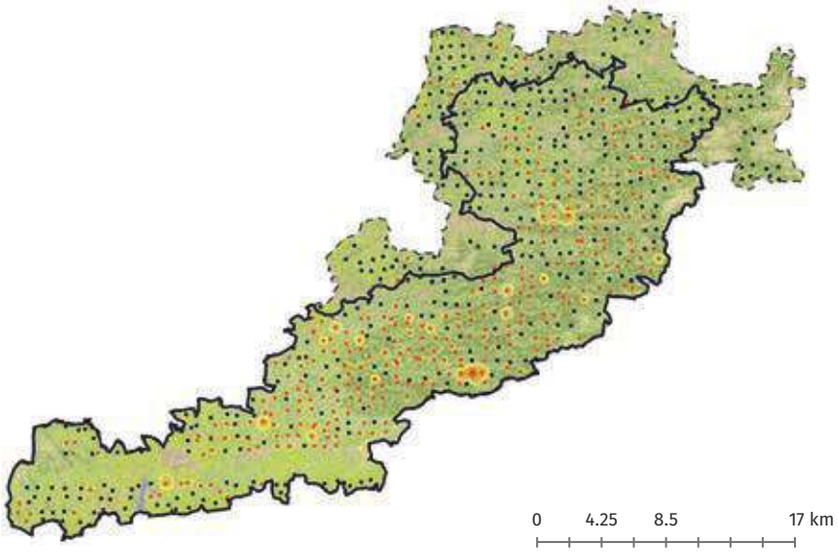


Figure 10.126
Distribution and relative spatial abundance of gaur in Melghat Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Low photo-captures of golden jackal indicated that it is distributed sparsely in the tiger reserve.

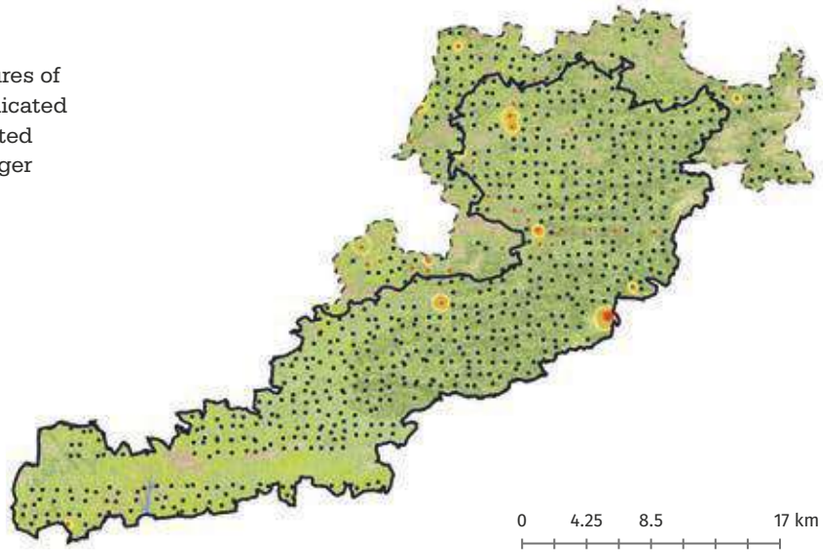


Figure 10.127
Distribution and relative spatial abundance of the golden jackal in Melghat Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Grey wolf was photo-captured mainly in the Gugamal range in the buffer area of the Melghat Tiger Reserve. This area is a mosaic of savanna and agricultural fields.

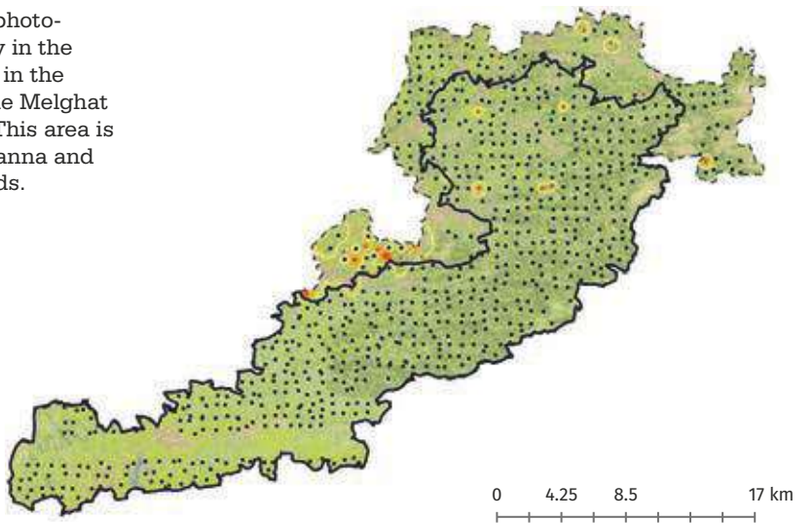


Figure 10.128

Distribution and relative spatial abundance of the grey wolf in Melghat Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Jungle cat was photo-captured in almost every camera trap, indicative of its distribution across the reserve.

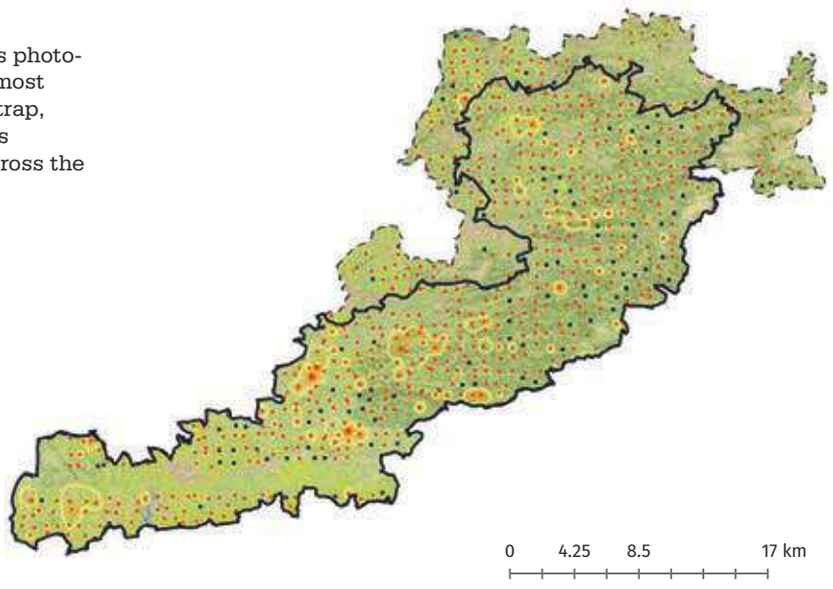


Figure 10.129

Distribution and relative spatial abundance of jungle cat in Melghat Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Leopard was distributed throughout the tiger reserve with a capture hotspot in the hilly terrain of Dargad and Dhakana ranges.

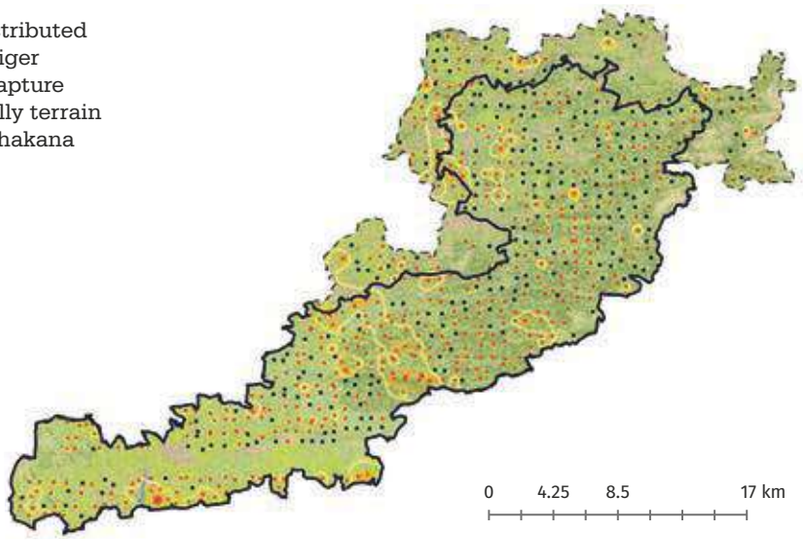


Figure 10.130

Distribution and relative spatial abundance of leopard in Melghat Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

There were very few photo-captures of rusty-spotted cat and the captures were mostly in moderately dense forest.

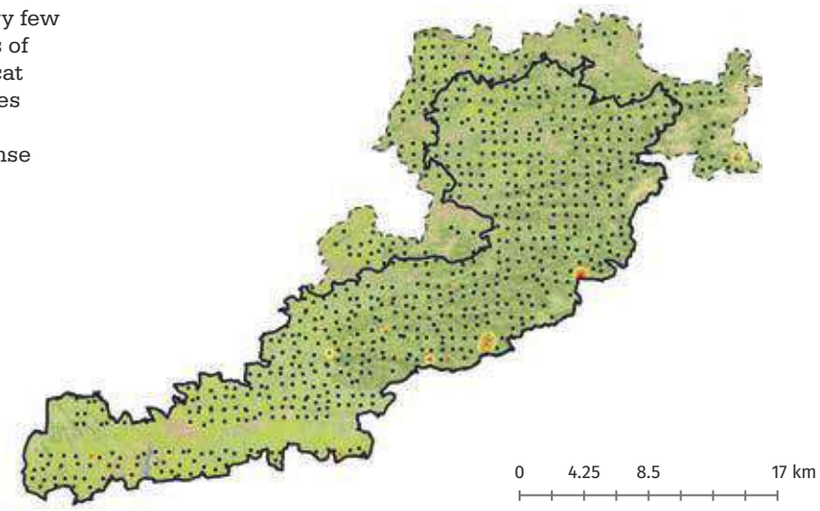


Figure 10.131

Distribution and relative spatial abundance of the rusty-spotted cat in Melghat Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Sloth bear was photo-captured in almost every camera trap, indicating their presence throughout the reserve.

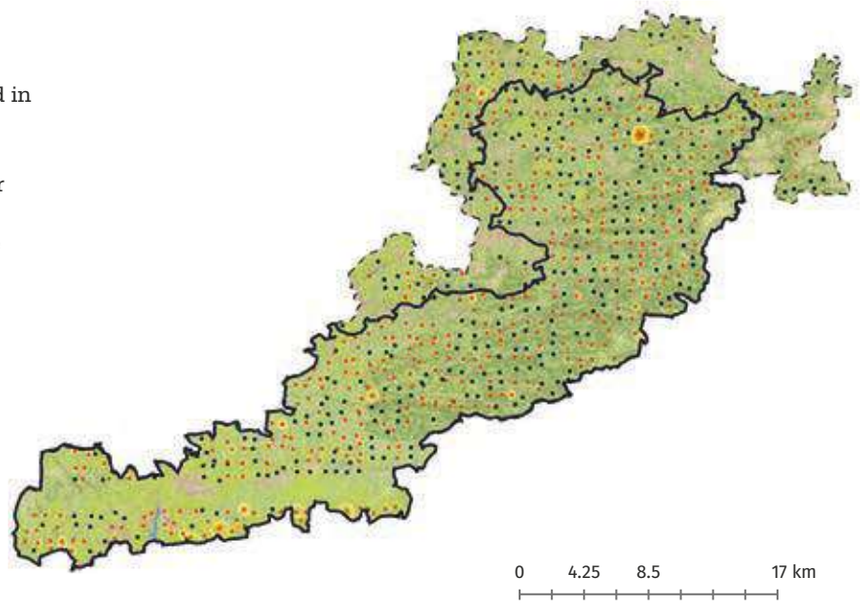


Figure 10.132

Distribution and relative spatial abundance of sloth bear in Melghat Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Striped hyena has mainly distributed in Chourakund, Hatru, Harisal and Raipur ranges of the tiger reserve. In addition, sparse distribution was also recorded towards the periphery of the south-west boundary of the tiger reserve.

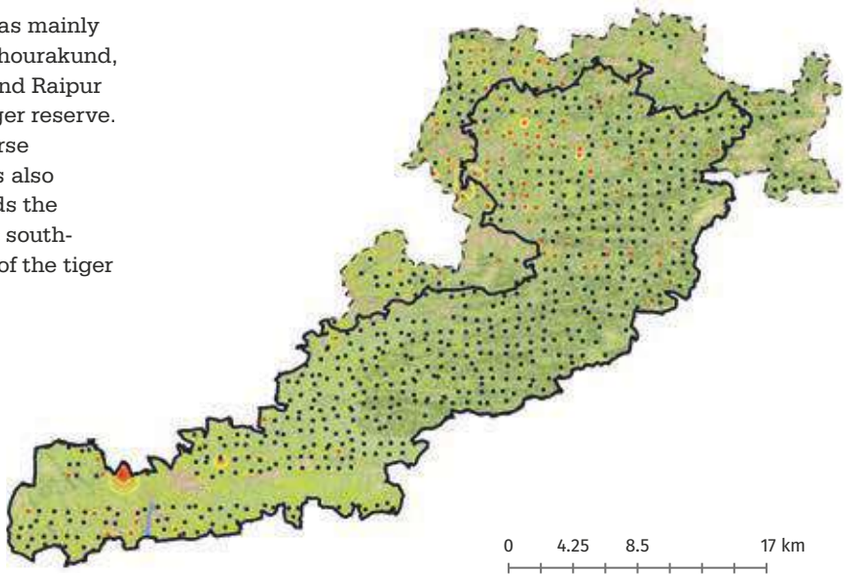


Figure 10.133

Distribution and relative spatial abundance of striped hyena in Melghat Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Table 10.47

Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Melghat Tiger Reserve, 2018

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Barking deer	1.97	51
Chinkara	0.01	11696
Chital	0.33	302
Domestic dogs	2.56	39
Four horned antelope	4.26	23
Gaur	2.61	38
Golden Jackal	0.13	780
Grey Mongoose	0.48	210
Grey Wolf	0.07	1418
Hanuman Langur	7.10	14
Honey badger	0.45	224
Indian Fox	0.01	7797
Indian Hare	9.45	11
Indian Pangolin	0.01	9357
Indian Porcupine	5.17	19
Jungle Cat	17.03	6
Leopard	3.54	28
Livestock	18.65	5
Nilgai	1.56	64
Palm Civet	3.38	30
Peafowl	1.60	63
Red Jungel fowl	0.63	159
Rhesus macque	1.16	86
Ruddy mongoose	1.17	85
Rusty spotted cat	0.06	1613
Sambar	9.45	11
Sloth Bear	2.43	41
Small Indian Civet	2.91	34
Striped Hyena	0.55	181
Tiger	2.50	40
Wild dog	1.66	60
Wild Pig	4.46	22

Relative Abundance of all Photocaptured Species in Melghat Tiger Reserve

A total of 30 wild species of ungulates, carnivores, primates, omnivores and galliformes were photo-captured in Melghat Tiger Reserve. Jungle cat, and Indian hare were the most common species with 7-14 days (Table 10.47) required to obtain one photograph. Chinkara and pangolin were the rarest photo-captured species.

DISCUSSION

Compared to 2014, the sampling area coverage for both camera traps and line transects were more extensive for the current cycle. Melghat tiger tensity is low, but has shown an upward trend. If protection and management to reduce human pressures within the Tiger reserve continue, both prey and tiger densities will improve further. Melghat in combination with Satpura Tiger Reserve is a viable tiger population if maintained as a meta-population. Therefore, the interveining forests of Betul division form a vital corridor link for both populations. Once tiger density increases in Melghat tigers will disperse westward to the Northern Western Ghats of Nashik and Dhule districts and onward into the Dang forests of Gujarat.

NAWEGAON NAGZIRA TIGER RESERVE

INTRODUCTION

Declared as a tiger reserve in 2013, Nawegaon Nagzira has an area of 1706.3 km^2 (79.6751° to 80.4115° E longitudes and 20.8452° to 21.4586° N latitudes) and is located in the Bhandara and Gondia districts of eastern Maharashtra. The tiger reserve is comprised of Nawegaon National Park, Nawegaon Wildlife Sanctuary, Nagzira Wildlife Sanctuary, New Nagzira Wildlife Sanctuary and Koka Wildlife Sanctuary.

The mesic savannahs and dry deciduous forests in the area are predominantly covered by *Tectona grandis, Terminalia* spp., *Diospyros melanoxylon* and bamboo thickets. In response to the varied habitat type, a diverse array of mammals is found in the region including dhole (*Cuon alpinus*), leopard (*Panthera pardus*), gaur (*Bos gaurus*), sloth bear (*Melursus ursinus*), chital (*Axis axis*), sambar (*Rusa unicolor*), Indian pangolin (*Manis crassicaudata*) and honey badger (*Mellivora capensis*).

The tiger population here has been consistently increasing since 2010, with 7 (4-10) tigers estimated to be present in 2014. Because of its close proximity to many tiger reserves (Tadoba Andhari, Pench and Kanha) and important tiger areas (like Balaghat, Brahmapuri, Chandrapur and Gadchiroli), Nawegaon Nagzira Tiger Reserve is at the centre of the Central Indian tiger meta-population. Its protection is crucial for repopulating tigers in the forests of Gadchiroli district of Maharashtra and forests adjoining it in the state of Chhattisgarh. In the wake of linear infrastructure dissecting the park (NH6), and dispersing tigers, it is important to monitor the surrounding areas and develop mitigation strategies to avoid conflict situations as well as road kills.

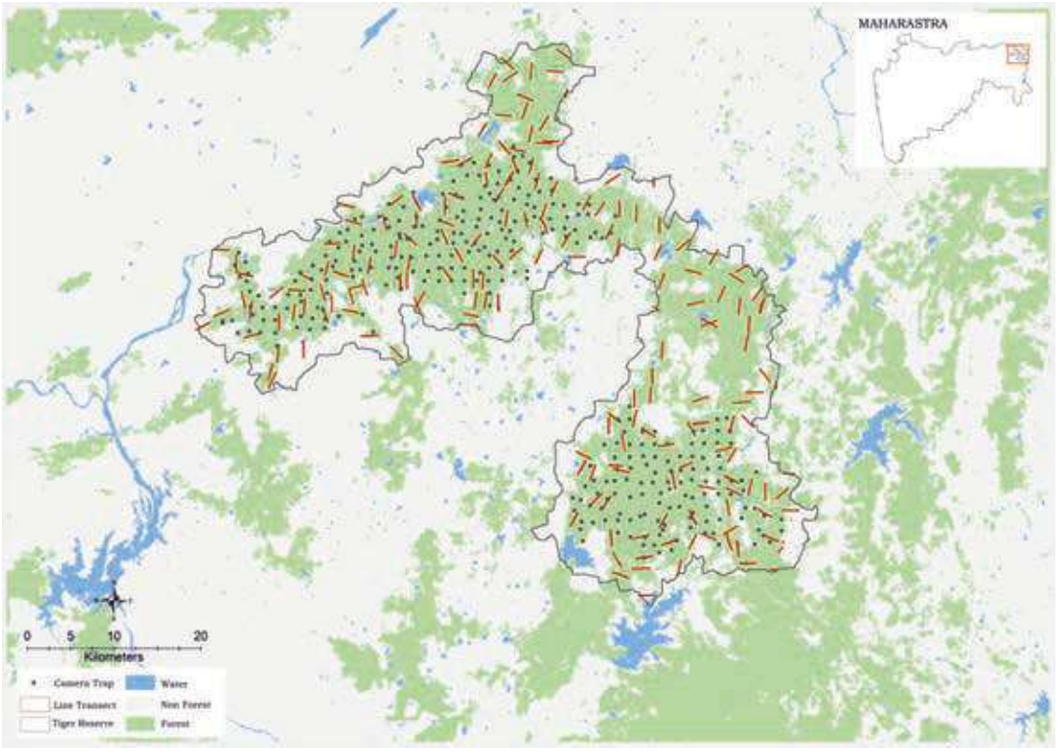


Figure 10.134
Camera trap and transect layout in Nawegaon Nagzira Tiger Reserve, 2018

RESULT

Tiger Density Estimates

A total of 170 detections of tigers were obtained during the sampling period from which 6 individual adult tigers were identified. The tiger density was estimated 0.49 (SE 0.20) tiger per 100 km^2 (Table 10.48). The detection corrected sex ratio was male biased (Table 10.48).

Table 10.48

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Nawegaon Nagzira Tiger Reserve, 2018.

Variables	Estimates
Model space (km^2)	1248.25
Camera points	315
Trap nights (effort)	8505
Unique tigers captured	6
Model	g_0 (.)σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.49(0.20)
σ (SE) km	4.46(0.29)
g_0 (SE)	0.030(0.006)
Pmix Female (SE)	0.33(0.19)
Pmix Male (SE)	0.67(0.19)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

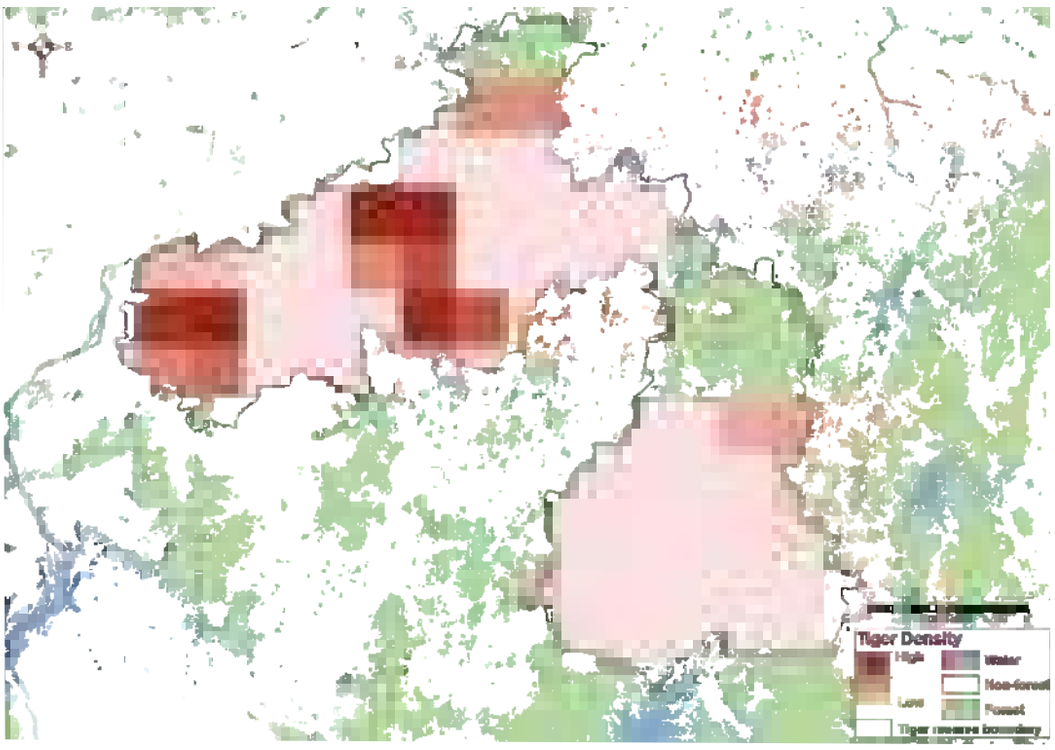
σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Figure 10.135

Spatial density of tigers in Nawegaon Nagzira Tiger Reserve, 2018



Higher tiger densities were observed in the Nagzira Wildlife Sanctuary of the tiger reserve and the forested areas west to it.

Prey Density Estimates

A total of 247 transects were sampled in Nawegaon Nagzira Tiger Reserve, which amounted to an effort of 478.51 km. Gaur was found to be the most abundant ungulate, followed by chital (Table 10.49).

Table 10.49

Model statistics and parameter estimates of line transect (n = 247, Total effort 478.51 km) based distance sampling for prey species in Nawegaon Nagzira Tiger Reserve, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital	41.11 (5.03)	39	5.21 (0.53)	0.34 (0.04)	0.08 (0.013)	0.99 (0.20)	5.16 (1.16)
Sambar	29.77 (4.78)	25	3.2 (0.44)	0.40 (0.06)	0.05 (0.010)	0.88 (0.22)	2.81 (0.80)
Gaur	29.08 (3.78)	39	5.33 (0.63)	0.28 (0.04)	0.08 (0.013)	1.40 (0.28)	7.47 (1.76)
Nilgai	38.98 (3.40)	67	2.36 (0.24)	0.29 (0.03)	0.14 (0.016)	1.80 (0.28)	4.24 (0.78)

Distribution of Major Mammalian Species Found in Nawegaon Nagzira Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Nawegaon Nagzira Tiger Reserve.

Leopard presence was recorded in most of the camera traps within the tiger reserve. The capture hotspots were observed in the hilly dry deciduous forests of the western Nagzira Wildlife Sanctuary. Another hotspot was observed in the northern fringe of Nawegaon Wildlife Sanctuary that has similar habitat.

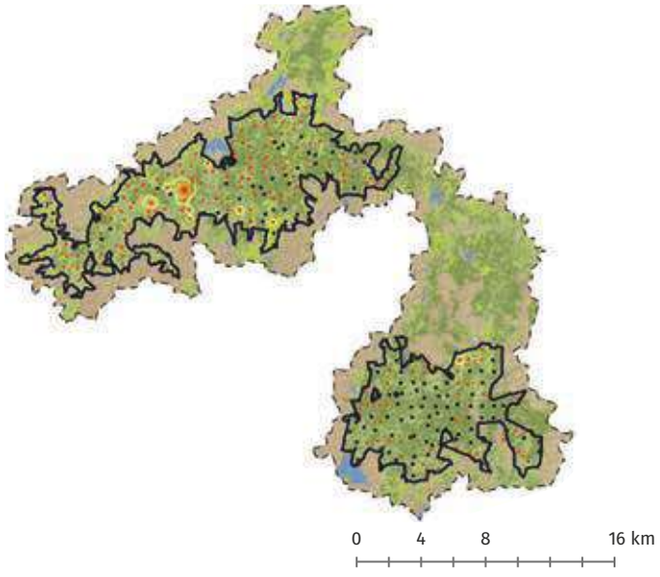


Figure 10.136

Distribution and relative spatial abundance of leopard in Nawegaon Nagzira Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Dhole was recorded across most of the camera traps in the tiger reserve, with hotspots in the central part of the core as well as the forest patches in the buffer. It was present in dense dry deciduous forest as well as the mesic savanna within the tiger reserve. The hotspots of dhole captures were spatially distinct from the tiger and leopard concentration of photo-captures, hinting towards the spatial segregation in these sympatric carnivores.

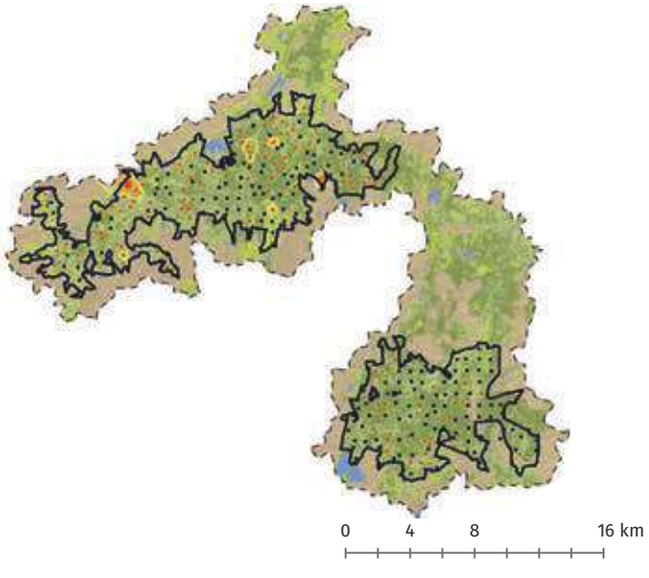


Figure 10.137

Distribution and relative spatial abundance of dhole in Nawegaon Nagzira Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

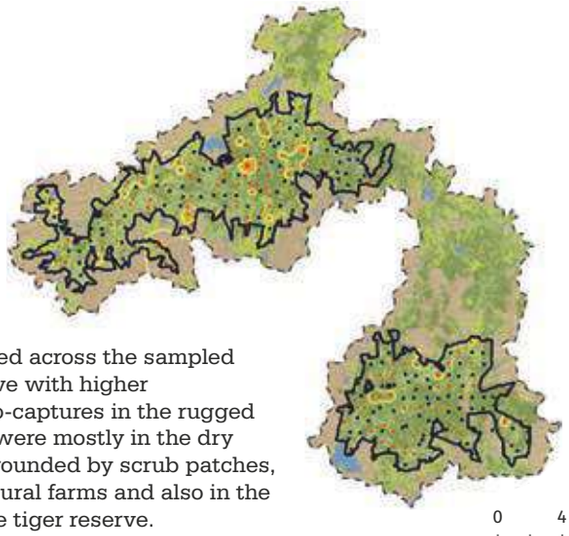


Figure 10.138

Distribution and relative spatial abundance of sloth bear in Nawegaon Nagzira Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Sloth bear was recorded across the sampled area of the tiger reserve with higher concentration of photo-captures in the rugged terrain. The hotspots were mostly in the dry deciduous forests surrounded by scrub patches, savannas and agricultural farms and also in the dense woodland of the tiger reserve.

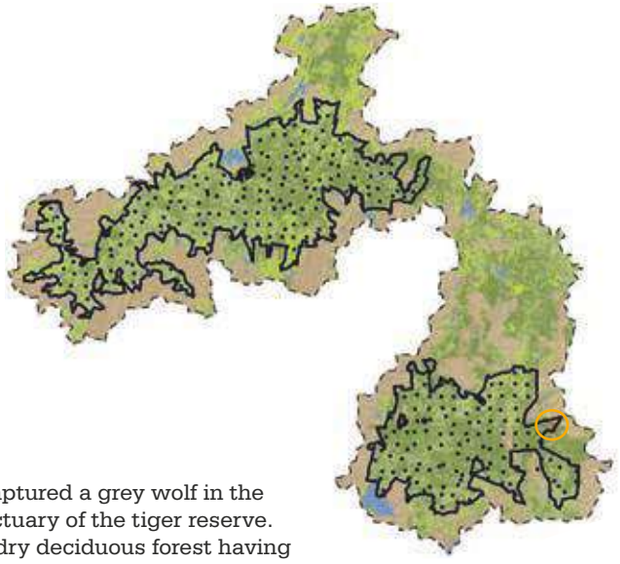


Figure 10.139

Distribution and relative spatial abundance of grey wolf in Nawegaon Nagzira Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Only one camera trap captured a grey wolf in the Nawegaon Wildlife Sanctuary of the tiger reserve. The capture was in the dry deciduous forest having a mosaic of savanna and agricultural fields.

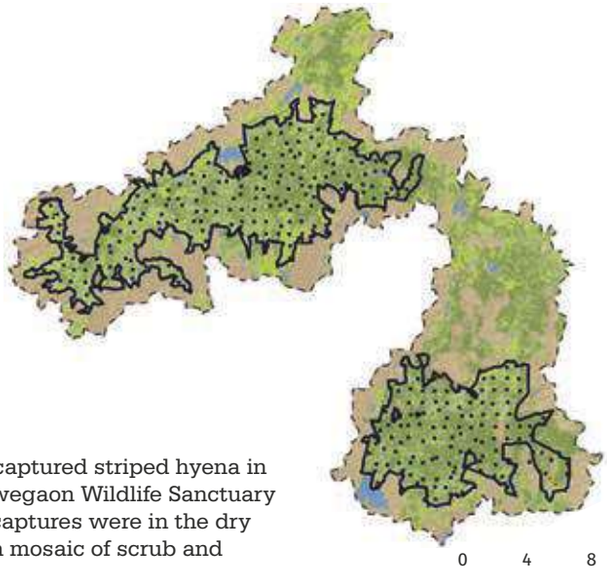
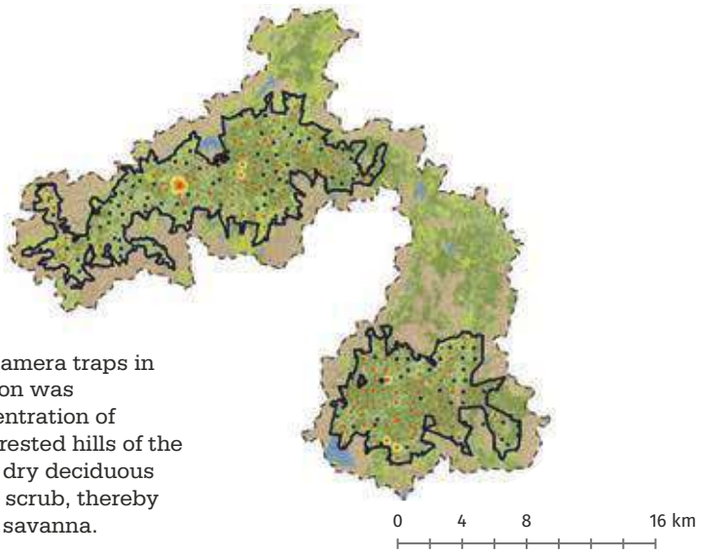


Figure 10.140

Distribution and relative spatial abundance of striped hyena in Nawegaon Nagzira Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

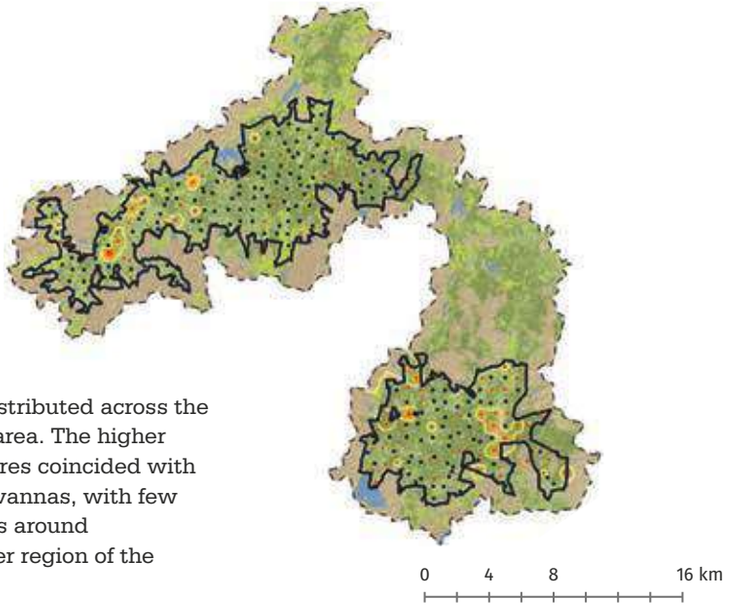
Only three camera traps captured striped hyena in the southern parts of Nawegaon Wildlife Sanctuary of the tiger reserve. The captures were in the dry deciduous forest having a mosaic of scrub and agricultural fields.



Gaur was recorded across the camera traps in the tiger reserve. The distribution was homogenous, with higher concentration of photo-captures in the central forested hills of the core region. These forests were dry deciduous with patches of grasslands and scrub, thereby making it structurally a rugged savanna.

Figure 10.141

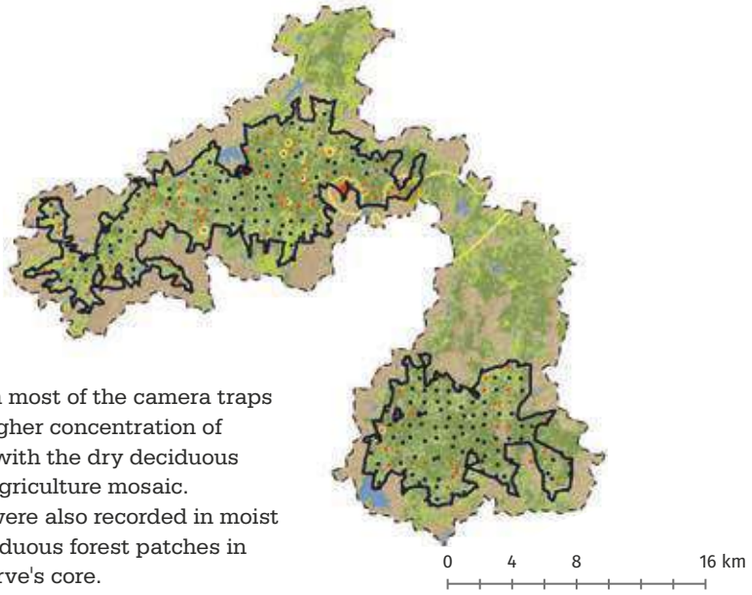
Distribution and relative spatial abundance of gaur in Nawegaon Nagzira Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture



Four-horned antelope was distributed across the open forests in the sampled area. The higher concentration of photo-captures coincided with the grasslands and mesic savannas, with few hotspots in the scrub patches around agricultural fields in the buffer region of the tiger reserve.

Figure 10.142

Distribution and relative spatial abundance of four-horned antelope in Nawegaon Nagzira Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture



Jungle cat was recorded in most of the camera traps of the tiger reserve. The higher concentration of photo-captures coincided with the dry deciduous forest patches and scrub-agriculture mosaic. However, many captures were also recorded in moist valleys and dense dry deciduous forest patches in the centre of the tiger reserve's core.

Figure 10.143

Distribution and relative spatial abundance of jungle cat in Nawegaon Nagzira Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

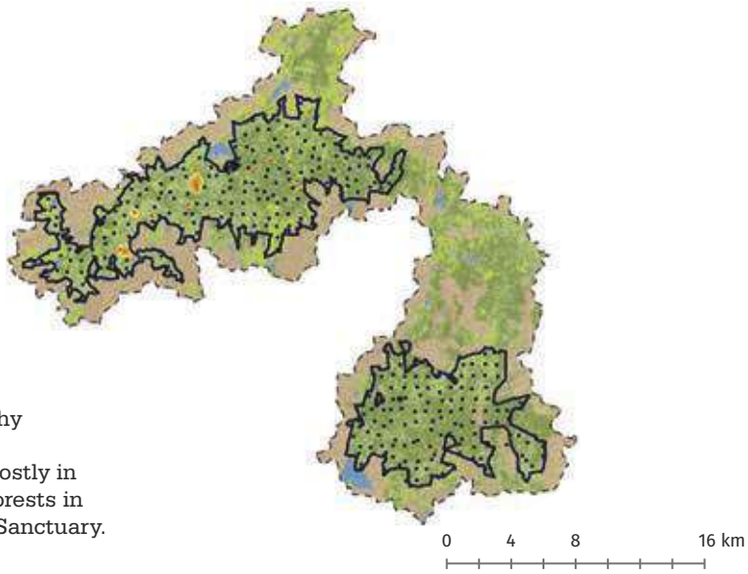


Figure 10.144

Distribution and relative spatial abundance of rusty spotted cat in Nawegaon Nagzira Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Rusty spotted cat had a patchy distribution in the park. The distribution hotspots were mostly in the hilly terrain of the open forests in and around Nagzira Wildlife Sanctuary.

Table 10.50

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Nawegaon Nagzira Tiger Reserve, 2018

Species	No. of Photos/ 100 trap night	No. of Trap nights to get one photo
Barking deer	0.15	654
Chinkara	0.04	2835
Chital	2.74	37
Common palm civet	4.86	21
Domestic dog	0.05	2126
Four-horned antelope	2.14	47
Gaur	9.05	11
Grey mongoose	0.19	532
Grey wolf	0.02	4253
Hanuman langur	17.07	6
Honey badger	1.15	87
Indian fox	0.06	1701
Indian hare	7.82	13
Indian pangolin	0.05	2126
Indian porcupine	9.44	11
Jungle cat	5.50	18
Leopard	6.41	16
Livestock	0.19	532
Nilgai	7.10	14
Peafowl	6.76	15
Red jungle fowl	0.46	218
Rhesus macaque	1.00	100
Ruddy mongoose	0.21	473
Rusty-spotted cat	0.24	425
Sambar	8.51	12
Sloth bear	4.32	23
Small Indian civet	2.32	43
Striped hyena	0.06	1701
Tiger	2.25	45
Wild dog	3.66	27
Wild pig	10.66	9

Relative Abundance of all Photocaptured Species in Nawegaon Nagzira Tiger Reserve

A total of 29 wild species of ungulates, carnivores, primates, omnivores, and galliformes were photo-captured in Nawegaon Nagzira Tiger Reserve. Hanuman langur and wild pig were the most common, while chinkara and grey wolf were the rarest photo-captured species (Table 10.50).

DISCUSSION

The increasing tiger population of NNTR can be explained by the availability of prey biomass and habitat connectivity with the neighbouring source populations (Pench Tiger Reserve).

PENCH TIGER RESERVE, MAHARASHTRA

INTRODUCTION

Pench Tiger Reserve is located in the Satpura Maikal hills of Nagpur district between the longitudes 79° 04' E - 79°24' E and latitudes 21° 04' N - 21° 43' N. This tiger reserve includes Pench National Park (257 km^2) and Mansingh Deo Wildlife Sanctuary (195 km^2). Pench Tiger Reserve is part of the biotic province 6E- Central Highlands (Rodgers and Panwar 1988) and its subdivision, the Satpura Maikal landscape.

The vegetation is classified as southern tropical dry deciduous forests (5A) (Champion and Seth 1968). The prominent trees species found here are Tectona grandis and its associates, namely *Terminalia bellirica, Diospyros melanoxylon, Madhuca longifolia, Aegle marmelos, Terminalia arjuna, Cassia fistula*, bamboo species. Tiger (*Panthera tigris*), leopard (*Panthera pardus*) and wild dog (*Cuon alpinus*) are the top predator species found here. Ungulats comprised of sambhar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), nilgai (*Boselaphus tragocamelus*), gaur (*Bos gaurus*), mouse deer (*Moschiola indica*). Pench Tiger Reserve, Maharashtra is contiguous with Pench Tiger reserve of Madhya Pradesh and is connected to Kanha Tiger reserve, via the Kanha-Pench corridor. In addition, this reserve is connected to Nawegaon-Nagzira Tiger Reserve via Nagpur and Bhandara forest divisions. Hence, this large forested tract is of immense conservation value as it allows dispersal and maintenance of genetic diversity of tigers.

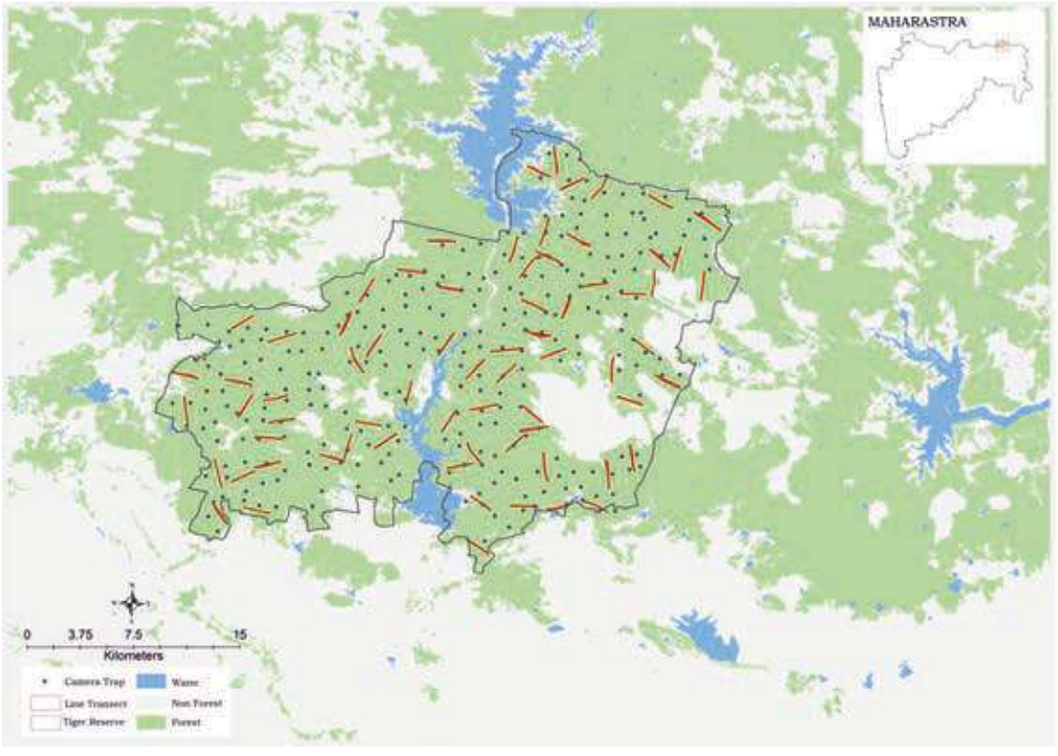


Figure 10.145
Camera trap and transect layout in Pench Tiger Reserve, Maharashtra, 2018

RESULTS

Tiger Density Estimates

A total of 1530 detections of tigers were obtained during the sampling period from which 48 individual adult tigers were identified. Tiger density was estimated at 4.64 (SE 0.71) tiger per 100 km^2 (Table 10.51). The detection corrected sex ratio was female biased (Table 10.51).

Table 10.51

Sampling details and tiger density parameter estimates using spatially explicit capture-recapture analysis in a likelihood framework for Pench Tiger Reserve, Maharashtra, 2018.

Variables	Estimates
Model space (km^2)	1111
Camera points	274
Trap nights (effort)	12012
Unique tigers captured	48
Model	g_0 (sex)σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	4.64(0.71)
σ Female (SE) km	2.16(0.06)
σ Male (SE) km	3.11(0.11)
g_0 Female (SE)	0.030(0.002)
g_0 Male (SE)	0.030(0.001)
Pmix Female (SE)	0.60 (0.07)
Pmix Male (SE)	0.40(0.07)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

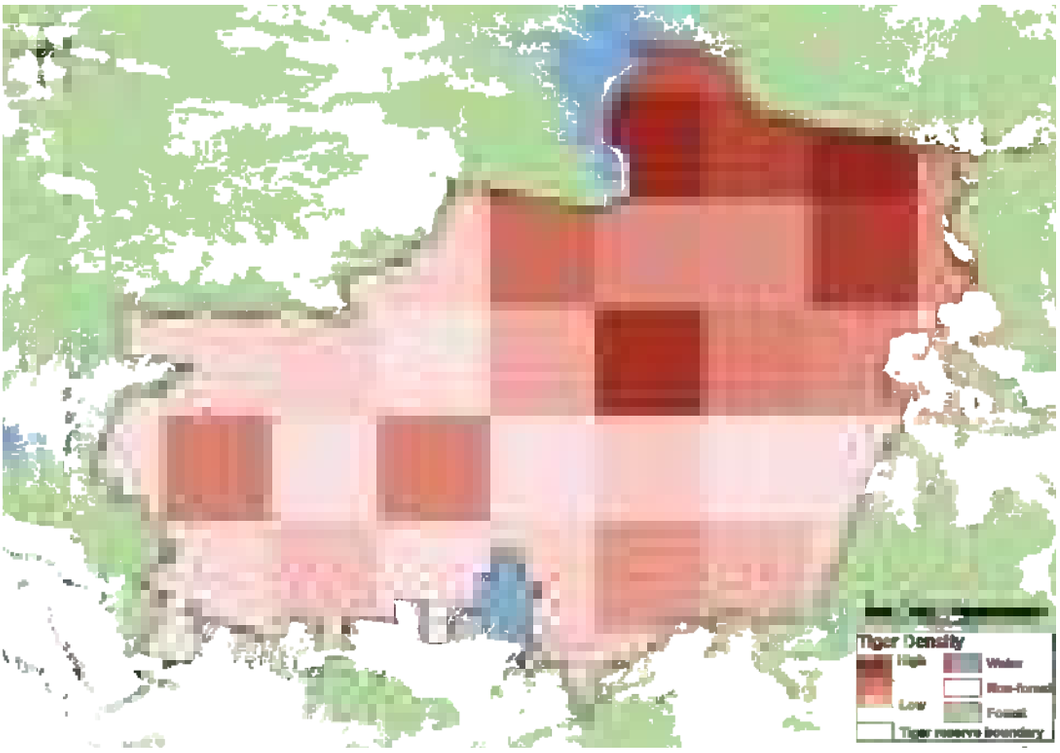
σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Figure 10.146

Spatial density of tigers in Pench Tiger Reserve, Maharshtra, 2018



Higher tiger density was observed on the forest adjoining the Pench Tiger Reserve of Madhya Pradesh, and Totladoh area of the tiger reserve.

Prey Density Estimates

A total of 234 transects were sampled in Pench Tiger Reserve which amounted to an effort of 458.97 km. Chital was found to be the most abundant ungulate with a density of 20.87 (SE 4.36) chital per km^2 (Table 10.52).

Table 10.52

Model statistics and parameter estimates of line transect (n=234, Total effort 458.97 km) based distance sampling for prey species in Pench Tiger Reserve, Maharashtra, 2018

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital	52.697 (4.49)	122	8.27 (1.32)	0.35 (0.03)	0.266 (0.026)	2.52 (0.34)	20.87 (4.36)
Sambar	48.919 (4.28)	87	2.79 (0.27)	0.55 (0.04)	0.190 (0.021)	1.93 (0.27)	5.41 (0.92)
Nilgai	40.669 (4.40)	57	2.21 (0.20)	0.51 (0.05)	0.124 (0.016)	1.52 (0.25)	3.37 (0.63)
Wild pig	40.325 (4.80)	45	5.88 (0.94)	0.50 (0.06)	0.098 (0.014)	1.21 (0.22)	7.15 (1.74)

Distribution of Major Mammalian Species Found in Pench Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Pench Tiger Reserve.

Dhole was distributed throughout the tiger reserve with a higher concentration of photo-captures in the Chaurbauli range of the buffer zone.

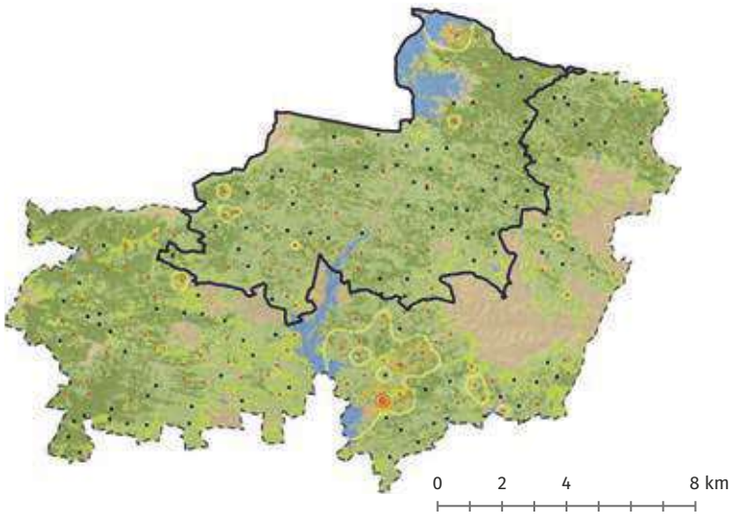


Figure 10.147

Distribution and relative spatial abundance of dhole in Pench Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Chaushinga was photo captured all throughout the tiger reserve. Capture hotspots were more in the buffer area of the tiger reserve

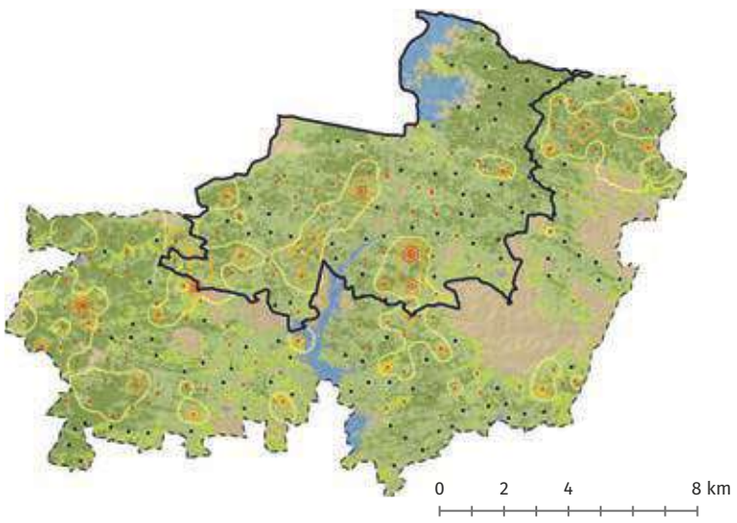


Figure 10.148

Distribution and relative spatial abundance of chaushinga in Pench Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Gaur was distributed throughout the tiger reserve with capture hotspots in the mesic savannas.

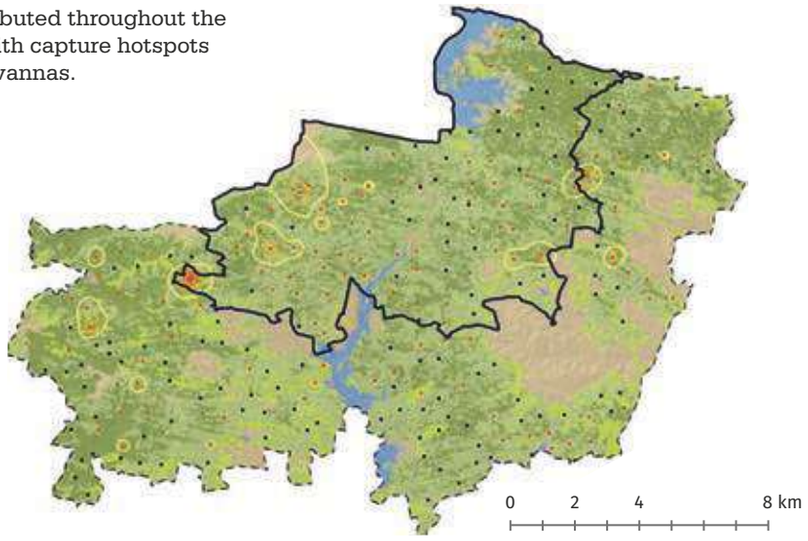


Figure 10.149

Distribution and relative spatial abundance of gaur in Pench Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Golden jackal was sparsely distributed in the tiger reserve with capture hotspots in open forest habitat in the East-Pench range of the tiger reserve.

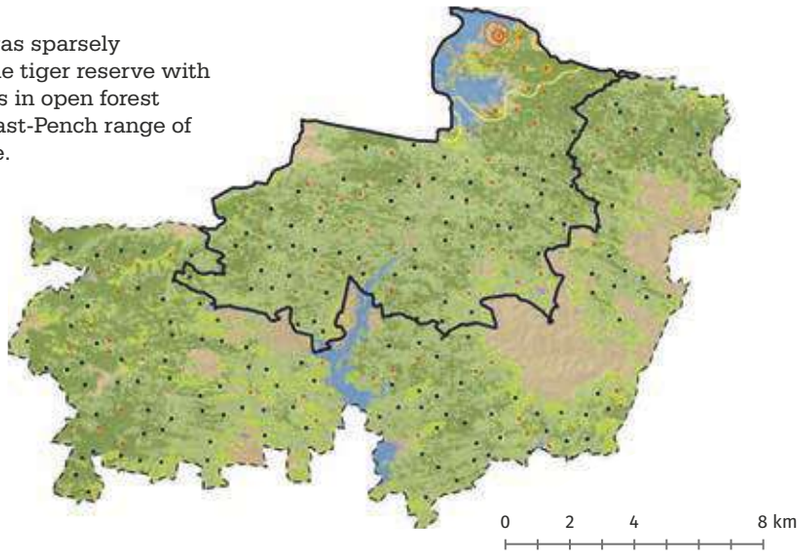


Figure 10.150

Distribution and relative spatial abundance of golden jackals in Pench Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Grey wolf had very few photo-captures in the forested habitat, with capture hotspots in the dry savannah and agriculture mosaic of the buffer area of the tiger reserve.

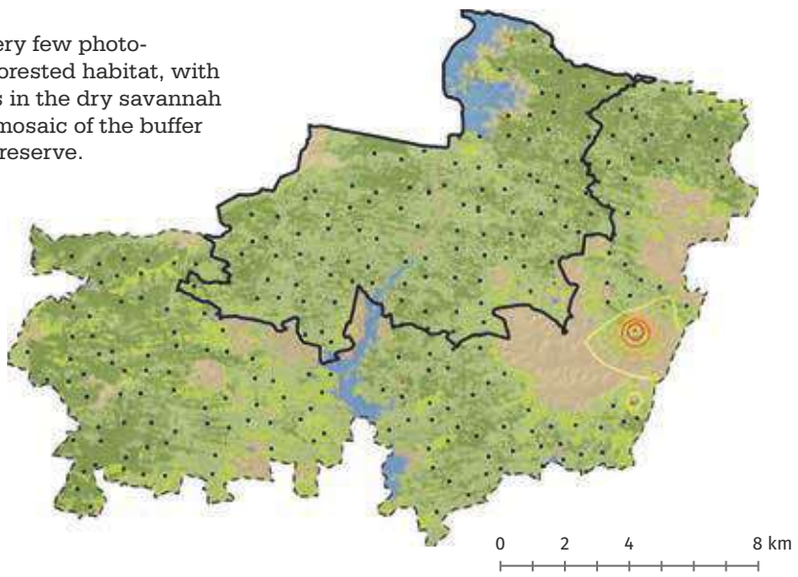


Figure 10.151

Distribution and relative spatial abundance of the grey wolf in Pench Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Jungle cat was distributed mainly at the border of the core and in the buffer zone of the tiger reserve with higher numbers of photo-captures in open forested habitats of the buffer zone.

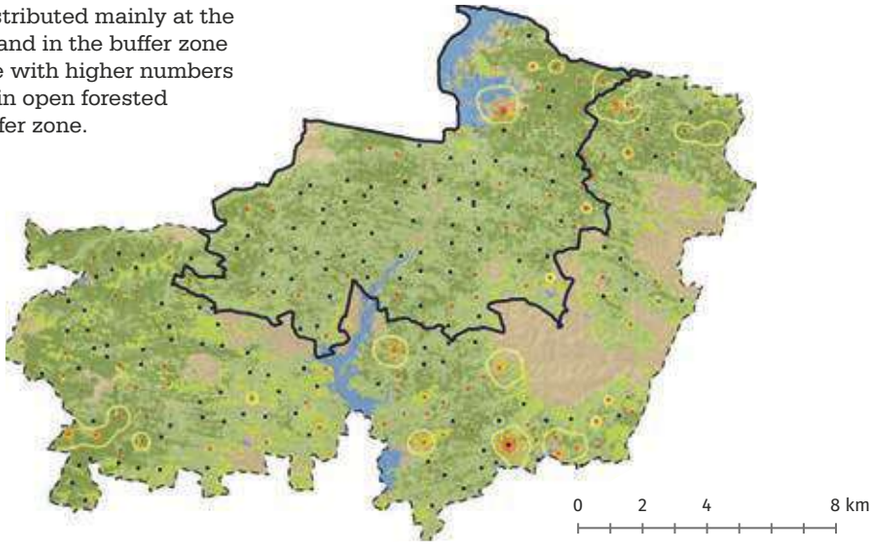


Figure 10.152

Distribution and relative spatial abundance of jungle cat in Pench Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Leopard was photo-captured in majority of the camera traps in the tiger reserve with capture hotspots primarily in the buffer zone.

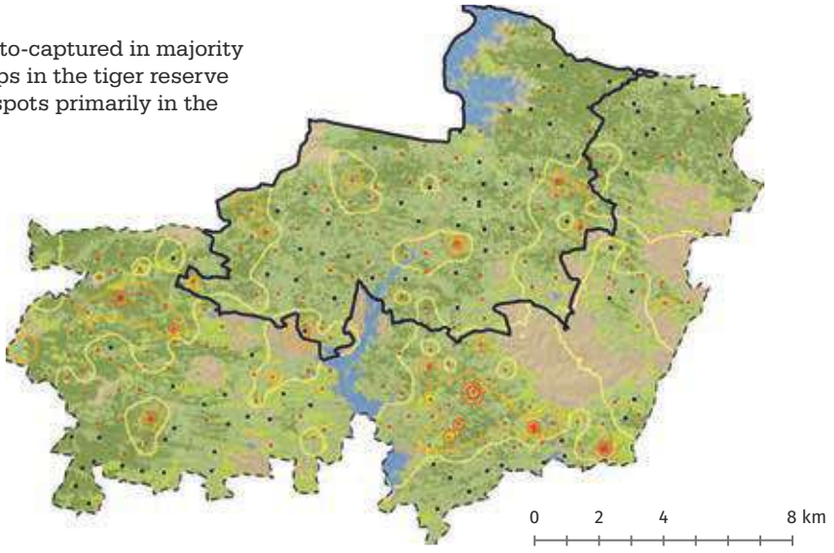


Figure 10.153

Distribution and relative spatial abundance of leopards in Pench Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Rusty-spotted cat had very few photo-captures and these were along the northern boundary of the tiger reserve in undulating forested terrain.

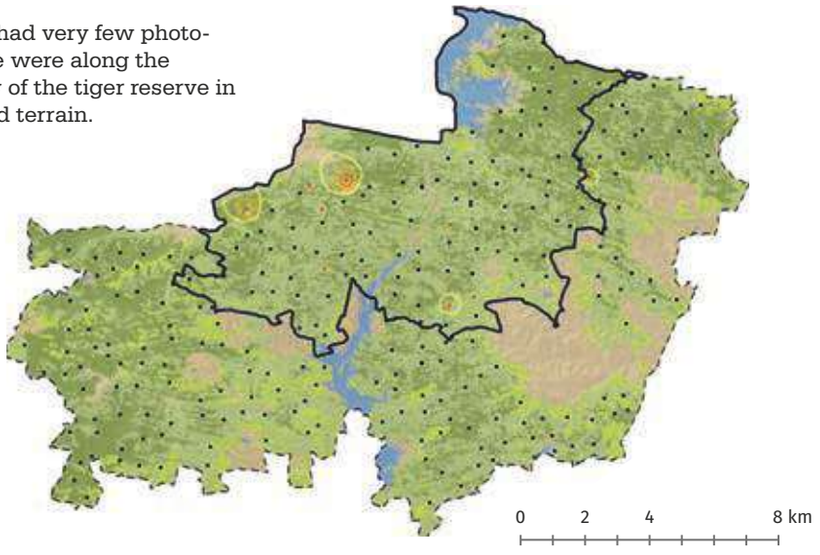


Figure 10.154

Distribution and relative spatial abundance of the rusty-spotted cat in Pench Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Sloth bear was distributed sparsely across the tiger reserve, with capture hotspots in moderately dense forest of the tiger reserve.

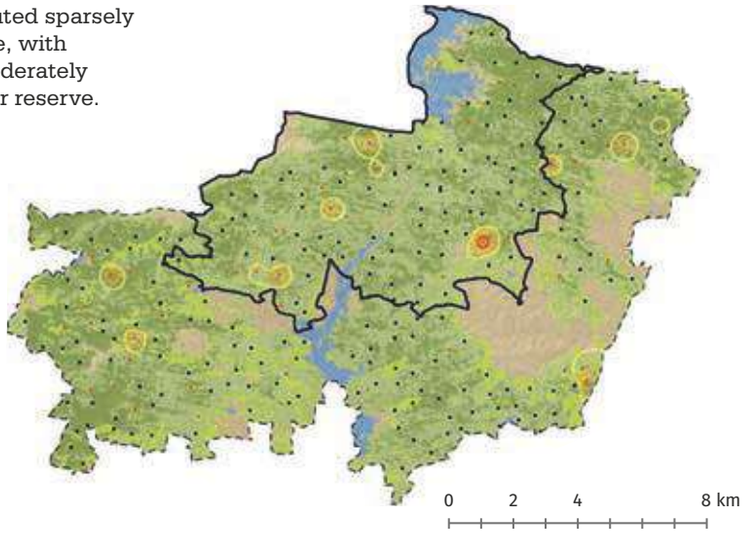


Figure 10.155

Distribution and relative spatial abundance of sloth bear in Pench Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Table 10.53

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Pench Tiger Reserve, 2018

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	0.09	1092
Chital	22.84	4
Domestic dog	0.97	103
Four horned antelope	4.14	24
Gaur	3.76	27
Golden Jackal	7.38	14
Grey Mongoose	0.55	182
Grey wolf	0.08	1201
Hanuman Langur	17.94	6
Honey Badger	0.62	162
Indian Fox	0.12	801
Indian hare	37.94	3
Indian Pangolin	0.02	6006
Indian Porcupine	3.40	29
Jungle Cat	4.25	24
Leopard	3.95	25
Livestock	3.16	32
Nilgai	5.62	18
Palm Civet	1.75	57
Peafowl	4.79	21
Red Jungle Fowl	0.07	1502
Rehsus Macaque	1.18	85
Ruddy Mongooes	0.78	128
Rusty spotted cat	0.13	751
Sambar	13.98	7
Sloth bear	0.62	160
Small Indian civet	2.16	46
Tiger	6.74	15
Wild dog	3.50	29
Wild pig	7.84	13

Relative Abundance of all Photocaptured Species in Pench Tiger Reserve

A total of 28 wild species of ungulates, carnivores, primates, omnivores, and galliformes were photo-captured in Pench Tiger Reserve. Indian hare and chital were the most common while red jungle fowl and pangolin were the rarest photo-captured species (Table 10.53).

DISCUSSION

With increase in the prey and tiger population, this tiger reserve along with Pench MP forms a major source population in Central India. This is important considering the habitat connectivity with the adjoining forest divisions and parks (Nagpur, Bhandara, Nawegaon Nagzira, and Kanha). Inter-state Coordination with Pench Tiger Reserve, of Madhya Pradesh is essential for shared conservation management and protection.

SAHYADRI TIGER RESERVE

INTRODUCTION

Sahyadri Tiger Reserve is the northernmost tiger reserve in the Western Ghats (but included here for convenience) roughly located between coordinates (16°54'43" N to 17°51'15" N and 73°32'23" E to 73°53'57" E). It covers and area of 1140 km^2 spread over of four districts (Satara, Sangli, Kolhapur and Ratnagiri) in western Maharashtra. Declared as a tiger reserve in 2008, Sahyadri Tiger Reserve includes Koyna Wildlife Sanctuary, Chandoli National Park and Radhanagari Wildlife Sanctuary. Predominantly formed by basaltic rocks, this hilly terrain holds dry savannahs, mesic savannahs, dry deciduous forests, moist deciduous forests, and patches of montane rainforest. The mountain top plateaus in the region holds diverse array of ephemerals that bloom in the monsoon season.

The region is inhabited by a varied mammalian diversity. While holding the northernmost population of dhole (*Cuon alpinus*) in the Western Ghats, this tiger reserve is also home to leopard (*Panthera pardus*), gaur (*Bos gaurus*), sloth bear (*Melursus ursinus*), sambar (*Rusa unicolor*), mouse deer (*Moschiola indica*) and Malabar giant squirrel (*Ratufa indica*). In recent years, there have been measures to increase the prey population in the area through habitat restoration and reintroduction of tiger prey species like chital (*Axis axis*). However, owing to the hilly terrain sandwiched between steep slopes in the west and urbanizing towns in the east, the current tiger carrying capacity of the tiger reserve is probably low and needs scientific investigation. Amongst the top threats to conservation in this region, is the construction of dams that are not only changing the vegetation dynamics but can also impede the genetic connectivity of large mammals and prevent them from moving into the forests of Western Ghats north of the tiger reserve. Linear infrastructure, urbanization and woody plantations on the natural savannahs can further escalate loss of biodiversity in the region.

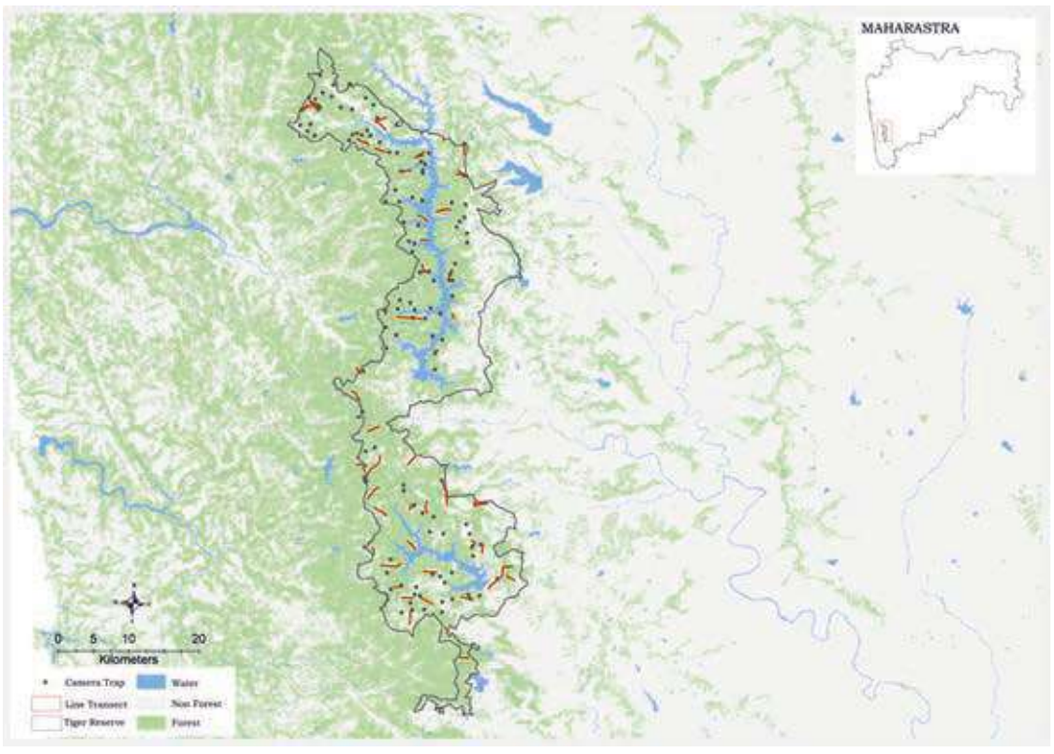


Figure 10.156
Camera trap and transect layout in Sahyadri Tiger Reserve, 2018

RESULTS

Camera Trap Results

During the sampling period with the sampling efforts shown in Table 10.54, no tiger was camera trapped in the area. However, one camera trap photograph of a tiger was subsequently obtained from a neighbouring district outside of the Tiger Reserve by Bombay Natural History Society team.

Table 10.54

Sampling details of camera trapping exercise in Sahyadri Tiger Reserve, 2018.

Sampling details	Counts
Camera points	120 (single sided)
Trap nights (effort)	1422

Prey Density Estimates

A total of 74 transects were sampled in Sahyadri Tiger Reserve, which amounted to an effort of 135 km. Gaur was found to be the most abundant ungulate with a density of 8.07 (SE 2) per km^2, followed by barking deer (Table 10.55). Only one observation of chital was recorded during the sampling period.

Table 10.55

Model statistics and parameter estimates of line transect (n=74, Total effort 135 km) based distance sampling for prey species in Sahyadri Tiger Reserve, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group) density/ km^2 (SE)	Individual density/ km^2 (SE)
Sambar	36.87 (4.83)	24	1.34 (0.14)	0.74 (0.1)	0.18 (0.043)	2.42 (0.67)	3.22 (0.94)
Gaur	37.68 (5.74)	35	2.35 (0.32)	0.63 (0.1)	0.26 (0.037)	3.45 (0.72)	8.07 (2)
Barking deer	29.81 (4.9)	29	1.11 (0.06)	0.6 (0.1)	0.22 (0.032)	3.61 (0.8)	3.98 (0.91)

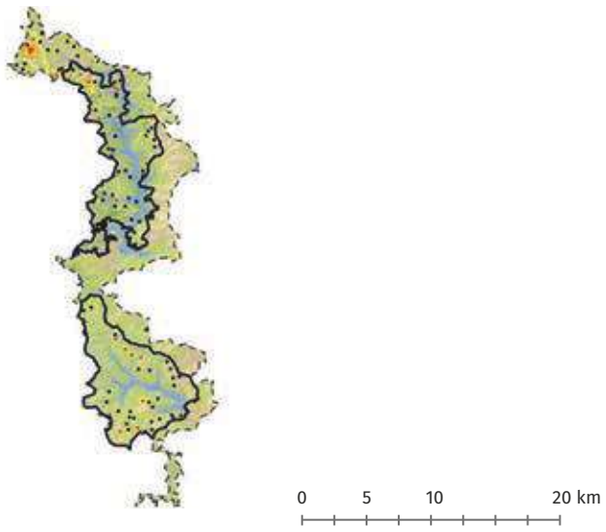
Distribution of Major Mammalian Species Found in Sahyadri Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Sahyadri Tiger Reserve.

Figure 10.157

Distribution and relative spatial abundance of leopard in Sahyadri Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Though leopard was photo-captured across the park, higher concentration of photo-captures were from the northern edge of the tiger reserve, which coincides with the agriculture-grassland mosaic in the buffer region. The other hotspots were in the mesic savanna of Chandoli National Park.



Two camera traps recorded dhole in the valleys with moist forests, in the Radhanagari Wildlife Sanctuary part of the tiger reserve. Though dhole presence was recorded from Chandoli National Park during the sign survey, it was not recorded in camera traps, probably due to scanty placement of traps on the western boundary of the park.

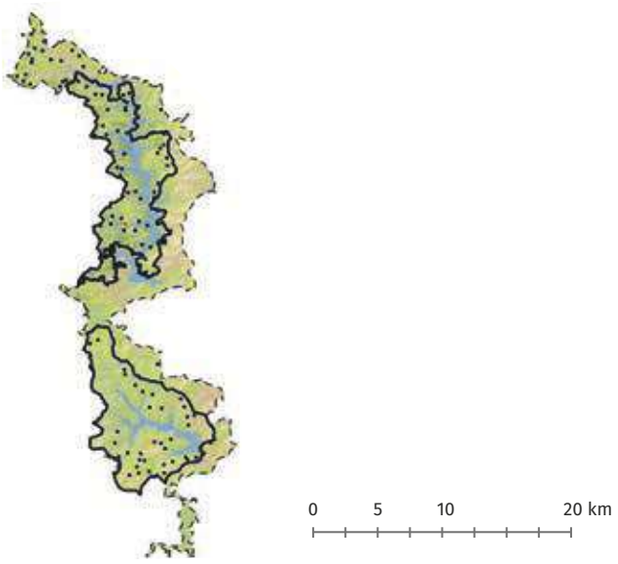


Figure 10.158

Distribution and relative spatial abundance of dhole in Sahyadri Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Sloth bear was recorded in a majority of the camera traps across the tiger reserve. The higher concentration of photo-captures coincided with the hilly rugged terrain in moist deciduous forests and mesic savanna at the northern boundary of the park. Sloth bear was also recorded in the vicinity of farms and villages on the eastern boundary of the tiger reserve.

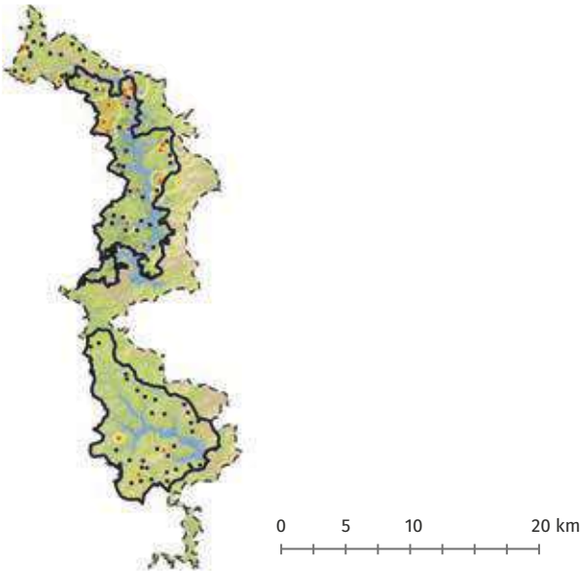


Figure 10.159

Distribution and relative spatial abundance of sloth bear in Sahyadri Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Radhanagri, part of the tiger reserve, was declared as a Wildlife Sanctuary with the focus on gaur conservation in the region. This is depicted from the presence of gaur across the park, with hotspots in the forest grassland mosaic around the Shivajisagar waterbody and mountain top grasslands.

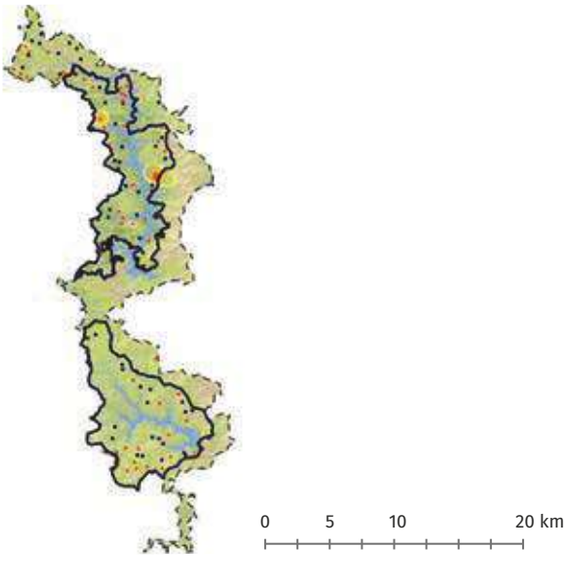


Figure 10.160

Distribution and relative spatial abundance of gaur in Sahyadri Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

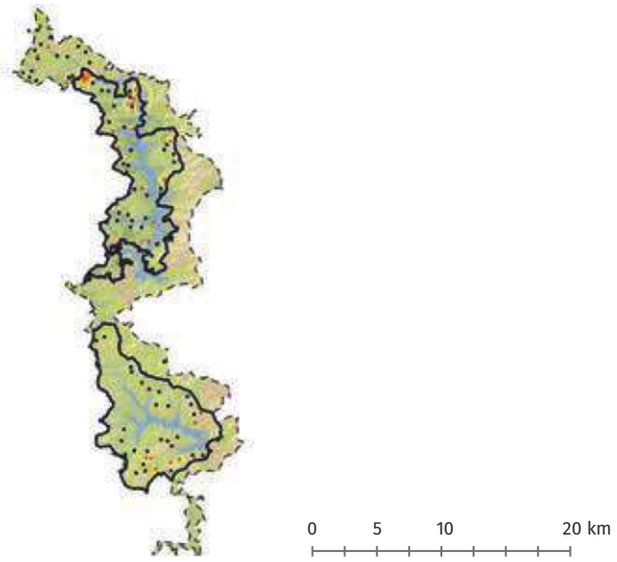


Figure 10.161
Distribution and relative spatial abundance of mouse deer in Sahyadri Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Mouse deer was recorded from camera traps placed in the valleys dominated with moist forests. The photo-capture hotspots were observed in the northern parts of the tiger reserve having contiguous moist deciduous forests and mountain top grasslands.

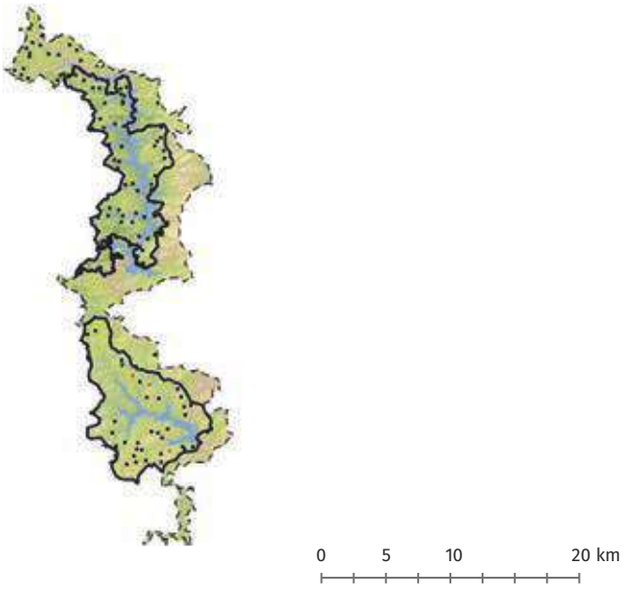


Figure 10.162
Distribution and relative spatial abundance of jungle cat in Sahyadri Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Jungle cat was recorded in only three camera traps in the Chandoli National Park. These camera traps were in the dry deciduous forest patches of the tiger reserve.

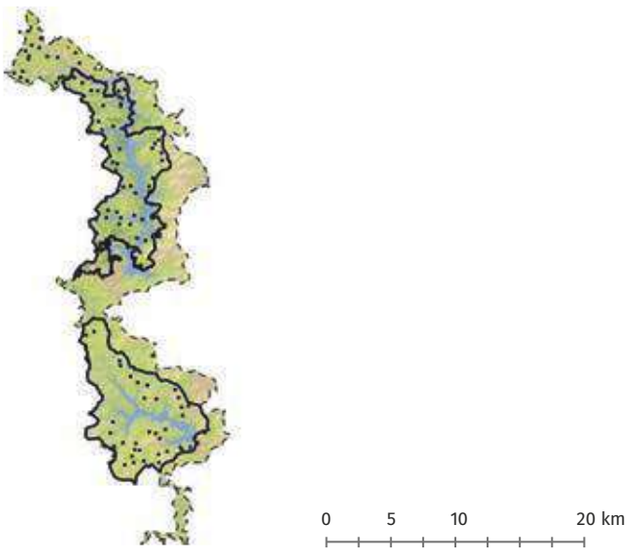


Figure 10.163
Distribution and relative spatial abundance of rusty spotted cat in Sahyadri Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo capture

Rusty spotted cat was recorded in one camera trap in the northern buffer zone of the tiger reserve. This camera trap was placed in the mountain top grasslands surrounded by dry deciduous forests.

Relative Abundance of all Photocaptured Species in Sahyadri Tiger Reserve

In the tiger reserve, 19 wild species of ungulates, carnivores, primates, omnivores, and galliformes were photo-captured. Wild pig and gaur were the most common while rusty-spotted cat was the rarest photo-captured species (Table 10.56).

Table 10.56
Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Sahyadri Tiger Reserve, 2018

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	8.37	11.95
Bonnet macaque	0.15	711
Common grey mongoose	0.92	109.39
Common palm civet	1.27	79
Gaur	13.72	7.3
Hanuman langur	4.37	22.94
Indian hare	3.03	33.07
Indian pangolin	0.29	355.5
Indian porcupine	10.34	9.68
Jungle cat	0.29	355.5
Leopard	3.1	32.32
Livestock	0.35	284
Mouse deer	5.77	17.35
Ruddy mongoose	1.97	50.79
Rusty-spotted cat	0.08	1422
Sambar	7.25	13.81
Sloth bear	5.49	18.24
Small Indian civet	1.97	50.79
Wild dog	0.15	711
Wild pig	24.06	4.16

DISCUSSION

In 2014, tigers' presence was confirmed in the region based on scat DNA identification. The first camera trapped tiger was recorded in the year 2018. Camera traps were deployed at a high density of ~1 per 2 km^2. However, while the sampling scale was intensive, cameras were not placed in the western edge of Chandoli National Park and the buffer forests between Radhanagri and Chandoli. This might limit the inference on habitat use by different camera trapped species. Across all species, largest number of photo-captures were recorded in the northern part of the tiger reserve, in all likelihood due to the presence of heterogeneous habitat of moist and dry forest patches, mountain top grasslands and dry and mesic savanna. This part is also relatively less fragmented by human activities, unlike the eastern fringes of the tiger reserve. The repopulation of Sahyadri Tiger Reserve by tigers depends on the source value of proximate tiger reserves and intervening corridor habitat. The closest potential source for tigers is Kali Tiger Reserve and the corridor forests through Goa. Since tiger status is poor in Kali as well as in Goa, Sahyadri is unlikely to improve in the near future. In this entire landscape of Northern Western Ghats management to 1) reduce human impacts through incentivized voluntary relocation of human settlements, 2) control of poaching through strict law enforcement and alternative livelihoods and 3) restoration of a good prey base, is required before augmentation of tigers can be considered.

TADOBA ANDHARI TIGER RESERVE

INTRODUCTION

Tadoba Andhari Tiger reserve also known as Tadoba Tiger Reserve, lies in the Chandrapur district of Maharashtra and is approximately 150 km from Nagpur city. It covers 1727 km^2, comprising of Tadoba National Park and Andhari Wildlife Sanctuary. The area lies between 19°58'23" N to 20°30'15" N and 79°12'51" E to 79°41'23" E. It is one of the oldest and largest national parks of Maharashtra. Tadoba gets its name from the local deity "Tadoba" or "Taru". According to the folklore, Taru was the chief of a village and who was killed in an encounter with the tiger. Thereafter, a shrine was made, dedicated to Taru and the shrine still exists on the bank of Tadoba lake.

Tadoba Andhari Tiger Reserve located in the 6-B Central Plateau Biotic province in the 6-Deccan Peninsula Bio-geographic zone (Rodgers and Panwar 1988). The vegetation is classified as southern tropical dry deciduous teak forests (5A) (Champion and Seth 1968). It has primarily Tectona grandis dominated mixed forests with other deciduous species being *Terminalia elliptica, Pterocarpus marsupium, Haldina cordifolia, Boswellia serrata, Bombax ceiba, Diospyros melanoxylon,* other *Terminalia spp., Sterculia urens, Madhuca longifolia,* and bamboo thickets. It serves as a prime habitat for tiger (*Panthera tigris*), leopard (*Panthera pardus*) and wild dog (*Cuon alpinus*). It is also home to mammalian species like sambhar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), nilgai (*Boselaphus tragocamelus*), gaur (*Bos gaurus*), wild pig (*Sus scrofa*), chausingha (*Tetracerus quadricornis*), sloth bear (*Melursus ursinus*), grey langur (*Semnopithecus*), rhesus monkey (*Macaca mulatta*), mouse deer (*Moschiola indica*), black-naped hare (*Lepus nigricollis*), porcupine (*Hystrix indica*) and flying squirrel (*Petaurista philippensis*) amongst others.

Tadoba Andhari Tiger Reserve constitutes a part of the vast expanse of forest tract in Central India. Tadoba is connected with Bramhapuri Forest Division towards the east and Chandrapur Forest Division towards the west. This contiguous habitat facilitates movement of wild animals across the landscape. However, habitat connectivity with Tipeshwar Wildlife Sanctuary and Indravati National Park and further south to Kawal Tiger Reserve is increasingly threatened by development projects and mining activity, thereby having the potential adverse effect on the meta-population dynamics.

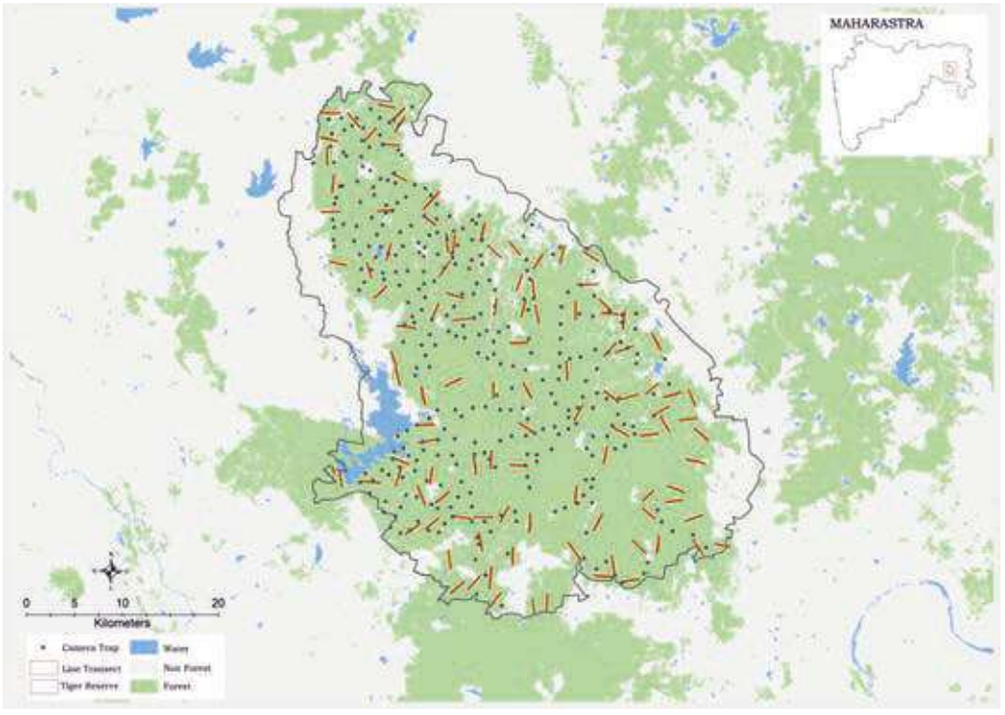


Figure 10.164
Camera trap and transect layout in Tadoba Andhari Tiger Reserve, 2018

RESULTS

Tiger Density Estimates

A total of 843 detections of tigers were obtained during the sampling period from which 82 individual adult tigers were identified. Tiger density was estimated at 6.09 (SE 0.67) tigers per 100 km^2 (Table 10.57). The detection corrected sex ratio was female biased (Table 10.57).

Table 10.57

Sampling details and tiger density parameter estimates using spatially explicit capture-recapture analysis in a likelihood framework for Tadoba Andhari Tiger Reserve, 2018.

Variables	Estimates
Model space (km^2)	1729.75
Camera points	327
Trap nights (effort)	9300
Unique tigers captured	82
Model	g_0 (sex)σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	6.09 (0.67)
σ Female (SE) km	2.39 (0.08)
σ Male (SE) km	3.49 (0.14)
g_0 Female (SE)	0.35 (0.030)
g_0 Male (SE)	0.18 (0.020)
Pmix Female (SE)	0.57 (0.06)
Pmix Male (SE)	0.43 (0.06)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

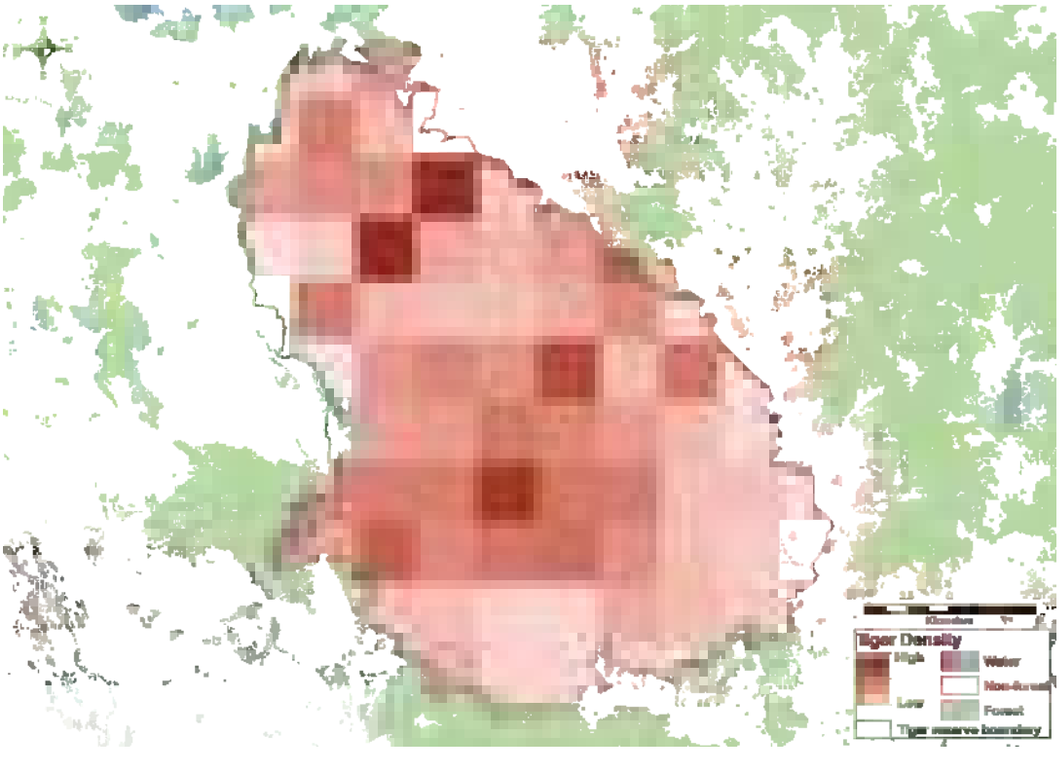


Figure 10.165

Spatial density of tigers in Tadoba Andhari Tiger Reserve, 2018

While tigers occurred at moderately high densities across the tiger reserve, relatively higher densities were observed in the open forests around Tadoba lake, Jamani and Botezari area.

Prey Density Estimates

A total of 105 transects were sampled in Tadoba Andhari Tiger Reserve, which amounted to an effort of 637.31 km. Chital was found to be the most abundant ungulate with a density of 14.37 (SE 2.93) per km^2 (Table 10.58).

Table 10.58

Model statistics and parameter estimates of line transect (n=105, Total effort 637.31 km) based on distance sampling for prey species in Tadoba Andhari Tiger Reserve, 2018

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group) density/ km^2 (SE)	Individual density/ km^2 (SE)
Chital	31.04 (5.21)	93	6.11 (0.44)	0.30 (0.05)	0.15 (0.013)	2.35 (0.44)	14.37 (2.93)
Sambar	34.40 (3.57)	55	2.58 (0.24)	0.43 (0.04)	0.09 (0.012)	1.25 (0.21)	3.23 (0.62)
Gaur	38.72 (4.36)	46	3.41 (0.47)	0.43 (0.05)	0.07 (0.010)	0.93 (0.17)	3.18 (0.72)
Nilgai	39.93 (4.63)	44	3.56 (0.50)	0.44 (0.05)	0.07 (0.010)	0.86 (0.15)	3.08 (0.71)
Wild pig	32.95 (4.18)	48	6.62 (0.70)	0.55 (0.07)	0.08 (0.010)	1.14 (0.21)	7.57 (1.62)

Distribution of Major Mammalian Species Found in Tadoba Andhari Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Tadoba Andhari Tiger Reserve.

There were only two photo-captures of desert cat, recorded in the buffer area of the tiger reserve.

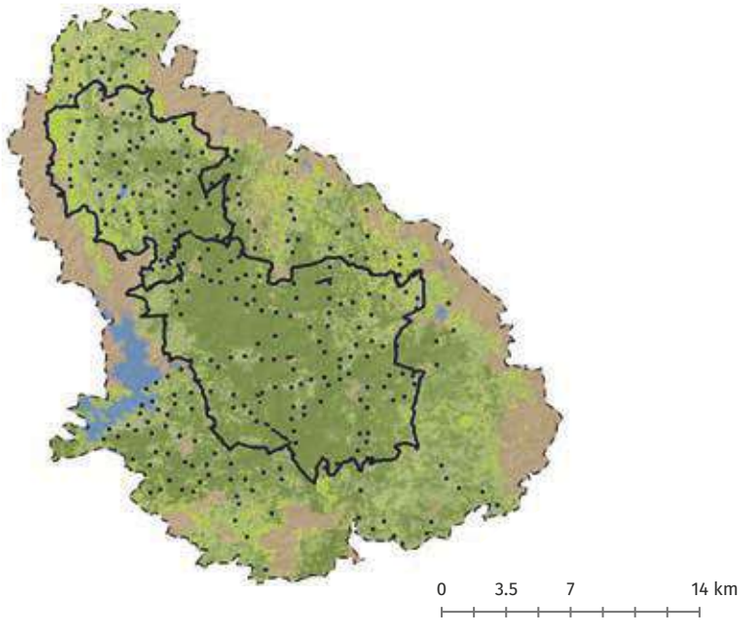


Figure 10.166

Distribution and relative spatial abundance of the desert cat in Tadoba Andhari Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Dhole was photo-captured in majority of the camera traps deployed across the tiger reserve with higher capture rate in southern buffer zone.

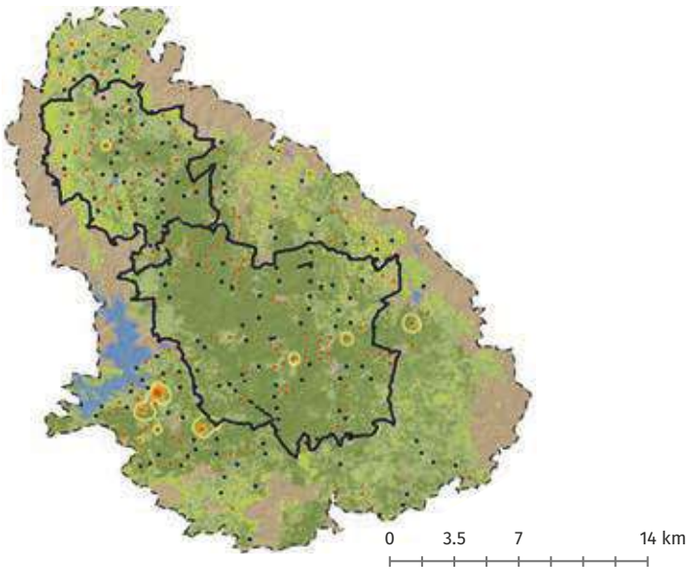


Figure 10.167

Distribution and relative spatial abundance of dhole in Tadoba Andhari Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Chaushinga was distributed throughout the tiger reserve with higher photo-captures in the buffer and peripheral areas.

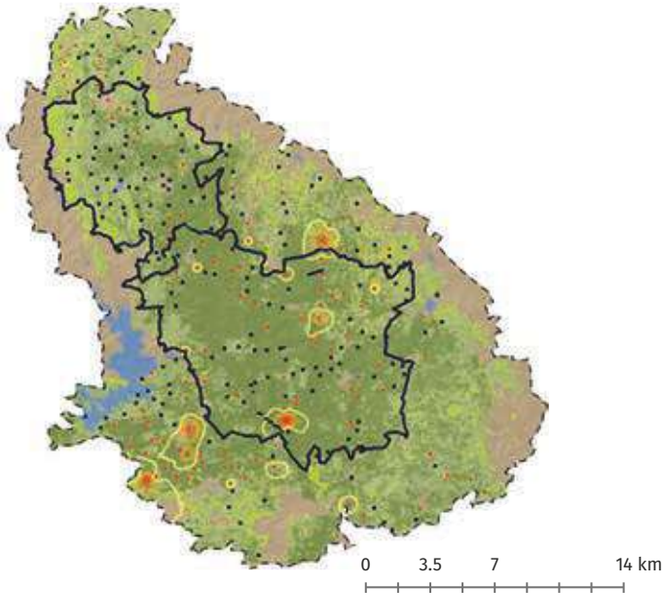


Figure 10.168

Distribution and relative spatial abundance of chaushinga in Tadoba Andhari Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Gaur was distributed throughout the tiger reserve. Higher photo-captures were obtained in Shioni range in the buffer area of the tiger reserve.

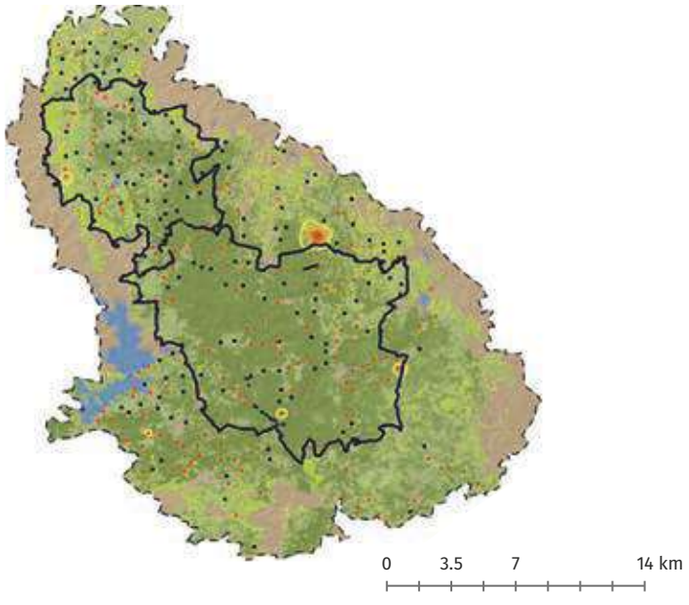


Figure 10.169

Distribution and relative spatial abundance of gaur in Tadoba Andhari Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

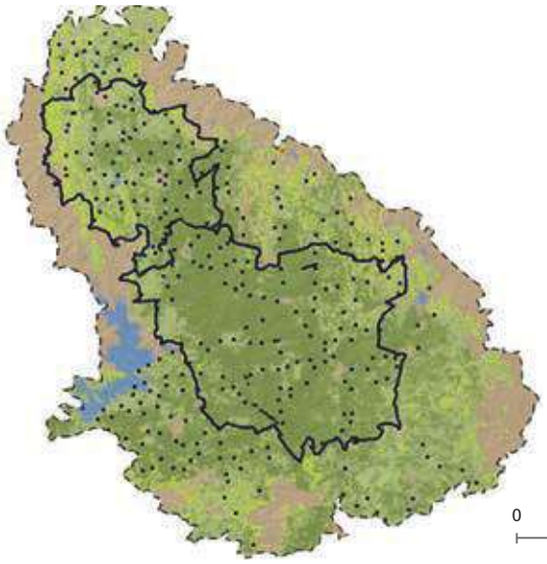


Figure 10.170

Distribution and relative spatial abundance of the golden jackal in Tadoba Andhari Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Surprisingly there were very few photo-captures of golden jackal. This requires and indepth study on the species in region.

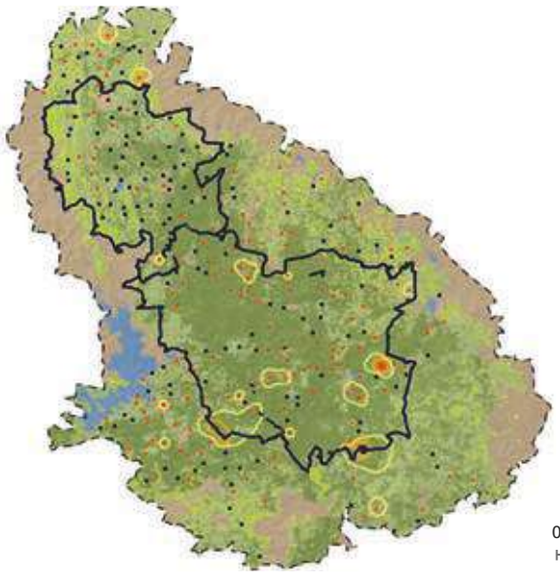


Figure 10.171

Distribution and relative spatial abundance of jungle cat in Tadoba Andhari Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Jungle cat was photo-captured almost throughout the tiger reserve. Capture hotspots were in the periphery of the core area.

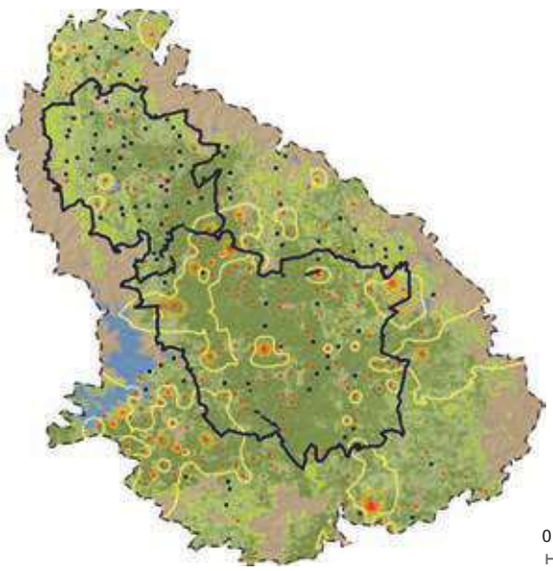


Figure 10.172

Distribution and relative spatial abundance of leopard in Tadoba Andhari Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Leopard was distributed throughout the tiger reserve with relatively high capture rates.

Rusty spotted cat was sparsely distributed in the tiger reserve with capture hotspots towards the south-western boundary of the park.

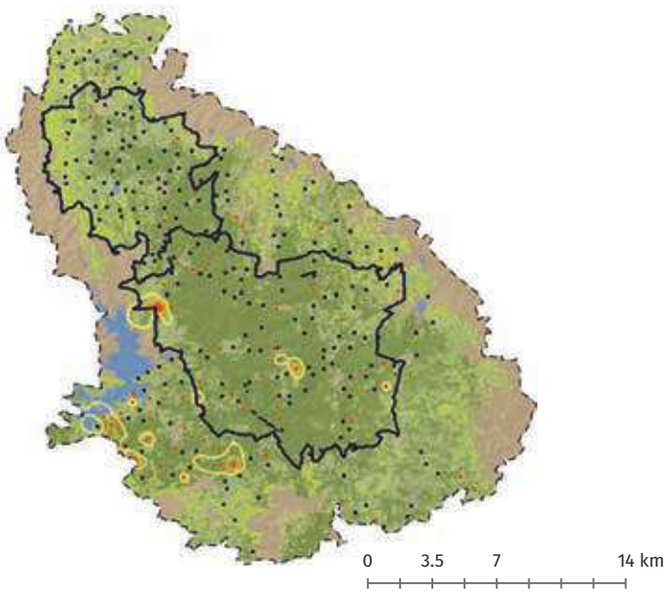


Figure 10.173

Distribution and relative spatial abundance of the rusty-spotted cat in Tadoba Andhari Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Sloth bear was distributed throughout the tiger reserve, with capture hotspots in the southern buffer area of the tiger reserve.

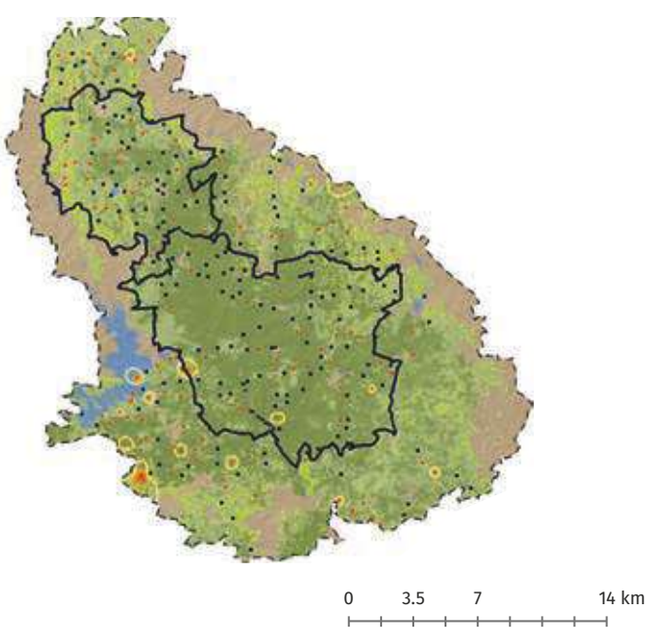


Figure 10.174

Distribution and relative spatial abundance of sloth bear in Tadoba Andhari Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict the intensity of photo-captures.

Table 10.59

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Tadoba Andhari Tiger Reserve, 2018

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Asiatic wild cat	0.02	4650
Barking Deer	3.03	33
Chital	8.62	12
Domestic dogs	2.86	35
Four-Horned Antelope	3.23	31
Gaur	4.72	21
Golden Jackal	0.03	3100
Hanuman Langur	4.44	23
Honey Badger	4.65	22
Indian Fox	0.09	1163
Indian Grey Mongoose	3.62	28
Indian Hare	47.72	2
Indian Pangolin	0.02	4650
Indian porcupine	6.63	15
Jungle cat	7.78	13
Leopard	6.25	16
Livestock	5.28	19
Nilgai	3.52	28
Palm Civet	10.33	10
Peafowl	9.44	11
Red jungle fowl	2.97	34
Rhesus Macaque	0.11	930
Ruddy Mongoose	2.98	34
Rusty-spotted Cat	1.74	57
Sambar	16.00	6
Sloth Bear	3.30	30
Small Indian Civet	11.15	9
Tiger	9.75	10
Wild Dog	3.01	33
Wild Pig	6.74	15

Relative Abundance of all Photocaptured Species in Tadoba Andhari Tiger Reserve

A total of 28 wild species of ungulates, carnivores, primates, omnivores and galliformes were photo-captured in the Tadoba Andhari Tiger Reserve. Indian hare and sambar were the most common species while desert cat and pangolin were the rarest photo-captured species (Table 10.59).

DISCUSSION

With the high ungulate biomass and habitat connectivity with neighbouring forest divisions, Tadoba AndhariTiger Reserve maintains a high tiger density in the region. This source population is important to maintain the meta-population of the adjoining forest divisions and protected areas (Bramhapuri, Chandrapur, Central Chanda, Tipeshwar and Bor).

BRAMHAPURI FOREST DIVISION

INTRODUCTION

Bramhapuri Forest Division is located in the northeaster part of Chandrapur district, Maharashtra at 20° 4'51" N to 20°43'23" N and 79° 9'50" E to 79°57'39" E. The total area of Bramhapuri Forest Division is 1,187.86 km^2 out of which 986.21 km^2 is the Bramhapuri Territorial Division and 201.65km^2 is the Bramhapuri Forest Development Corporation of Maharashtra. The territorial area is further divided as reserved forest, protected forest and unclassified forest.

The major forest type here is southern tropical dry deciduous forests (5A) (Champion and Seth 1968). The prominent trees species found here are *Tectona grandis* and its associates, like *Terminalia spp., Diospyros melanoxylon, Madhuca longifolia*, etc. The major carnivores and herbivores include tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), wolf (*Canis lupus*), wild pig (*Sus scrofa*), sambar (*Rusa unicolor*), chital (*Axis axis*), and chaushinga (*Tetracerus quadricornis*). Bramhapuri is connected to Tadoba Andhari Tiger Reserve on the western side through a patch of mixed deciduous forest. The area serves as an extension of the wildlife habitat of Tadoba and a connecting corridor to the Gadhchiroli forests further east. Bramhapuri is also connected to Chandrapur Forest Division on the south-western side and Central Chanda on the south. Bramhapuri is part of the important corridor between Tadoba Andhari Tiger Reserve -Umred Karhandla Wildlife Sanctuary and Tadoba Andhari Tiger Reserve - Nawegaon Nagzira Tiger Reserve.

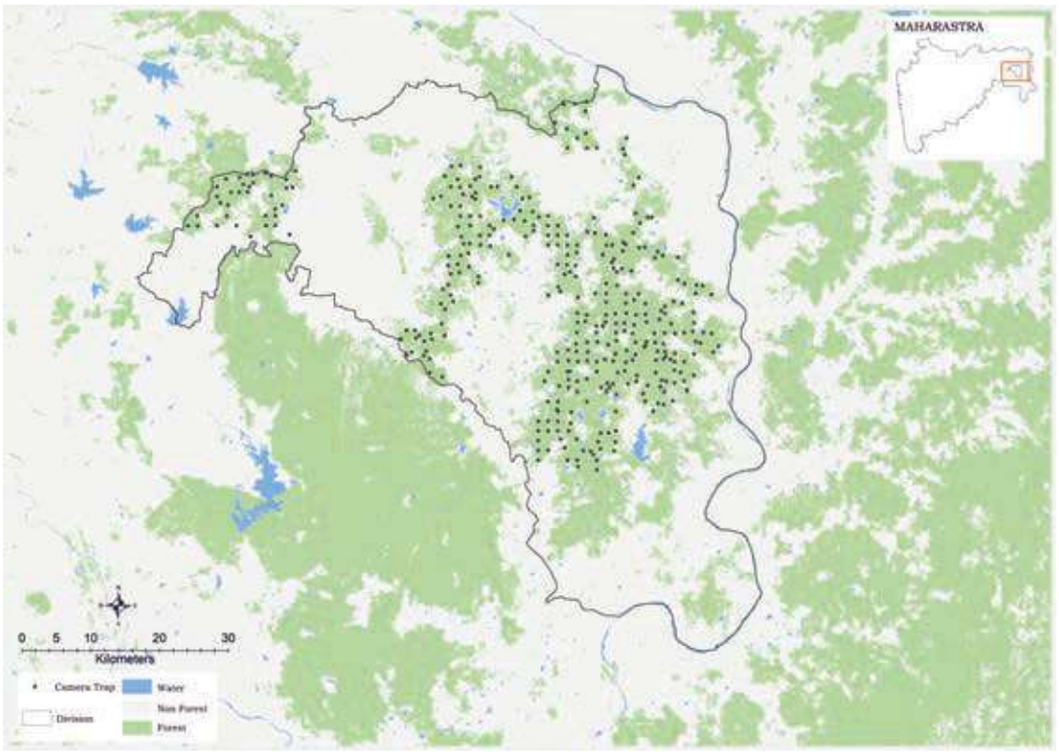


Figure 10.175
Camera trap layout in Bramhapuri Forest Division, 2018

RESULTS

Tiger Density Estimates

A total of 314 detections of tigers were obtained during the sampling period from which 39 individual adult tigers were identified. Tiger density was estimated at 2.50 (SE 0.40) tiger per 100 km^2 (Table 10.60). The detection corrected sex ratio was female biased (Table 10.60).

Table 10.60

Sampling details tiger density parameter estimates in spatially explicit capture-mark-recapture analysis using the likelihood framework for Terai West Forest Division, 2018.

Variables	Estimates
Model space (km^2)	2202.75
Camera points	353
Trap nights (effort)	9112
Unique tigers captured	39
Model	g_o (sex) σ (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	2.50 (0.40)
σ Female (SE) km	3.30 (0.23)
σ Male (SE) km	5.34 (0.25)
g_o Female (SE)	0.017 (0.002)
g_o Male (SE)	0.020 (0.002)
Pmix Female (SE)	0.63 (0.08)
Pmix Male (SE)	0.37 (0.08)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_o: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Bramhapuri Forest Division shares many of its tigers with Tadoba Andhari Tiger Reserve.These forests serve as sink habitats to dispersing tigers from Tadoba and are therefore important in longterm viability this important central Indian tiger population. Since these forests are interspersed with human habitation managing conflict situations and conflict tigers in a timely manner is the crux of preventing retaliation. Wildlife based sustainable ecotourism that supports local livelihoods would provide the much needed incentive for coexistence in these forests. .

CHANDRAPUR FOREST DIVISION

INTRODUCTION

Chandrapur Forest Division is located in eastern Maharashtra. Chandrapur lies between 18° 41' to 19° 30' N latitudes and 79° 55' to 80° 22' E longitudes. The total area of the Chandrapur Forest division is 362.23 km^2.

According to Champion and Seth (1968), the forest type of Chandrapur is southern-tropical dry mixed deciduous forests (5A). Chandrapur is a *Tectona grandis* dominated forest with its associates like *Pterocarpus marsupium, Diospyros melanoxylon, Terminalia spp*., bamboo, etc. Chandrapur Forest Division is home to many wildlife species including some endangered species, including tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), wolf (*Canis lupus*) and sloth bear (*Melursus ursinus*). Prey species like barking deer (*Muntiacus vaginalis*), chital (*Axis axis*), wild pig (*Sus scrofa*), grey langur (Semnopithecus entellus), etc. are found here.

Chandrapur is connected to Tadoba Andhari Tiger Reserve on the east and Central Chanda Forest Division on the south. This area serves as a potential habitat for wild fauna and corridor for movement of dispersing animals.

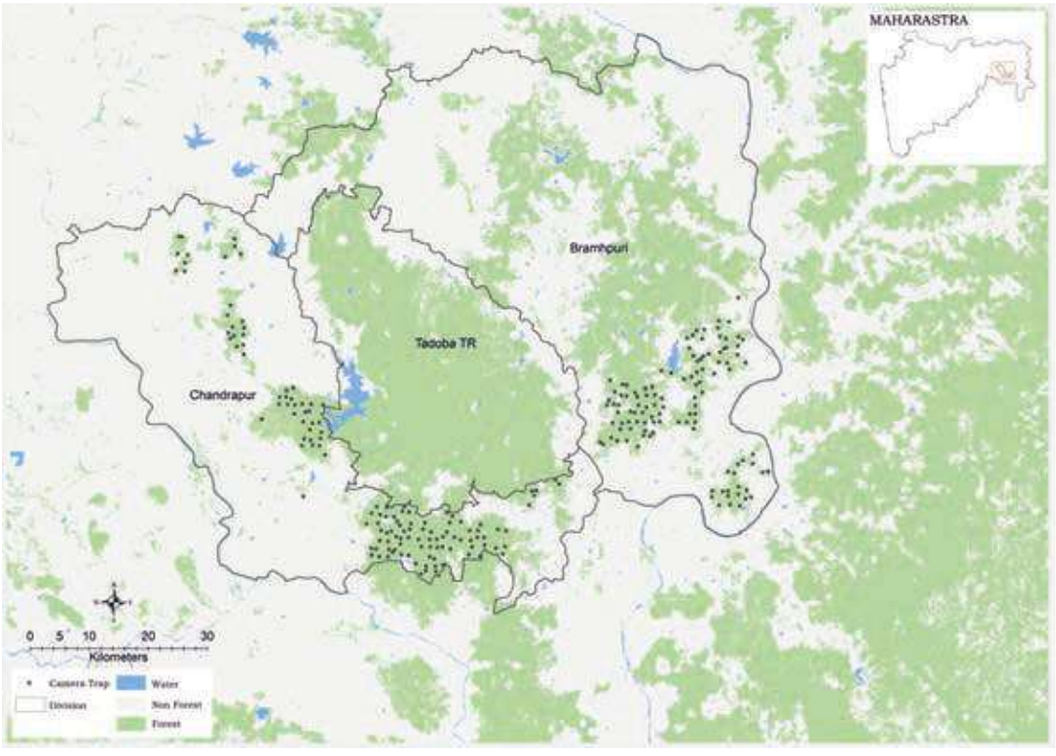


Figure 10.176
Camera trap layout in Chandrapur Forest Division, 2018

RESULTS

Tiger Density Estimates

A total of 136 detections of tigers were obtained during the sampling period from which 31 individual adult tigers were identified. Tiger density was estimated at 2.60 (SE 0.45) tiger per 100 km^2 (Table 10.61). The detection corrected sex ratio was female biased (Table 10.61).

Table 10.61

Sampling details tiger density parameter estimates in spatially explicit capture-mark-recapture analysis using the likelihood framework for Chandrapur Forest Division, 2018.

Variables	Estimates
Model space (km^2)	2230.5
Camera points	250
Trap nights (effort)	6157
Unique tigers captured	31
Model	go (sex) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	2.60 (0.45)
σ Female (SE) km	1.70 (0.18)
σ Male (SE) km	7.05 (0.70)
g_o Female (SE)	0.002 (0.001)
g_o Male (SE)	0.001 (0.000)
Pmix Female (SE)	0.54 (0.10)
Pmix Male (SE)	0.46 (0.10)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_o: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Chandrapur Forest Division had a reasonable tiger density and along with Brahmpuri forests acts as a sink habitat for Tadoba to maintain the longterm viability of tigers in this landscape. It forms an important corridor for tigers dispersing to Tipeshwar WLS, and further south to Kawal and east to Indrawati Tiger Reserve.

CENTRAL CHANDA FOREST DIVISION

INTRODUCTION

Central Chanda Forest Division comes under Chandrapur circle in the Chandrapur district of Maharashtra. It lies between latitudes 19°30'39" N to 20° 0'29" N and 78°58'25" E 79°47'58" E. The total area of Central Chanda forest division is 1143.094 km^2 out of which 888.62 km^2 is reserved forest, 196.47 km^2 protected forest and 57.99 km^2 unclassified forest.

According to Champion and Seth (1968), the forest type is southern tropical dry deciduous forests (5A). The common trees found here are *Terminalia chebula, Aegle marmelos, Terminalia bellirica, Chloroxylon swietenia, Pterocarpus marsupium, Madhuca longifolia, Tectona grandis, Terminalia elliptica, Diospyros melanoxylon*, bamboo, etc. The major carnivores and herbivores species include tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), wolf (*Canis lupus*), wild pig (*Sus scrofa*), sambar (*Rusa unicolor*), chital (*Axis axis*), and chaushinga (*Tetracerus quadricornis*). Central Chanda has connectivity with Kawal Tiger Reserve (Telangana) and Tipeshwar Wildlife Sanctuary via Adilabad Forest Division on the west. It is connected to Bramhapuri Forest Division and Chandrapur Forest Division on the north and Kagaznagar Forest Division in the north.

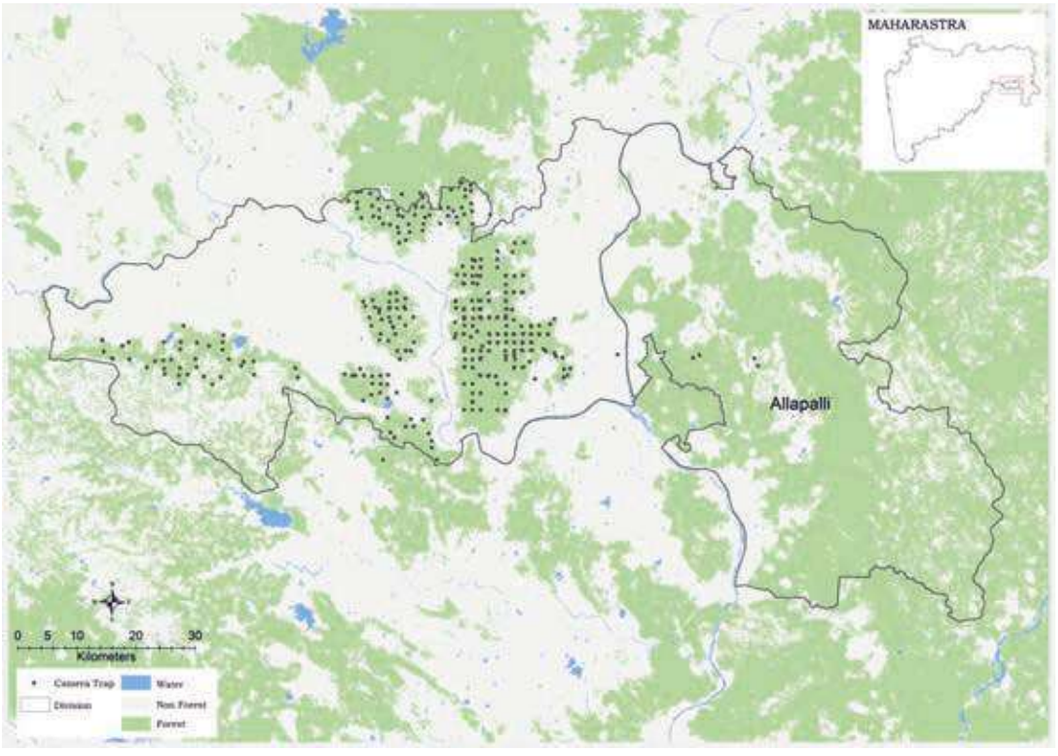


Figure 10.177
Camera trap layout in Central Chanda Forest Division, 2018

RESULTS

Tiger Density Estimates

A total of 96 detections of tigers were obtained during the sampling period from which 23 individual adult tigers were identified. Tiger density was estimated at 2.09 (SE 0.45) tiger per 100 km^2 (Table 10.62). The detection corrected sex ratio was female biased (Table 10.62).

Table 10.62

Sampling details tiger density parameter estimates in spatially explicit capture-mark-recapture analysis using the likelihood framework for Central Chanda Forest Division, 2018.

Variables	Estimates
Model space (km^2)	1754.25
Camera points	354
Trap nights (effort)	8426
Unique tigers captured	23
Model	σ (.) g_0 (.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	2.09 (0.45)
σ (SE) km	4.6 (0.0007)
g_0 (SE)	0.004 (0.00)
Pmix Female (SE)	0.6 (0.11)
Pmix Male (SE)	0.4 (0.11)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Central Chanda Forest Division had a reasonable tiger density and adds to the tiger occupied habitat of this globally important tiger population. The presence of tigers in this division represents the functional use of this habitat corridor that connects Tadoba source south sink habitats in adjoining areas of Telangana state. This corridor is vital for repopulating Kawal Tiger Reserve as well as supplement depleted populations of Indravati Tiger Reserve, Adilabad forests and Khamam forests. The Central Chanda forests are threated with development, agricultural intensification and infrastructure. Appropriate mitigation measures are urgently required for maintaining the corridor and sink value of these forests.

PAINGANGA WILDLIFE SANCTUARY

INTRODUCTION

Painganga Wildlife Sanctuary is located in the Yawatmal district of Maharashtra in 19°26' to 19°41' N latitudes and 77°57' to 78°12' E longitudes. Situated on the banks of river Painganga, this wildlife sanctuary has an area of 364 km^2.

The area has an undulating terrain with dry savannahs and riverbanks dominated by dry deciduous forest patches. There are villages and agricultural fields in the sanctuary area, particularly around the seasonal water streams. The forests are dominated by *Tectona grandis, Terminalia spp*., *Diospyros melanoxylon, Madhuca longifolia*, etc. These habitats in and around the sanctuary is also home to tiger (*Panthera tigris*), dhole (*Cuon alpinus*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), chital (*Axis axis*), sambar (*Rusa unicolor*), etc.

Painganga Wildlife Sanctuary plays a pivotal role as a potential sink habitat in the tiger meta-population dynamics of this landscape. Habitat connectivity with the adjoining forest divisions and protected areas is chiefly dominated by savanna vegetation; and has been fragmented by agricultural fields, townships and linear infrastructure. As savannas are not considered in the legal definition of forests, their conversion into human modified landuse could be rampant. Conserving these habitats is crucial in wake of the numerable mining projects and infrastructures coming up in the area, which will threaten tiger movement through this vital bottleneck corridor.

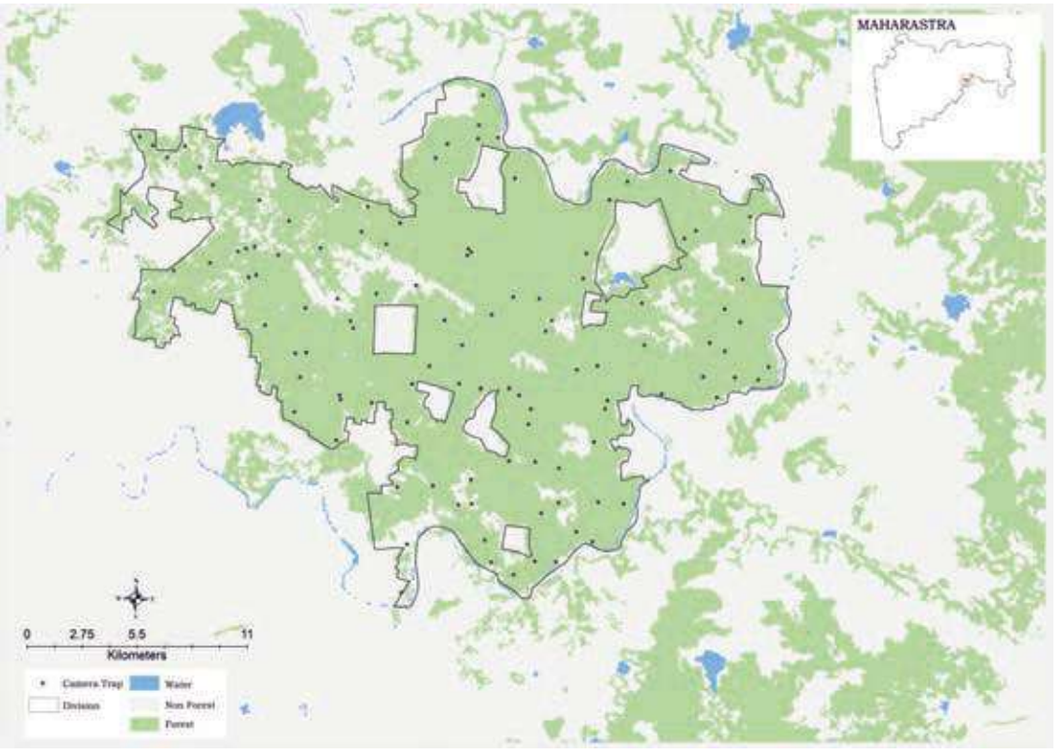


Figure 10.178
Camera trap and transect layout in Painganga Wildlife Sanctuary, 2018

RESULTS

Camera Trap Results

A total of 17 images of tigers of a single tiger were obtained during the sampling period. As only one tiger was photocaptured, density was not modelled (Table 10.63).

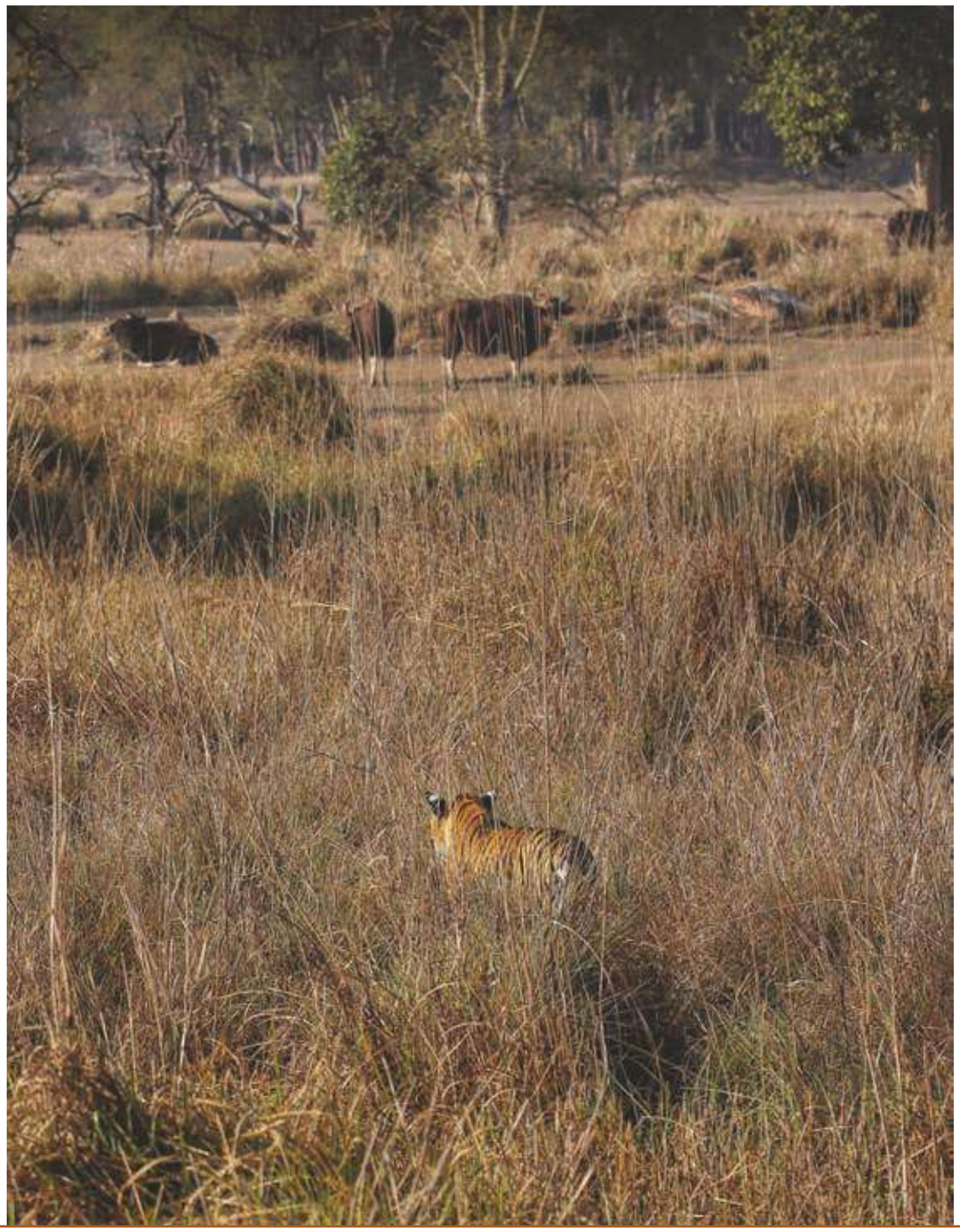
Table 10.63

Sampling details of camera trapping exercise in Painganga Wildlife Sanctuary, 2018.

Sampling details	Counts
Camera points	113
Trap nights (effort)	4059
Unique tigers captured	1

DISCUSSION

Even though only one tiger was detected, this detection validates the importance of Painganga Wildlife Sanctuary as a stepping stone patch for maintaining the meta-population of tigers in this landscape.



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TIPESHWAR WILDLIFE SANCTUARY

INTRODUCTION

Tipeshwar Wildlife Sanctuary is situated in Patanbori and Parwa ranges of the Pandharkawada Forest Division of Yavatmal district in the Vidharbha region of Maharashtra. It is situated within the confines of 78°20' to 78°47' E longitudes and 19o 50' to 19 o 55' N Latitude. The total area of TWS is 148.63 km^2.

TWS is part of the biotic province 6D- central plateau. The major forest type here is the southern tropical dry deciduous forests. Tectona grandis forms up to 60% of the forest composition here. Other prominent tree species include *Buchanania lanzan, Madhuca longifolia* and *Lagerstroemia parviflora*. Tipeshwar is home to many wildlife species including several endangered and endemic species. It is home to tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bears (*Melursus ursinus*), pangolins (*Manis crassicaudata*), chausingha (*Tetracerus quadricornis*), etc.

Tipeshwar is connected to Kawal Tiger Reserve via Adilabad territorial forest division of Telangana. These forest corridors allow movement of wild animals for dispersal.

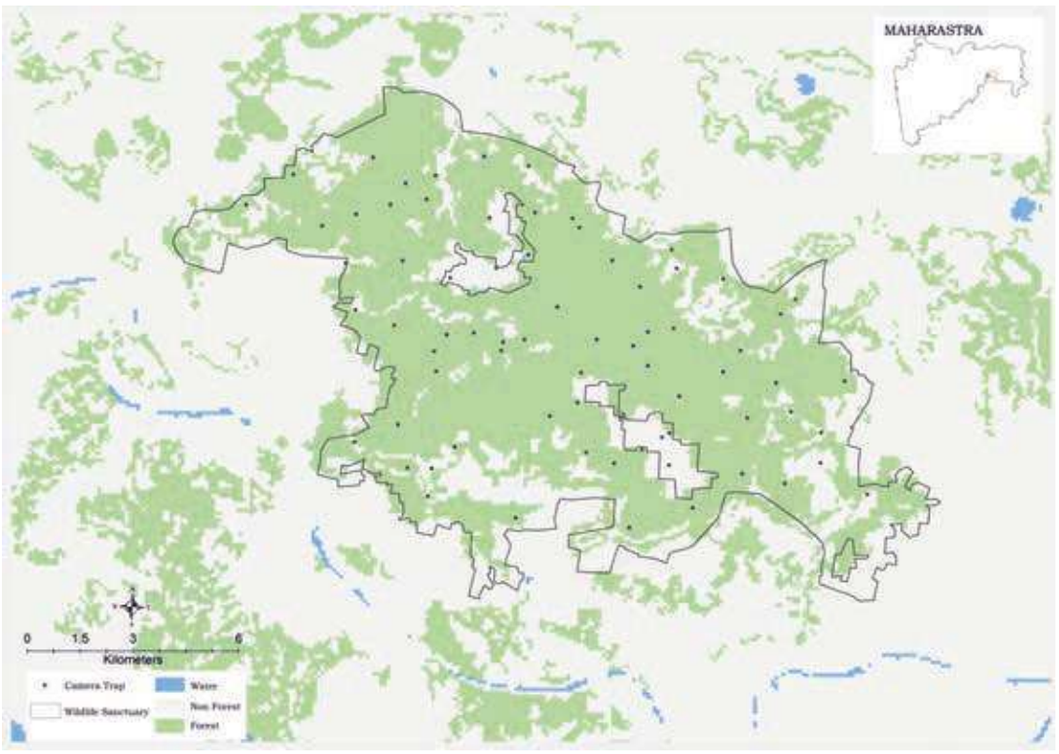


Figure 10.179
Camera trap layout in Tipeshwar Wildlife Sanctuary, 2018

RESULTS

Tiger Density Estimates

A total of 106 detections of tigers were obtained during the sampling period from which 5 individual adult tigers were identified. Tiger density was estimated at 2.50 (SE 1.20) tiger per 100 km^2 (Table 10.64). The detection corrected sex ratio was female biased (Table 10.64).

Table 10.64

Sampling details tiger density parameter estimates in spatially explicit capture-mark-recapture analysis using the likelihood framework for Tipeshwar Wildlife Sanctuary, 2018.

Variables	Estimates
Model space (km^2)	199.75
Camera points	73
Trap nights (effort)	2354
Unique tigers captured	5
Model	g_0 (.) σ (.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	2.50 (1.20)
σ (SE) km	3.17 (0.48)
g_o (SE)	0.030 (0.004)
Pmix Female (SE)	0.80 (0.17)
Pmix Male (SE)	0.20 (0.17)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Tipeshwar Wildlife Sanctuary was camera trapped for the first time for the All India Tiger Monitoring exercise, where five unique individual tigers were captured. Tipeshwar along with its adjoining forests forms the Tadoba metapopulation. Maintaining and managing this metapopulation will ensure longterm viability of this globally important tiger population.

UMRED KARHANDLA WILDLIFE SANCTUARY

INTRODUCTION

Umred Wildlife Sanctuary is located in Bhandara and Nagpur districts (20°46'59" N to 20°55'9" N and 79°22'40" E to 79°37'1" E) in eastern Maharashtra.

Located on the banks of the river Wainganga, the sanctuary is composed of dry savannahs and dry deciduous forests dominated by *Tectona grandis, Terminalia spp*., *Diospyros melanoxylon* and bamboo thickets. Though relatively small in size, the sanctuary is home to varied mammals including dhole (*Cuon alpinus*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), chital (*Axis axis*), sambar (*Rusa unicolor*), Indian pangolin (*Manis crassicaudata*) and honey badger (*Mellivora capensis*).

Due of the proximity to tiger reserves in the area (Tadoba Andhari, Pench (Maharashtra), Nawegaon-Nagzira and Bor) and other tiger bearing areas (Chandrapur and Brahmapuri) this sanctuary has become a haven for tigers since the recent past. Acting as a stepping stone corridor, this sanctuary is important for long-term persistence of tiger meta-population in the region. However, increased traffic on the state highway and expanding townships around this sanctuary can have potential consequences on the dispersing tigers and cause human-tiger conflict.

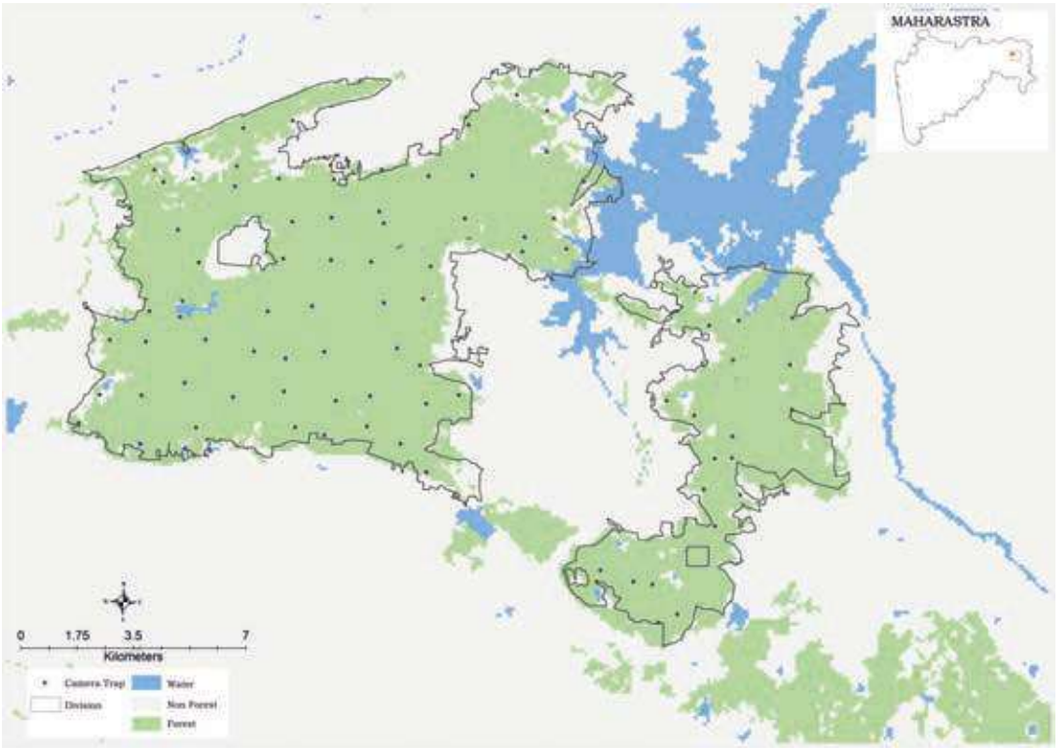


Figure 10.180
Camera trap and transect layout in Umred Karhandla wildlife sanctuary, 2018

RESULTS

Tiger Density Estimates

A total of 181 detections of tigers were obtained during the sampling period from which 11 individual adult tigers were identified. Tiger density was estimated at 4.87 (SE 1.60) tiger per 100 km^2 (Table 10.65). The detection corrected sex ratio was female biased (Table 10.65).

Table 10.65

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Umred Karhandla wildlife sanctuary, 2018.

Variables	Estimates
Model space (km^2)	220.75
Camera points	89
Trap nights (effort)	4497
Unique tigers captured	11
Model	g_0 (sex) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	4.87 (1.60)
σ Female (SE) km	2.16 (0.01)
σ Male (SE) km	6.38 (0.08)
g_0 Female (SE)	0.070 (0.009)
g_0 Male (SE)	0.030 (0.007)
Pmix Female (SE)	0.81 (0.11)
Pmix Male (SE)	0.19 (0.11)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

The site has 11 tigers with a high tiger density, which depicts its active usage as a sink habitat as well as a stepping stone patch for dispersal into Navegoan-Nagzira, Pench, and Kanha Tiger Reserves that maintains geneflow in the Central Indian landscape.

ACHANAKMAR TIGER RESERVE

INTRODUCTION

Achanakmar Tiger Reserve is located in Chhattisgarh and it is an extended to an area of 914 km^2, This area is constituted of a core zone of 626.2 km^2 and 287.8 km^2 of buffer zone. It is situated between 22^0 38' to 22^0 17' N and 81^0 31' to 81^0 57' E at the Eastern part of Maikal hills of Satpuda ranges. Temperature varies from maximum 24 to 39 °C to minimum from 7 to 26 °C in the reserve. According to forest type classification, Achanakmar is characterized by "Tropical moist and dry deciduous type".

Achanakmar tiger reserve is rich in terms of both flora and fauna. Mainly, sal is the dominated species in Achanakmar but other vegetation includes *Adina cordifolia, Anogeissus latifolia, Butea monosperma, Boswellia serrata, Cassia fistula, Dalbergia paniculata, Diospyros melanoxylon, Garuga pinnata, Madhuca indica, Mitragyna parvifolia, Pterocarpus marsupium, Syzygium cumini Terminalia tomentosa, Tectona grandis* amongst others. Lower and higher slopes have bamboo (*Dendrocalamus strictus*).

Major carnivore species found in Achanakmar are tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), hyena (*Hyeana hyeana*), dhole (*Cuon alpinus*), golden jackal (*Canis aureus*), jungle cat (*Felis chaus*) and Indian fox (*Vulpes bengalensis*). Chital (*Axis axis*), sambar (*Rusa unicolor*), gaur (*Bos gaurus*), nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*), barking deer (*Muntiacus vaginalis*) and chowsingha (*Tetracerus quadricornis*) are the major wild ungulates. Indian grey langur (*Semnopithecus entellus*) and rhesus macaque (*Macaca mulatta*), Indian porcupine (*Hystrix indica*), black-naped hare (*Lepus nigricollis*) and Indian giant squirrel (*Ratufa indica*) are also found in the reserve.

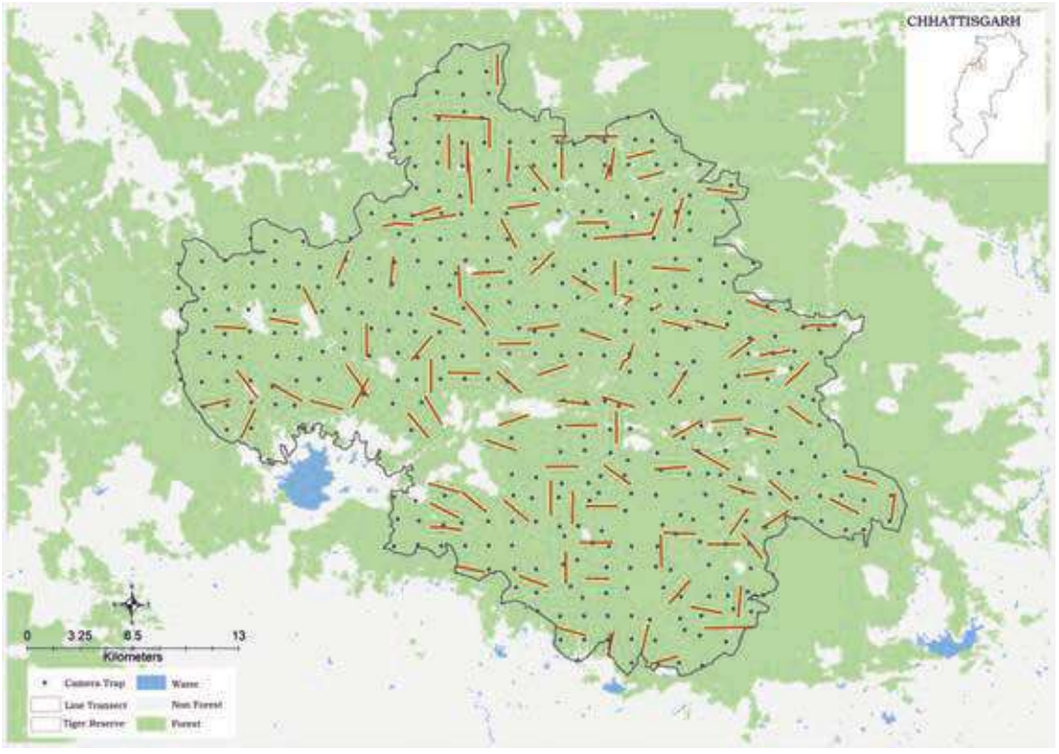


Figure 10.181
Camera trap and transect layout in Achanakmar Tiger Reserve, 2018

RESULTS

Tiger Density Estimates

A total of 397 cameras were deployed, 95 tiger images were obtained and 5 unique tiger individuals were identified. Tiger density was estimated at 0.46 (SE 0.21) tigers per 100 km^2. The detection corrected sex ratio was male biased (Table 10.66)

Table 10.66

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Achanakmar Tiger Reserve, 2018.

Variables	Estimates
Model space (km^2)	1089
Camera points	397
Trap nights (effort)	10645
Unique tigers captured	5
Model	$g_0(.)\sigma(.)$ Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.46 (0.21)
σ (SE) km	9.29 (1.32)
g_0 Female (SE)	0.04 (0.009)
Pmix Female (SE)	0.40 (0.20)
Pmix Male (SE)	0.60 (0.22)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

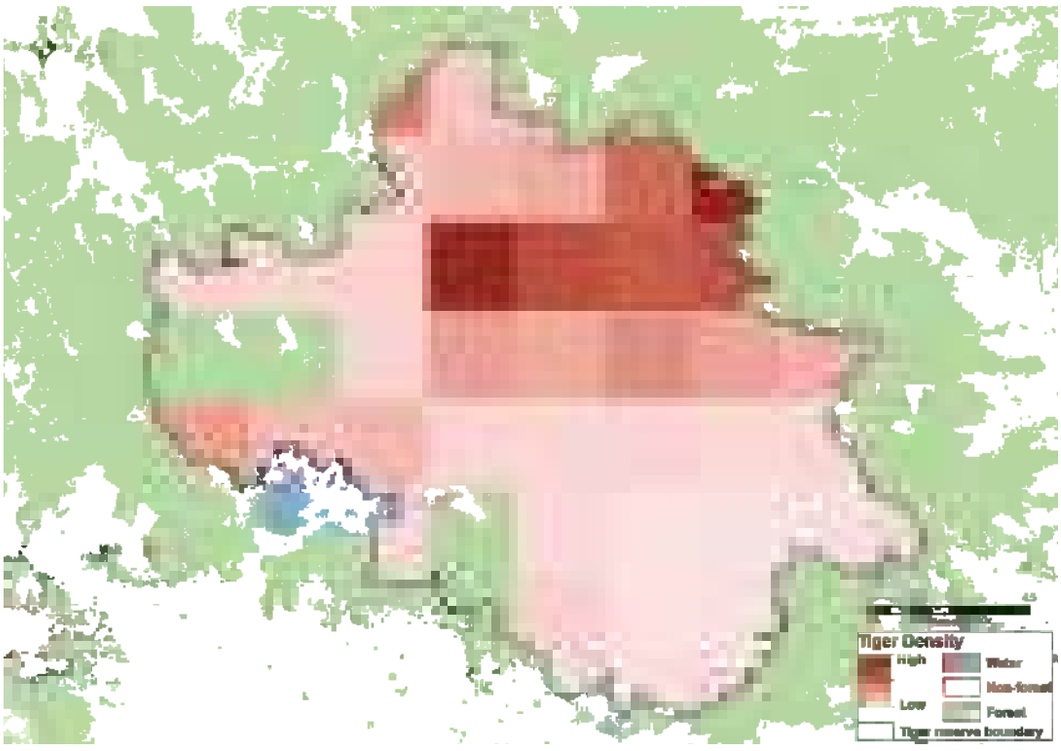
σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Figure 10.182

Spatial density of tigers in Achanakmar Tiger Reserve, 2018



North eastern area of Achanakmar has high tiger density.

Prey Density Estimates

A total of 324 samples were walked in Achanakmar Tiger Reserve which amounted to an effort of 650.15 km. Chital was found to be the most abundant ungulate with a density of 12.60 (SE 1.78) chital per km^2 followed by wild pig and gaur (Table 10.67).

Table 10.67

Model statistics and parameter estimates of line transect (n=324, Total effort 650.15 km) based distance sampling for prey species in Achanakmar Tiger Reserve, 2018-19.

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/km^2 (SE)	Individual density/ km^2 (SE)
Chital	39.56 (2.42)	114	5.69 (0.52)	0.26 (0.02)	0.18 (0.015)	2.22 (0.24)	12.60 (1.78)
Sambar	40.73 (4.50)	17	2.00 (0.53)	0.34 (0.04)	0.03 (0.007)	0.32 (0.09)	0.64 (0.24)
Barking Deer	36.49 (1.91)	55	1.16 (0.09)	0.30 (0.02)	0.08 (0.011)	1.16 (0.16)	1.34 (0.22)
Wild Pig	22.14 (1.73)	50	6.07 (1.87)	0.26 (0.02)	0.08 (0.011)	1.74 (0.28)	10.55 (3.67)
Gaur	48.94 (5.84)	59	5.97 (1.00)	0.49 (0.06)	0.09 (0.012)	0.93 (0.17)	5.53 (1.36)

Distribution of Major Mammalian Species Found in Achanakmar Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Achanakmar Tiger Reserve.

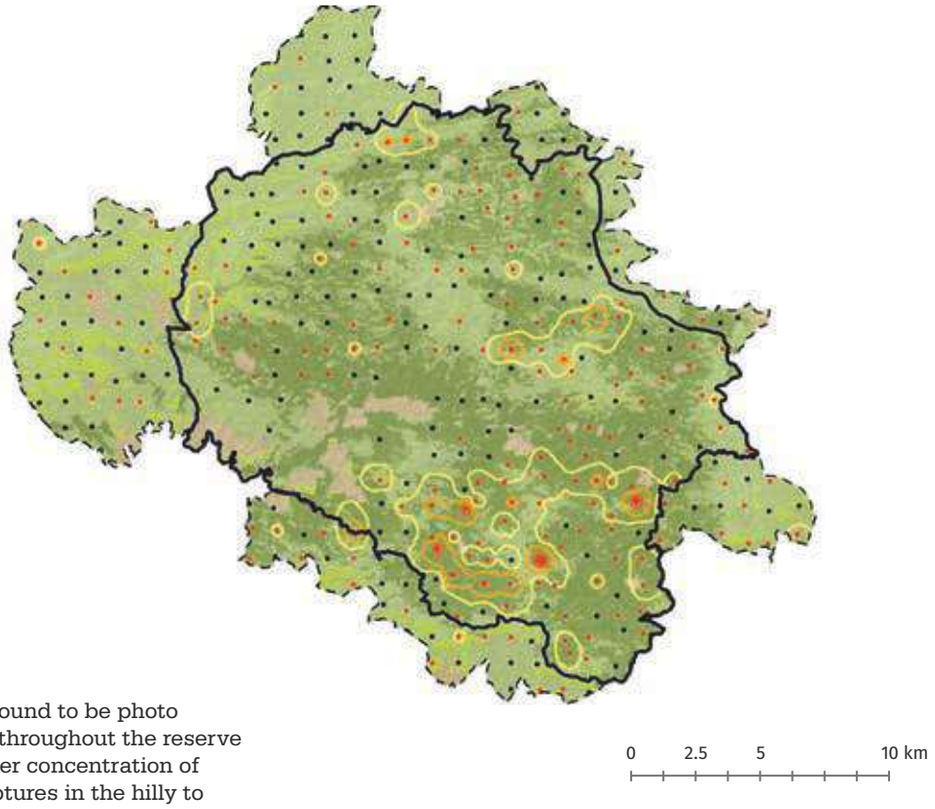


Figure 10.183

Distribution and relative spatial abundance of leopard in Achanakmar Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard found to be photo captured throughout the reserve with higher concentration of photo-captures in the hilly to moderately hilly terrain.

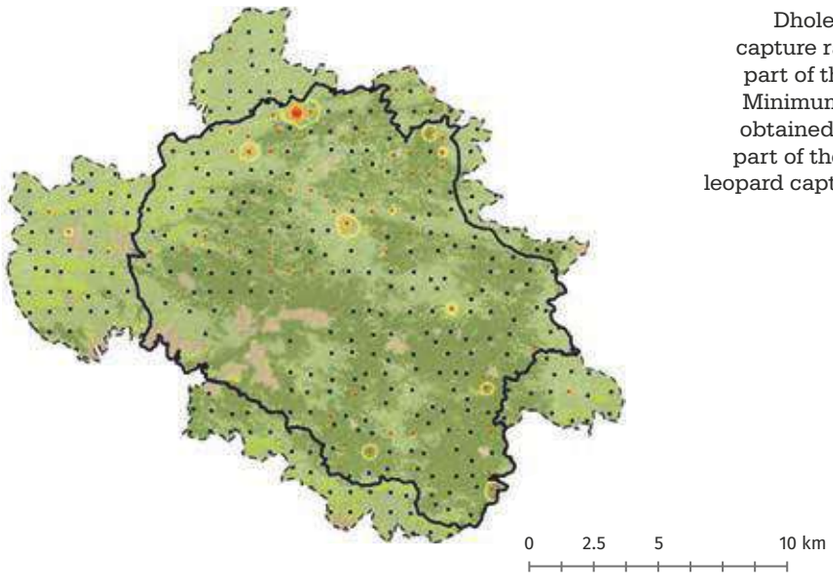


Figure 10.184

Distribution and relative spatial abundance of Dhole in Achanakmar Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Dhole had high photo capture rates in northern part of the tiger reserve. Minimum captures were obtained in the southern part of the reserve where leopard captures were high.

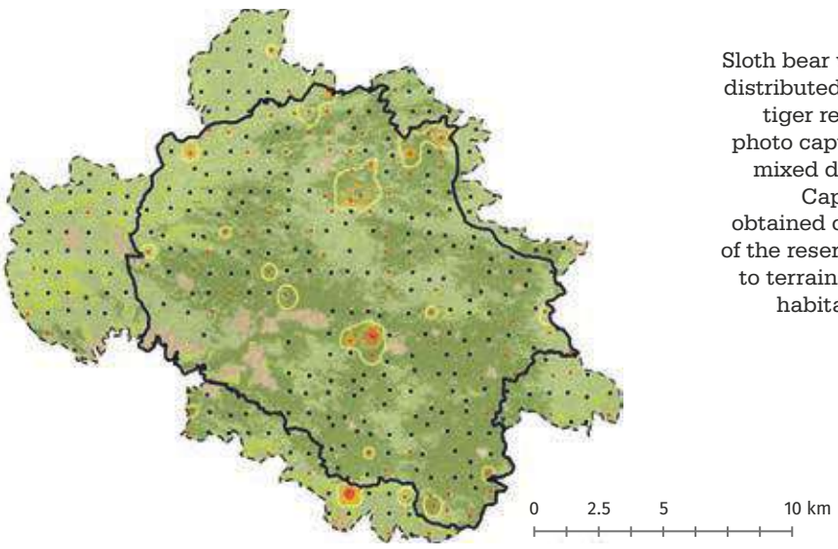


Figure 10.185

Distribution and relative spatial abundance of Sloth bear in Achanakmar Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear was found to be distributed throughout the tiger reserve with high photo capture rates in the mixed deciduous forest. Captures were also obtained on the boundary of the reserve possibly due to terrain complexity and habitat requirements.

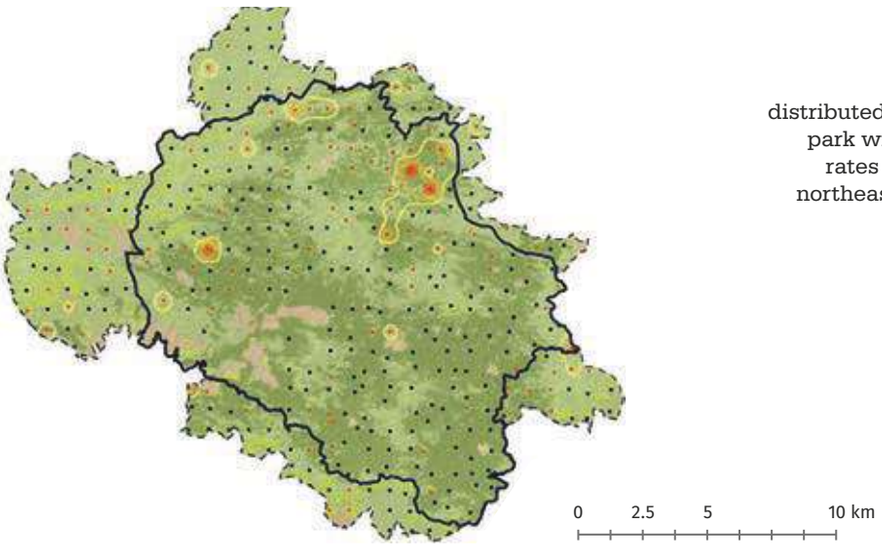


Figure 10.186

Distribution and relative spatial abundance of Jungle cat in Achanakmar Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was distributed throughout the park with high capture rates in northern and northeastern part of the reserve.

Striped hyena was photo-captured mostly in the northern part of the tiger reserve.

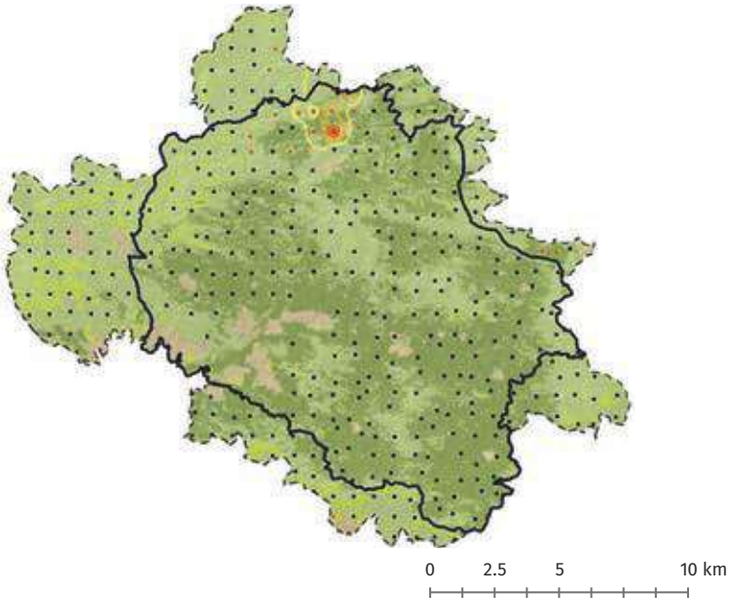


Figure 10.187

Distribution and relative spatial abundance of striped hyena in Achanakmar Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Four horned antelope was distributed throughout the tiger reserve with higher concentration of photo-captures in the hilly to moderately hilly terrain of in the eastern boundary.

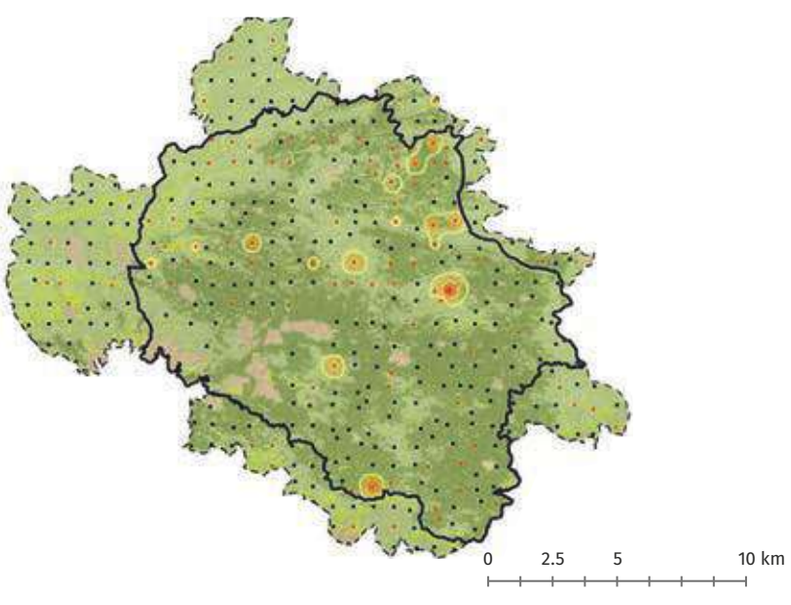


Figure 10.188

Distribution and relative spatial abundance of four horned antelope in Achanakmar Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Table 10.68

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Achanakmar Tiger Reserve, 2018

Common Name	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Asian Palm Civet	1.06	94
Barking Deer	3.08	32
Bengal Fox	0.70	142
Chital	4.54	22
Dhole	0.95	105
Domestic dog	4.29	23
Domestic cat	0.02	5323
Four horned antelope	1.77	57
Gaur	7.96	13
Grey mongoose	0.18	560
Hanuman langur	9.29	11
Honey badger	0.70	142
Indian crested porcupine	0.86	116
Indian hare	9.52	11
Indian peafowl	1.59	63
Jackal	2.80	36
Jungle cat	2.65	38
Leopard	4.42	23
Livestock	33.70	3
Red junglefowl	0.63	159
Rhesus macaque	6.44	16
Ruddy mongoose	0.35	288
Sambar	2.15	46
Sloth bear	1.40	71
Small Indian civet	0.85	117
Striped hyena	0.70	144
Tiger	0.49	205
Wild pig	10.12	10

Relative Abundance of all Photocaptured Species in Achanakmar Tiger Reserve

A total of 28 wild species of ungulates, carnivores, primates, omnivores and galliformes were photo-captured in Achanakmar Tiger Reserve. Wild pig were the most common species. Ruddy mongoose and red jungle fowl were the rarest photo-captured species (Table 10.68).

DISCUSSION

Achanakmar Tiger Reserve had poor tiger status in 2014, it has further deteriorated in 2018. Strict law enforcement by the management and implementation of foot patrolling through MSTrIPES is required to stem the decline. The corridor between Kanha tiger reserve and Achanakmar tiger reserve is crucial for the sustenance of the tiger population in Achanakmar.

UDANTI-SITANADI TIGER RESERVE

INTRODUCTION

Udanti-Sitanadi Tiger Reserve is situated in the district Gariyaband in Chhattisgarh. The Udanti (20° 08' 16" N, 82° 22' 17.69" E) and Sitanadi (20° 8'40" N, 81° 58' 31" E) wildlife sanctuaries derive their name from the rivers Udanti and Sitanadi which flow through the respective sanctuaries. The geographical area of the tiger reserve is 1842.54 km^2. out of which 851.09 km^2 is Core Area and 991.45 km^2 is Buffer Area.

The Udanti-Sitanadi Tiger Reserve (USTR) includes ranges of Tourenga, Mainpur, Indagaon and Kulhadighat of Udanti Forest Division, parts of Dhawalpur range of East Raipur Forest Division, Gariaband District, and parts of Sankara range of Dhamtari Forest Division, Dhamtari District. The eastern periphery of Udanti Sanctuary forms an interstate boundary between Chhattisgarh and Odisha. Both the sanctuaries are well connected with a 30 km forest stretch, which allows wild animals to move between them.

The forest types of USTR are "Tropical Peninsular Sal forest and Southern Tropical Dry Deciduous Mixed forest" (Champion and Seth 1968). The dominant tree species is Sal (*Shorea robusta*) mixed with species of *Anogeissus latifolia, Pterocarpus marsupium Terminalia arjuna, Terminalia elliptica* and Bamboo. Teak (*Tectona grandis*) is also found in USTR.

Tiger (*Panthera tigirs*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*), wild dog (*Cuon alpinus*), golden jackal (*Canis aureus*), gaur (*Bos gauras*), elephant (*Elephas maximas*), sambar (*Rusa unicolor*), nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*), barking deer (*Muntiacus vaginalis*) and chowsingha (*Tetraceros quadricornis*) are the major faunal species found in Udanti-Sitanadi tiger reserve.

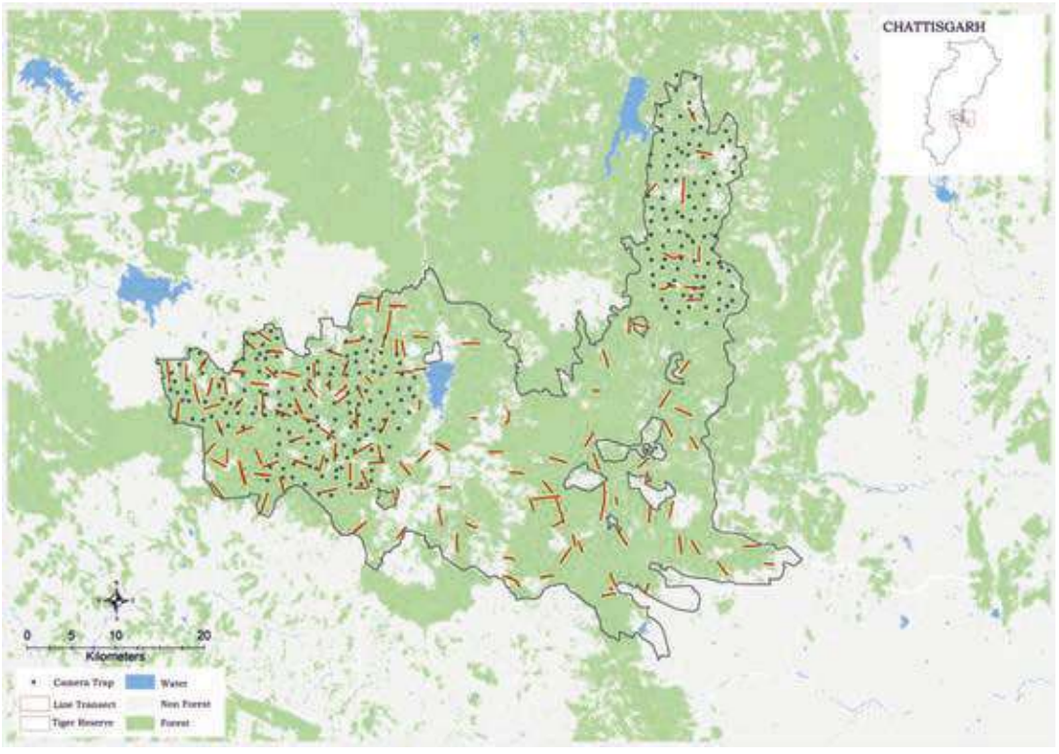


Figure 10.189
Camera trap and transect layout in Udanti Sitanadi Tiger Reserve, 2018

RESULTS

Camera Trap Results

A total of 09 detections of a single tigeress were obtainted during the sampling period, hence density could not be estimated (Table 10.69)

Table 10.69

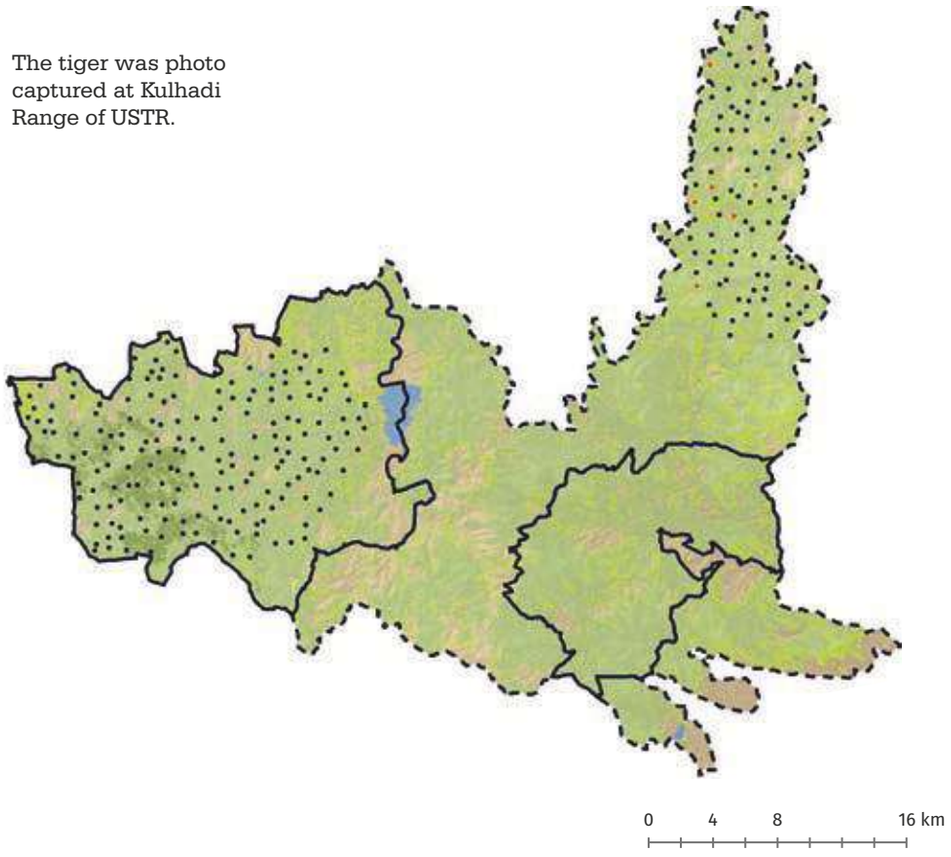
Sampling details of camera trapping exercise in Udanti-Sitanadi Tiger Reserve, 2018.

Variables	Counts
Camera points	279
Trap nights (effort)	6630
Unique tigers captured	1

Figure 10.190

Photo capture locations of tiger in Udanti-Sitanadi Tiger Reserve.

The tiger was photo captured at Kulhadi Range of USTR.



Prey Density Estimates

A total of 260 transects were walked in Udanti-Sitanadi Tiger Reserve which amounted to an effort of 507.43 km. Chital was found to be the most abundant ungulate with a density of 1.02 (SE 0.33) chital per km^2 followed by barking deer (Table 10.70).

Table 10.70

Model statistics and parameter estimates of line transect (n=260, Total effort 507.43 km) based distance sampling for prey species in Udanti-Sitanadi Tiger Reserve, 2018

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/sq.km (SE)	Individual density/ sq.km (SE)
Chital	39.56 (2.42)	14	2.92 (0.50)	0.26 (0.02)	0.028 (0.007)	0.35 (0.09)	1.02 (0.33)
Nilgai		7			0.014 (0.005)		
Barking Deer	36.49 (1.91)	21	1.10 (0.07)	0.30 (0.02)	0.041 (0.008)	0.57 (0.12)	0.62 (0.14)
Wild Pig	34.19 (2.68)	8			0.016 (0.005)		

Distribution of Major Mammalian Fauna in Udanti-Sitanadi Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Udanti-Sitanadi Tiger Reserve.

Leopard was distributed throughout the tiger reserve with higher concentration of photo-captures in the hilly to moderately hilly terrain of Sitanadi range in the western boundary.

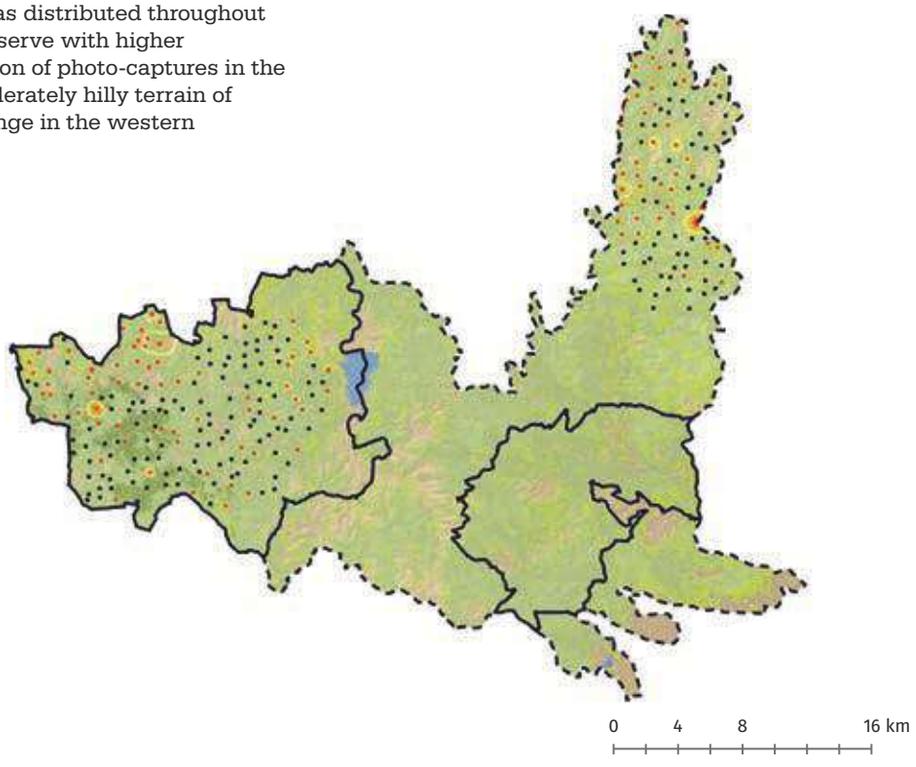


Figure 10.191

Distribution, and relative spatial abundance of leopard in Udanti-Sitanadi Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

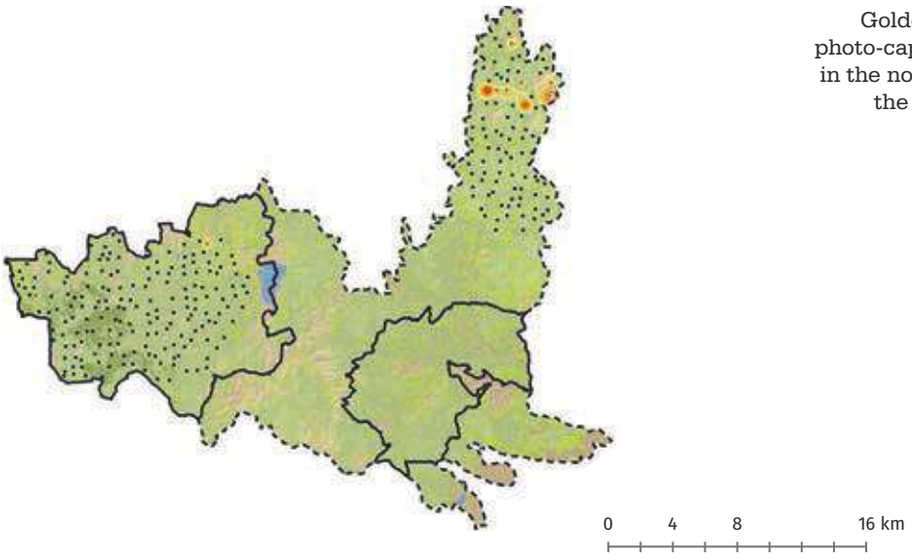


Figure 10.192

Distribution, and relative spatial abundance of golden jackal in Udanti-Sitanadi Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Golden jackal was photo-captured mostly in the northern part of the tiger reserve.

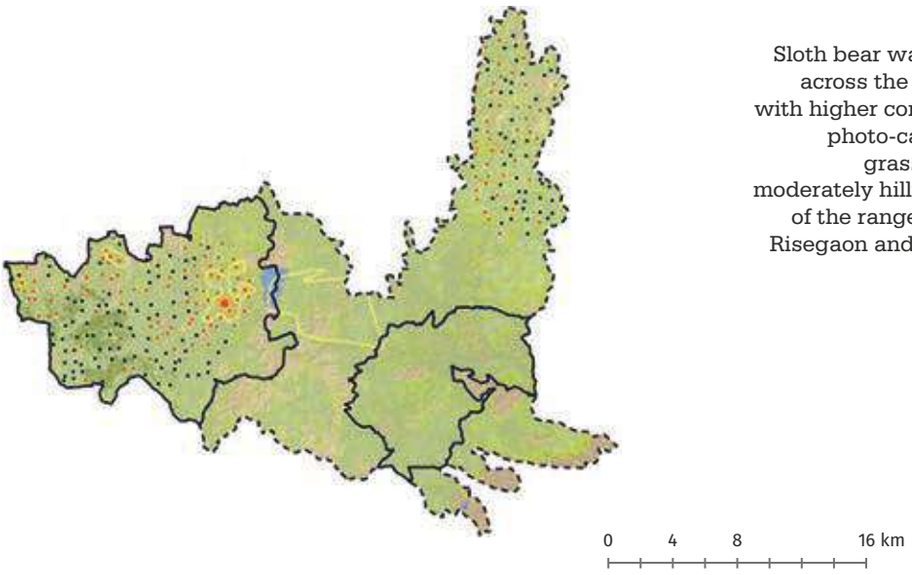


Figure 10.193

Distribution, and relative spatial abundance of Sloth bear in Udanti-Sitanadi Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear was distributed across the tiger reserve, with higher concentration of photo-captures in the grassland and the moderately hilly to flat areas of the ranges of Sitanadi, Risegaon and Kulhadighat.

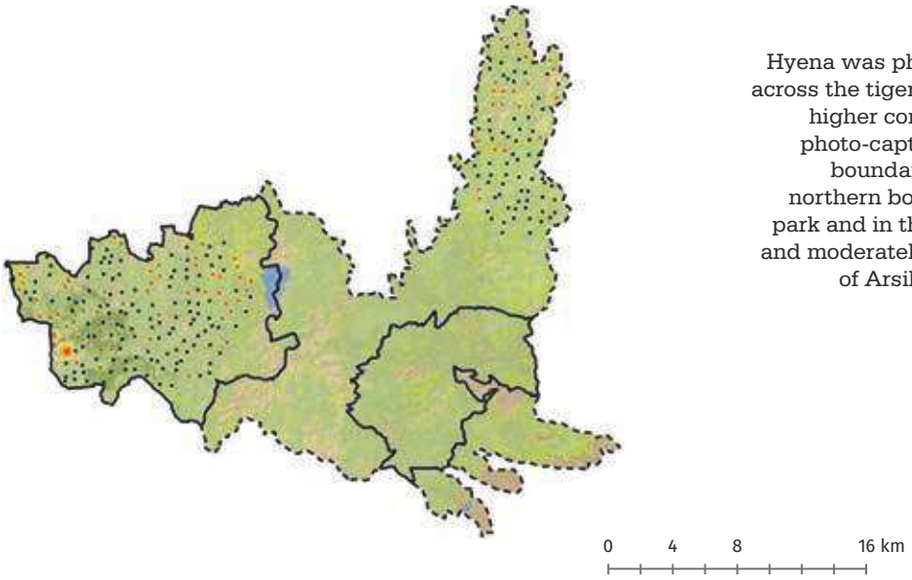


Figure 10.194

Distribution, and relative spatial abundance of striped hyena in Udanti-Sitanadi Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Hyena was photo-captured across the tiger reserve with higher concentration of photo-captures near the boundaries along the northern boundary of the park and in the grasslands and moderately hilly terrain of Arsikanhar range.

Grey wolf had clumped distribution in the tiger reserve, with most of photo-captures near the southwest edge of the park.

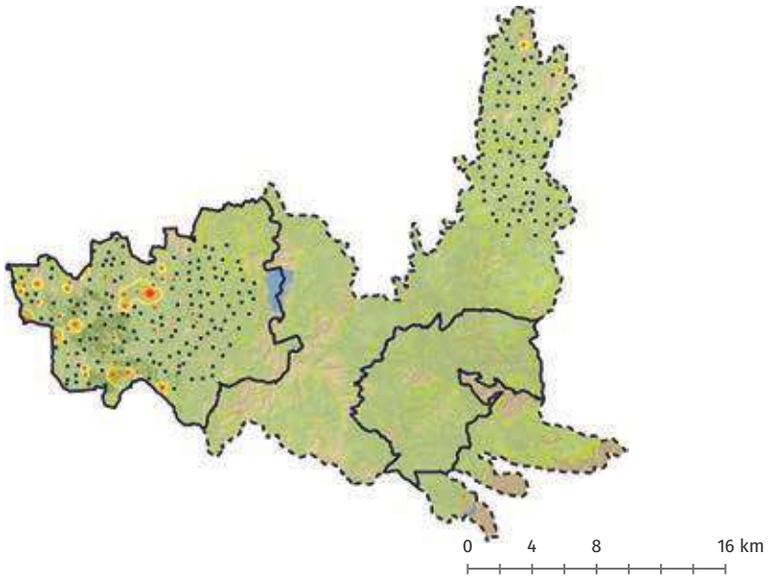


Figure 10.195

Distribution, and relative spatial abundance of grey wolf in Udanti-Sitanadi Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was distributed throughout the tiger reserve, with higher concentration of photo-captures in the sal and mixed forests.

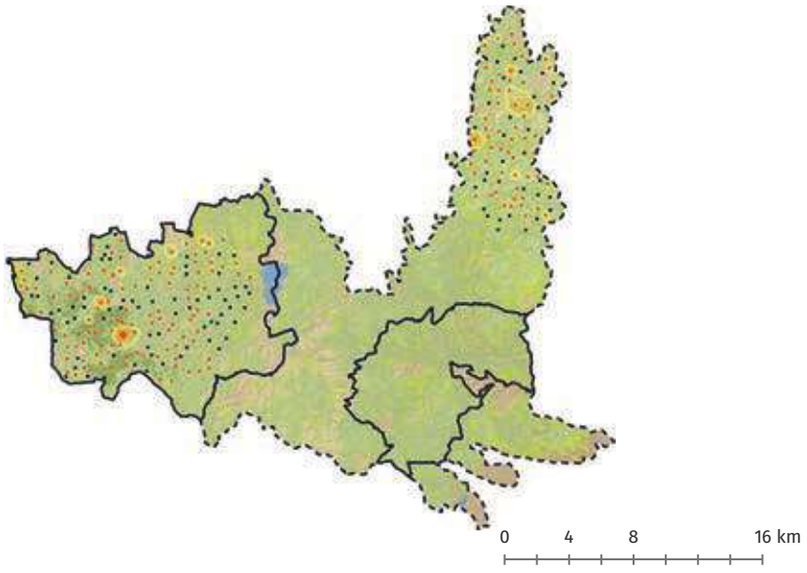


Figure 10.196

Distribution, and relative spatial abundance of jungle cat in Udanti-Sitanadi Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Rusty spotted cat was sporadically distributed in pockets within the tiger reserve.

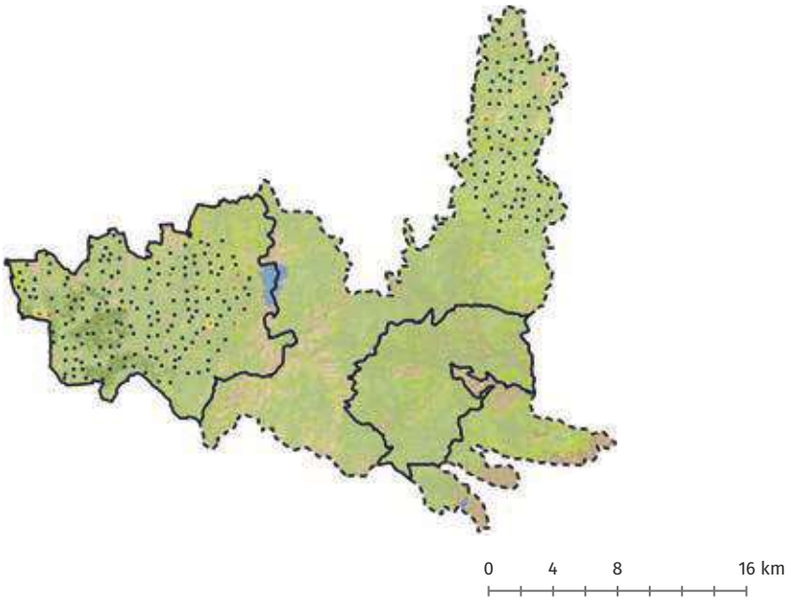


Figure 10.197

Distribution, and relative spatial abundance of rusty spotted cat in Udanti-Sitanadi Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

There were very few gaur photo-captures and these were entirely in the western part of the tiger reserve.

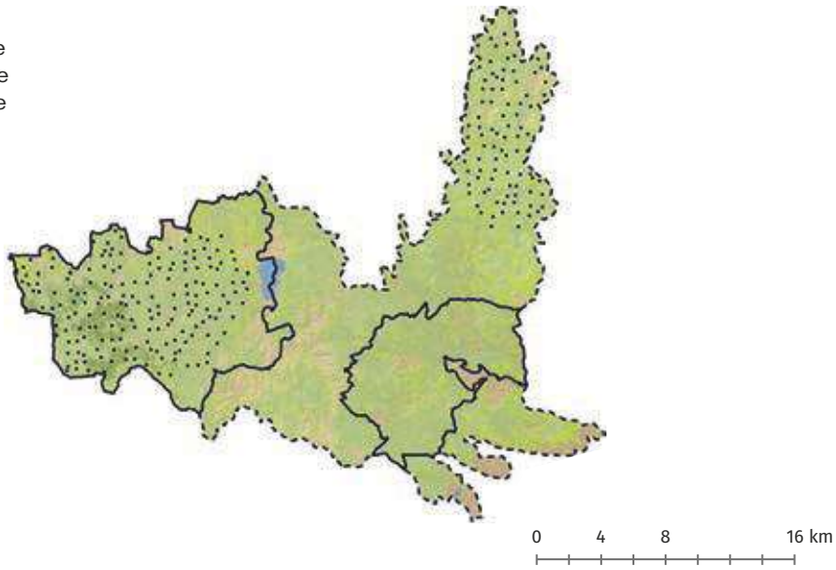


Figure 10.198

Distribution, and relative spatial abundance of gaur in Udanti-Sitanadi Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Four horned antelope was distributed mostly in the western part of the park, where no photos were obtained in the eastern part of the reserve.

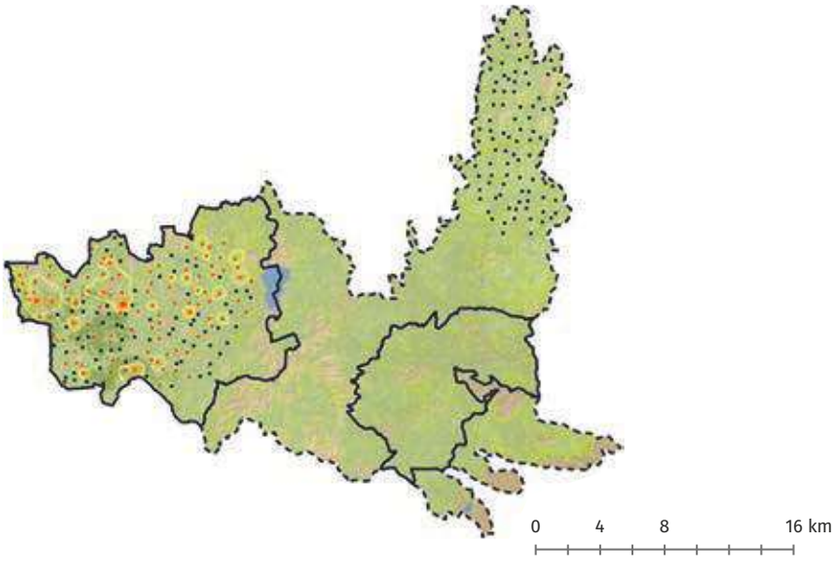


Figure 10.199

Distribution, and relative spatial abundance of four horned antelope in Udanti-Sitanadi Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Mouse deer was distributed mostly in the northern part of the park, no photos were obtained from the eastern part of the reserve.

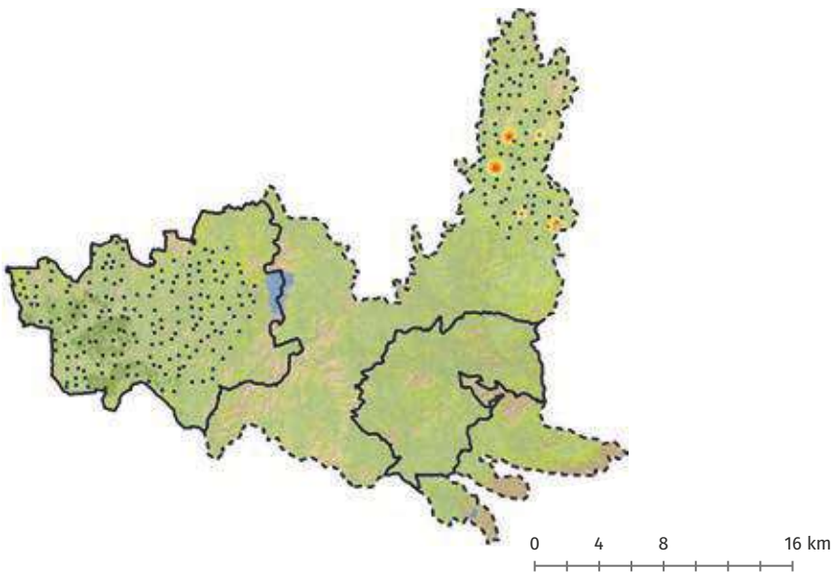


Figure 10.200

Distribution, and relative spatial abundance of mouse deer in Udanti-Sitanadi Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Relative Abundance of all Photocaptured Species in Udanti-Sitanadi Tiger Reserve

A total of 33 species of ungulates, carnivores, domestic animals, omnivores and galliformes were photo-captured in the tiger reserve. Livestock and domestic dogs were the most common animals (Table 10.71) while gaur was the rarest animal with just two photo-captures, followed by smooth coated otter.

Common Name	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Asian Palm Civet	2.10	48
Barking Deer	5.90	17
Bengal Fox	0.11	947
Chital	3.24	31
Dog	23.77	4
Domestic Cat	0.09	1105
Four Horned Antelope	4.68	21
Gaur	0.02	6630
Golden Jackal	0.24	414
Grey Mongoose	0.24	414
Grey Wolf	1.37	73
Hanuman langur	17.63	6
Honey badger	2.84	35
Indian Creasted Porcupine	1.31	76
Indian Hare	21.72	5
Indian Pangolin	0.02	6630
Indian peafowl	2.82	35
Jungle Cat	7.21	14
Leopard	3.91	26
Livestock	59.56	2
Mouse deer	0.17	603
Nilgai	3.53	28
Red junglefowl	2.49	40
Rhesus macaque	0.65	154
Ruddy Mongoose	1.04	96
Rusty-spotted Cat	0.21	474
Sambar	0.29	349
Sloth Bear	9.98	10
Small Indian Civet	4.25	24
Smooth-coated Otter	0.02	6630
Striped Hyena	2.91	34
Tiger	0.15	663
Wild Pig	15.67	6

Table 10.71
Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) USTR, 2018.

DISCUSSION

With very low prey and tiger density in Udanti-Sitanadi tiger reserve, major investment in protection and reduction of human impacts is required. After control of poaching, prey augmentation could help in improving the status of large carnivores. Udanti-Sitanadi tiger reserve is connected to the proposed tiger reserve Sunabeda wildlife sanctuary of Odisha and to Indravati tiger reserve through Kanker and North Kondagaon forest divisions. Connectivity between these sites should be protected for the future tiger and wildlife conservation.

PALAMAU TIGER RESERVE

INTRODUCTION

Palamau Tiger Reserve (83°50' and 84°36' E longitudes and 23°25' and 23°55' N latitudes) is located on the western side of Latehar district on the Chhotanagpur plateau in Jharkhand and was one amongst the first 9 tiger reserves declared in India. The forest is surrounded by the Netarhat forest in the south, Auranga river in the north, Latehar Forest Division on the east and Garhwa Forest Division and Sarguja District Forest of Chhattisgarh on the west. Palamau is spread over an area of 1129.93 km^2, of which 414.08 km^2 core area and the rest 715.85 km^2 is buffer area. Of the total core area, 226.32 km^2 is Betla National Park. The tiger reserve is a part of the "red corridor" and has been affected by Naxalite insurgent presence since 1986 with some parts of the reserve being beyond access of the forest department. Increased presence of Naxalites and central police forces within the tiger reserve over the past three decades has caused severe degradation of wildlife values and the habitats of the region. Moreover, the reserve also faces high levels of anthropogenic disturbances due to the presence of three villages (Ramandag, Latoo and Kujrum) in the core zone and 72 villages in the buffer zone. Another 113 villages are located within 5 km from the tiger reserve boundary and depend heavily on the tiger reserve for forest products and for livestock grazing. Tigers occurred in good numbers across Palamau Tiger Reserve in the past as observed from historical hunting and forest department records. However, owing to the factors discussed above, the tiger population of Palamau declined from approximately 50 individuals in 1974 to 38 in 2005 and 10 in the 2010 tiger census (based on pugmark census carried out by Jharkhand Forest Department). According to 2014 cycle of All India Tiger Monitoring exercise, presence of three individual tigers were confirmed from Palamau Tiger Reserve based on DNA profiling of tigers from scat samples (Jhala et al. 2015). Major forest types of the area are Dry Mixed Forest, Dry Sal Forest, Moist Sal Forest, High level Plateau Sal Forest, and Moist Mixed Forest. Major mammalian fauna in the Tiger Reserve include tiger, leopard, dhole, sloth bear, wolf, elephant, chital, sambar, barking deer, gaur, nilgai and mouse deer.

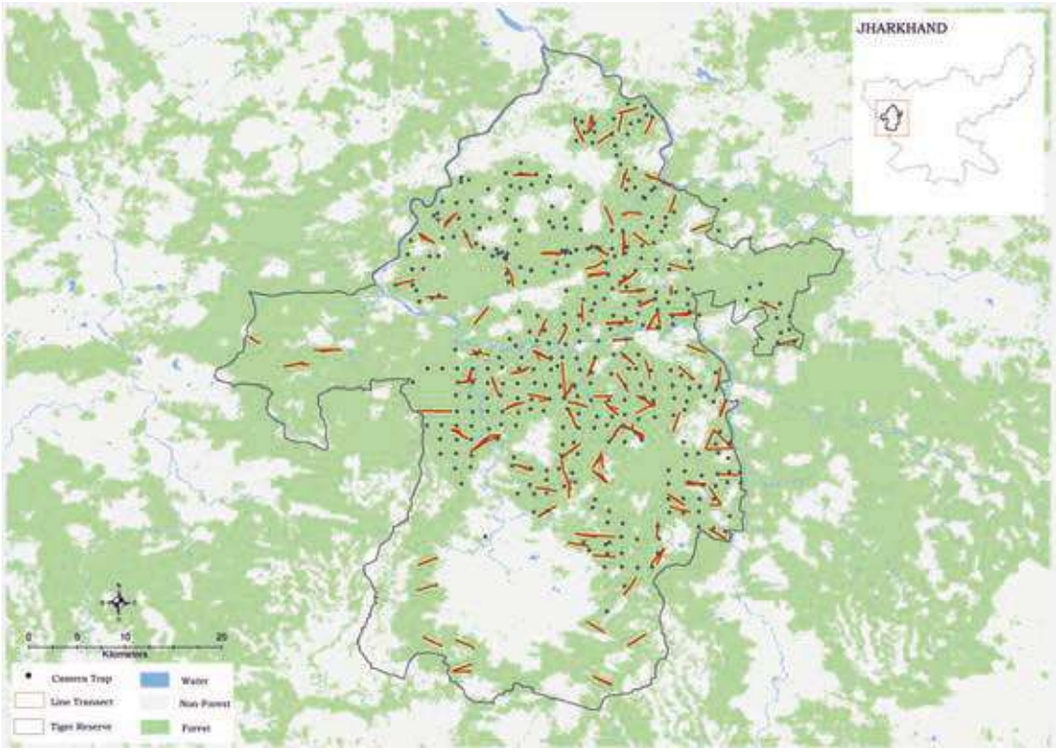


Figure 10.201
Camera trap and transect layout in Palamau Tiger Reserve, 2018

RESULTS

Camera Trap Results

No tiger images, nor tiger scat were obtained during the sampling period, (Table 10.72).

Variables	Counts
Camera points	374
Trap nights (effort)	10142

Table 10.72
Sampling details for Palamau Tiger Reserve, 2018-19.

Prey Density Estimates

A total of 279 transects were walked in Palamau Tiger Reserve which amounted to an effort of 570.4 km. Wild pig was found to be the most abundant ungulate in Palamau Tiger Reserve (Table 10.73).

Table 10.73
Model statistics and parameter estimates of line transect (n=279, Total effort 570.4 km) based distance sampling for prey species in Palamau Tiger Reserve, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/km^2 (SE)	Individual density/ km^2 (SE)
Chital	108.77 (6.09)	20	8.25 (2.14)	0.68 (0.03)	0.03 (0.008)	0.16 (0.03)	1.33 (0.47)
Wild pig	85.33 (4.80)	62	4.46 (0.45)	0.28 (0.01)	0.10 (0.014)	0.63 (0.09)	2.84 (0.49)
Barking deer	51.24 (4.40)	35	1.31 (0.09)	0.27 (0.02)	0.06 (0.010)	0.59 (0.10)	0.78 (0.15)

Distribution of Major Mammalian Fauna in Palamau Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of photo-capture rates. The black line on the map represents the critical tiger habitat of Palamau Tiger Reserve.

Elephants were photo-captured throughout the tiger reserve with maximum concentration in grasslands and valleys of Betla and Chhipadohar East ranges.

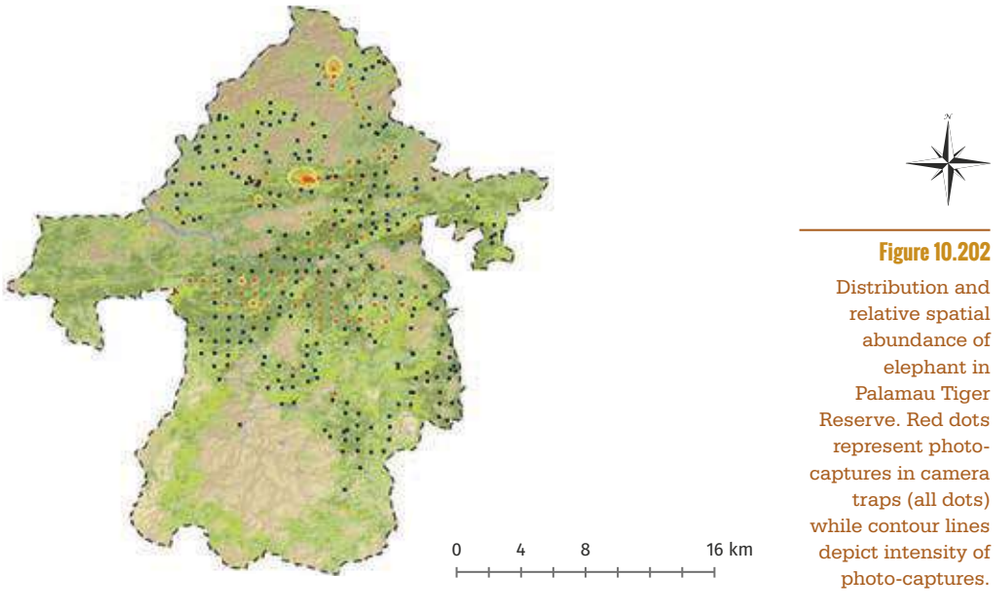


Figure 10.202
Distribution and relative spatial abundance of elephant in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

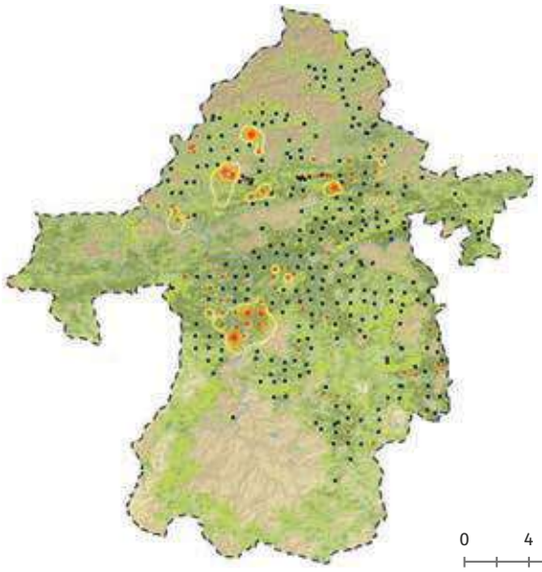


Figure 10.203

Distribution and relative spatial abundance of chowsingha in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Maximum photo-captures of chowsingha were recorded from hilly tracts of Chhipadohar West and Baresnar ranges of Palamau Tiger Reserve

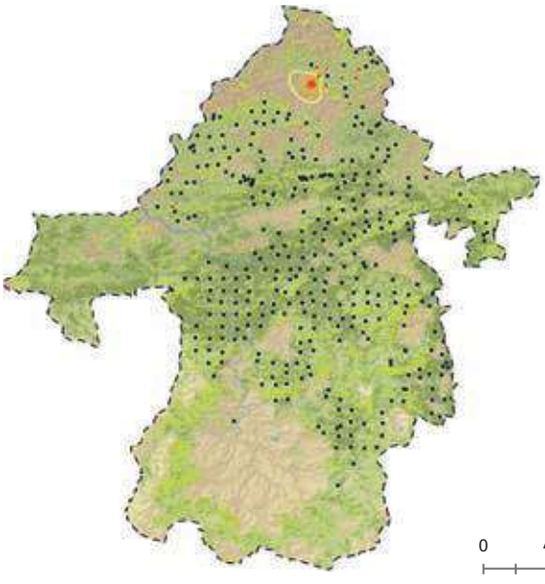


Figure 10.204

Distribution and relative spatial abundance of gaur in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Gaur was recorded only from valleys of Betla range of Palamau Tiger Reserve.

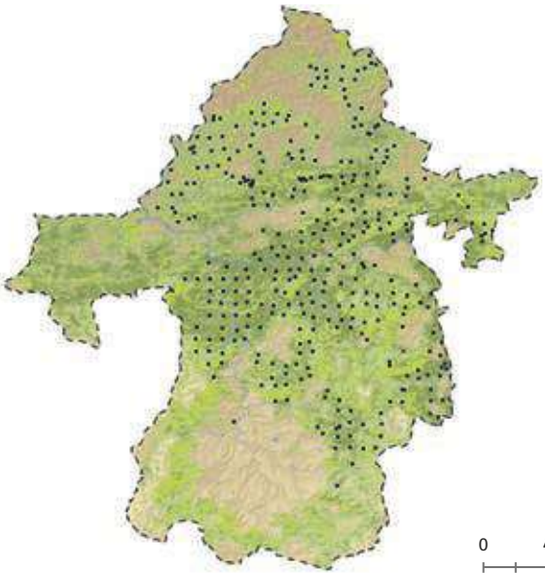


Figure 10.205

Distribution and relative spatial abundance of mouse deer in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Mouse deer photo-capture was low and only from the ranges of Baresnar and Garu West of Palamau Tiger Reserve.

Leopard photo-captures were relatively few but from throughout the tiger reserve with maximum concentration within the hilly and moderately steep terrain of Garu West and Baresnar ranges of Palamau Tiger Reserve.

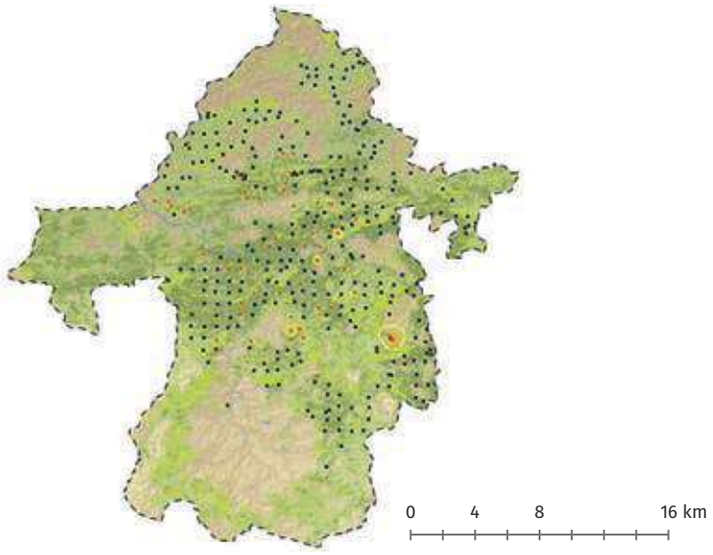


Figure 10.206

Distribution and relative spatial abundance of leopard in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Dhole was photo-captured from a from only one small hilly areas of Garu West range of Palamau Tiger Reserve.

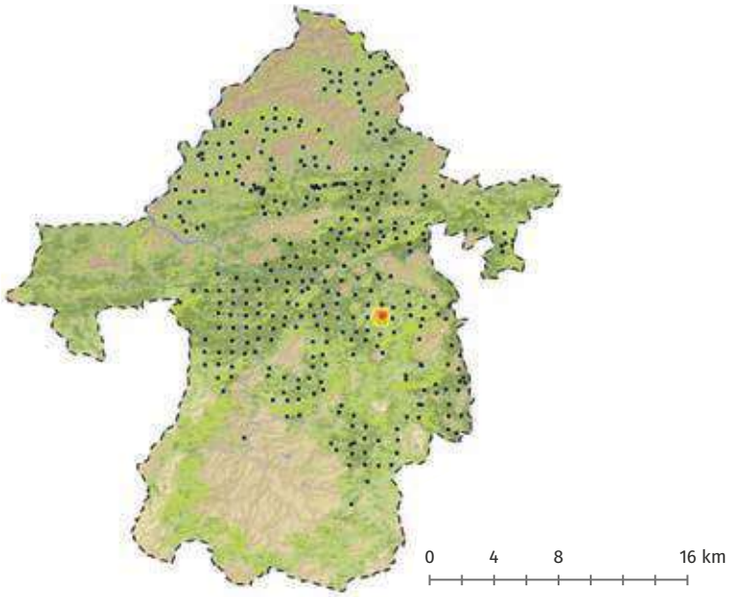


Figure 10.207

Distribution and relative spatial abundance of dhole in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Grey wolf photo-captures were maximum from grasslands and valleys of Chhipadohar East and West ranges of Palamau Tiger Reserve. Although Mahuadnar wolf sanctuary has been made buffer of Palamau Tiger Reserve, but no camera trapping was done in this sanctuary.

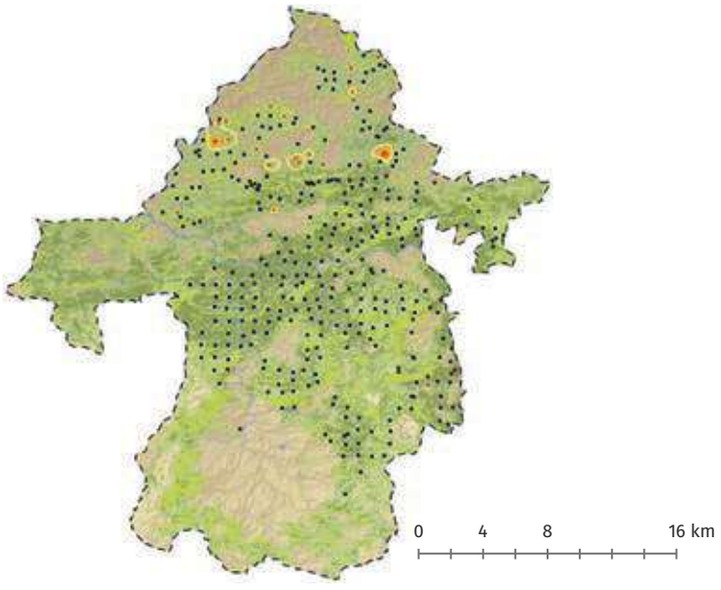


Figure 10.208

Distribution and relative spatial abundance of grey wolf in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

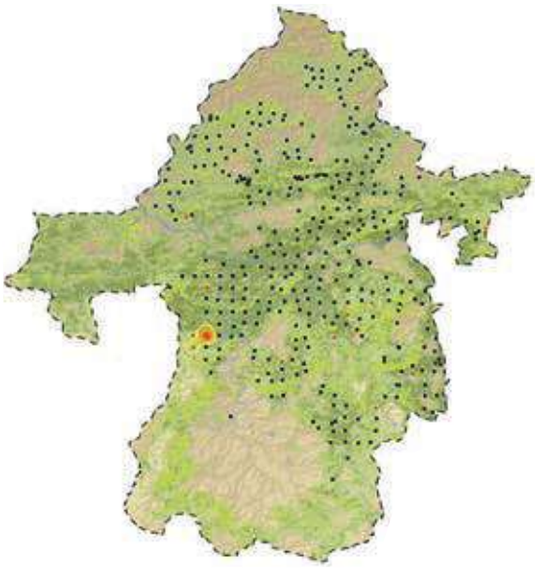


Figure 10.209

Distribution and relative spatial abundance of sloth bear in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear photo-captures were from moderately hilly terrain of South Division (Baresnar range) of the tiger reserve.

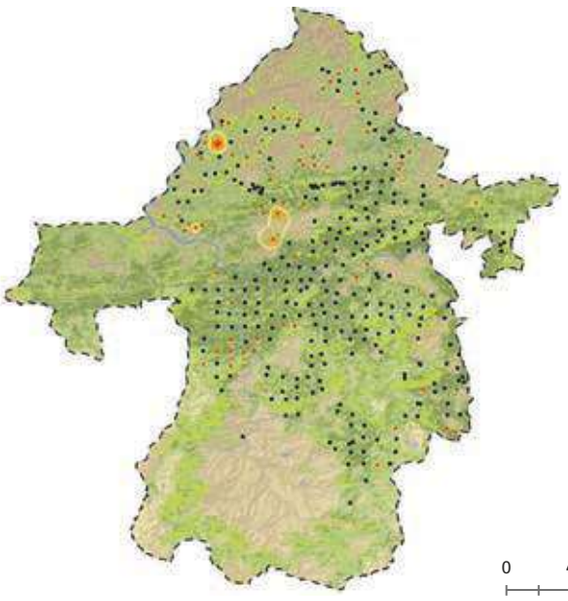


Figure 10.210

Distribution and relative spatial abundance of golden jackal in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Golden jackal photo-captures were from grasslands and moderately hilly areas of Chhipadohar West range of Palamau Tiger Reserve.

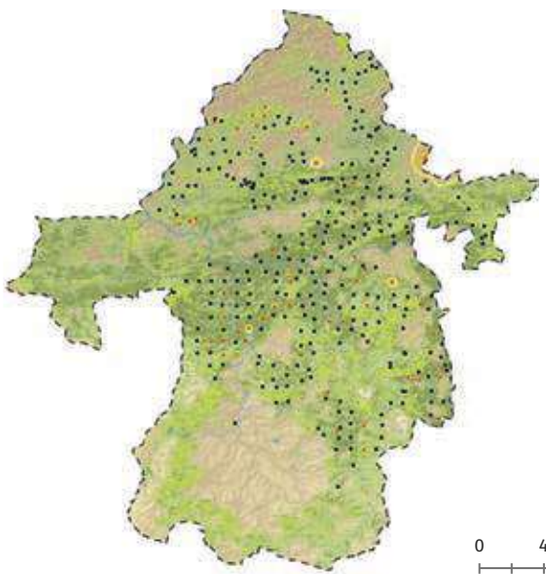


Figure 10.211

Distribution and relative spatial abundance of jungle cat in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was photo captured across the tiger reserve with concentration in the lower valleys of the eastern periphery of the tiger reserve.

This is the first authentic report of the rusty spotted cat in Palamau Tiger Reserve. The cat was photo-captured in hilly and forested terrain during this exercise.

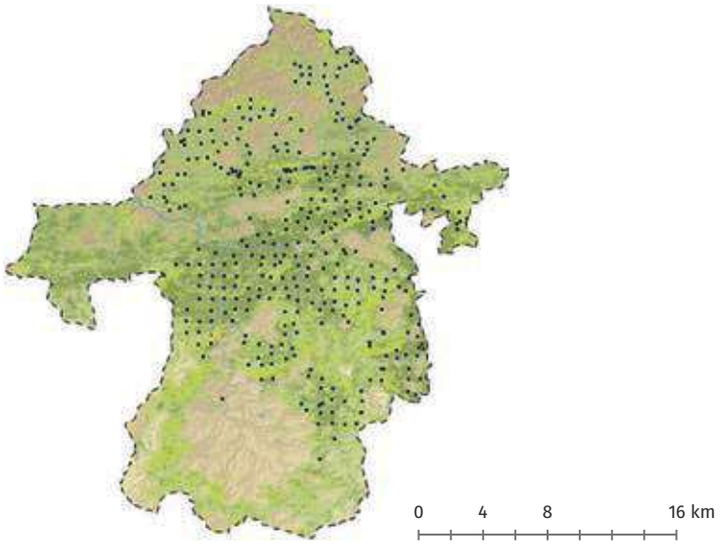


Figure 10.212

Distribution and relative spatial abundance of rusty spotted cat in Palamau Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Relative Abundance of all Photocaptured Species in Palamau Tiger Reserve

A total of 34 species of ungulates, carnivores, omnivores, domestic animals, and galliformes were photo-captured in Palamau Tiger Reserve. Langur and rhesus macaque were the most commonly photo-captured species (Table 10.74). Pangolin was the rarest species photo-captured followed by mouse deer and rusty spotted cat. Relative abundance index of livestock was higher than any other species photo-captured in the tiger reserve and is indicative of a high level of human disturbance in the park.

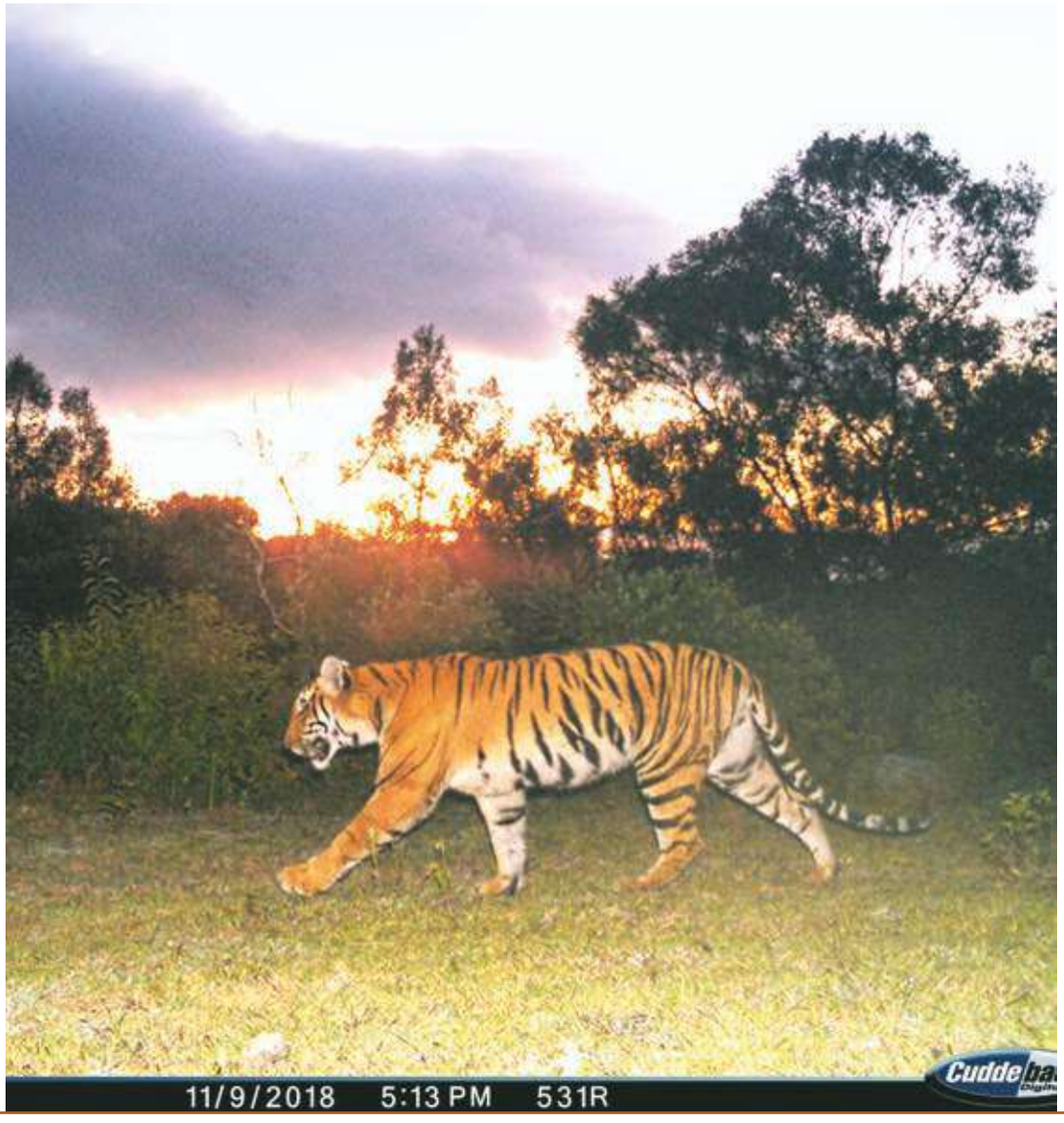
Table 10.74

Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Palamau Tiger Reserve, 2018

Common Name	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	0.78	128
Chital	2.24	45
Common palm civet	0.24	423
Domestic dog	4.92	20
Elephant	2.24	45
Four horned antelope	1.88	53
Gaur	0.45	220
Golden jackal	2.20	45
Grey mongoose	0.62	161
Grey wolf	0.42	236
Hanuman langur	8.42	12
Honey badger	0.09	1127
Hyena	0.84	119
Indian crested porcupine	0.52	191
Indian Hare	0.73	137
Indian pangolin	0.01	10142
Indian peafowl	1.42	70
Jungle cat	0.94	107
Leopard	0.65	154
Livestock	26.24	4
Monitor Lizard	0.08	1268
Mouse deer	0.03	3381
Nilgai	0.09	1127
Painted spur fowl	0.12	845
Red jungle fowl	1.59	63
Rhesus macaque	10.32	10
Ruddy mongoose	0.43	231
Rusty-spotted cat	0.03	3381
Sloth bear	0.32	317
Small Indian civet	0.40	247
Wild Pig	5.99	17

DISCUSSION

One tiger was photo captured from Chhipadohar range of Palamau Tiger Reserve after the completion of the All India Tiger Monitoring exercise in 2019. This individual was subsequently found dead within the Tiger Reserve in March 2020. Thus, tiger population status is precariously low in Palamau and under severe threat of extinction. Current level of anthropogenic disturbances in terms of livestock grazing, NTFP collection and movement of security forces and Naxalites within Palamau is high and no inviolate area can effectively be found. Such disturbance free areas are an essential element of a tiger reserve to support a breeding nucleus of tigers. Even the core area of the tiger reserve has human settlements which need to be resettled with incentivised voluntary relocation packages by NTCA and state government initiatives. Jharkhand Forest Department does not have a direct control on reducing political unrest in the region. Without proper law and order situation within Palamau Tiger Reserve, wildlife restoration including prey supplementation is a futile effort. First priority would be to restore total control of Palamau to the wildlife wing of the forest department. Second priority should be given to the voluntary, incentivized resettlement of villages and their livestock from core zone of the tiger reserve as per NTCA guidelines to create an inviolate core of several hundred km^2 (ideally >800 km^2, but current 414 km^2 designated core is also not inviolate). Resettled village agricultural lands should be managed as grasslands. After the first two priority objectives have been achieved, prey restoration should be considered. Once the habitat is consolidated a source population of tigers for supplementation in this area is required. Tigers from Bandhavgarh Tiger Reserve of Madhya Pradesh are the closest genetic population that should be used for supplementation to the tiger population of Palamau.



SATKOSIA TIGER RESERVE

INTRODUCTION

Satkosia Tiger Reserve comprises of two sanctuaries namely Satkosia Gorge Wildlife Sanctuary and Baisipalli Wildlife Sanctuary. The tiger reserve is located on the banks of the river Mahanadi between 20°26' to 20°47' N latitudes and 84°38' to 85°07' E longitudes. The tiger reserve has an area of 963 km^2 with 523 km^2 declared as the core and is spread over 4 districts of Angul, Cuttack, Nayagarh and Boudh. The area is also part of Mahanadi Elephant Reserve. Satkosia Tiger Reserve lies in the biogeographic zone of the Deccan Peninsula at the junction of two biotic provinces (Chhotnagpur Plateau and Eastern Ghats). As a result, it harbors biodiversity from both the biotic provinces. The annual average rainfall of 1250-1700 mm along with the hilly terrain in the area produces a mosaic of different habitats.

Tree species diversity is high and comprises mainly of *Shorea robusta, Dillenia pentagyna, Terminalia alata, Terminalia arjuna, Syzygium cuminii, Lagerstroemia parviflora, Pterocarpus marsupium, Terminalia bellerica*, etc. *Bambusa arundinaceae* and *Dendrocalamus strictus* are the common bamboo species in the tiger reserve. Major carnivores include tiger (*Panthera tigris*), leopard (*Panthera pardus*), fishing cat (*Prionailurus viverrinus*) while elephant (*Elephas maximus indicus*), chital (*axis axis*), sambar (*Rusa unicolor*) and barking deer (*Muntiacus vaginalis*) are the common herbivores. The tiger reserve is an important habitat for gharial (*Gavialis gangeticus*) and mugger (*Crocodylus palustris*). The declining gharial population in the reserve, has been supplemented by translocating additional individuals from captivity and from nearby area.

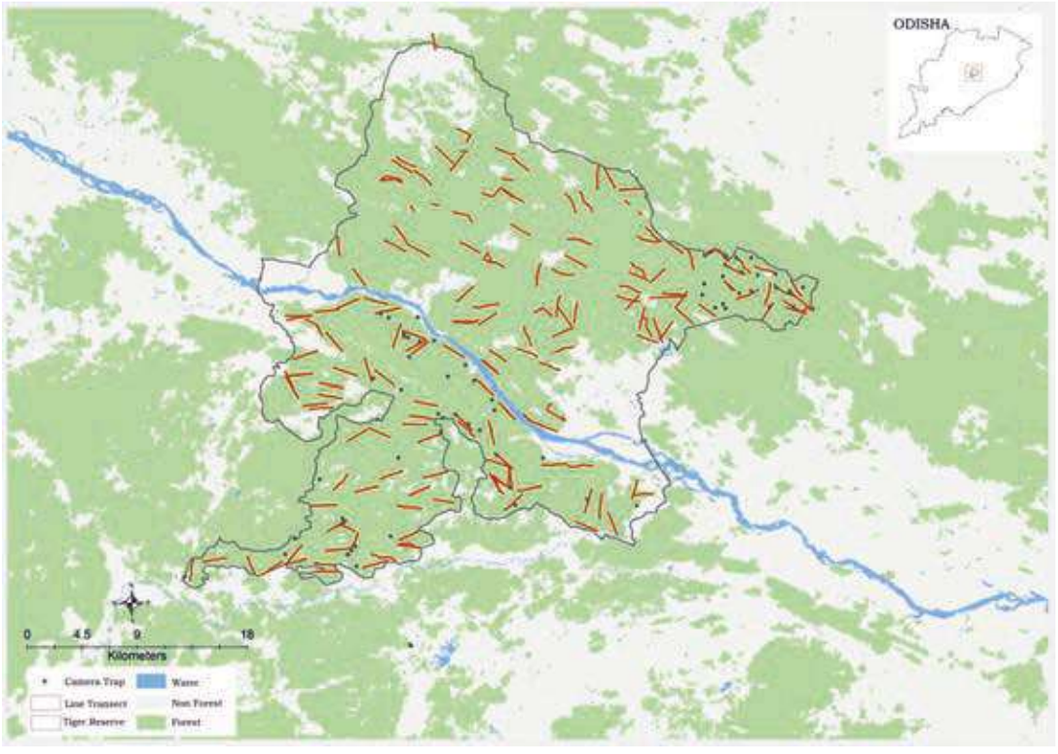


Figure 10.213
Camera trap and line transect layout in Satkosia Tiger Reserve, 2018.

RESULTS

Camera Trap Results

A total of 04 detections of a single tigeress were obtainted during the sampling period, hence density could not be estimated (Table 10.75).

Table 10.75

Sampling details of camera trapping exercise in Satkosia Tiger Reserve, 2018.

Variables	Estimates
Camera points	68
Trap nights (effort)	2829
Unique tigers captured	1

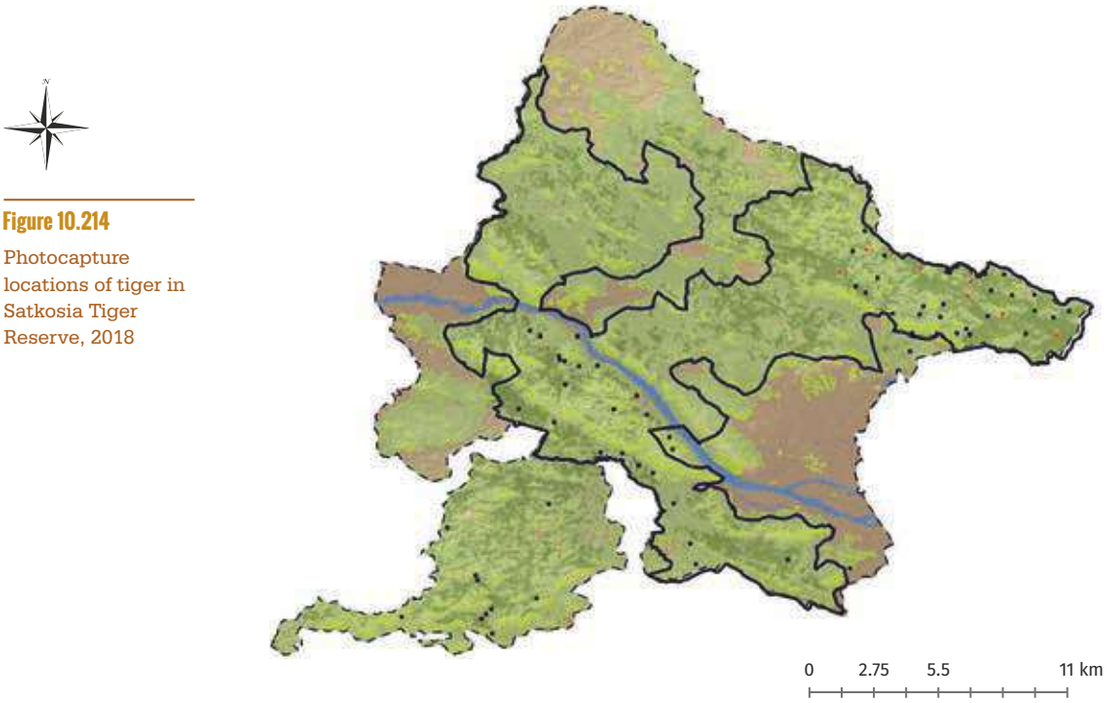


Figure 10.214

Photocapture locations of tiger in Satkosia Tiger Reserve, 2018

The tigeress was photo-captured in the northern part of the reserve near the river Mahanadi. These forests are also the only contiguous patches of dry and moist deciduous forests in the region.

Prey Density Estimates

A total of 271 transects were walked in Satkosia Tiger Reserve which amounted to an effort of 626.66 km. Chital was found to be the most abundant ungulate with a density of 14.06 (SE 1.52) chital per km^2 followed by sambar (Table 10.76).

Table 10.76

Model statistics and parameter estimates of line transect (n=271, Total effort 626.66 km) based distance sampling for prey species in Satkosia Tiger Reserve, 2018.

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/km^2 (SE)	Individual density/ km^2 (SE)
Chital	31.28 (1.23)	106	5.20 (0.28)	0.34 (0.01)	0.17 (0.014)	2.70 (0.25)	14.06 (1.52)
Sambar	34.08 (1.05)	113	1.87 (0.10)	0.34 (0.01)	0.18 (0.018)	2.65 (0.28)	4.94 (0.58)
Barking Deer	25.61 (0.67)	224	1.24 (0.04)	0.28 (0.01)	0.36 (0.023)	6.98 (0.48)	8.63 (0.65)
Wild Pig	27.55 (1.01)	41	3.51 (0.37)	0.23 (0.01)	0.07 (0.011)	1.19 (0.20)	4.17 (0.82)

Distribution of Major Mammalian Fauna in Satkosia Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Satkosia Tiger Reserve.

Gaur was recorded in most of the camera traps placed in the reserve while capture hotspots were mostly in the densely forested Labangi area.

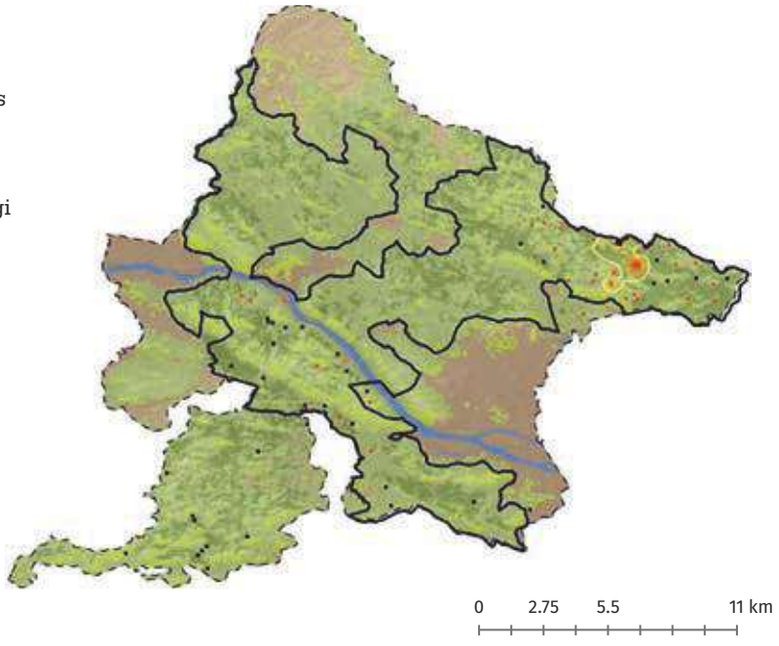


Figure 10.215

Distribution and relative spatial abundance of gaur in Satkosia Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

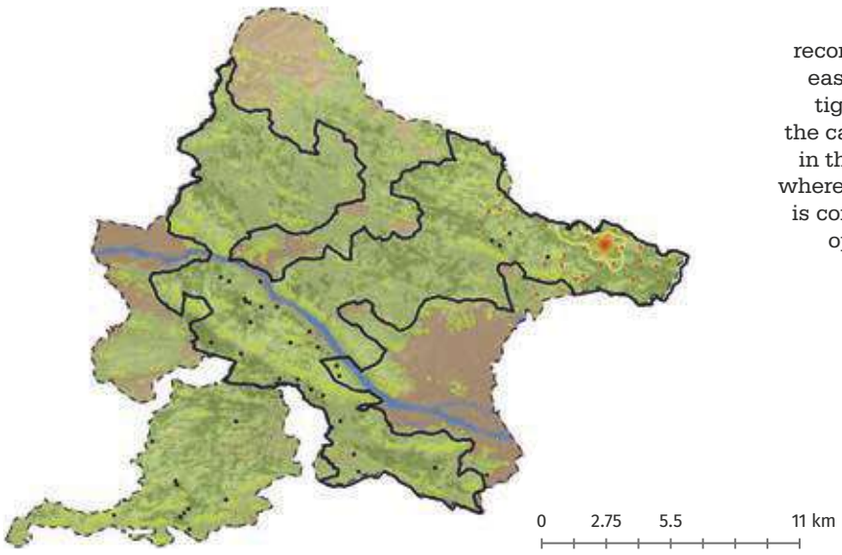


Figure 10.216

Distribution and relative spatial abundance of elephant in Satkosia Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Elephant was recorded only in the eastern part of the tiger reserve with the capture hotspots in the Raigoda area where the vegetation is composed of both open forests and grasslands.

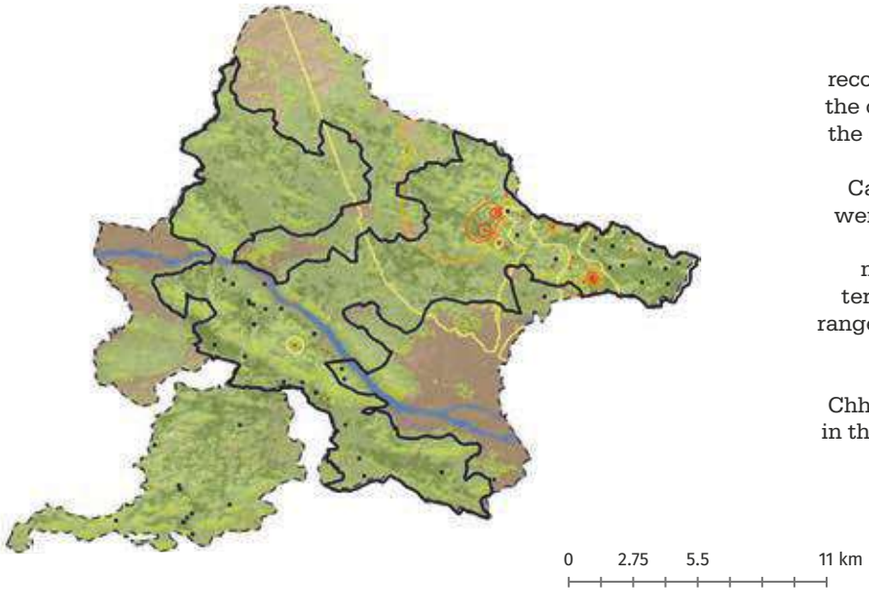


Figure 10.217

Distribution and relative spatial abundance of leopard in Satkosia Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was recorded in most of the camera traps in the core area of the tiger reserve. Capture hotspots were mostly in the hilly to the moderately hilly terrain of Raigoda range in the eastern boundary and around the Chhamundia range in the northern part of the reserve.

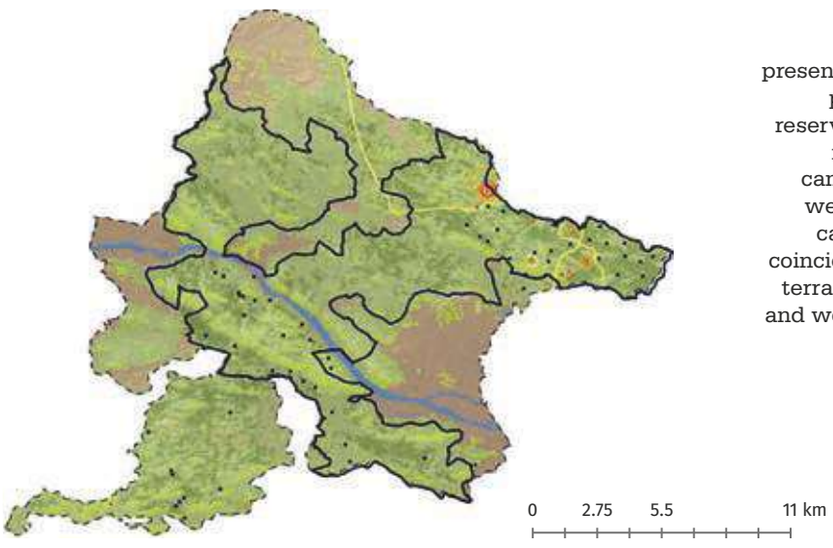


Figure 10.218

Distribution and relative spatial abundance of sloth bear in Satkosia Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear was present in the eastern part of the tiger reserve but was also recorded in one camera trap in the western part. The capture hotspots coincide with rugged terrain, open forests and woody savannas.

There were only two locations where leopard cat was captured. These camera traps were in the moist deciduous forests of the hilly slopes in the eastern part of the tiger reserve.

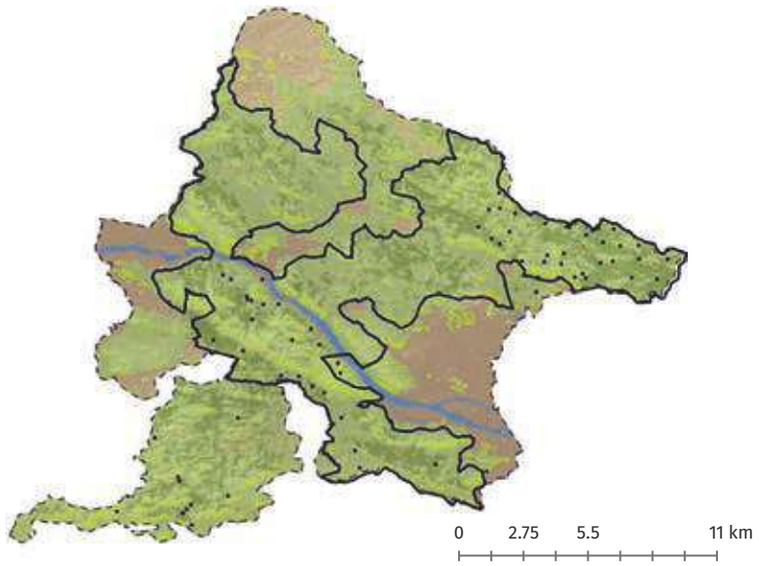


Figure 10.219

Distribution and relative spatial abundance of leopard cat in Satkosia Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Four horned antelope had clumped distribution in the tiger reserve, with most of the photo-captures around the Chhamundia range on the southwest edge of the tiger reserve.

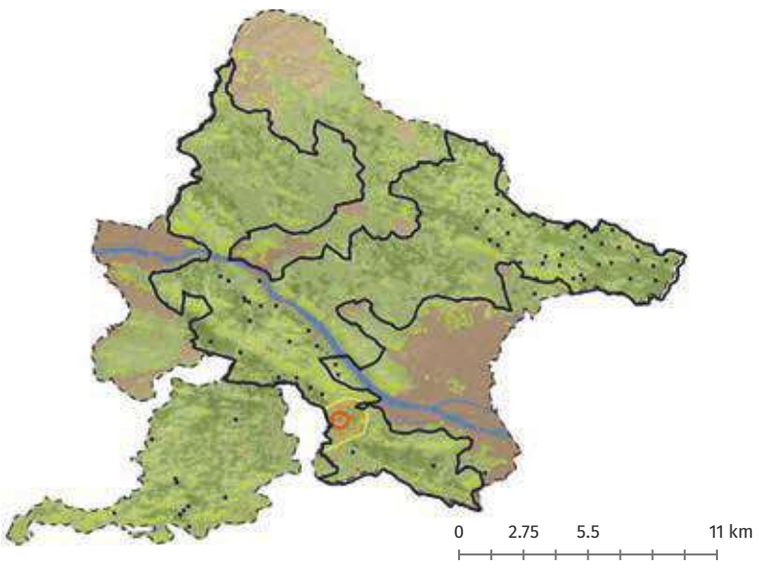


Figure 10.220

Distribution and relative spatial abundance of four horned antelopes in Satkosia Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Mouse deer was photo-captured in both the divisions of Satkosia and Mahanadi. Capture hotspots were in the undulating terrain and valleys of the tiger reserve with moist forest patches.

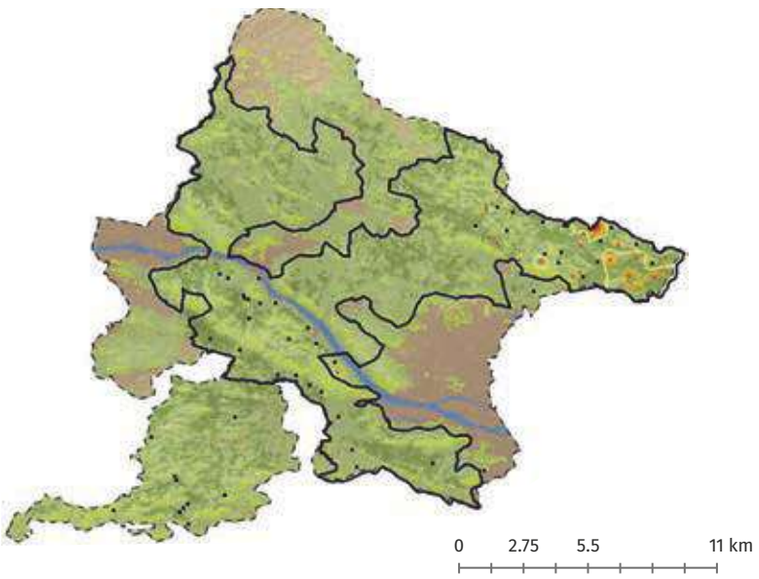


Figure 10.221

Distribution and relative spatial abundance of mouse deer in Satkosia Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Table 10.77

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) Satkosia Tiger Reserve, 2018

Common Name	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Asian Palm Civet	0.28	354
Barking Deer	61.89	2
Chital	24.92	4
Dog	0.11	943
Four Horned Antelope	0.21	472
Gaur	6.65	15
Grey Mongoose	0.42	236
Hanuman langur	12.97	8
Indian Creasted Porcupine	9.12	11
Indian Hare	0.85	118
indian peafowl	0.07	1415
Jungle Cat	0.04	2829
Leopard	2.05	49
Leopard Cat	0.21	472
Livestock	10.71	9
Mouse deer	3.15	32
Red Jungle Fowl	1.73	58
Rhesus macaque	4.91	20
Ruddy Mongoose	0.18	566
Sambar	18.10	6
Sloth Bear	0.60	166
Small Indian Civet	1.06	94
Tiger	0.49	202
Wild Pig	28.42	4

Relative Abundance of all Photocaptured Species in Satkosia Tiger Reserve

A total of 24 species of ungulates, carnivores, domestic animals, omnivores and galliformes were photo-captured in the tiger reserve. Barking deer and wild pig were the most common species (Table 10.77) while jungle cat was the rarest species with just two photo-captures, followed by Indian peafowl.

DISCUSSION

Only one tiger individual was recorded in the north part of the tiger reserve. Though, the tiger population is currently less, the prey biomass available in the park is indicative of its potential to sustain more tigers. For further growth of tiger population, habitat connectivity with adjoining forest divisions and protected areas is of paramount importance. Relatively less occurrence of many species, including the tiger, in the southern parts of river Mahanadi indicates the importance of actively protecting the wildlife and its habitat in this area. As the parts of the tiger reserve and corridors are shared with people it is also important to strengthen the social carrying capacity. Community participation, alternative livelihoods, and law enforcement are required before tigers can be supplemented here. The failed supplimentation of tigers here was primarily due to hostility of local communities and their intensive use of the Tiger Reserve resources for livelihoods.

SIMILIPAL TIGER RESERVE

INTRODUCTION

Similipal Tiger Reserve is located in the central portion of Mayurbhanj district in the northern most part of Odisha and lies between 20° 17' to 22° 34' N latitudes and 85 40' to 87° 10' E longitudes. The core and the buffer zones encompass an area of 1194.75 km^2 and 1555.25 km^2 respectively, with the total area of the tiger reserve being 2750 km^2. Similipal Tiger Reserve is located in the Chhotnagpur biotic province of the Deccan Peninsular biogeographic zone. The terrain is mostly undulating and hilly with open grasslands, mesic savannas and wooded areas.

The vegetation is a mix of different forest types and habitats, with northern tropical moist deciduous dominating some semi-evergreen patches. It is home to 1078 species of plants, including 94 species of orchids. Similipal harbours a mixture of species found in Eastern Ghats and Sub-Himalayas. Shorea robusta is the dominant tree species while *Syzygium cumuni, Buchanania lanzan, Terminaliaspp., Madhuca longifolia, Anogeissus latifolia* are also found here (Mishra et al. 2018). There are 55 species of mammals, 361 species of birds, 62 species of reptiles, 21 species of amphibians, 38 species of fishes and 164 species of butterflies recorded from the reserve. It holds the highest tiger (*Panthera tigris*) population in Orissa, and harbours the only population of melanistic tigers in the world. Other carnivores found here are leopard (*Panthera pardus*), leopard cat (*Prionailurus bengalensis*), fishing cat (*Prionailurus viverrinus*), jungle cat (*Felis chaus*) and wolf (*Canis lupus*). The active management of mugger (*Crocodylus palustris*) has revived its population on the banks of the rivers Khairi and Deo. Similipal Tiger Reserve is also home to the largest population of elephants in Odisha. The major ungulate species found here are sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), gaur (*Bos gaurus*) and mouse deer (*Moschiola indica*). Poaching is one of the biggest threats to the tiger reserve and urgent and inclusive mitigation measures are needed to ensure the perpetuity of this unique tiger population.

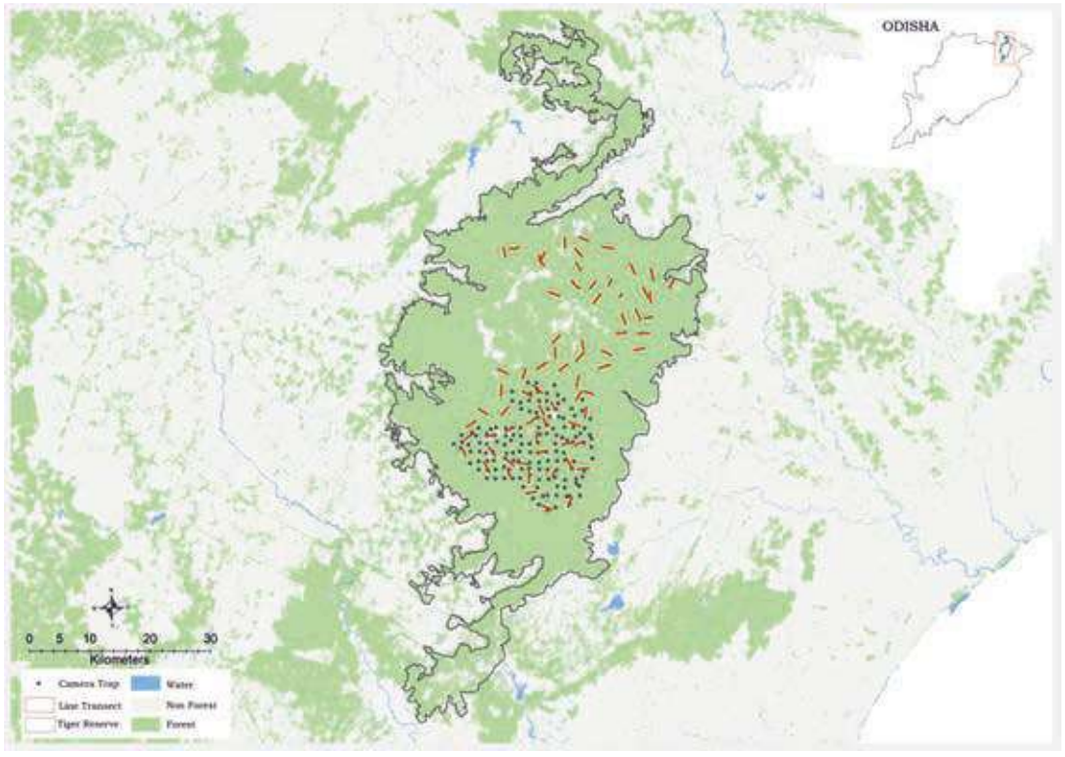


Figure 10.222
Camera trap and transect layout in Similipal Tiger Reserve, 2018

RESULTS

Tiger Density Estimates

A total of 248 tiger images were obtained from which 8 individuals adult tigers (7 female and only one male) were identified. Tiger density was estimated at 1.02 (SE 0.39) tiger per 100 km^2 (Table 10.78).

Table 10.78

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Similipal Tiger Reserve, 2019.

Variables	Estimates
Model space (km^2)	847
Camera points	141
Trap nights (effort)	4400
Unique tigers captured	8
Model	$g_0(.)\ \sigma(.)$
$\hat{D}$ SECR (per 100 km^2)	1.02 (0.39)
σ (SE) km	4.23 (0.44)
g_0 (SE)	0.20 (0.030)

SE: Standard error

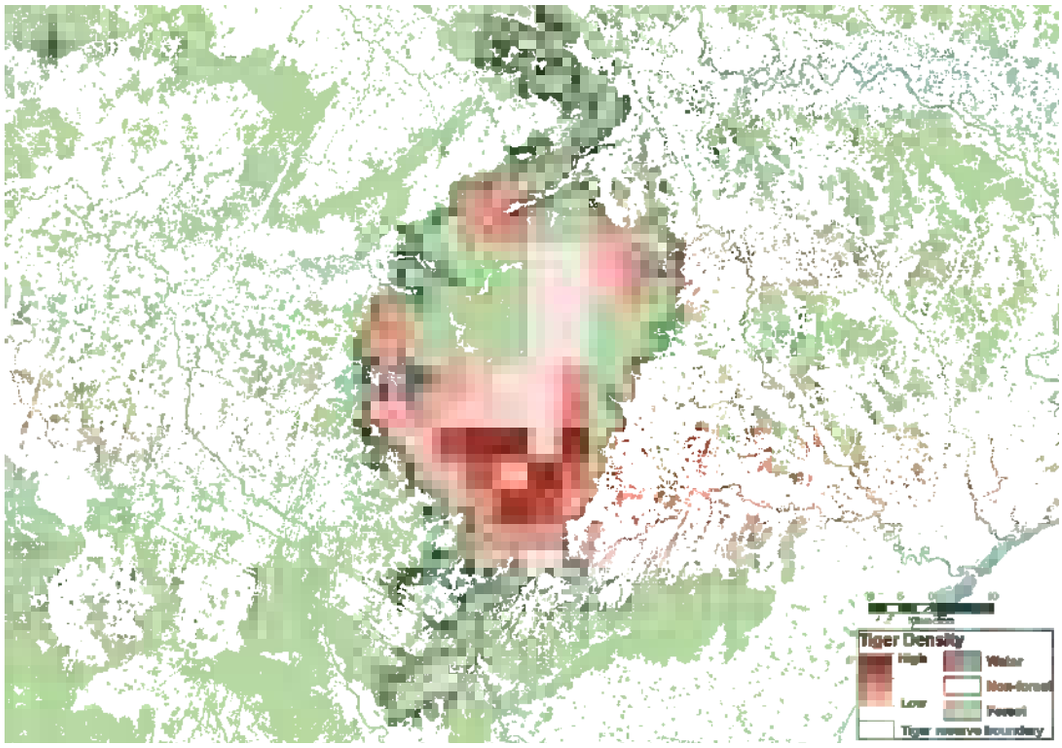
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Figure 10.223

Spatial density of tigers in Similipal Tiger Reserve, 2018



Higher tiger densities were observed in the upper Barahakamuda range and Jenabil range of the tiger reserve. These areas have contiguous forest patches with grasslands and rugged terrain. The modeled tiger density depicted in Fig 10.223 is camera trapped SECR covariate model based and was restricted to forested areas in the northern part.

Prey Density Estimates

A total of 417 transects were walked in Similipal Tiger Reserve which amounted to an effort of 843.08 km. Sambar was found to be the most abundant ungulate with a density of 11.24 (SE 1.23) per km^2 followed by barking deer (Table 10.79).

Table 10.79

Model statistics and parameter estimates of line transect (n=417, Total effort 843.08km) based distance sampling for prey species in Similipal Tiger Reserve, 2018.

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/km^2 (SE)	Individual density/ km^2 (SE)
Chital	48.20 (3.46)	98	6.14 (0.53)	0.54 (0.04)	0.11 (0.013)	1.21 (0.16)	7.41 (1.19)
Sambar	37.06 (2.20)	226	3.11 (0.17)	0.45 (0.43)	0.27 (0.020)	3.62 (0.34)	11.24 (1.23)
Barking Deer	31.69 (1.25)	437	1.20 (0.03)	0.62 (0.08)	0.51 (0.027)	8.18 (0.54)	9.79 (0.68)
Wild Pig	34.19 (2.68)	81	4.38 (0.34)	0.57 (0.04)	0.10 (0.010)	1.40 (0.19)	6.16 (0.94)

Distribution of Major Mammalian Fauna in Similipal Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Similipal Tiger Reserve.

Elephant was photo-captured throughout the camera trapped area with capture hotspots around in open deciduous forest patches in the central parts of the tiger reserve.

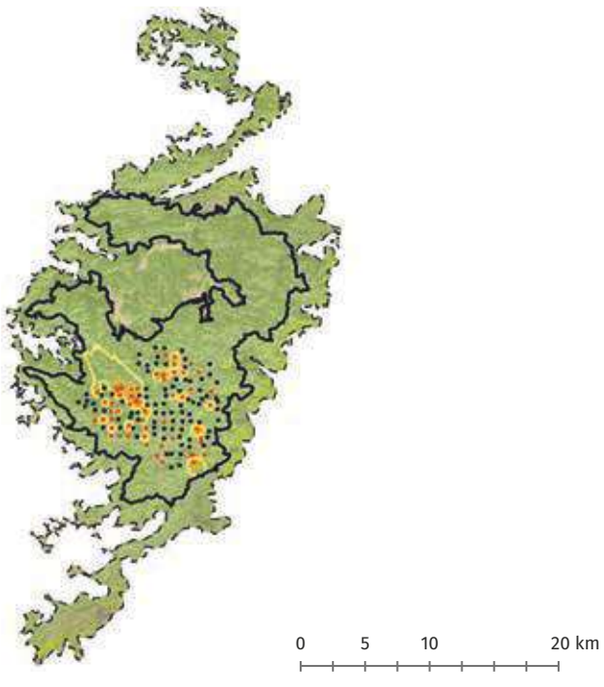


Figure 10.224

Distribution and relative spatial abundance of elephant in Similipal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

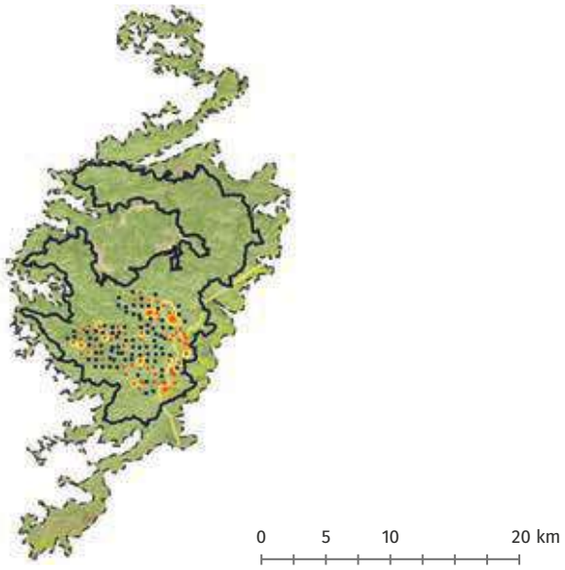


Figure 10.225

Distribution and relative spatial abundance of leopard in Similipal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was distributed throughout the camera trapped area. The capture hotspots were in the hilly to moderately hilly terrain of Jenabil range in the northern boundary and also near the boundary of Upper Barakamuda range in the southern part of the reserve. The hotspots coincide with rugged terrain and dense forests.

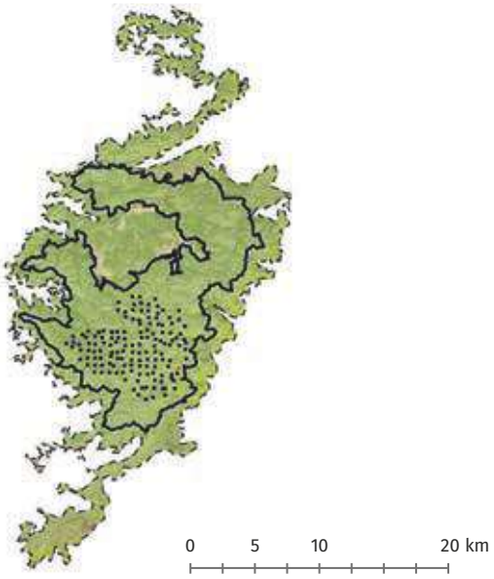


Figure 10.226

Distribution and relative spatial abundance of sloth bear in Similipal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth Bear had only one photo capture in the entire tiger reserve, on the hilly slopes near Damasahi range.

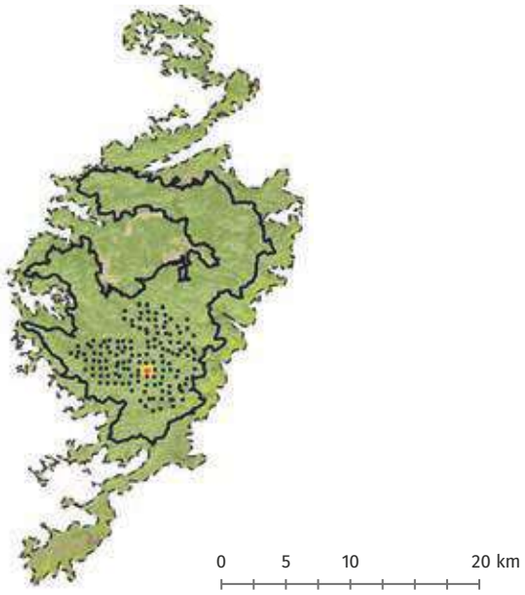


Figure 10.227

Distribution and relative spatial abundance of golden jackal in Similipal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Only one camera trap recorded golden jackal in the center of the tiger reserve core.

Leopard cat was recorded in most of the camera traps of Similipal Tiger Reserve with capture hotspots in hilly to moderately hilly terrain in moist and semi-evergreen forest patches.

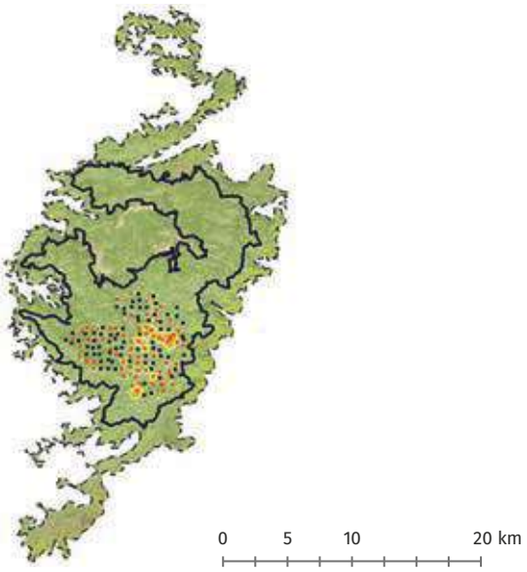


Figure 10.228

Distribution and relative spatial abundance of leopard cat in Similipal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was recorded on the western part of the sampled area that coincides with dry deciduous forests and grasslands.

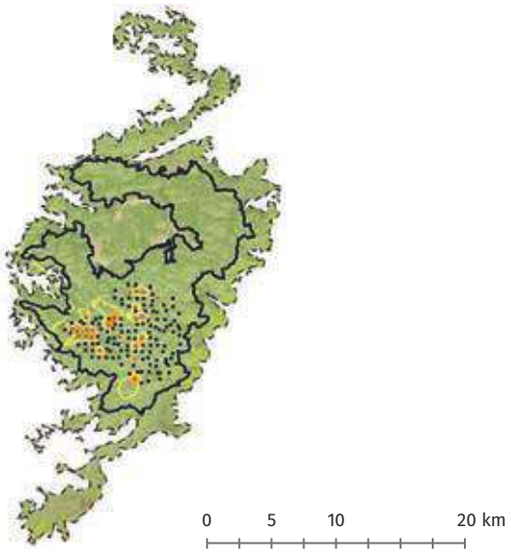


Figure 10.229

Distribution and relative spatial abundance of jungle cat in Similipal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Table 10.80

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Similipal Tiger Reserve, 2019.

Common Name	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Asian Palm Civet	9.11	11
Barking Deer	69.25	1
Chital	22.25	4
Elephant	2.34	43
Gaur	0.73	138
Giant Squirrel	0.02	4400
Golden Jackal	0.02	4400
Grey Mongoose	1.95	51
Hanuman langur	3.02	33
Honey badger	0.14	733
Indian Creasted Porcupine	3.43	29
Indian Hare	4.18	24
Indian peafowl	4.32	23
Jungle Cat	1.20	83
Leopard	2.70	37
Leopard Cat	4.68	21
Mouse deer	12.59	8
Red junglefowl	2.34	43
Red spurfowl	0.20	489
Rhesus macaque	5.73	17
Ruddy Mongoose	5.27	19
Sambar	39.89	3
Sloth Bear	0.02	4400
Small Indian Civet	2.73	37
Smooth-coated Otter	0.02	4400
Stripe-necked Mongoose	1.59	63
Tiger	3.39	30
Wild Pig	4.32	23

Relative Abundance of all Photocaptured Species in Similipal Tiger Reserve

A total of 28 species of ungulates, carnivores, domestic animals, omnivores and galliformes were photo-captured in Similipal Tiger Reserve. Barking deer and giant squirrel were the most common species, while golden jackal, sloth bear and smooth-coated otter were rarest (Table 10.80).

DISCUSSION

With a high reasonably good ungulate biomass in the park, Similipal Tiger Reserve has the potential to sustain higher tiger densities. However, consistently low density of tiger in the tiger reserve over the years calls for active management intervention to retain this genetically unique population. The tiger population, if increased, can then act as a source population to neighboring forest divisions of Keonjhar and Kuldiha. The management has done a good job of relocating several human settlements from the Tiger Reserve and with good protection from poaching tiger population should recover in the near future. However, due to the current small size of the tiger population it may be prudent to supplement a few tigers from Bandhavgard tiger reserve (Kolipakam et al. 2018) to circumvent stochastic extinction events that operate in small populations.

BARGARH FOREST DIVISION

INTRODUCTION

Bargarh Forest Division is located in the western most corner of Odisha between 21° 41' N to 20° 43' latitudes and 82° 39' to 83° 58' E longitudes. The division comprises parts of Sambalpur Division and Khariar Forest Division and has an area of 5,837 km^2.

The forests of Bargarh Forest Division are categorized as tropical dry deciduous and moist type forest type (Champion and Seth, 1968). Bargarh Forest Division is rich in medicinal plants e.g. *Aristolochia indica, Diplocyclos palmatus, Erythrina suberosa, Ficus racemosa, Heliotropium indicum, Marsdenia tenacissima, Pergularia daemia, Tinospora cordifolia* (Sen et al. 2015).

Leopard (*Panthera pardus*) is the apex predator of this forest, while other carnivores found here are golden jackal (*Canis aureus*), sloth bear (*Melursus ursinus*) and jungle cat (*Felis chaus*). Ungulate species found in this area include gaur (*Bos gaurus*), sambar (*Rusa unicolor*), wild pig (*Sus scrofa*), nilgai (*Bosephalus tragocamelus*) and barking deer (*Muntiacus vaginalis*).

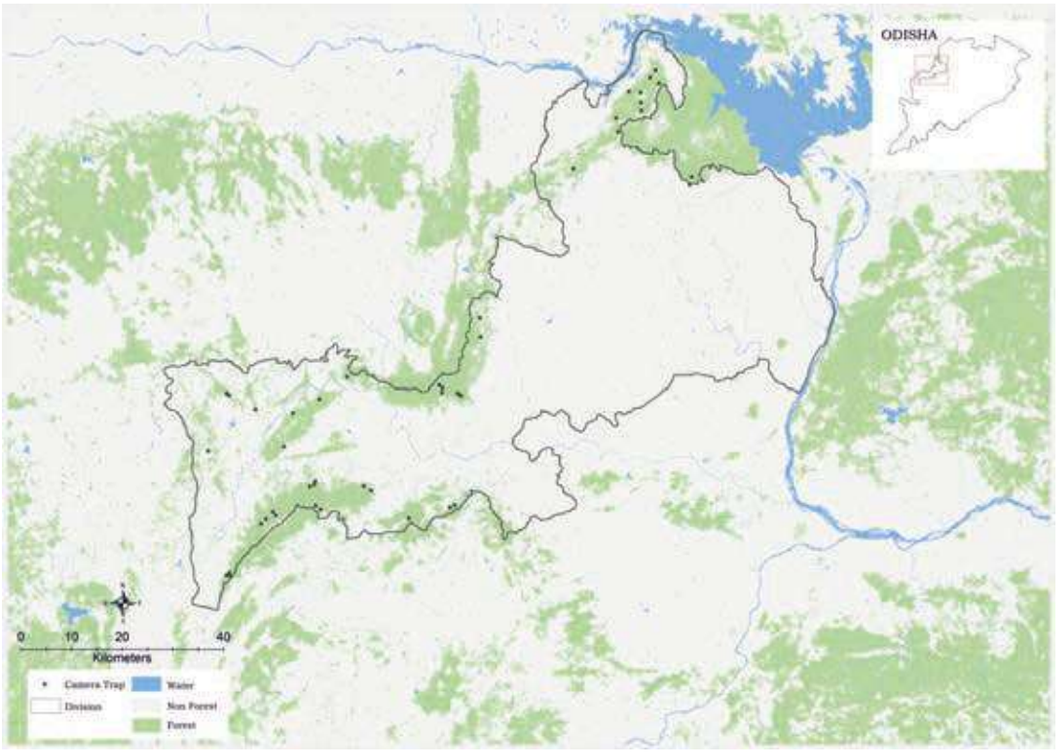


Figure 10.230
Camera trap layout in Bargarh Forest Division, 2018

RESULTS

Camera Trap Results

No tigers were photo-captured during the camera trapping exercise (Table 10.81).

Sampling details	Counts
Camera points	45
Trap nights (effort)	1367

Table 10.81
Sampling details of camera trapping exercise in Bargarh Forest Division 2018

DISCUSSION

Bargarh forest division has potential to develop as connecting link between Sunabeda-Bargarh-Debrigarh wildlife sanctuary through Badrama wildlife sanctuary to Simlipal-Satkosia tiger corridors if the degraded land between these area can be restored.

BAMRA FOREST DIVISION

INTRODUCTION

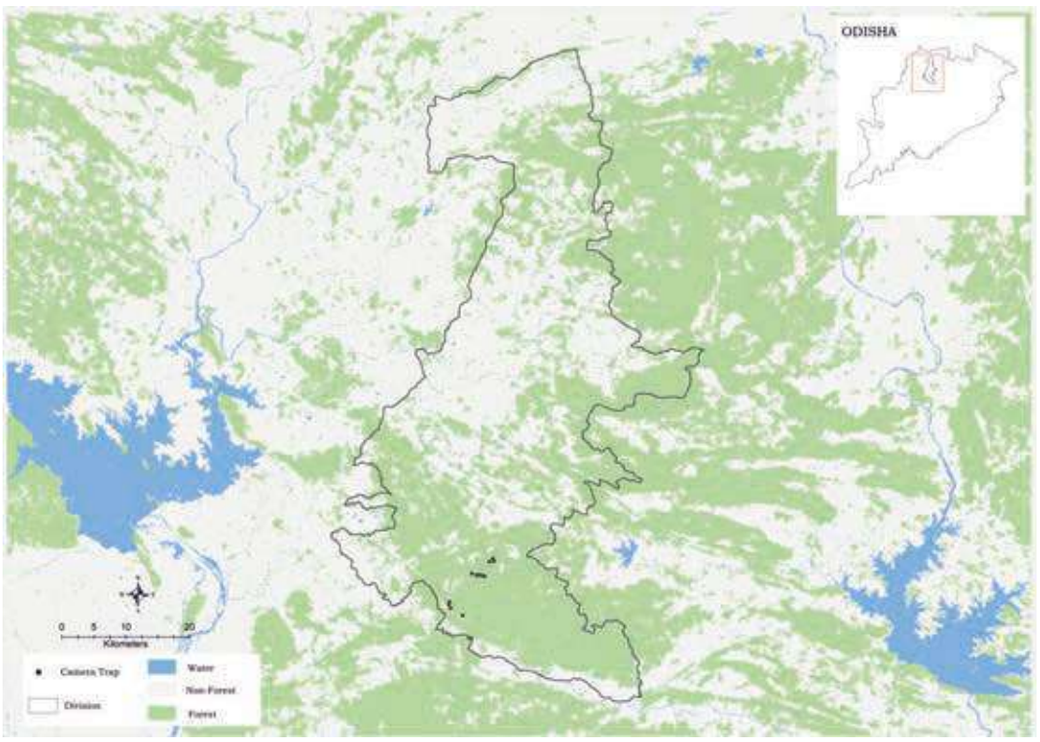
Bamra Forest Division is located in Sambalpur district and lies between 21° 34' to 21° 21' N latitudes and 84° 12' to 84° 28' E longitudes. The area of this division is 304 km^2. Bamra Forest Division encompasses Badrama Wildlife Sanctuary and Khalasuni Wildlife Sanctuary and it makes a contiguous patch which acts as a corridor for wild animals especially elephants to move across Satkosia to Bamra Forest Division.

The forest vegetation is represented by tropical dry deciduous type in which the dominant vegetation comprises of *Aegle marmelos, Buchanania lanzan, Cleistanthus collinus, Cassia fistula, Embelica officinalis, Gmelina arboria, Ougeinia oojeinensis, Terminalia chebula and Terminalia bellerica*.

Faunal diversity includes leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), golden jackal (*Canis aureus*), wild dog (*Cuon alpinus*), elephant (*Elephas maximus*), chowsingha (*Tetracerus quadricornis*), barking deer (*Muntiacus vaginalis*), sambar (*Rusa unicolor*) amongst others.

Figure 10.231

Camera trap layout in Bamra Forest Division, 2018



RESULTS

Camera Trap Results

No tiger photos were obtained during the sampling period (Table 10.82).

Table 10.82

Sampling details of camera trapping exercise in Bamra Forest Division, 2018.

Sampling details	Counts
Camera points	23
Trap nights (effort)	736

DISCUSSION

Though tiger captures were not obtained but this division is connected with the Satkosia Tiger Reserve through Badrama Wildlife Sanctuary and Khalasuni Wildlife Sanctuary. Connectivity could be improved for the movement of the elephants from Satkosia to Bamra.

BONAI FOREST DIVISION

INTRODUCTION

Bonai Forest Division is located in Sundargarh district within the geographic coordinates of 21° 39' to 22° 8' N latitudes and 84° 30' to 85° 23' E longitudes. This division has an area of 2934.21 km^2.

The forests of Bonai Forest Division belong to the tropical moist and dry deciduous forest and semi evergreen forest type. Dominant vegetation is represented by *Anogeissus latifolia, Diospyros melanoxylon, Holarrhina antidysentrica, Lagerstroemia parviflora, Madhuca latifolia, Meyna spinosa, Shorea robusta, Syzygium cumini, Terminalia elliptica, Terminalia tomentosa*.

Faunal species include leopard (*Panthera pardus*), jackal (*Canis aureus*), jungle cat (*Felis chaus*), elephant (*Elephas maximus*), wild pig (*Sus scrofa*), barking deer (*Muntiacus vaginalis*), rhesus macaqeue (*Macaca mulatta*) and porcupine (*Hystrix indicus*).

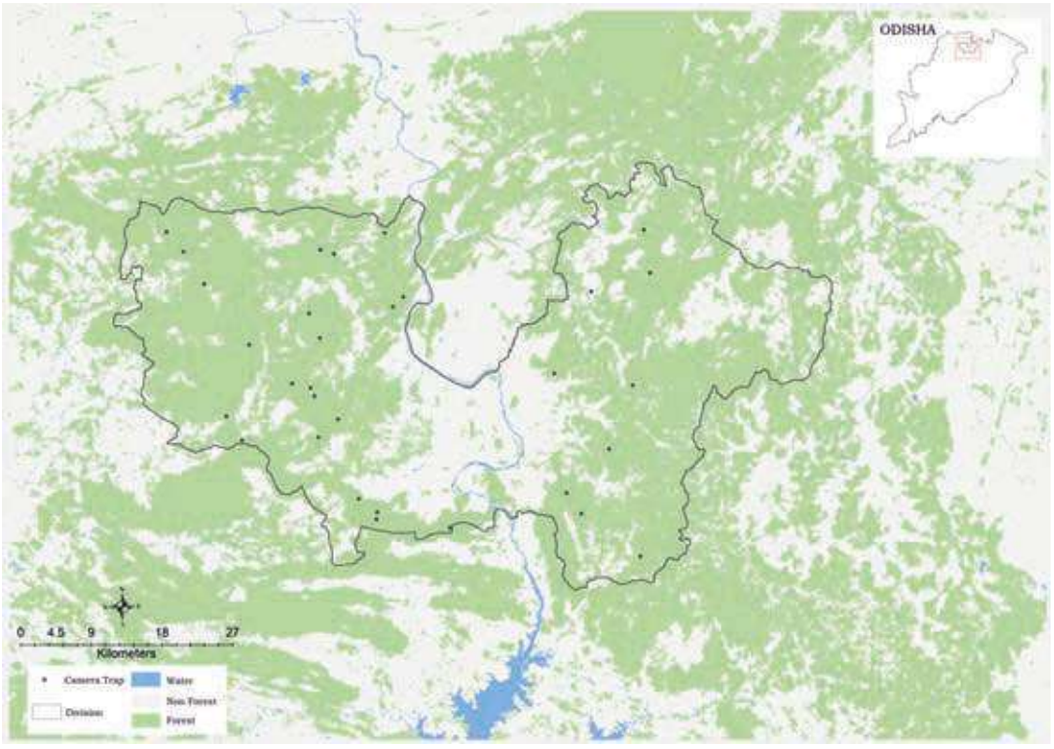


Figure 10.232
Camera trap layout in Bonai Forest Division, 2018.

RESULTS

Camera Trap Results

No tiger photos were obtained during the sampling period (Table 10.83).

Sampling details	Counts
Camera points	31
Trap nights (effort)	814

Table 10.83
Sampling details of camera trapping exercise in Bonai Forest Division, 2018.

DISCUSSION

Bonai forest division is one of the largest forest division of Odhisa with contiguous forest. It is potential site for the tiger recovery if simlipal tiger population restored. This division is connected to Simlipal through the forests of Dhenkanal and Kendujhar division.

DEBRIGARH WILDLIFE SANCTUARY

INTRODUCTION

Debrigarh Wildlife Sanctuary is situated in Bargarh district of Odisha and shares its southern and western boundaries with Bargarh Forest Division. The sanctuary has an area of 353 km^2, and is located between the 21^0 28' to 21^0 44' N latitudes and 83^0 30' to 83^0 46' E longitudes. The sanctuary shares one third of its boundary with the Hirakud Reservoir. Most of the sanctuary is characterized by hilly terrain and is covered by tropical dry deciduous forest while the valleys have patches of moist deciduous forest (Champion and Seth 1968). The important tree species in the area are *Dalbergia sissoo, Pterocarpus marsupium,Terminalia chebula, and Terminalia bellirica*.

Apart from the occasional presence of tiger (*Panthera tigris*) and leopard (*Panthera pardus*), carnivores such as grey wolf (*Canis lupus*), golden jackal (*Canis aureus*), hyena (*Hyaena hyaena*) and sloth bear (*Melursus ursinus*) are found here. Wild pig (*Sus scrofa*), sambar (*Rusa unicolor*) and chital (*Axis Axis*) are the commonly sighted ungulate species in this area. Large numbers of migratory birds come in the winter every year to Hirakud Reservoir, thereby adding to the avian diversity of Debrigarh Wildlife Sanctuary.

Figure 10.233

Camera trap layout in Debrigarh Wildlife Sanctuary, 2018

RESULTS

Camera Trap Results

Only one tiger image was obtained, yielding 1 tiger individual (Table 10.84). Hence, due to low photo-capture, tiger density was not estimated.

Table 10.84

Sampling details of camera trapping exercise in Debrigarh Wildlife Sanctuary, 2018.

Sampling details	Counts
Camera points	33
Trap nights (effort)	697
Unique tigers captured	1

DISCUSSION

Debrigarh Wildlife Sanctuary was camera trapped for the first time for the National Tiger Estimation program. A small area was sampled and even though only one tiger was detected, this detection validates the importance of this wildlife sanctuary in maintaining the meta-population of tiger occupancy in this landscape.

KALAHANDI FOREST DIVISION

INTRODUCTION

Kalahandi Forest Division is located in the south-western part of Odisha and is in one of the most economically impoverished district of the state. It is spread out over an area of 7,920 km^2 and is situated between 19° 12' to 20° 27' N latitudes and 82° 31' to 83° 48'E longitudes.

The forests of Kalahandi Forest Division is composed of tropical moist and dry deciduous forests type (Champion and Seth, 1968) and are dominated by *Shorea robusta* and *Tectona grandis*. Other vegetation includes *Alstonia scholaris, Azadirachta indica, Boswellia serata, Cassia fistula, Largerstroemia parvifolia, Lannea coromandelica, Mallotus philpipensis, Pongamia pinnata, Terminalia arjuna, Terminalia chebula* amongst others.

Faunal diversity includes leopard (*Panthera pardus*), jackal (*Canis aureus*), jungle cat (*Felis chaus*), elephant (*Elephas maximus*), wild pig (*Sus scrofa*), nilgai (*Bosephalus tragocamelus*), barking deer (*Muntiacus vaginalis*) etc.

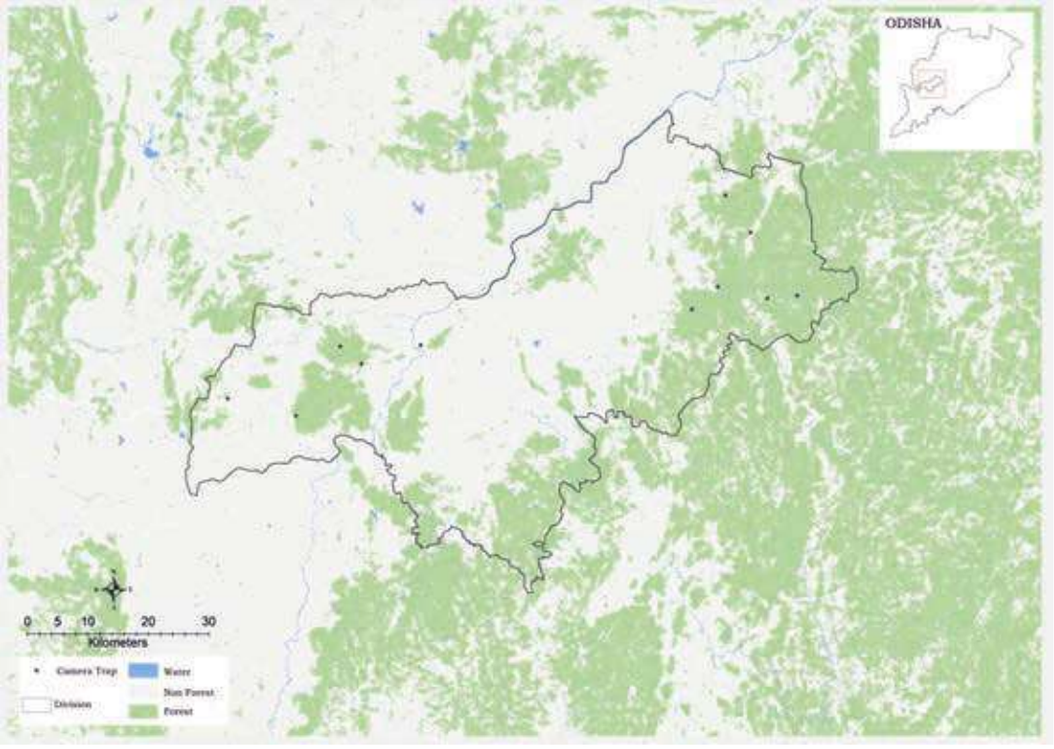


Figure 10.234
Camera trap layout in Kalahandi Forest Division, 2018.

RESULTS

Camera Trap Results

No tiger photos were obtained during the sampling period (Table 10.85).

Sampling details	Counts
Camera points	11
Trap nights (effort)	183

Table 10.85
Sampling details of camera trapping exercise in Kalahandi Forest Division, 2018.

DISCUSSION

This forest divsiosn is crucial for elephant population and part of the Karlapat-Ueladani elephant corridor.

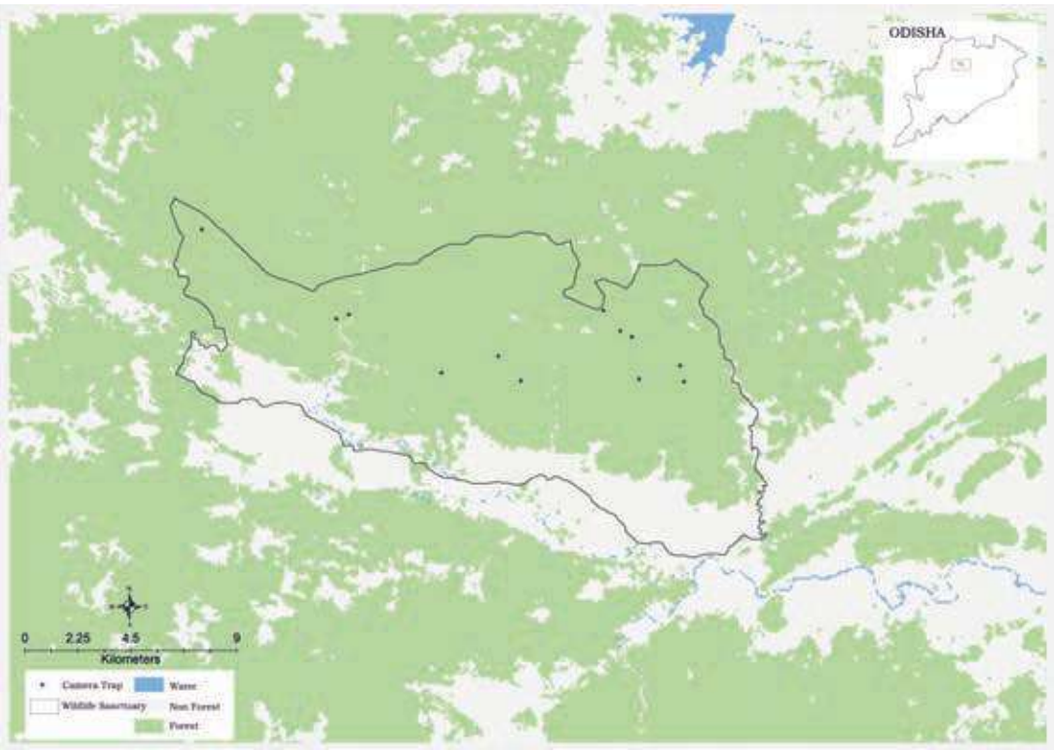
KHALASUNI WILDLIFE SANCTUARY

INTRODUCTION

Khalasuni Wildlife Sanctuary is situated in Rairakhol sub-division of Sambalpur district between 84° 15' and 84 ° 35' E and latitudes 21° 15' and 21° 25' N. The area of the sanctuary is 116 km^2. The Khalasuni- Satkosia corridor is an important elephant corridor in the state where it connects Satkosia through Badrama Wildlife Sanctuary.

The forest of Khalasuni is categorized as moist deciduous and tropical dry deciduous type (Champion and Seth 1968). Dominant vegetation found here are *Anogeissus latifolia, Albizia procera, Dalbergia latifolia, Pterocarpus marsupium, Schleichera oleosa, Shorea robusta, Terminalia elliptica, Terminalia chebula* and varieties of bamboo like *Bambusa arundinacea* and *Dendrocalamus strictus*. This sanctuary is also rich in faunal diversity where carnivores like leopard (*Panthera pardus*), jungle cat (*Felis chaus*), jackal (*Canis aureus*), and wolf (*Canis lupus*) occur. It is also home to elephant (*Elephas maximus*), sloth bear (*Melursus ursinus*), sambar (*Rusa unicolor)*, chital (*Axis axis*), wild pig (*Sus scrofa*), and gaur (*Bos gauras*).

Figure 10.235
Camera trap layout in Khalasuni Wildlife Sanctuary, 2018



RESULTS

Camera Trap Results

No tiger photos were obtained during the camera trap sampling period (Table 10.86).

Table 10.86
Sampling details of camera trapping exercise in Khalasuni Wildlife Sanctuary, 2018

Sampling details	Counts
Camera points	12
Trap-nights (effort)	411

DISCUSSION

The Khalasuni- Satkosia corridor is an important elephant corridor in the state where it connects Satkosia through Badrama Wildlife Sanctuary.

KEONJHAR WILDLIFE DIVISION

INTRODUCTION

Keonjhar Wildlife Division is situated between 21° 01' to 21° 32' N latitudes and 86° 22' to 85° 36' E longitudes with an elevation of about 500 msl. The river Baitarani runs through the hilly north-western side of the division.

The forest type of the Keonjhar Wildlife Division is northern tropical moist deciduous forest (Champion & Seth, 1968). Dominant vegetation in this area is *Anogeissus latifolia, Bombax ceiba, Madhuca indica, Shorea robusta, Syzygium cumini, Schleichera oleosa, Terminalia elliptica, Xylia xylocarpa* (Kar et al. 2009). Major carnivores found are leopard (*Panthera pardus*), jungle cat (*Felis chaus*) and golden jackal (*Canis aureus*). The ungulate species found in the division include elephant (*Elephas maximus*), chital (*axis axis*), barking deer (*Muntiacus vaginalis*) and mouse deer (*Moschiola indica*).

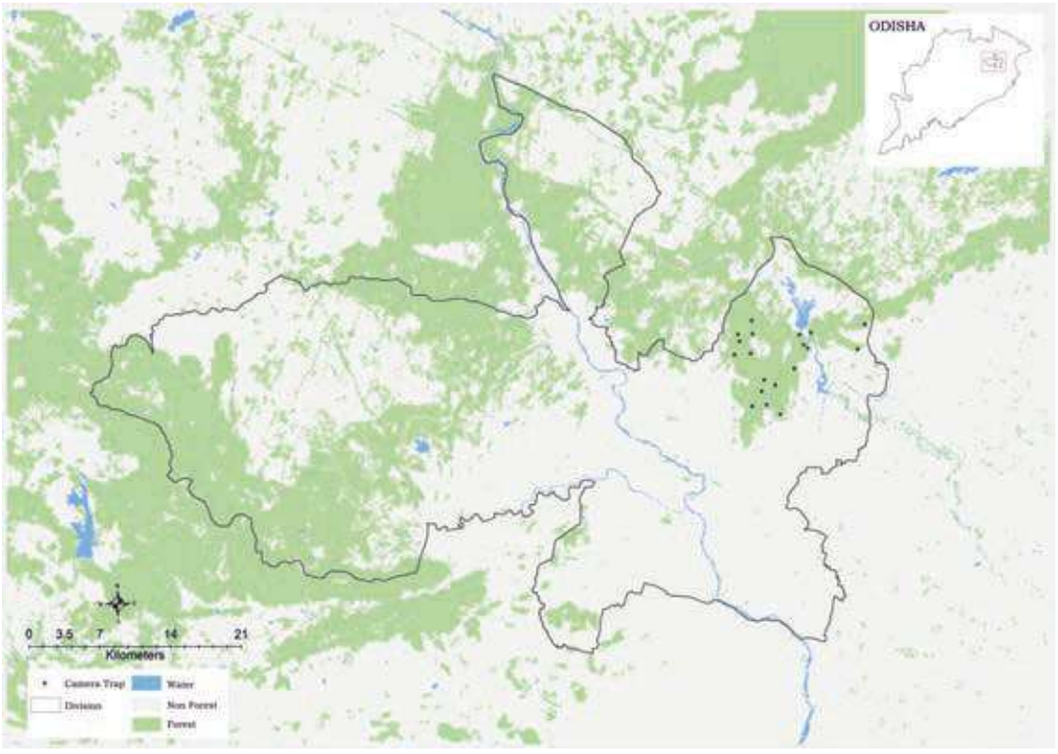


Figure 10.236
Camera trap layout in Keonjhar Wildlife Division, 2018

RESULTS

Camera Trap Results

No tigers were captured during the camera trap sampling period (Table 10.87).

Sampling details	Counts
Camera points	19
Trap nights (effort)	456

Table 10.87
Sampling details of camera trapping exercise in Keonjhar Wildlife Division 2018

DISCUSSION

During the camera trapping exercise, tiger was not captured but this division has connectivity with the Similipal Tiger Reserve which further extends to the Kuldiha Wildlife Sanctuary. Proper management interventions could be a helpful in the conservation of this entire region.

KULDIHA WILDLIFE SANCTUARY

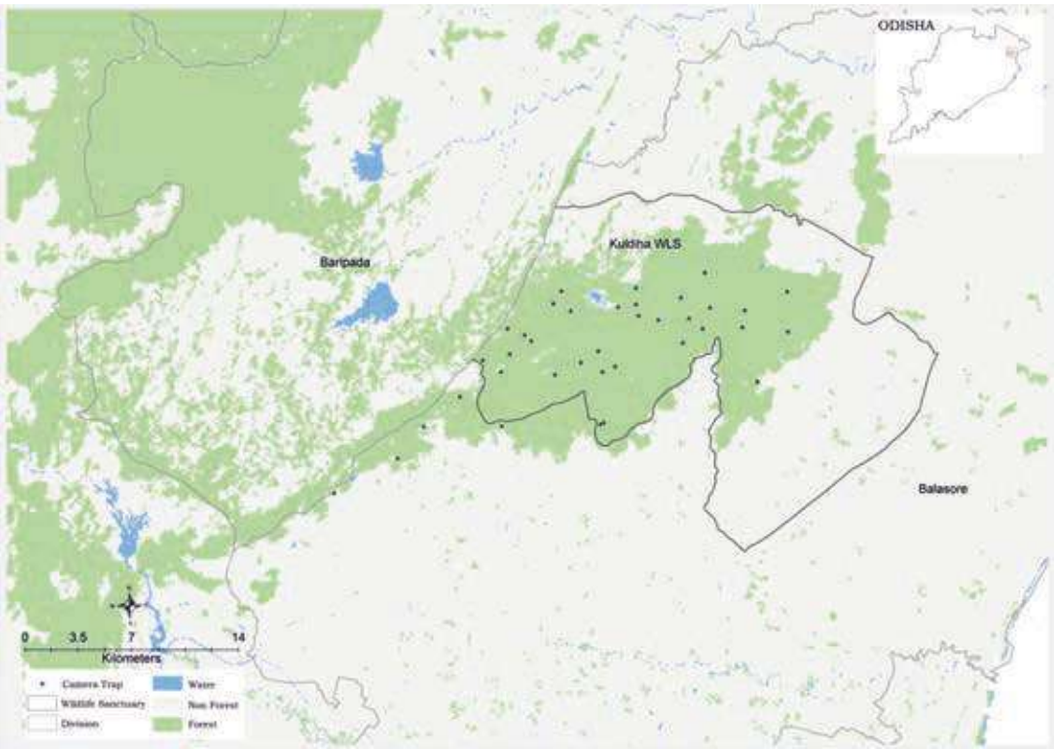
INTRODUCTION

Kuldiha Wildlife Sanctuary is situated on the south-western part of Balasore district of Odisha between 21°30' to 21°45' N latitudes and 86°30' 86°45' E longitudes. It has an area of 272.75 km^2. The sanctuary acts as a probable corridor for tigers and elephants moving from Similipal Tiger Reserve to Satkosia Tiger Reserve. It includes the reserve forests of Kuldiha, Devgiri and Tenda and parts of the adjoining protected forests of Sarisua.

The vegetation is mostly tropical mixed deciduous (Champion and Seth 1968) dominated by *Shorea robusta, Terminalia tomentosa, Pterocarpus marsupium, Anogeisus latifolia, Dalbergia latifolia, Diospyros melanoxylon, Emblica officinalis, Madhuca indica, Scleichera oleosa, Mangifera indica*, etc. Major faunal species found here leopard (*Panthera pardus*), jackal (*Canis aureus*), jungle cat (*Felis chaus*), sloth bear (*Melursus ursinus*), Gaur (*Bos gauras*), chital (*Axis axis*), sambar (*Rusa unicolor*), wild pig (*Sus scrofa*), etc.

Figure 10.237

Camera trap layout in Kuldiha Wildlife Sanctuary, 2018.



RESULTS

Camera Trap Results

No tiger photos were obtained during the sampling period (Table 10.88).

Table 10.88

Sampling details of camera trapping exercise in Kuldiha Wildlife Sanctuary, 2018.

Sampling details	Counts
Camera points	38
Trap nights (effort)	92

DISCUSSION

Kuldiha Wildlife Sanctuary is connected to Similipal Tiger Reserve through Keonjhar Forest Division which could act as the possible corridor for the tiger movement in the future once tiger status in the region recovers.

ROURKELA FOREST DIVISION

INTRODUCTION

Rourkela Forest Division has a forested area of 912.54 km^2. Rourkela Forest Division lies in the catchment areas of the rivers Brahmani, Koel, Sankha and Deo.

According to Champion and Seth (1968) classification dry peninsular sal forest and dry deciduous scrub forests abound here. *Shorea robusta* is the dominant tree species in these forests. Other species found in this division include *Bombax ceiba, Cassia fistula, Dalbergia latifolia, Embelica officinalis, Pterocarpus marsupium, Terminalia arjuna,* and *Tectona grandis* amongst others.

Leopard (*Panthera pardus*) is the major predator here with occurrence of other animals like hyena (*Hyaena hyaena*), golden jackal (*Canis aureus*) and sloth bear (*Melursus ursinus*) Gaur (*Bos gaurus*), wild pig (*Sus scrofa*), and barking deer (*Muntiacus vaginalis*).

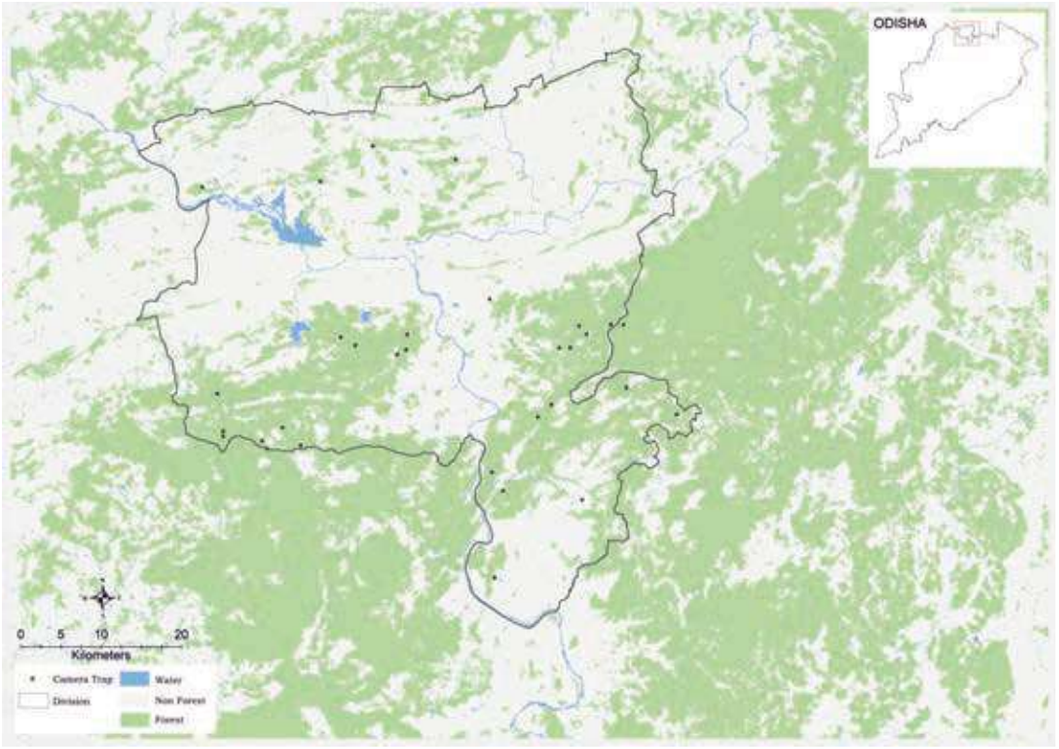


Figure 10.238
Camera trap and transect layout in Rourkela Forest Division, 2018

RESULTS

Camera Trap Results

No tiger photos were obtained during the sampling period (Table 10.89).

Sampling details	Counts
Camera points	32
Trap nights (effort)	941

Table 10.89
Sampling details of camera trapping exercise in Rourkela division, 2018.

DISCUSSION

Roulkela forest division is continuous to Bonai forest division. Rouklela together with Bonai forest division can be part of tiger recovery sites if the forest of the both division can brought under the ambit of protected area and poper management intervention for prey recovery and habitat management.

SUNABEDA WILDLIFE SANCTUARY

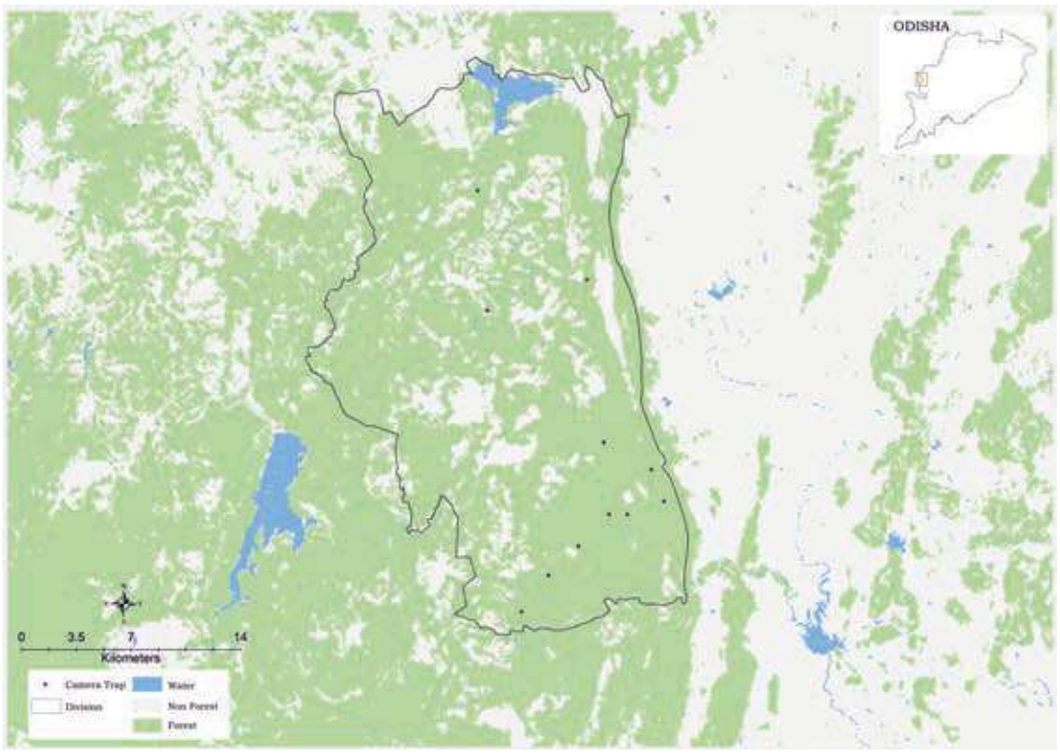
INTRODUCTION

Sunabeda Wildlife Sanctuary is located in Nuapada district within the geographic bounds of 20° 24' to 20° 44' N latitudes and 82°20'to 82° 34' E longitudes. The total area of the sanctuary is 600 km^2. Recently, this wildlife sanctuary has been proposed for declaration as a tiger reserve.

The forest type of Sunabeda Wildlife Sanctuary is categoried as tropical dry deciduous and dry peninsular and teak forest and is dominated by *Adina cordifolia, Anogeissus latifolia, Buchanania lanzan, Careya arborea, Dalbergia latifolia, Madhuca indica, Mitragyna parviflora, Lannea coromandelica, Lagerstroemia parviflora, Pterocarpus marsupium, Santalum album, Shorea robusta, Tectona grandis, Terminalia tomentosa*, etc. Faunal diversity includes leopard (*Panthera pardus*), hyena (*Hyeana hyeana*), sloth bear (*Melursus ursinus*), jackal (*Canis aureus*), wolf (*Canis lupus*), ratel (*Mellivora capensis*), sambar (*Rusa unicolor*), gaur (*Bos gauras*), chowsingha (*Tetracerus quadricornis*), wild pig (*Sus scrofa*) etc.

Figure 10.239

Camera trap layout in Sunabeda Wildlife Sanctuary, 2018



RESULTS

Camera Trap Results

No tiger photos were obtained during the sampling period (Table 10.90).

Table 10.90

Sampling details of camera trapping exercise in Sunabeda Wildlife Sanctuary, 2018.

Sampling details	Counts
Camera points	11
Trap-nights (effort)	95

DISCUSSION

Tiger capture was not obtained in this area but it is proposed as the potential tiger reserve. It has connectivity with the Indravati Tiger Reserve of Chhattisgarh. Better management interventions such as minimzing human disturbance and prey augmentation would be required for improving the wildlife conservation status for this site.

SUNDARGARH FOREST DIVISION

INTRODUCTION

Sundargarh Forest Division lies between 21° 47' to 22° 32' N latitudes and 83° 32' to 84° 34' E longitudes. The forest division lies near the state boundaries of Odisha, Chhattisgarh and Jharkhand. It covers an area of 3576.39 km^2.

Forest type of the division is categorized as tropical dry-deciduous, northern tropical dry-deciduous and northern dry-mixed deciduous forest (Champion and Seth 1968). Major flora in Sundargarh Forest Division is represented by *Adina cordifolia, Albizzia procera, Anogeissus latifolia, Bridelia retusa, Dalbergia latifolia, Gmelina arboria, Mytragyna parvifolia, Ougeinia oojinensis, Pterocarpus marsupium, Shorea robusta, Syzygium cumini* etc. (Palei et al. 2019). Faunal species found here include carnivores like tiger (*Panthera tigris*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*), golden jackal (*Canis aureus*) and ungulate species like elephant (*Elephas maximus*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*) and mouse deer (*Moschiola indica*). Recently, Indian grey wolf (*Canis lupus*) has also been recorded from Sundargarh Forest Division (Palei et al. 2019).

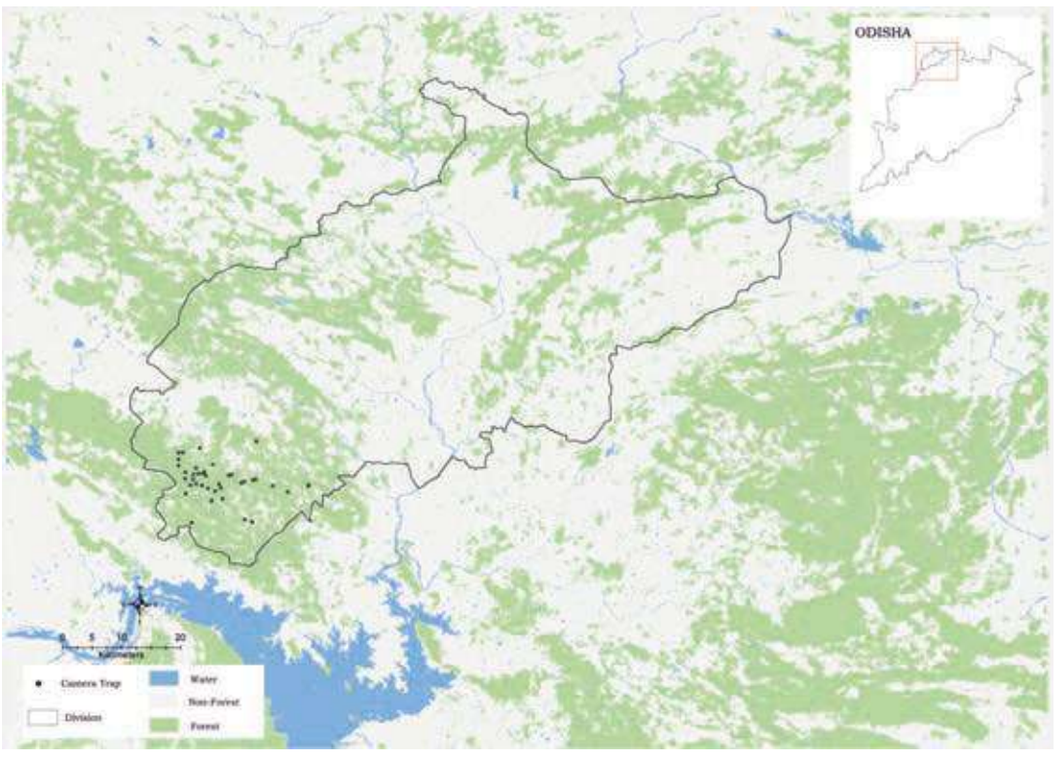


Figure 10.240
Camera trap layout in Sundargarh Forest Division, 2018.

RESULTS

Camera Trap Results

No tigers were captured during the camera trap sampling period (Table 10.91).

Sampling details	Counts
Camera points	40
Trap nights (effort)	1726

Table 10.85
Sampling details of camera trapping exercise in Sundargarh Forest Division, 2018.

DISCUSSION

During the camera trapping exercise, no tiger was photo captured in Sundargarh Forest Division but it is connected to the Debrigarh Forest Division where one tiger was photo-captured which shows that this landscape has a potential to hold tigers. Prey augmentation and control on the anthropogenic activities can be a stepping stoneare required for the conservation strategies improving the status of wildlife in these forests.

AMRABAD TIGER RESERVE

INTRODUCTION

Amrabad Tiger Reserve (ATR) is situated in the Nallamala hills of Southern Eastern Ghats of Telangana. It is located at the longitudes and latitudes of 79°.40' N 16°.70' E and 78°.48' N, 16°.21' E (North) and 78°.73' N, 16°.00' E and 79°.42' N. 16°.58' E (South). The park extends till Mahabubnagar and Nalgonda districts and is about 150 km south of Hyderabad on the southern bank of river Krishna. The core covers a total area of 2166.37 km^2 and has a buffer area of 445.02 km^2.

The forest type of Amrabad Tiger Reserve comes under southern tropical dry deciduous miscellaneous type (Champion and Seth 1968). Major trees comprises of *Terminalia arjuna, Terminalia elliptica, Boswellia serrata, Syzygium cumini*. Grass species include *Aristida adscensionis, Cynodon dactylon, Heteropogon contortus, Imperata cylindrica, Sporobolus orientalis,* and *Chrysopogon zizanoides*. Faunal diversity includes tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), wild dog (*Cuon alpinus*), striped hyena (*Hyena hyena*), and Jackal (*Canis aureus*). Prey species like sambar (*Rusa unicolor*), chital (*Axis axis*), chousingha (*Tetracerus quadricornis*), nilgai (*Boselaphus tragocamelus*), mouse deer (*Moschiola indica*), wild pig (*Sus scrofa*), and chinkara (*Gazella bennettii*) are also found here.

This tiger reserve is adjacent to the Nagarjunasagar Srisailam Tiger Reserve of Andhra Pradesh (from which it was bifurcated with the formation of Telangana State). Apart from ecological importance, this entire landscape has high heritage value with several ancient temples located in and around the reserve like Srisailam, Uma Maheshwaram, Maddimadugu, Akkamahadevi caves, Kadilivanam, and Mallelatheertham., etc. Along with this, this landscape is also home to many sacred groves and ancient rock formations.

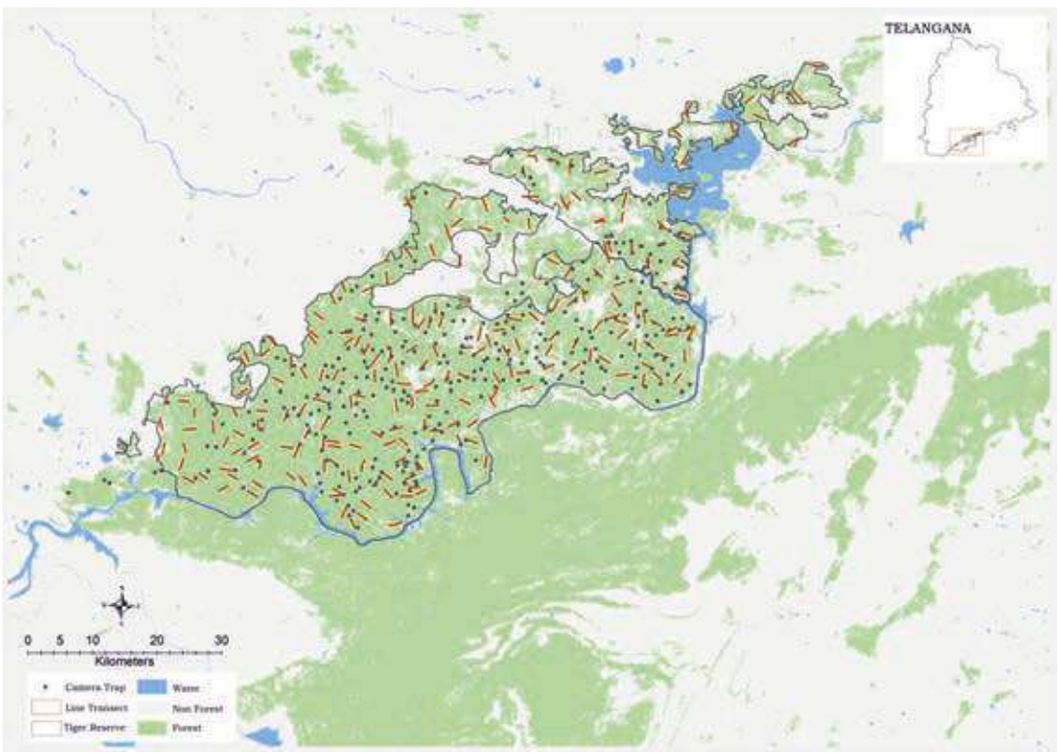


Figure 10.241
Camera trap and transect layout in Amrabad Tiger Reserve, 2018

RESULTS

Tiger Density Estimates

A total of 37 usable tiger images were obtained from which 7 tiger individuals were identified. Tiger density was estimated as 0.19 (SE 0.07) tiger per 100 km^2 (Table 10.92). The detection corrected sex ratio was male biased (Table 10.92).

Variables	Estimates
Model space (km^2)	4741.75
Camera points	338
Trap nights (effort)	7218
Unique tigers captured	7
Model	g_0 (.)σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.19 (0.07)
Sigma (SE)	9.30 (1.12)
g_0 (SE)	0.001 (0.000)
Pmix Female (SE)	0.40 (0.21)
Pmix Male (SE)	0.60 (.21)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
σ(Sigma): Spatial scale of detection function,
g_0: Magnitude (intercept) of detection function
Pmix: Detection corrected estimate of proportion of males and females

Table 10.92
Sampling details and tiger density parameter estimates using spatially explicit capture-recapture analysis in a likelihood framework for Amrabad Tiger Reserve, 2018

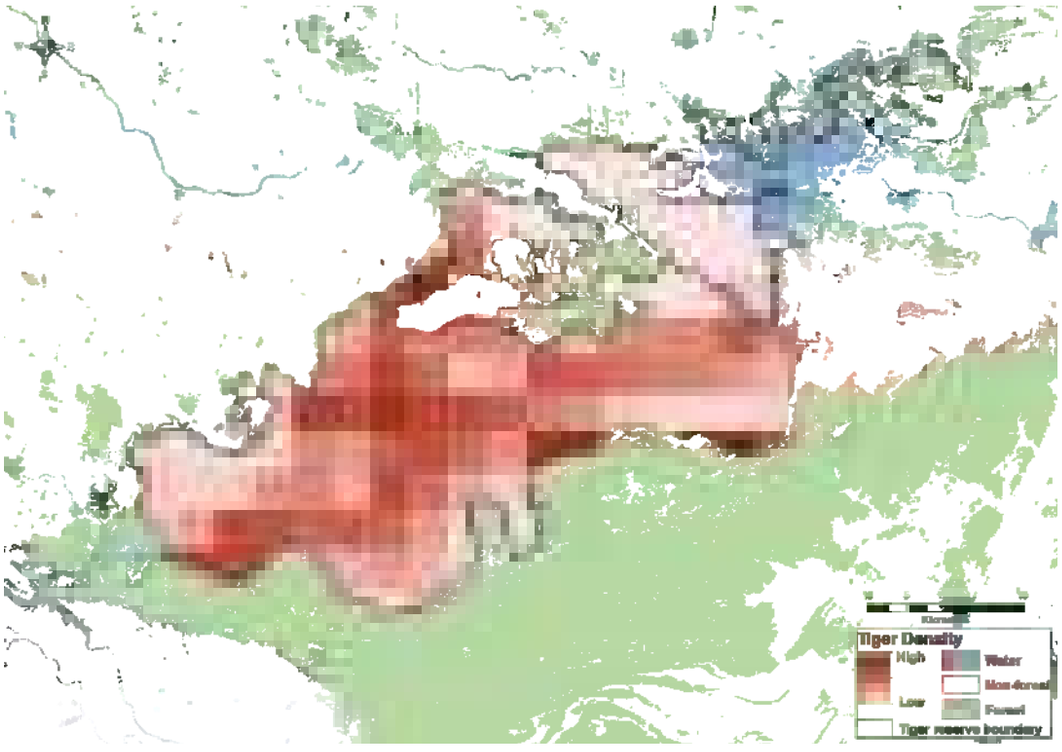


Figure 10.242
Spatial density of tigers in Amrabad Tiger Reserve, 2018

Amrabad Tiger Reserve is a new tiger reserve for the state of Telangana and sampled for the first time for All India Tiger Monitoring exercise after the state bifurcation. The population had a low The adult tiger density but the large proportion of young tigers (07) in the population is suggestive of improved status and a rapid growth in the population. was found to be within the reserve tiger density was relatively high in the Amrabad and Maddimadugu range which is dominated by dry mixed deciduous and dry teak forests.

Distribution of Major Mammalian Fauna Found in Amrabad Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Amrabad Tiger Reserve.

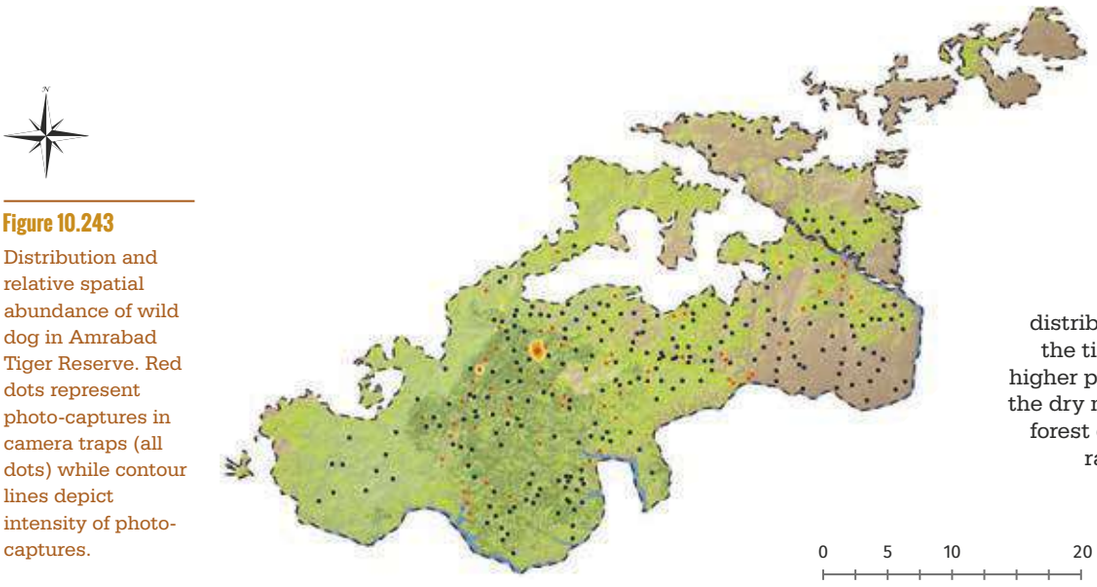


Figure 10.243
Distribution and relative spatial abundance of wild dog in Amrabad Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Wild dog was distributed throughout the tiger reserve with higher photo-captures in the dry mixed deciduous forest of the Mannanur range of the park.

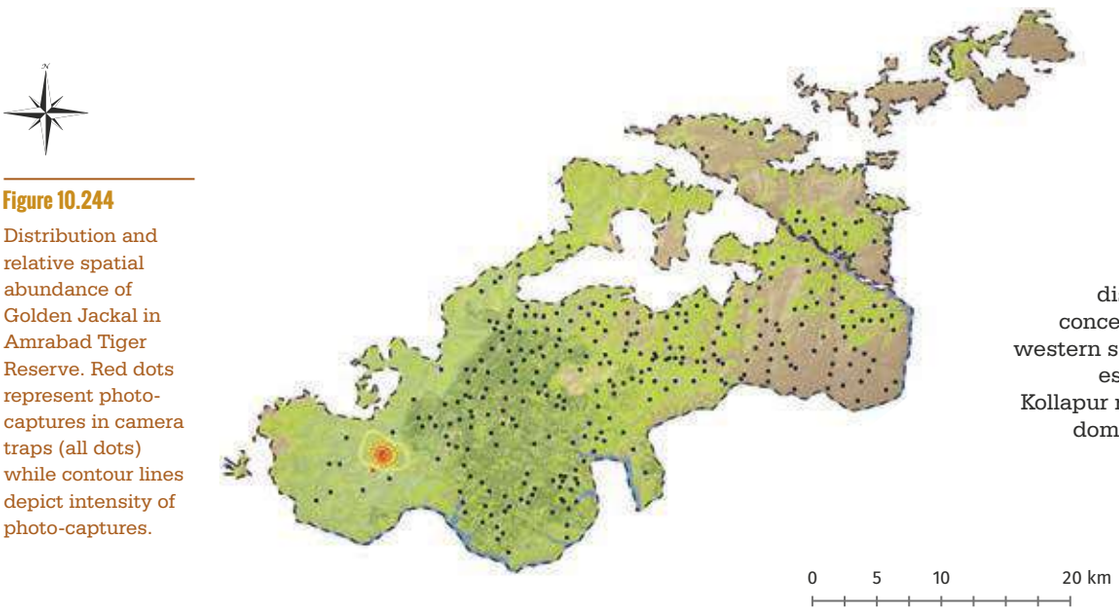


Figure 10.244
Distribution and relative spatial abundance of Golden Jackal in Amrabad Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Golden jackal distribution was concentrated on the western side of the park especially in the Kollapur range which is dominated by teak forest.

Wolf were mainly photo-captured on dry deciduous and dry scrub forest areas of the Mannanur range of the park.

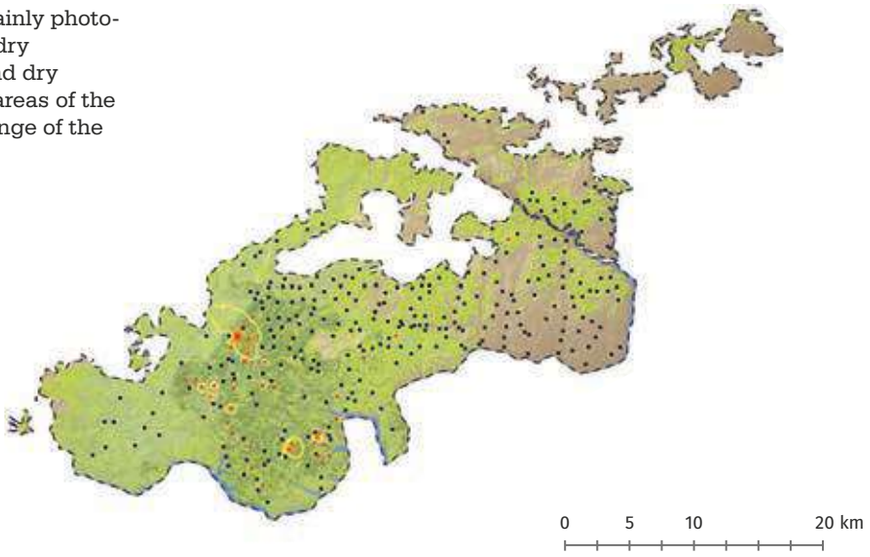


Figure 10.245

Distribution and relative spatial abundance of Wolf in Amrabad Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was distributed throughout the tiger reserve with higher photo-captures in dry mixed deciduous and dry deciduous scrub forest areas of Amrabad Tiger Reserve.

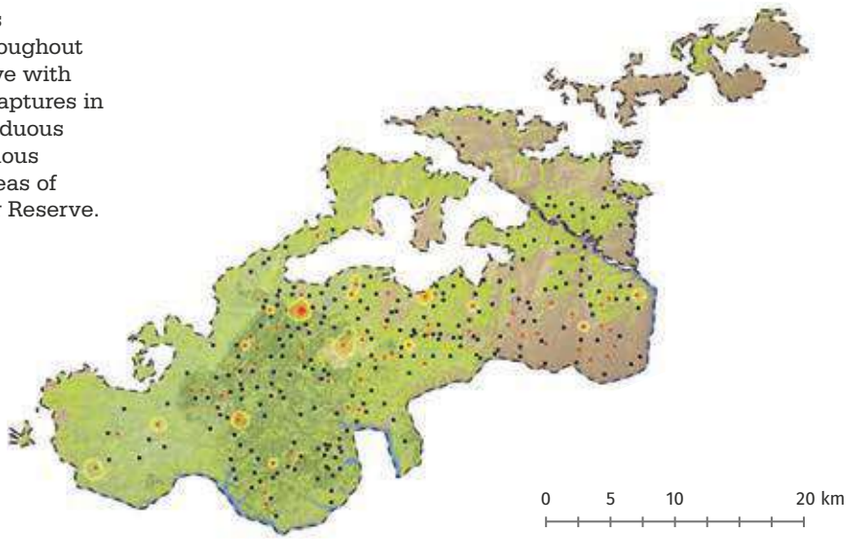


Figure 10.246

Distribution and relative spatial abundance of Jungle cat in Amrabad Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Rusty-spotted cat were distributed throughout the tiger reserve with higher photo-captures in dry mixed deciduous and dry deciduous scrub forest areas of Amrabad Tiger Reserve.

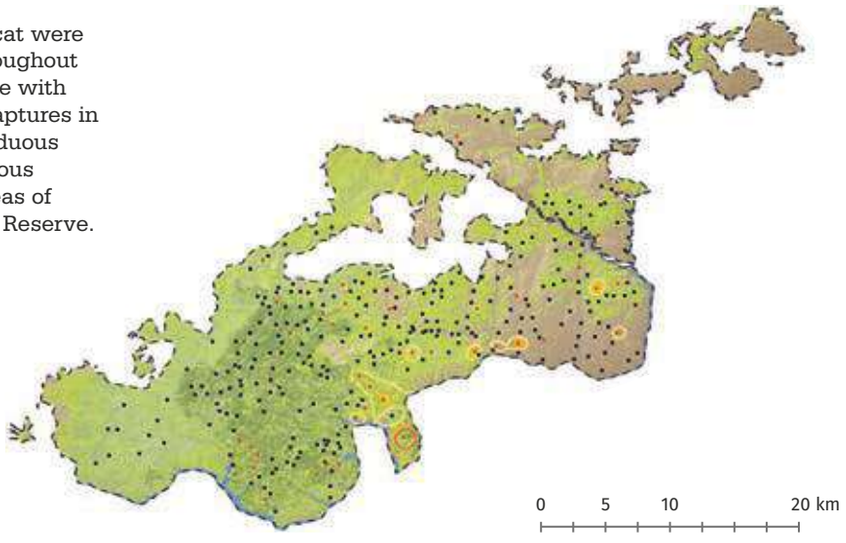


Figure 10.247

Distribution and relative spatial abundance of Rusty-Spotted Cat in Amrabad Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

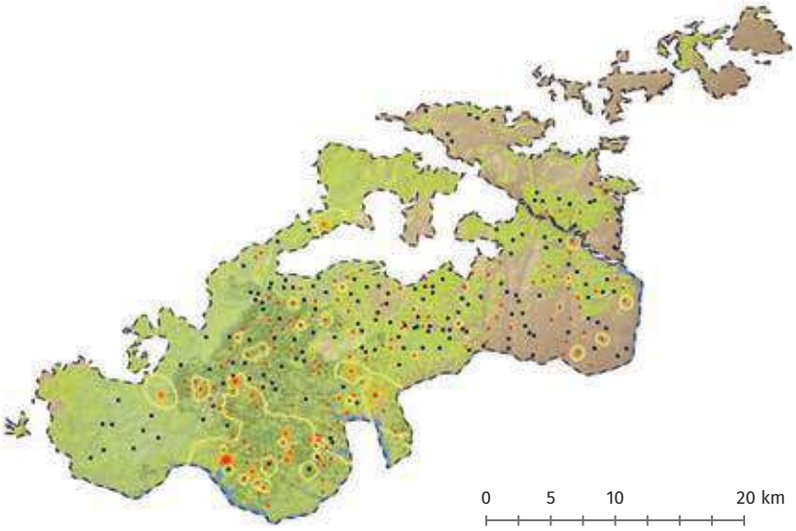


Figure 10.248
Distribution and relative spatial abundance of Leopard in Amrabad Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Leopard was distributed throughout the park but higher photo-captures were mainly in the dry mixed deciduous forest patches and in few non-forested areas in the eastern part of the reserve.

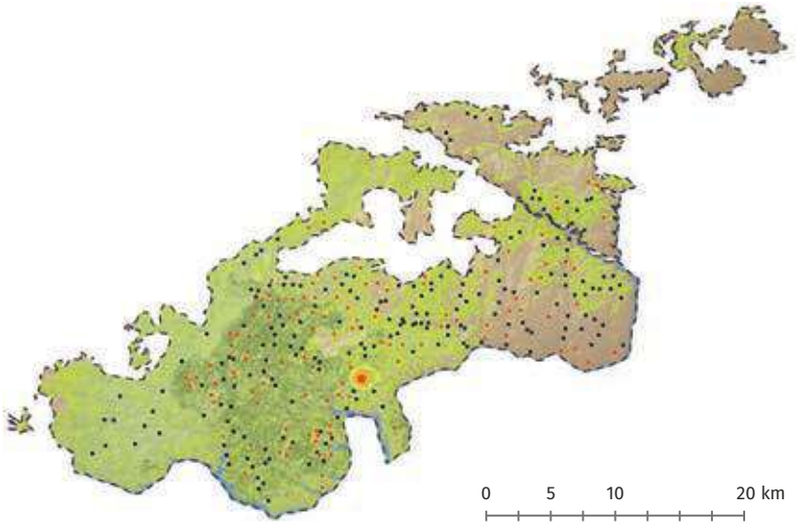


Figure 10.249
Distribution and relative spatial abundance of Slothbear in Amrabad Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear was distributed throughout the park with higher photo captures in the dry mixed deciduous forest patch of the Dommalapenta range in the reserve.

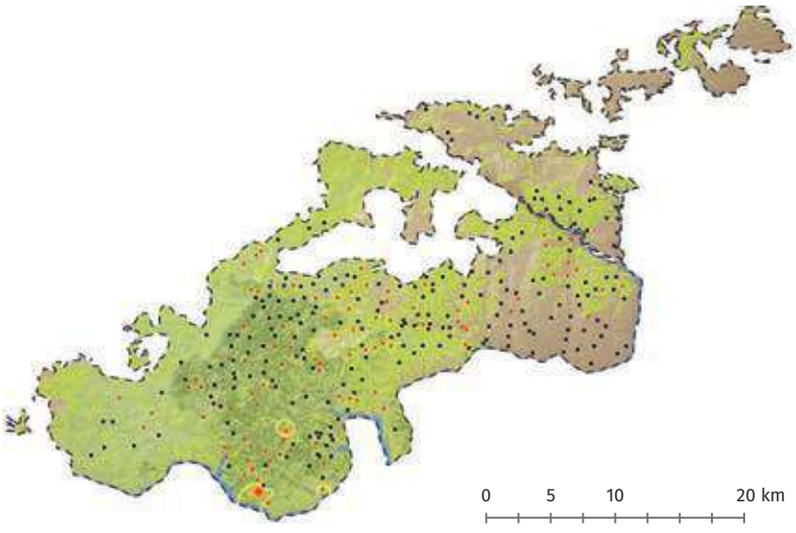


Figure 10.250
Distribution and relative spatial abundance of Chousingha in Amrabad Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Chousingha was distributed throughout the park but the photo captures were highly concentrated in the southern thorn forest patch of Mannanur and Dommalapenta ranges in the reserve.

Relative Abundance of all Photocaptured Species in Amrabad Tiger Reserve

A total of 42 species of ungulates, carnivores, domestic animals, omnivores, reptiles, and galliformes were photo-captured in Amrabad Tiger Reserve. Livestock were most frequently photo-captured while species like domestic cat and Indian fox were captured low in number (Table 10.93).

Table 10.93

Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Amrabad Tiger Reserve,2018.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Chinkara	0.44	225.56
Chital	5.49	18.23
Chousingha	4.14	24.14
Common palm civet	2.48	40.32
Domestic cat	0.01	7218.00
Domestic dog	7.34	13.62
Grey mongoose	0.55	180.45
Honey badger	0.22	451.13
Indian fox	0.11	902.25
Indian hare	19.23	5.20
Indian porcupine	9.03	11.07
Jackal	0.21	481.20
Jungle cat	1.62	61.69
Leopard	5.50	18.18
Livestock	23.66	244.38
Nilgai	3.39	29.46
Ruddy mongoose	4.86	20.56
Rusty spotted cat	0.85	118.33
Sambar	12.26	8.16
Slothbear	4.23	23.67
Small indian civet	4.24	23.59
Tiger	0.65	153.57
Wild dog	3.38	29.58
wild pig	11.42	8.76
Wolf	2.19	45.68

DISCUSSION

The 2014 tiger estimates are not comparable for this site as the estimate given included the old boundaries of Nagarjunasagar Srisailam Tiger Reserve before the state bifurcation. However, there has been no change in the number of tiger individuals captured in 2014 from this part of former Nagarjunasagar Srisailam Tiger Reserve. Livestock grazing, smuggling of timber, hunting and resource extraction by the local populace makes the park vulnerable to habitat degradation and biodiversity extinction. 629 transects were walked with an effort of 1241.60 km covering the tiger reserve. Since the number of sightings were too low during these transects, prey density was not estimated. Removal of human pressures especially settlements from within the Tiger Reserve and reduction of livestock is required to improve wildlife and tiger status.

KAWAL TIGER RESERVE

INTRODUCTION

Kawal Tiger Reserve lies under the administrative boundary of Telangana state. It spans across Nirmal, Mancherial, Adilabad and Asifabad districts of Telangana. It is located at a distance of 260 km from Hyderabad and lies in the catchment of rivers Godavari and Kadam. The total area of Kawal is 2015.35 km^2 of which the core area is 892.23 km^2 while the buffer covers 1123.12 km^2.

According to Champion and Seth 1968 classification, the vegetation of the Kawal Tiger Reserve is composed of southern tropical dry deciduous forest miscellaneous type. The major trees are *Tectona grandis, Terminalia alata, Anogeissus latifolia, Mitragyna parviflora, Chloroxylon swietenia, Terminalia arjuna, Madhuca latifolia, Cleistanthus collinus, Boswellia serrata* and *Lannia coromondilica*. The faunal diversity in Kawal Tiger Reserve includes carnivores like tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), jackal (*Canis aureus*), grey wolf (*Canis lupus*), and sloth bear (*Melursus ursinus*). Prey species include the ungulates like gaur (*Bos gaurus*), nilgai (*Boselaphus tragocamelus*), sambar (*Rusa unicolor*), chital (*Axis axis*), chinkara (*Gazella benetti*), wild pig (*Sus scrofa*), chousingha (*Tetracerus quadricornis*), and blackbuck (*Antelope cervicapra*).

This park forms the southernmost part of the Central Indian tiger landscape where it has connectivity with Tadoba-Andhari Tiger Reserve (100 km) in the north and Indravati Tiger Reserve (150 km) in the east. This reserve can be helpful for the dispersal ofpart of the tiger metapopulation between Tadoba-Indrawati-Tipeshwars of theprovided intervening habitat connectivity remains intact. The Tiger Reserve has high potential and is in need of conservation investmenst in the form of incentivized voluntary relocation of human settlements, protection through implementation of MSTrIPES, ecodevelopment for alternative livelihoods of local communities.connected areas if the prey augmentation and the mitigation of various disturbance factors are addressed.

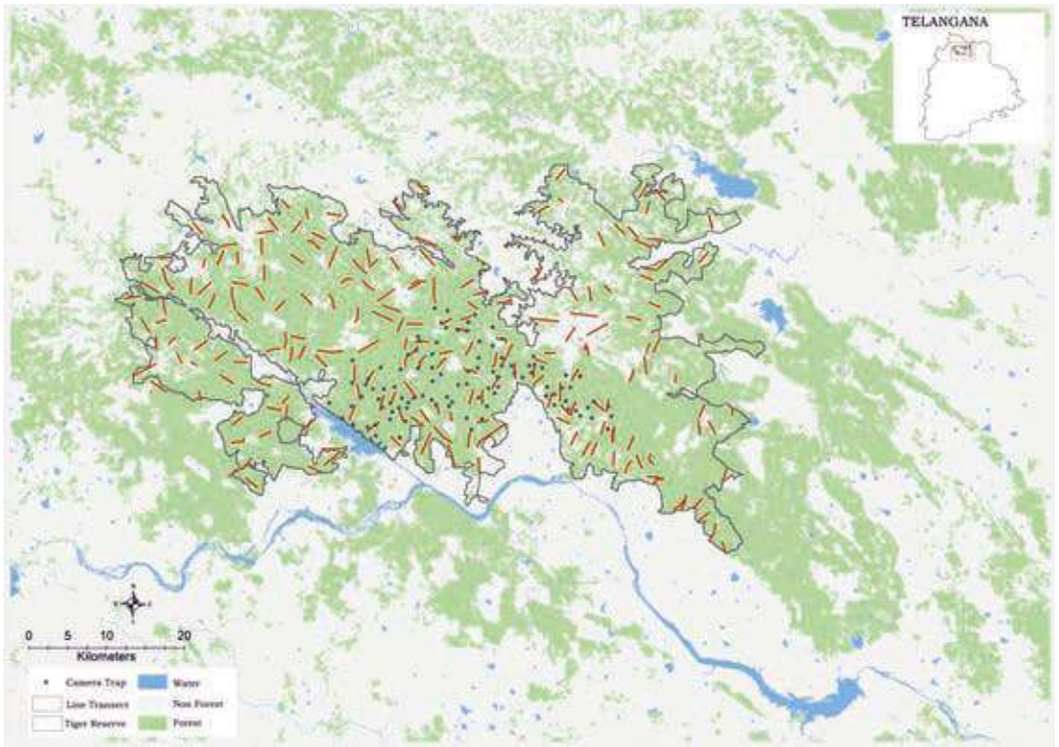


Figure 10.251

Camera trap and transect layout in Kawal Tiger Reserve, 2018

RESULTS

Camera Trap Results

A total of 2 tiger images were obtained from which 1 tiger individual were identified. The density of tigers was not estimated for Kawal Tiger Reserve as only one individual was captured.

Sampling details	Counts
Camera points	100
Trap nights (effort)	2616
Unique tigers captured	1

Table 10.94

Sampling details of camera trapping exercise in Kawal Tiger Reserve ,2018

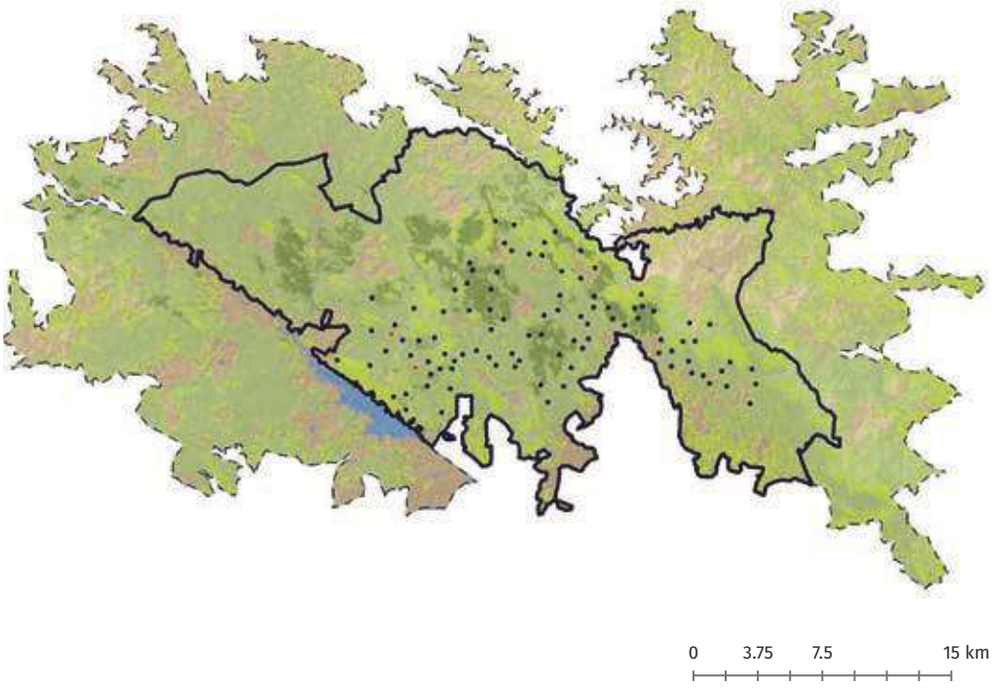


Figure 10.252

Photocapture locations of tiger in Kawal Tiger Reserve, 2018

The tiger movement is mostly was observed in Khanapur division inside the reserve which is dominated by dry teak and dry mixed deciduous forests.

Distribution of Major Mammalian Fauna Found in Kawal Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Kawal Tiger Reserve.

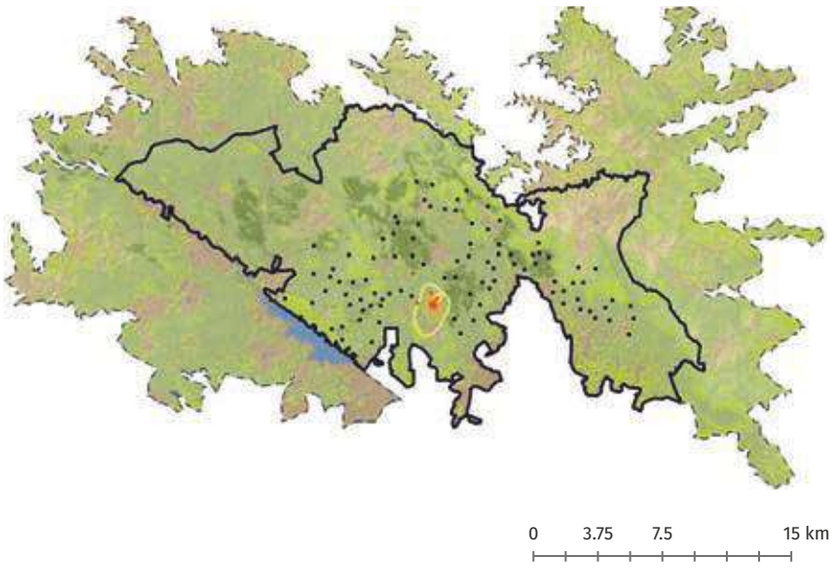


Figure 10.253

Distribution and relative spatial abundance of Wild dog in Kawal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Wild dog photo-captures were concentrated mainly in the dry teak forested area of Khanapur division

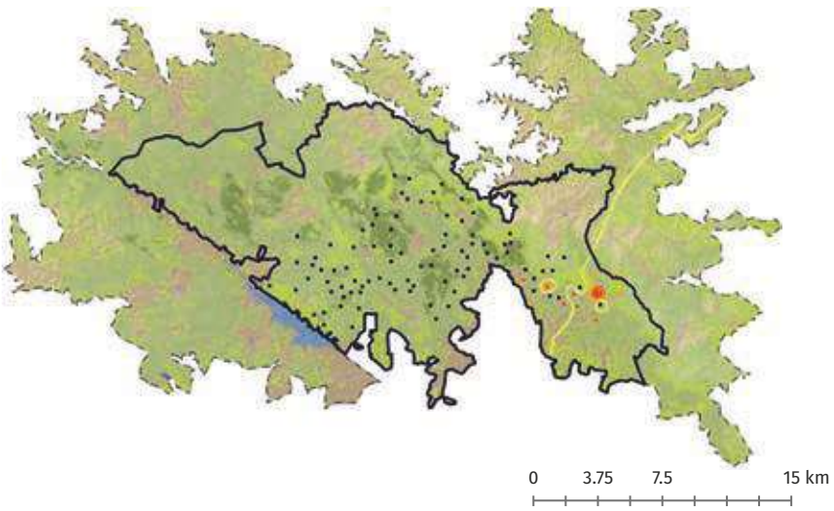


Figure 10.254

Distribution and relative spatial abundance of Wolf in Kawal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures ?

Wolf was mainly photo-captured in the eastern dry teak forest of the reserve in Asifabad division.

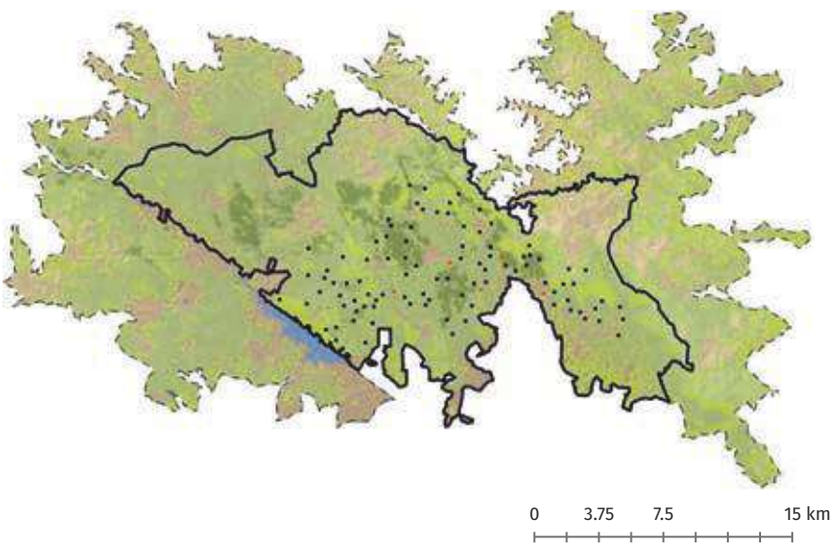


Figure 10.255

Distribution and relative spatial abundance of Golden Jackal in Kawal Tiger Reserve . Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Golden Jackal had very few photo-captures mostly in the dry teak forest of both Jannaram and Khanapur divisions

Indian fox was mainly photo-captured in the dry teak forest with very few captures in southern dry mixed deciduous forests of the reserve and there are no captures in the eastern part of the reserve.

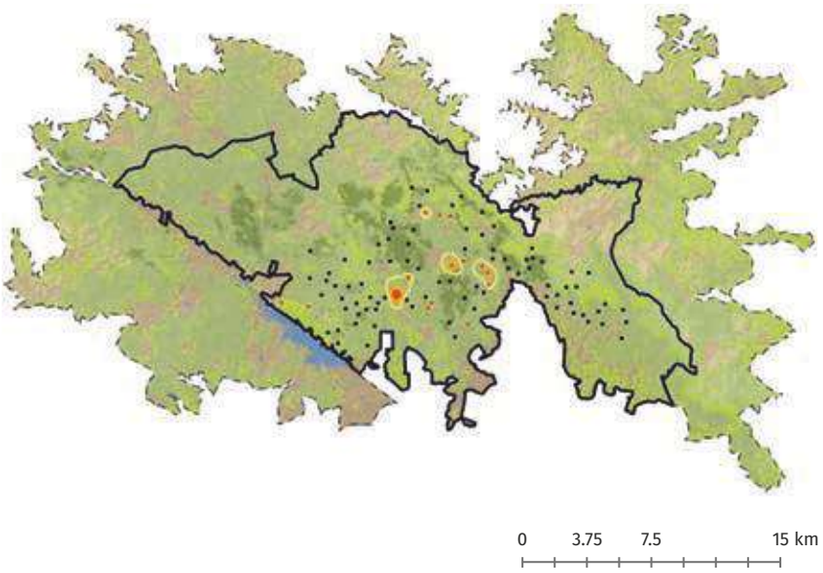


Figure 10.256

Distribution and relative spatial abundance of Indian Fox in Kawal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

Leopard had high photo-captures in the dry teak forest and dry mixed deciduous forest patches of Khanapur division of the reserve.

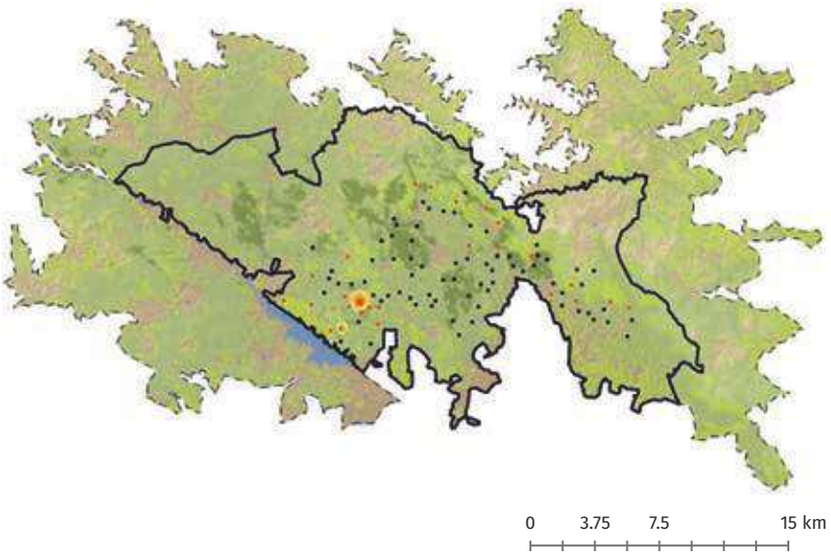


Figure 10.257

Distribution and relative spatial abundance of Leopard in Kawal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

Jungle cat was photo-captured across the tiger reserve mostly in the dry teak and dry mixed deciduous forests of Khanapur division and few captures were in dry teak forests of Jannaram division of the reserve.

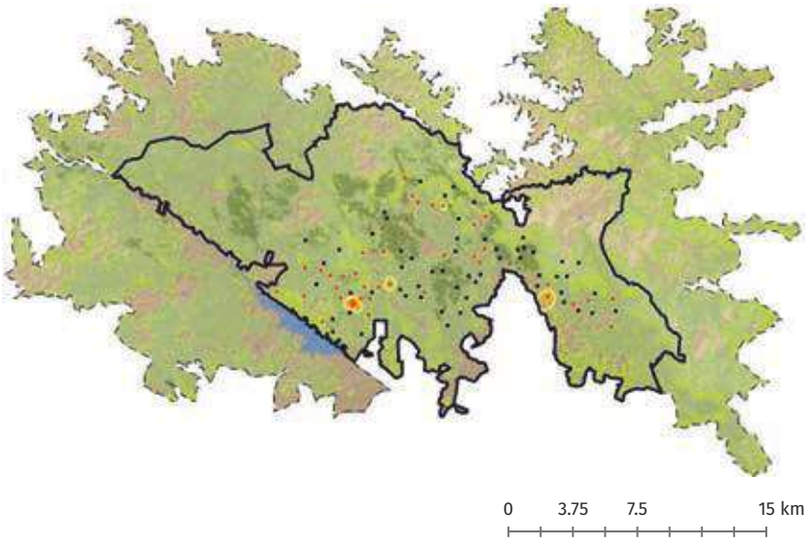


Figure 10.258

Distribution and relative spatial abundance of Jungle Cat in Kawal Tiger Reserve . Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

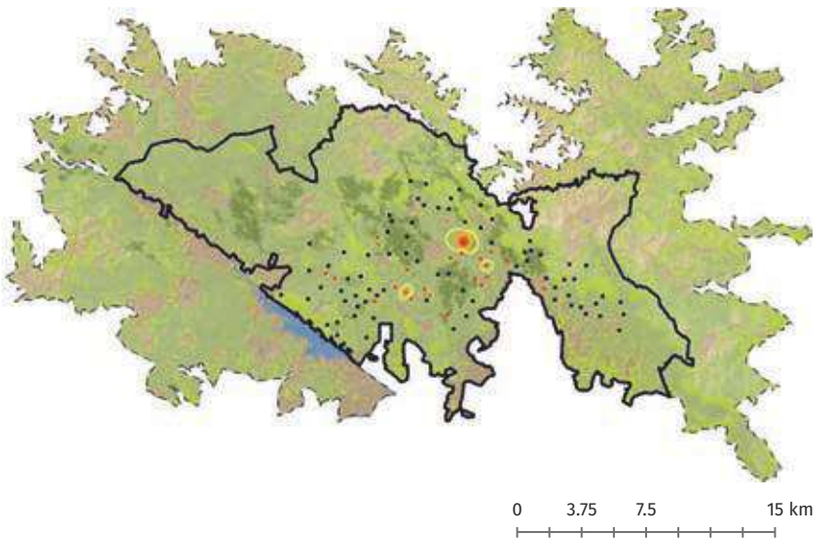


Figure 10.259

Distribution and relative spatial abundance of Chinkara in Kawal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

Chinkara was mostly photo-captured in the dry teak forest patches of Khanapur division.

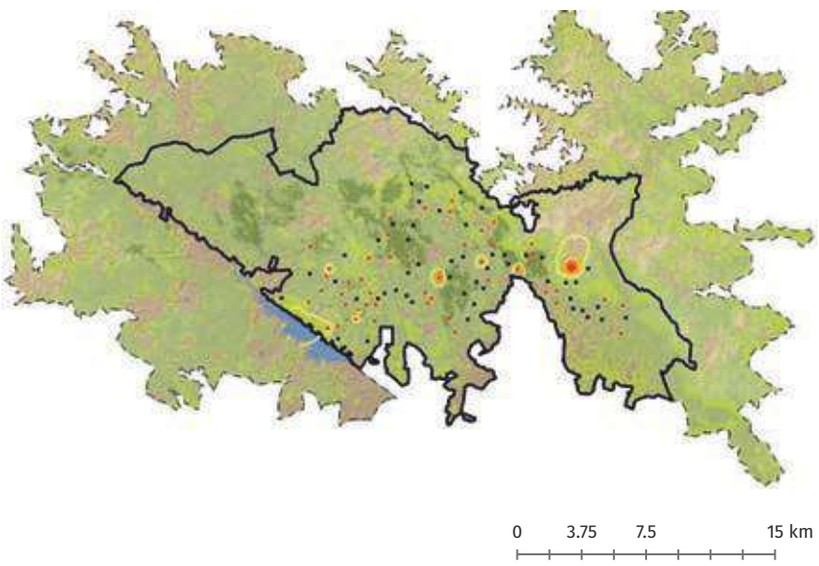


Figure 10.260

Distribution and relative spatial abundance of Chousingha in Kawal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

Chousingha was photo captured throughout the camera trapping area with high photo-capturesin the dry mixed deciduous forests of Khanapur division.

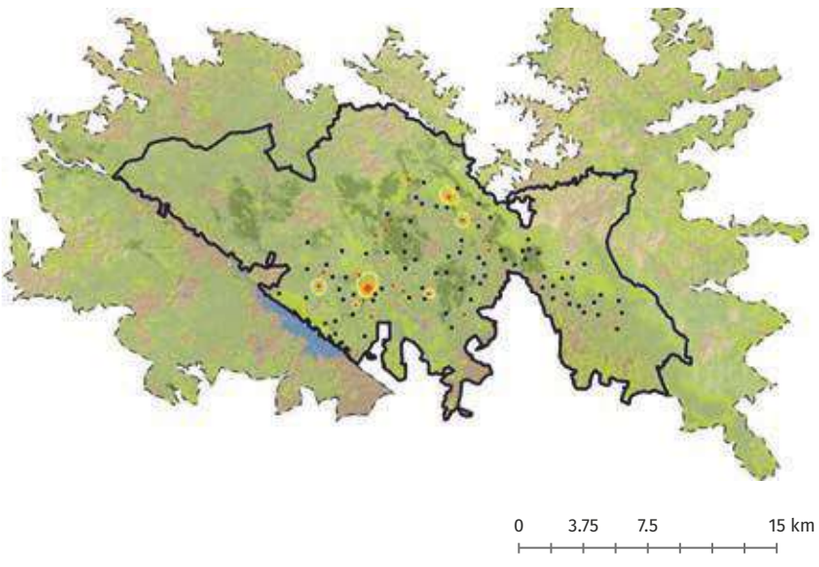


Figure 10.261

Distribution and relative spatial abundance of Gaur in Kawal Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

Gaur was photo-captured across the tiger reserve, higer capture rates were from dry teak forest patches of both Khanapur and Asifabad divisions of Kawal Tiger Reserve.

Sloth bear was distributed throughout the camera trapped area with higher photo-captures in the dry teak and dry mixed deciduous forest habitat of Jannaram and Khanapur divisions

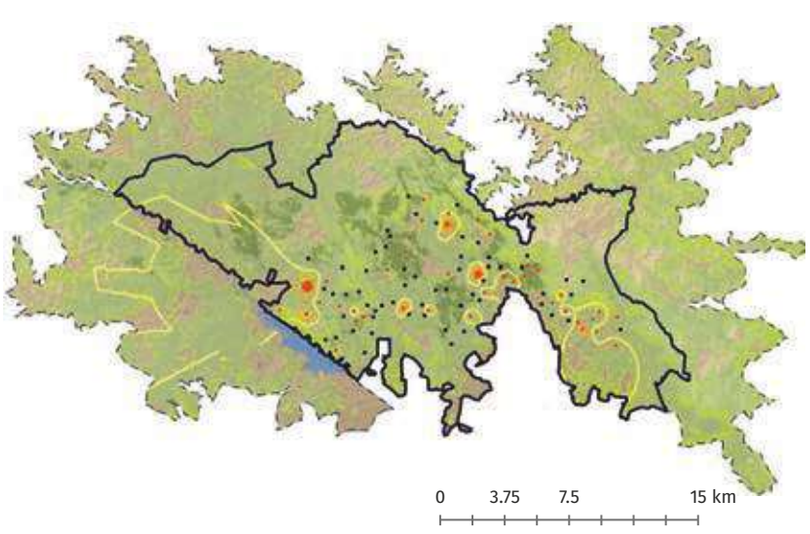


Figure 10.262

Distribution and relative spatial abundance of Sloth bear in Kawal Tiger Reserve.Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

Relative Abundance of all Photocaptured Species in Kawal Tiger Reserve

A total of 40 species of ungulates, carnivores, domestic animals, omnivores, reptiles, and galliformes were photo-captured in Kawal Tiger Reserve. Maximum photocaptures were of livestock while domestic cat and tiger had very few photo-captures (Table 10.95).

Table 10.95

Details of all photo-captured species and their relative abundance (relative abundance index (RAI) in Kawal Tiger Reserve,2018.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Chinkara	3.52	28.43
Chital	4.40	22.75
Chousingha	3.90	25.65
Common palm civet	3.59	27.83
Domestic cat	0.08	1308.00
Domestic dog	9.25	10.81
Gaur	1.22	81.75
Grey mongoose	0.88	113.74
Hanuman langur	2.94	33.97
Honey badger	3.25	30.78
Indian fox	2.33	42.89
Indian hare	14.33	6.98
Indian porcupine	4.78	20.93
Jackal	0.23	436.00
Jungle cat	4.17	24.00
Leopard	1.41	70.70
Livestock	19.11	8.04
Nilgai	11.31	8.84
Peafowl	0.42	237.82
Ruddy mongoose	1.15	87.20
Sambar	3.13	31.90
Sloth bear	2.56	39.04
Small indian civet	2.33	42.89
Tiger	0.11	872.00
Wild dog	0.54	186.86
Wild pig	8.49	11.78
Wolf	0.61	163.50

DISCUSSION

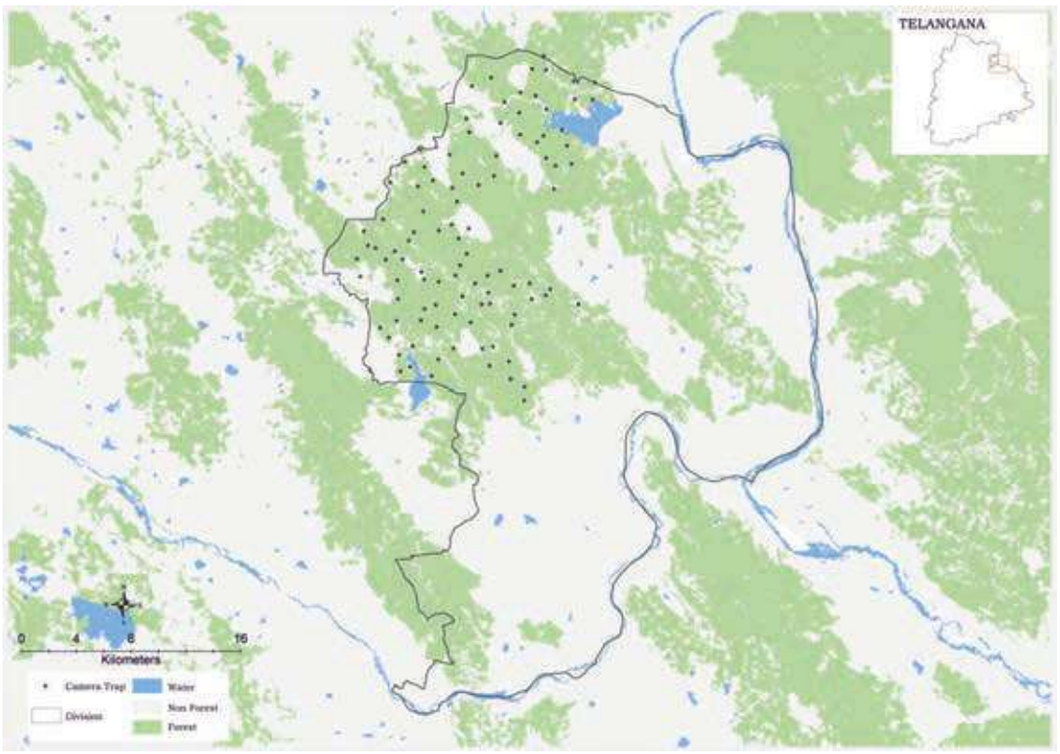
In the last cycle of AITE 2014, no tigers were photo captured in this reserve. 515 transects were walked with an effort of 1009 km covering the tiger reserve and as sightings were very low, prey density was not estimated. Currently, the reserve does not have a resident population of tigers and acts as a corridor between Tadoba and Indravati as well as between Tadoba and northern Telangana. Repopulating this reserve with tigers is only possible through restorative management efforts such as reduction of resource extraction, incentivised voluntary relocation of human habitation, and control of poaching.

CHENNUR FOREST DIVISION

INTRODUCTION

Chennur forest division in Mancherial district of Telangana has an area of 1126.49 km^2. Chennur forest division forms a key connecting habitat between Kawal Tiger Reserve, Tadoba Tiger Reserve and Tipeshwar Wildlife Sanctuary through Kagaznagar Wildlife Division. Chennur forest vegetation type is southern tropical dry deciduous forest with major flora being *Tectona grandis, Anogeissus latifolia, Diospyros melanoxylon, Madhuca latifolia, Boswellia serrata, flame of the forest Butea monosperma,* and *Azadirachta indica*. Major fauna includes tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyena hyena*), jackal (*Canis aureus*), chital (*Axis axis*), sambar (*Rusa unicolor*), wild pig (*Sus scrofa*), nilgai (*Boselaphus tragocamelus*) and chousingha (*Tetracerus quadricornis*). Prey augmentation and minimization of disturbance in this area can enhance tiger occupancy and thereby ensure gene flow across the tiger populations surrounding it.

Figure 10.263
Camera trap layout in Chennur forest divsion, 2018



RESULTS

Camera Trap Results

A total of 4 tiger images were obtained from which 1 tiger individual was identified and the density of tigers was not estimated using SECR for the Chennur forest division.

Table 10.96
Sampling details of camera trapping exercise in Chennur Forest Division,2018

Sampling details	Counts
Camera points	101
Trap nights (effort)	2393
Unique tigers captured	1

DISCUSSION

Camera-trapping was carried out for the first time in this forest division. Chennur forest division forms a link for tigers from Tadoba-Tipeshwar that move into core of Kawal Tiger Reserve in Telangana. This forest division is vulnerable to poaching with the use of snares.

KAGAZNAGAR FOREST DIVISION

INTRODUCTION

Kagaznagar forest division of Telangana comprises of five ranges namely Kaghaznagar, Sirpur, Karjelli, Bejjur and Penchikalpet covering an area of 917.19 km^2.

The vegetation type is southern tropical dry deciduous forest, mixed teak and scrub forests. Dominant species found in this division include *Tectona grandis, Hardwickia binate, Terminalia alata and major grass species are Aristida adscensioni, Cynodon dactylon* and *Heteropogon contortus*. Major fauna present in the forest division are herbivores such as gaur (*Bos gaurus*), nilgai (*Boselaphus tragocamelus*), sambar (*Rusa unicolor*), chital (*Axis axis*), chousingha (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), and carnivores such as tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), striped hyena (*Hyena hyena*), wolf (*Canis lupus*) and sloth bear (*Melursus ursinus*).

Most of the forest fringe villages are directly dependent on the forest for their domestic needs which leads to illicit felling of timber, unsustainable resource extraction of non-timber forest produces like tendu leaves, soap nut, and gum. This has resulted insubstantial habitat degradation in parts of this forest division. However, despite anthropogenic pressure, Kagaznagar Forest Division continues to be an important wildlife habitat and known as a breeding ground for the highly threatened long-billed vulture (*Gyps indicus*). The Kagaznagar forest division acts as a sink for the tiger population from Tadoba Tiger Reserve and Tipeshwar WLS of Maharashtra.

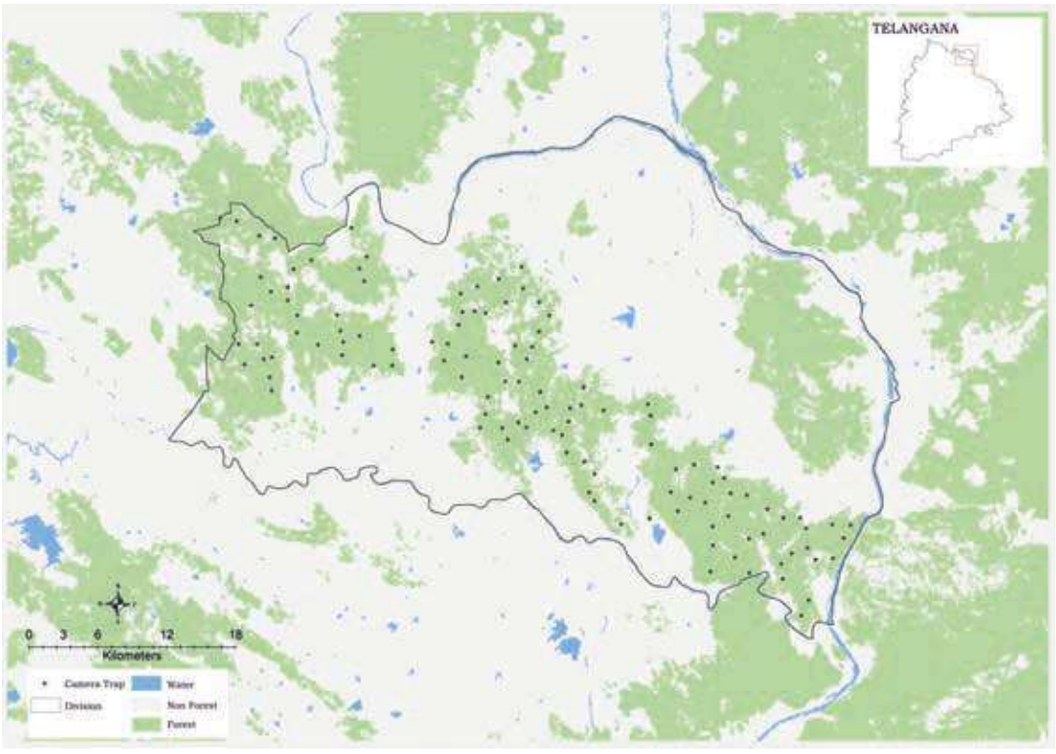


Figure 10.264
Camera trap layout in Kagaznagar forest division, 2018

RESULTS

Camera Trap Results

Camera trapping was carried out by the forest department, where 14 tiger photo-captures yielded 1 tiger individual (Table 10.97). Due to insufficient photo-captures, the density of tigers for this site was not estimated by SECR.

Table 10.97

Sampling details of camera trapping exercise in Kagaznagar Forest Division,2018

Sampling details	Counts
Camera points	119
Trap-nights (effort)	3852
Unique tigers captured	1

DISCUSSION

Camera-trapping was carried out for the first time camera-trapping was carried out for the All India Tiger Monitoring exercise, in Kagaznagar forest division. Conservation of this forest habitat is essential as tigers move from between Maharashtra to TelanganaTadoba-Indrawati and Kawal Tiger Reserve through the Kagaznagar forest corridor.

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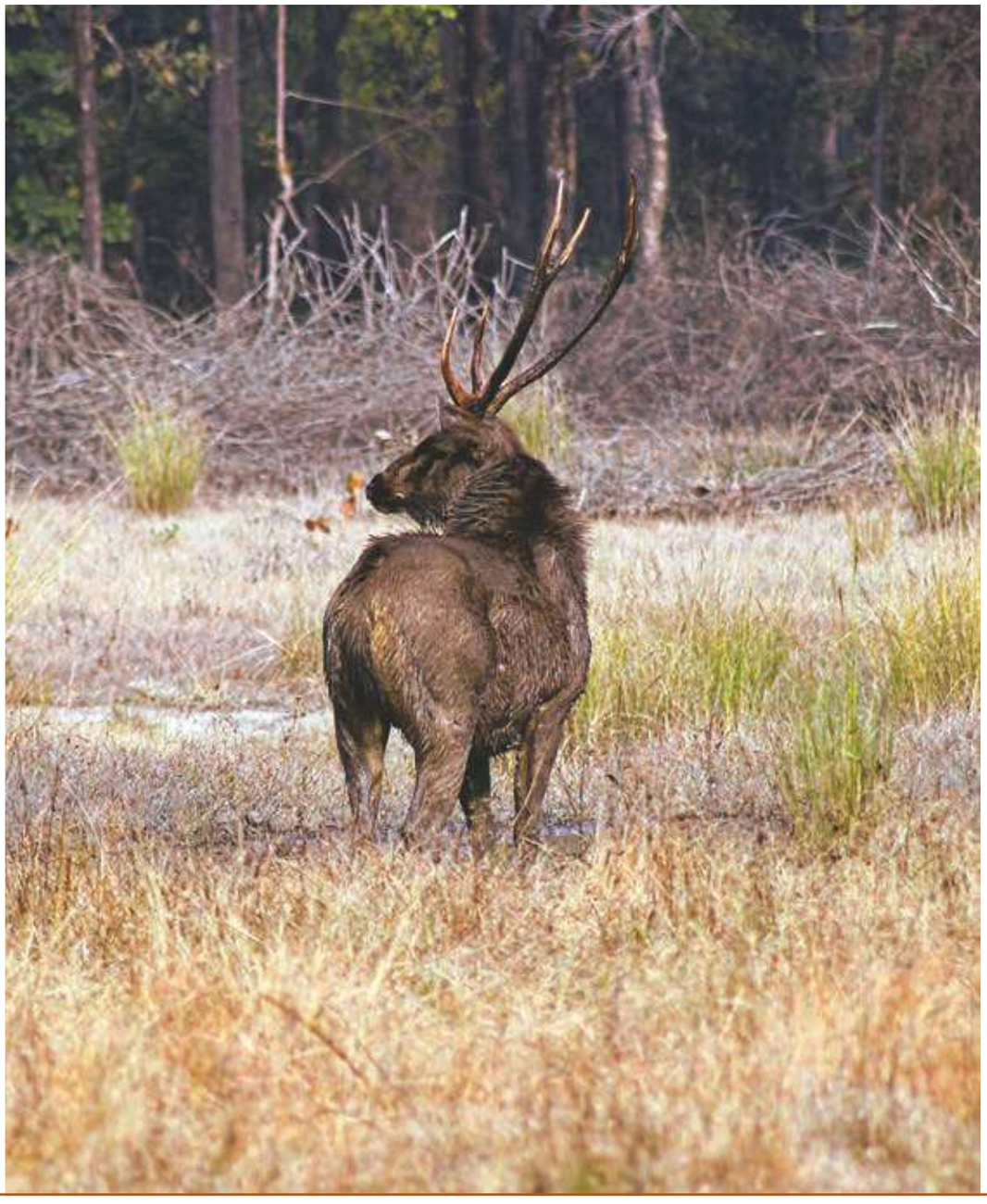


NAGARJUNASAGAR SRISAILAM TIGER RESERVE

INTRODUCTION

Nagarjunsagar Srisailam Tiger Reserve is situated in Nallamala hills, an offshoot of the southern Eastern Ghats in the state of Andhra Pradesh. After the bifurcation of the state into Andhra Pradesh and Telangana, this tiger reserve has also been bifurcated into Nagarjunasagar Srisailam tiger reserve in Andhra Pradesh and Amrabad tiger reserve in Telangana. The state government notified Gundla Brameswaram Sanctuary with an area of 1194 km^2 as an extended core of Nagarjunsagar-Srisailam Tiger Reserve in 2012. The total landscape of 5938 km^2 includes the core area of 3721 km^2 and the buffer area of 2217 km^2 outside the sanctuary. The river Krishna traverses through this critical tiger habitat for a linear distance of 130 km.

The vegetation of Nagarjunasagar Srisailam Tiger Reserve falls under the southern dry mixed deciduous forest category (Tiger Conservation Plan 2013) and overlaps with teak bearing forest. Tree species like *Tectona grandis, Terminalia elliptica, Boswellia serrata, Hardwickia binnata* are found at dry elevated areas. *Aristida adscensionis, Cynodon dactylon, Heteropogon contortus, Imperata cylindrica, Sporobolus orientalis,* and *Chrysopogon zizanoides* composed the major grass species. This park also supports carnivores like tiger (*Panthera tigris*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), grey wolf (*Canis lupus*), striped hyena (*Hyaena hyena*), jackal (*Canis aureus*), and sloth bear (*Melursus ursinus*). Wild herbivores found in the park are chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*), nilgai (*Boselaphus tragocamelus*), chousingha (*Tetracerus quadricornis*) and wild pig (*Sus scrofa*) (Tiger Conservation Plan 2013).

There are 24 villages situated in the core area of Nagarjunasagar Srisailam Tiger Reserve. These villages are home to two tribal communities - the Chenchus and the Lambadas who along with their livestock are dependent on the park resources. Presently, the extended core of Nagarjunasagar Srisailam Tiger Reserve, with minimal human disturbance has higher tiger presence compared to the areas where there is high human presence.

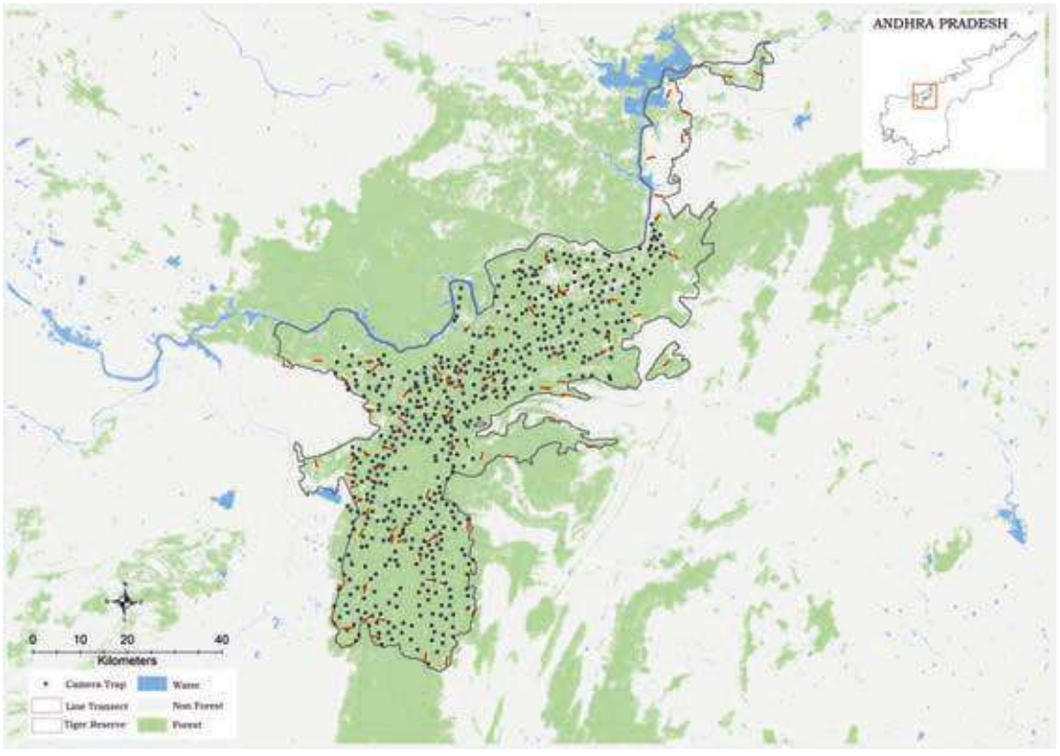


Figure 10.265
Camera trap and line transect layout in Nagarjunasagar SrisailamTiger Reserve, 2018

RESULTS

Tiger Density Estimates

A total of 1057 usable tiger images were obtained from which 38 tiger individuals were identified. Tiger density was estimated at 0.91 (SE 0.14) tigers per 100 km^2 (Table 10.98). The detection corrected was female biased (Table 10.98).

Table 10.98

Sampling details and tiger density parameter estimates using spatially explicit capture-recapture analysis in a likelihood framework for NagararjunasagarSrisailam Tiger Reserve, 2018.

Variables	Estimates
Model space (km^2)	4687.5
Camera points	572
Trap nights (effort)	19938
Unique tigers captured	38
Model	g_0 (sex) σ (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.91 (0.14)
σ Female (SE) km	4.14 (0.08)
σ Male (SE) km	6.09 (0.28)
g_0 Female (SE)	0.040 (0.002)
g_0 Male (SE)	0.20 (0.002)
Pmix Female (SE)	0.76 (0.06)
Pmix Male (SE)	0.24 (0.06)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

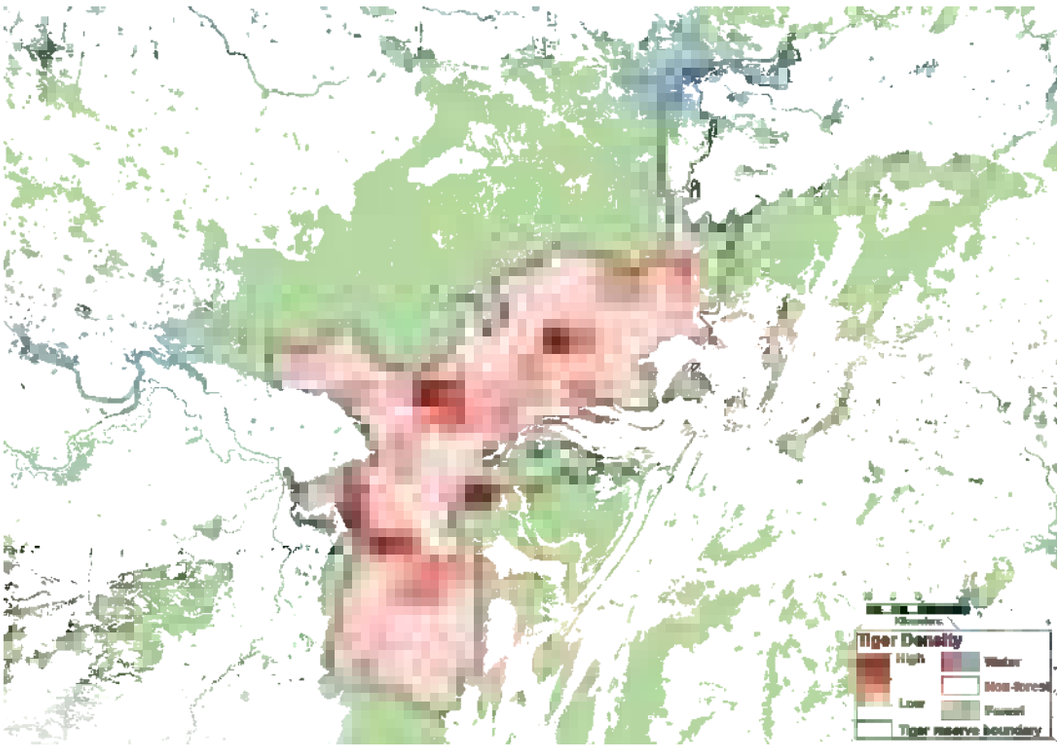
σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Figure 10.266

Spatial density of tigers in Nagarjunasagar Srisailam Tiger Reserve, 2018



Nagarjunasagar Srisailam Tiger Reserve is the only tiger reserve in the state of Andhra Pradesh. Within the tiger reserve Gundla Brameswaram Sanctuary in the southern part of the reserve and Dornala and Srisailam ranges in the northern portion of the reserve (which is dominated by dry mixed deciduous forest and teak forests) had the highest density of tigers.

Distribution of Major Mammalian Fauna in Nagarjunasagar Srisailam Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Nagarjunasagar Srisailam Tiger Reserve.

Wild dogs were distributed throughout the tiger reserve with a higher concentration of photo-captures in the dry teak and mixed deciduous habitat of the Dornala range of the reserve.

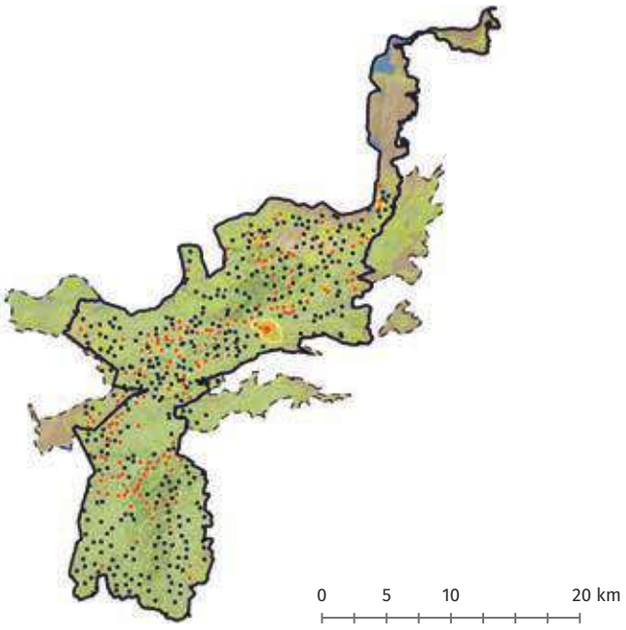


Figure 10.267
Distribution and relative spatial abundance of wild dog in Nagarjunasagar Srisailam Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Jungle cat was photo captured across the tiger reserve and occurred in various habitats like dry deciduous scrub, dry teak, and grasslands.

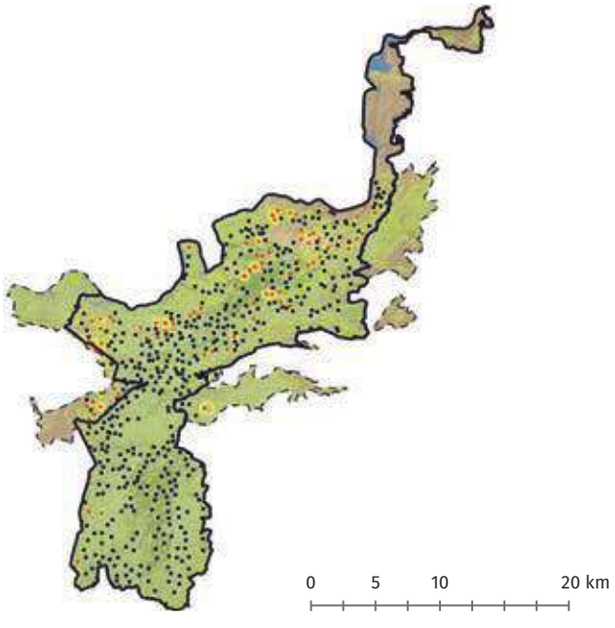


Figure 10.268
Distribution and relative spatial abundance of Jungle cat in Nagarjunasagar Srisailam Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

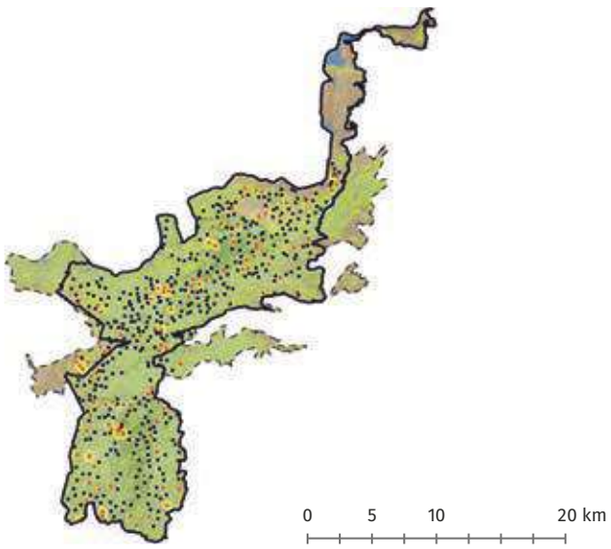


Figure 10.269

Distribution and relative spatial abundance of Rusty-spotted cat in Nagarjunasagar Srisailam Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

Rusty-spotted cat was distributed throughout the reserve and the captures were concentrated in dry mixed deciduous scrub habitats. Higher photo-captures were also obtained in the Velgode range of the extended core of Nagarjunasagar Srisailam Tiger Reserve.

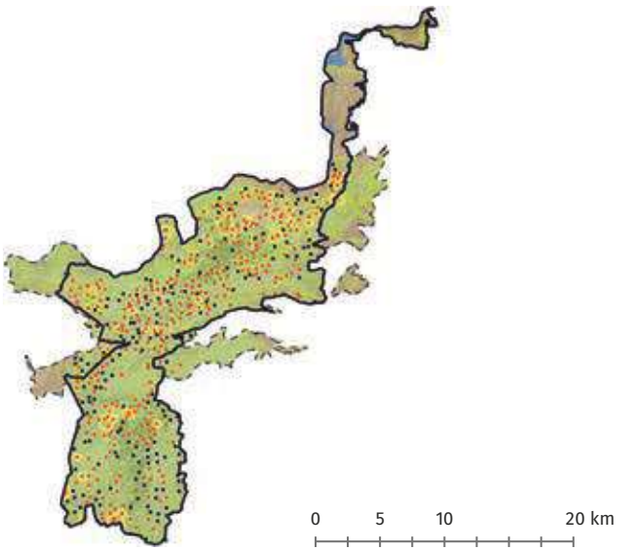


Figure 10.270

Distribution and relative spatial abundance of Leopard in Nagarjunasagar Srisailam Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

Leopard was distributed throughout the park with higher photo-captures in the southern and northern portion of the park in dry mixed deciduous scrub and grassland habitats.

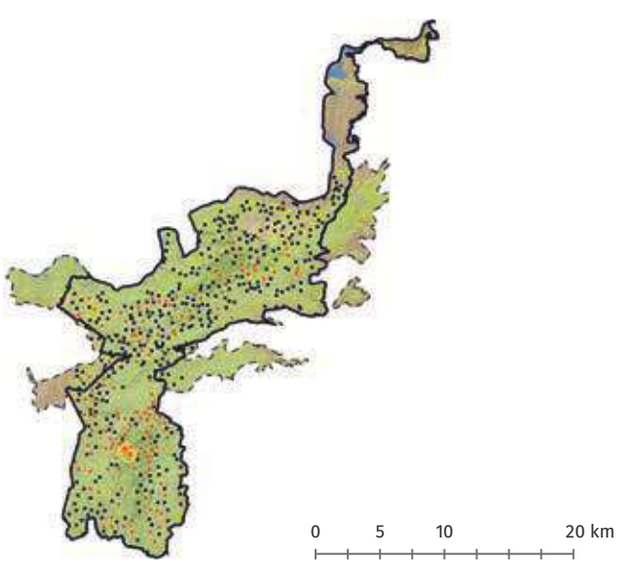


Figure 10.271

Distribution and relative spatial abundance of Mousedeer in Nagarjunasagar Srisailam Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures

The photo captures of mouse deer were found to be high and distributed throughout the park except for V.P. South range. Higher photo-captures were obtained from Gundla Brameswaram Sanctuary within Gundlakamma range which is dominated by dry mixed deciduous forest habitat with few patches of grassland.

Blackbuck was captured only in the Gundla Brameswaram Sanctuary part of Nagarjunasagar Srisailam Tiger Reserve in Bairlutty range which is dominated by dry deciduous scrub forest.

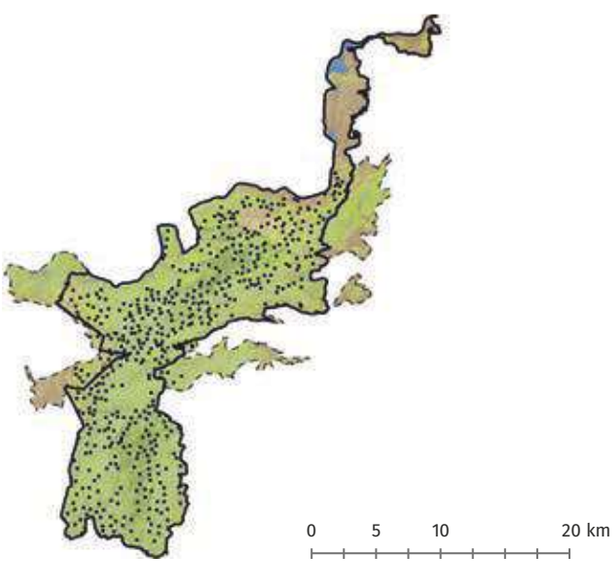


Figure 10.272
Distribution and relative spatial abundance of Blackbuck in Nagarjunasagar Srisailam Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Chousingha was photo captured throughout the reserve with higher photo-captures in the northwestern part of Nagarjunasagar Srisailam Tiger Reserve. This region of Markapur division, and Bairlutty range of Gundla Brameswaram Sanctuary was dominated by dry mixed deciduous forest patches in Markapur division and in the Gundla Brameswaram Sanctuary part of Bairlutty range.

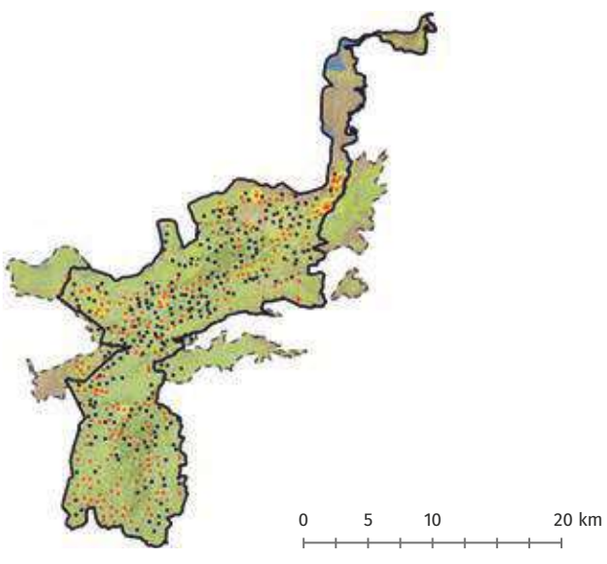


Figure 10.273
Distribution and relative spatial abundance of Chousingha in Nagarjunasagar Srisailam Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Sloth bear was distributed throughout the reserve and was mainly concentrated in the western part of the reserve in Bairlutty range of Gundla Brameswaram Sanctuary.

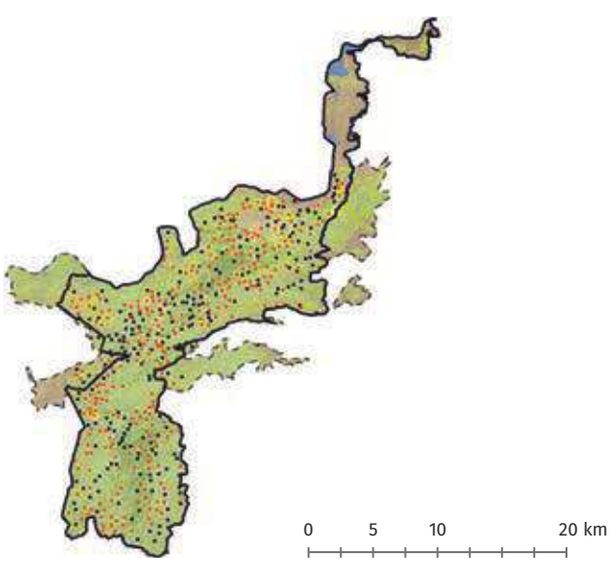


Figure 10.274
Distribution and relative spatial abundance of Slothbear in Nagarjunasagar Srisailam Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour lines depict intensity of photo-captures.

Table 10.99

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Nagarjunasagar Srisailam Tiger Reserve,2018.

Common Name	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Blackbuck	0.02	4984.50
Chital	5.00	20.02
Chousingha	4.85	20.62
Common palm civet	3.03	33.01
Domestic cats	0.02	6646.00
Domestic dogs	8.25	12.12
Hanuman langur	4.44	22.53
Honey badger	2.48	40.36
Honey badger	2.48	40.36
Indian crested porcupine	15.97	6.26
Indian grey mongoose	0.62	162.10
Indian hare	20.71	4.83
Jungle cat	1.04	96.32
Leopard	5.78	17.29
Livestock	5.49	76.35
Mouse deer	2.47	40.52
Nilgai	1.46	68.28
Nilgai	1.46	68.28
Pangolin	0.01	19938.00
Peafowl	5.30	18.88
Ruddy mongoose	4.74	21.08
Rusty spotted cat	0.84	119.39
Sambar	13.61	7.35
Sloth bear	4.97	20.14
Small indian civet	5.16	0.11
Tiger	3.11	32.11
Wild dog	1.94	51.65
Wild pig	6.68	14.98

Relative Abundance of all Photocaptured Species in Nagarjunasagar Srisailam Tiger Reserve

A total of 42 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Hare was the most frequent photo-captured mammal while pangolin was the rarest species photo-captured followed by domestic cat (Table 10.99).

DISCUSSION

Compared to the previous estimates obtained in 2014 (0.85±0.8, Jhala et al. 2015), there has been no change in the tiger density. A total of 339 transects were walked giving an effort of 687.6 km, covering the entire tiger reserve. Prey sighting was very low and hence prey densities could not be estimated. For the health and growth of the tiger population, it is imperative to focus on the prey population and control the anthropogenic pressure inside the park like livestock grazing and hunting of wild animals. The local tribal hemlets within the tiger reserve are a major source of anthropogenic disturbances and need to be targeted for incentivized voluntary relocation. Till human pressure is reduced the Tiger Reserve is unlikely to improve in its prey and tiger status any further. Nagarjunasagar Srisailam Tiger Reserve is connected to Seshachalam biosphere reserve through forested patches and three protected areas- Sri Lankamalleswaram Wildlife Sanctuary, Sri Venkestwara National Park and Sri Penusila Narasimha Wildlife Sanctuary (Qureshi et al. 2014). This corridor is important for tiger movement in the landscape and hence must be prioritized for effective conservation.

PAPIKONDA NATIONAL PARK

INTRODUCTION

Papikonda National Park is named after the Papi hills of the Eastern Ghats. The national park with an area of 1012.85 km^2, lies between 18° 49' 20" N to 19° 18' 14" N, 79° 54' 13" E to 83° 23' 35" E and spreads across the East and West Godavari districts of Andhra Pradesh.

Papikonda National Park primarily consists of southern tropical mixed moist deciduous, along with some semi-evergreen and dry deciduous forest patches (Champion and Seth 1968, Rao 2000, Reddy et al. 2010). The area is mostly inaccessible with high steep slopes, valleys and has high rainfall.

Major flora includes *Tectona grandis, Lagerstroemia parviflora, Adina cordifolia, Pterocarpus marsupium, Dalbergia latifolia, Gmelina arborea, Artocarpus intergrifolia, Madhuca latifolia, Dendrocalamus strictus* and *Bambusa arundinacea*. Papikonda National Park harbors a high faunal diversity that includes tiger (*Panthera tigris*), leopard (*Panthera pardus*), leopard cat (*Prinailurus bengalensis*), rusty-spotted cat (*Prionailurus rubiginosus*), wild dog (*Cuon alpinus*), jackal (*Canis aureus*), grey wolf (*Canis lupus*), striped hyena (*hyena hyena*), sloth bear (*Melursus ursinus*), gaur (*Bos gaurus*), nilgai (*Boselaphus tragocamelus*), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), chinkara (*Gazella benetti*), wildpig (*Sus scrofa*), chousingha (*Tetracerus quadricornis*) and blackbuck (*Antelope cervicapra*), amongst others.

Papikonda National Park is a unique place acting as a potential nursery for many wild animals guarded by a series of hillocks on either side of the river Godavari. The hilltops are devoid of any human population, support dry savannah forests (5D/S2) and form an excellent breeding ground for gaur and in all likelihood harbors tigers.

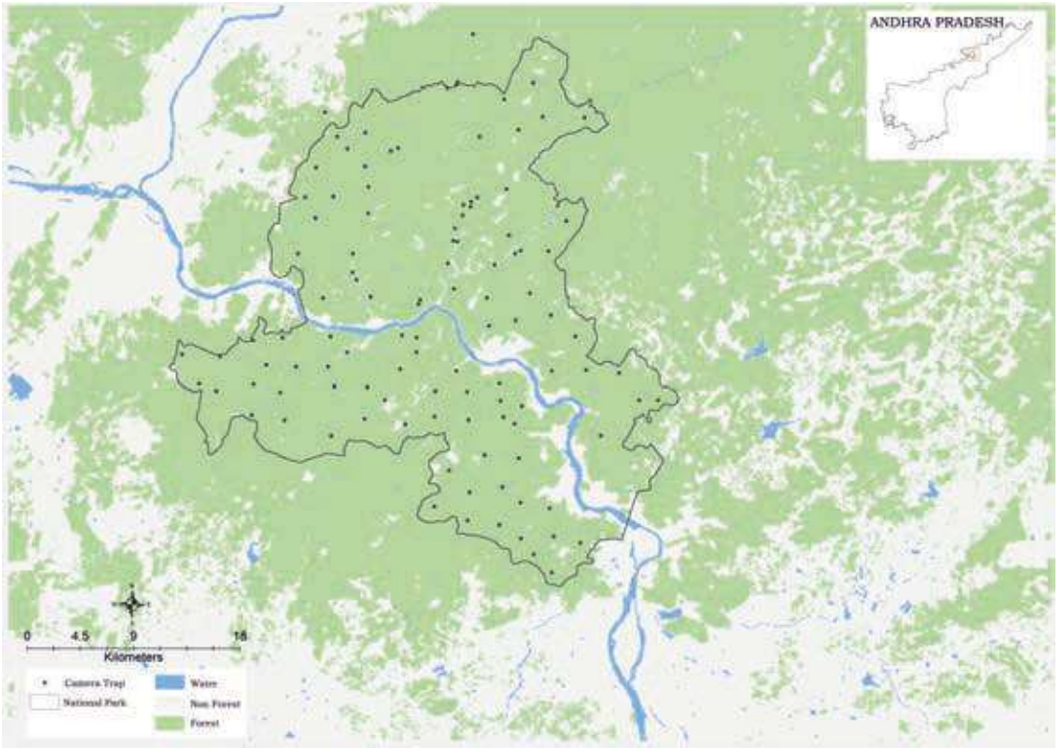


Figure 10.275
Camera trap layout in Papikonda National Park, 2018

RESULTS

Camera Trap Results

No tiger was photo-captured during the camera trap session (Table 10.100).

Table 10.100

Sampling details of camera trapping exercise in Papikonda National Park,2018

Sampling details	Counts
Camera points	110
Trap nights (effort)	2395

DISCUSSION

Threats such as shifting cultivation and plantation caused loss of moist deciduous forests. Mitigating the impacts of shifting cultivation, dams and other development projects in and around Papikonda National Park, particularly in the easily accessible low elevation dry deciduous forests would aid in the long-term conservation in Papikonda National Park (Aditya and Ganesh 2017).

SESHACHALAM

INTRODUCTION

Seshachalam Biosphere Reserve is situated in the districts of Chittoor and Kadapa in Andhra Pradesh. The total geographical area of the reserve is 4,755 km^2. Seshachalam is divided into three parts core (750 km^2), buffer (1865.15 km^2) and transition zones (2140 km^2).

SBR falls under the biogeographic zone of the Deccan peninsula and province 6E-Deccan south of India. The forest of Seshachalam is categorized as southern dry mixed deciduous forest miscellaneous type by (Champion and Seth 1968). This forest type includes endemic vegetation like *Pterocarpus santalinus, Shorea tumbaggaia, Boswellia ovalifoliota* and *Syzygium alternifoliu*. This landscape harbors a rich diversity of fauna which includes carnivores likes the tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), jackal (*Canis aureus*), wolf (*Canis lupus*), sloth bear (*Melursus ursinus*). Ungulates include Asian elephant (*Elephas maximus*), gaur (*Bos gaurus*), nilgai (*Boselaphus tragocamelus*), sambar (*Rusa unicolor*), chital (*Axis axis*), chinkara (*Gazella bennettii*), wild pig (*Sus scrofa*), chousingha (*Tetracerus quadricornis*) and blackbuck (*Antelope cervicapra*).

Seshachalam is connected to Nagarjunasagar Srisailam Tiger Reserve through Giddalur, Nandyala division and the protected areas of Sri Lankamalleswaram Wildlife Sanctuary, Sri Venkestwara National Park and Sri Penusila Narasimha Wildlife Sanctuary. However, there are several national and state highways cutting across this corridor. The adverse effects of these linear structures need to be appropriately mitigated by constructing under and over-wildlife passes. The major pinch point is a patch of revenue land and the township of Sidhavatam covering a stretch of 2 km of the corridor, which would benefit from restorative measures need to be undertaken to minimise this barrier to wildlife movement. The tiger density in Nagarjunasagar Srisailam Tiger Reserve especially in Gundla Brahmeswaram Wildlife Sanctuary is slowly recovering; once this population increases, dispersing tigers are likely to recolonize from where they have become locally extinct.

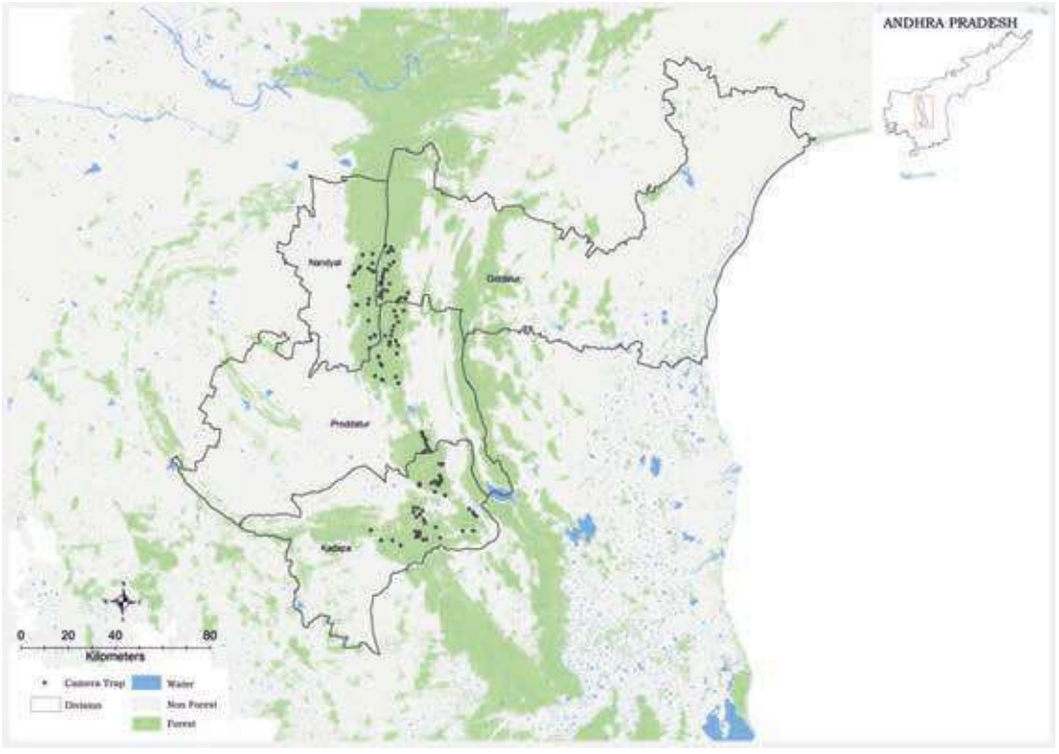


Figure 10.276
Camera trap layout in Seshachalam Landscape, 2018

RESULTS

Tiger Density Estimates

A total of 33 usable tiger images were obtained from which 8 tiger individuals were identified. 150 cameras were deployed throughout the landscape, where tiger density was estimated as 0.29 (SE 0.10) tiger per 100 km^2. The detection corrected sex ratio was female biased (Table 10.101).

Table 10.101

Sampling details and tiger density parameter estimates using spatially explicit capture-recapture analysis in a likelihood framework for Seshachalam landscape, 2018.

Variables	Estimates
Model space (km^2)	3274.75
Camera points	150
Trap nights (effort)	2679
Unique tigers captured	8
Model	g_0 (.) σ (.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.29 (0.10)
Sigma (SE)	6.62 (1.00)
g_o (SE)	0.012 (0.003)
Pmix Female (SE)	0.57 (0.18)
Pmix Male (SE)	0.43 (0.18)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_o: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Camera-trapping was carried out for the first time in this landscape. If this landscape is well protected by minimizing the anthropogenic pressure especially the 2 km corridor stretch it can sustain a good tiger population along with Nagarjunasagar Srisailam Tiger Reserve and potentially permit tiger occupancy in the southern parts of the Eastern Ghat landscape.

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ANSHI DANDELI (KALI) TIGER RESERVE

INTRODUCTION

Kali (Dandeli-Anshi) Tiger Reserve is constituted together with Dandeli Wildlife Sanctuary and Anshi National Park and covers a total area of 1,306 km^2. It was declared as a tiger reserve in the year 2007.It lies in Uttara Kannada district of Karnataka at a location 74° 26' E and 15° 7' N. Together with seven other neighboring protected areas in Karnataka, Goa and Maharashtra, the tiger habitats around Dandeli-Anshi extend over 5,000 km^2 of deciduous and semi-evergreen forests. The western parts of the reserve receive seasonal heavy rainfall from the South-West Monsoon to of 3000-6000 mm. A number of villages and even townships are located within the Dandeli-Anshi Tiger Reserve and the Tiger Reserve has widespread anthropogenic human modifications such as large human settlements, reservoirs and industries. The vegetation comprises of tropical evergreen, semi-evergreen and moist deciduous forests. These forests of Malenad landscape in the Western Ghats supports large assemblages of carnivores and herbivores: tiger (*Panthera tigris*), leopard (*Panthera pardus*), Asiatic wild dog (*Cuon alpinus*) and sloth bear (*Melursus ursinus*), Asiatic elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), muntjac (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), mouse deer (*Moschiola indica*) and hanuman langur (*Semnopithecus entellus*).

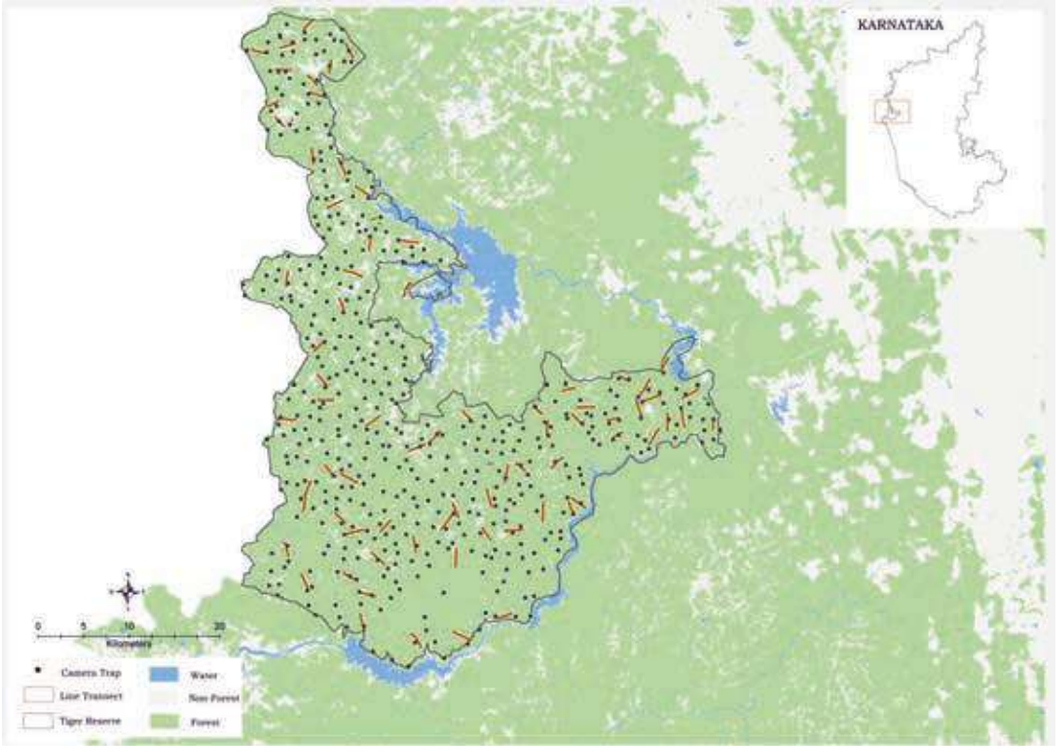


Figure 11.1
Camera trap and transect layout in Anshi Dandeli (Kali) Tiger Reserve, 2018-19

RESULTS

Camera Trap Results

A total of 461 camera traps were deployed in Kali TR yielding 43 tiger images from which 4 individual tigers were identified (Table 11.1).

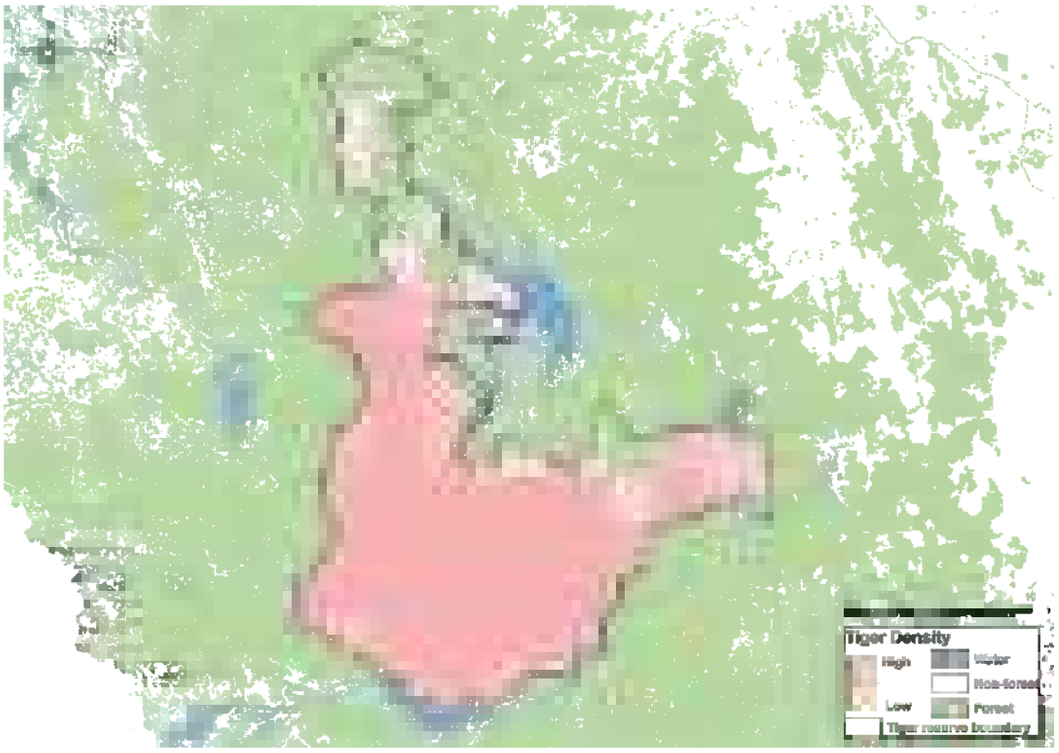
Table 11.1

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Kali Tiger Reserve, 2018-19.

Variables	Estimates
Camera points	461
Trap nights (effort)	11131
Unique tigers captured	4

Figure 11.2

Spatial density of tigers in Kali Tiger Reserve, 2018-19. generated from SECR covariate model for the Western Ghat Landscape



Tigers were more or less evenly distributed within the Kali Tiger Reserve except the northern part of Bhimgad Wildlife Sanctuary.

Prey Density Estimates

A total of 440 transects were sampled in Kali Tiger Reserve which amounted to an effort of 836.37 km. Barking deer was found to be the most abundant ungulate in Kali TR (Table 11.2).

Table 11.2

Model statistics and parameter estimates of line transect (n=440, Total effort 836.37 km) based distance sampling for prey species in Kali TR, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital	29.84 (1.69)	25	3.56 (0.49)	0.24 (0.01)	0.03	0.50 (0.10)	1.78 (0.44)
Sambar	29.76 (2.09)	30	1.16 (0.08)	0.11 (0.008)	0.03	0.60 (0.11)	0.70 (0.14)
Gaur	24.99 (2.65)	21	3.57 (0.65)	0.19 (0.02)	0.02	0.50 (0.12)	1.79 (0.55)
Barking deer	29.17 (2.18)	23	1.04 (0.04)	0.22 (0.01)	0.02	0.47 (0.10)	0.49 (0.10)
Wild pig		13	4.76 (1.78)		0.01		

Distribution of Major Mammalian Fauna in Kali Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Kali Tiger Reserve.

Elephant photo-captures were maximum from the easternmost part of the park (Ambikanagar area).

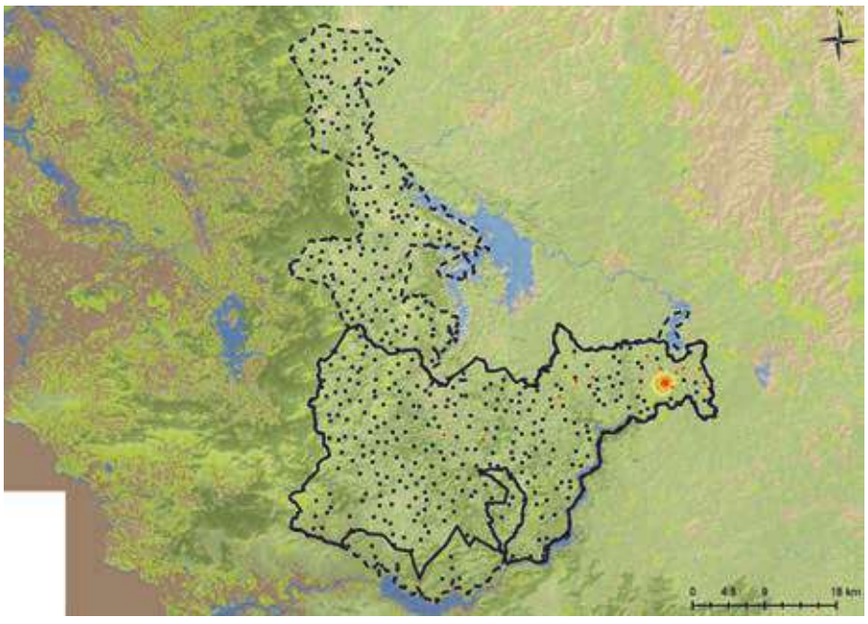


Figure 11.3

Distribution, and relative spatial abundance of elephant in Kali TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

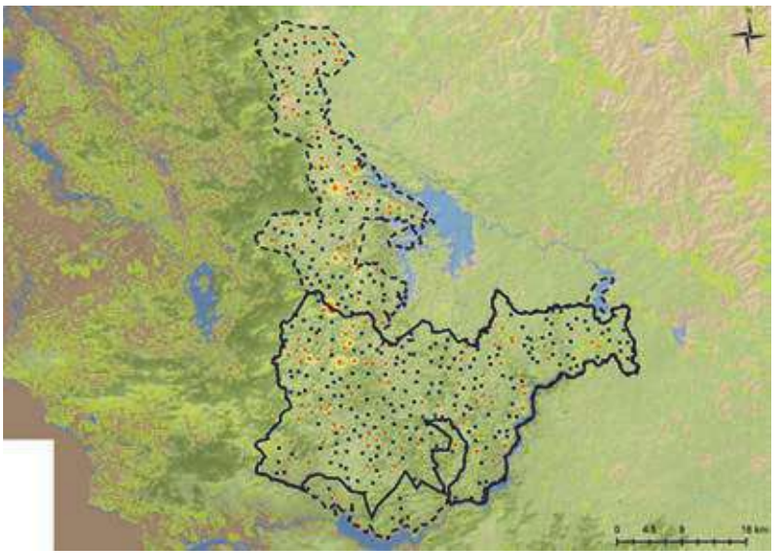


Figure 11.4

Distribution, and relative spatial abundance of gaur in Kali TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Gaur photo-captures were from across the tiger reserve.

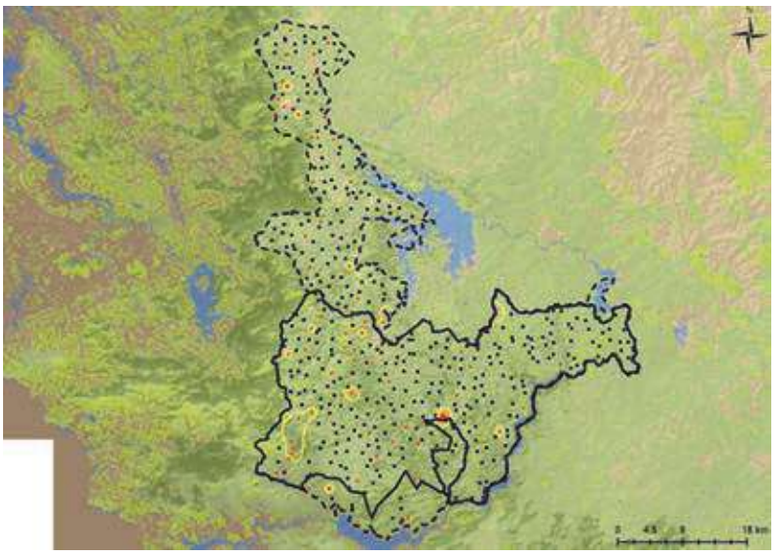


Figure 11.5

Distribution, and relative spatial abundance of mouse deer in Kali TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Mouse deer were photocaptuted across the tiger reserve with maximum concentration from Anshi.

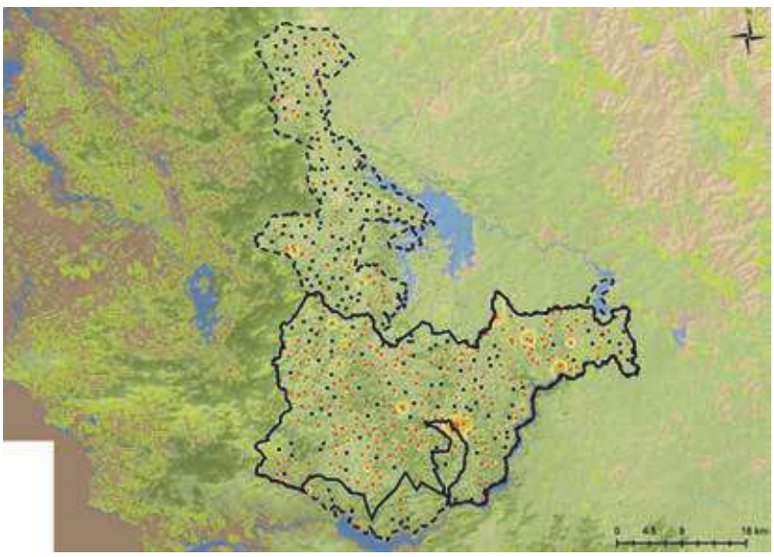


Figure 11.6

Distribution, and relative spatial abundance of leopard in Kali TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard distribution was widespread from all across the tiger reserve.

Dhole was photocaptured from both Anshi and Dandeli divisions of the tiger reserve.

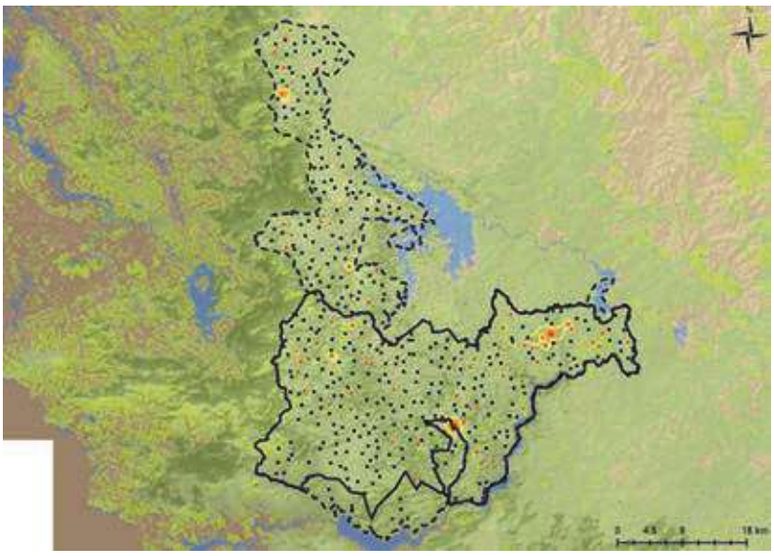


Figure 11.7

Distribution, and relative spatial abundance of dhole in Kali TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Sloth bear was also photcaptured from both Anshi and Dandeli divisions with maximum captures from Patoli Cross area.

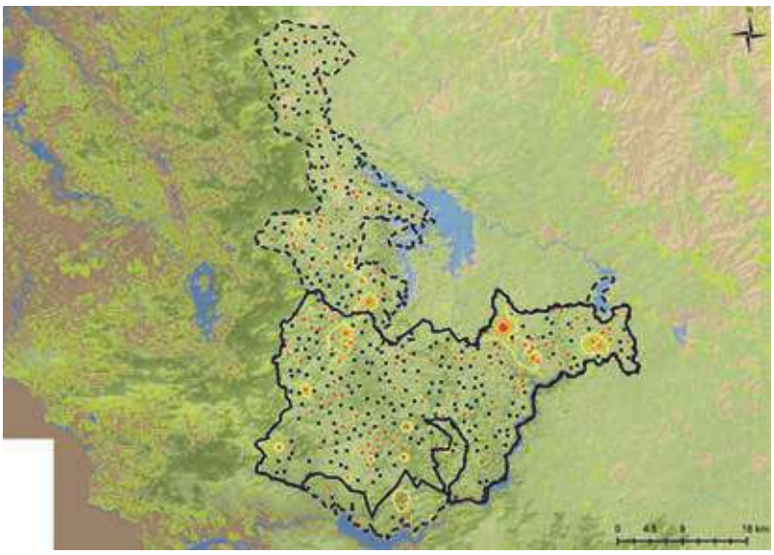


Figure 11.8

Distribution, and relative spatial abundance of sloth bear in Kali TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Jungle cat photocapture s were few with maximum captures from Kumbarwada area of the tiger reserve.

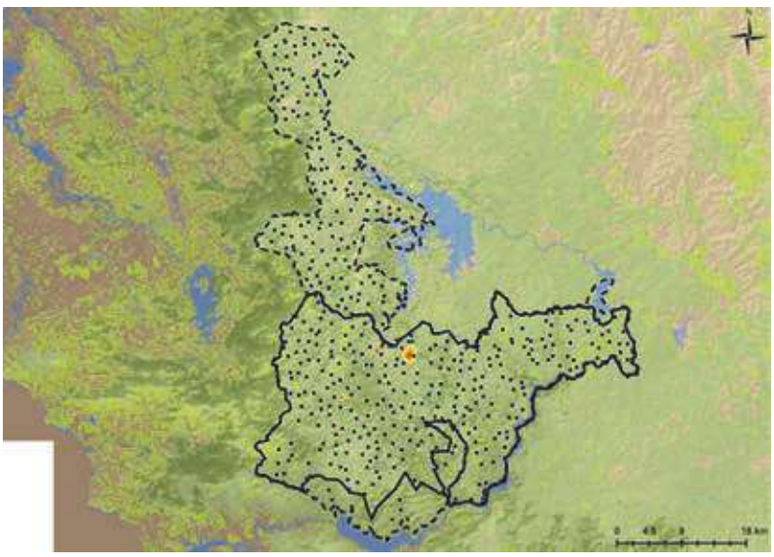


Figure 11.9

Distribution, and relative spatial abundance of jungle cat in Kali TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

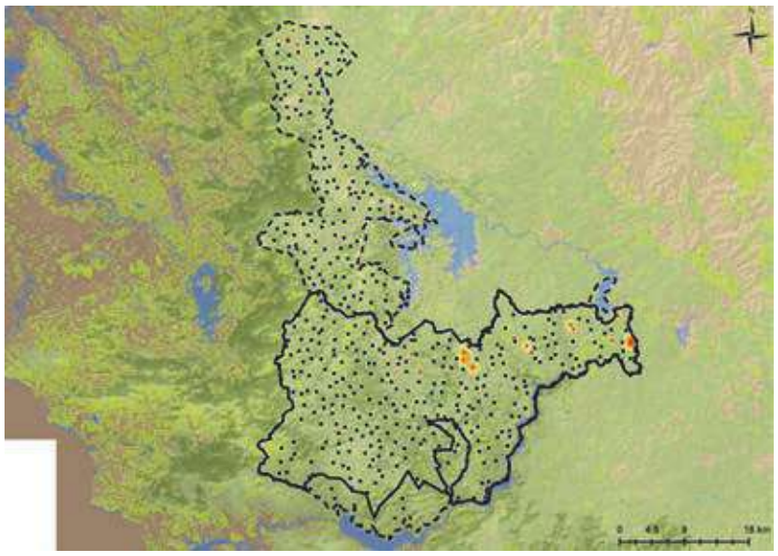


Figure 11.10

Distribution, and relative spatial abundance of golden jackal in Kali TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Golden jackal was photcaptured sparsely and mostly from Anshi Division of the tiger reserve.

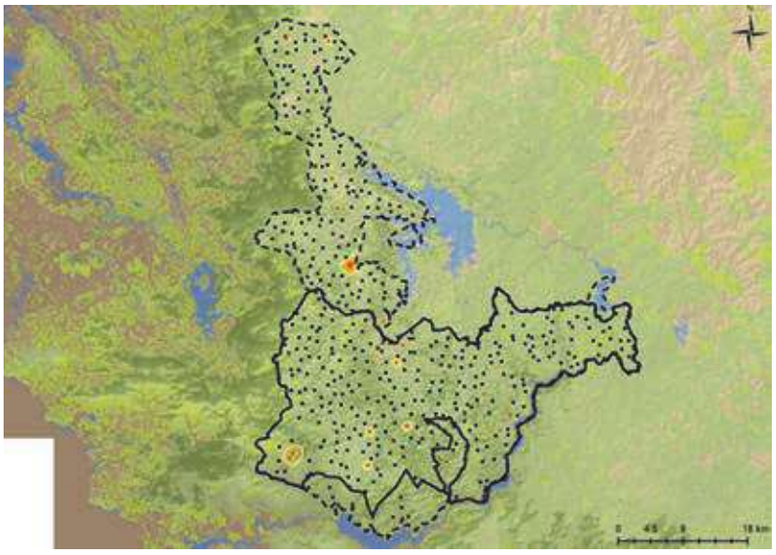


Figure 11.11

Distribution, and relative spatial abundance of leopard cat in Kali TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard cat distribution was recorded from both Anshi and Dandeli divisions of the tiger reserve.

Relative Abundance of all Photocaptured Species in Kali Tiger Reserve

A total of 28 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Wild pig, leopard and porcupine were the most commonly photo-captured species (Table 11.3). Bonnet macaque was the rarest species photo-captured followed by pangolin.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	2.01	50
Black-naped hare	1.87	54
Bonnet macaque	0.07	1391
Chital	1.78	56
Common palm civet	0.34	293
Domestic cat	0.02	5566
Domestic dog	6.78	15
Elephant	0.52	192
Gaur	3.85	26
Golden jackal	0.35	285
Grey jungle fowl	0.37	271
Hanuman langur	1.80	56
Indian grey mongoose	0.23	428
Indian pangolin	0.08	1237
Indian porcupine	5.35	19
Jungle cat	0.18	557
Leopard	5.79	17
Leopard cat	0.21	484
Livestock	25.60	4
Monitor Lizard	0.04	2783
Mouse deer	0.88	114
Peafowl	4.06	25
Sambar	5.16	19
Sloth bear	2.94	34
Small Indian civet	2.62	38
Stripe-necked mongoose	0.26	384
Tiger	0.27	371
Wild dog	0.92	109
Wild pig	7.80	13

Table 11.3
Details of all photocaptured species and their relative abundance index (RAI) in Anshi-Dandeli Tiger Reserve, 2018-19.

DISCUSSION

Ungulate and tiger densities were low in Kali Tiger Reserve, likely due to the high human pressures within the Tiger Reserve. There are 52 villages within critical core tiger habitat which need to be resettled outside the Tiger Reserve following NTCA's incentivized voluntary village resettlement scheme.

BANDIPUR TIGER RESERVE

INTRODUCTION

Bandipur Tiger Reserve in Karnataka is a 912 km^2 protected area predominantly consisting of tropical deciduous forests and dry-deciduous scrub forests. Bandipur was declared as a national park in the year 1974. The National Park is situated at 76° 45' E and 11° 48' N. It receives an annual rainfall of 700-1200mm. Bandipur supports four habitat types: dense forest, woodland to savanna woodland, tree savanna and scrub woodland and dense thicket. The areas surrounding the park have large anthropogenic habitat modifications such as agricultural lands, plantations and pasture lands. There are over 156 villages located around the park, supporting a population of 1, 26,000 people and livestock population of 1,16,000. The forests of Malenad landscape in the Western Ghats supports large assemblages of carnivores and herbivores: tiger (*Panthera tigris*), leopard (*Panthera pardus*), Asiatic wild dog (*Cuon alpinus*) and sloth bear (*Melursus ursinus*), Asiatic elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), muntjac (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), mouse deer (*Moschiola indica*) and hanuman langur (*Semnopithecus entellus*).

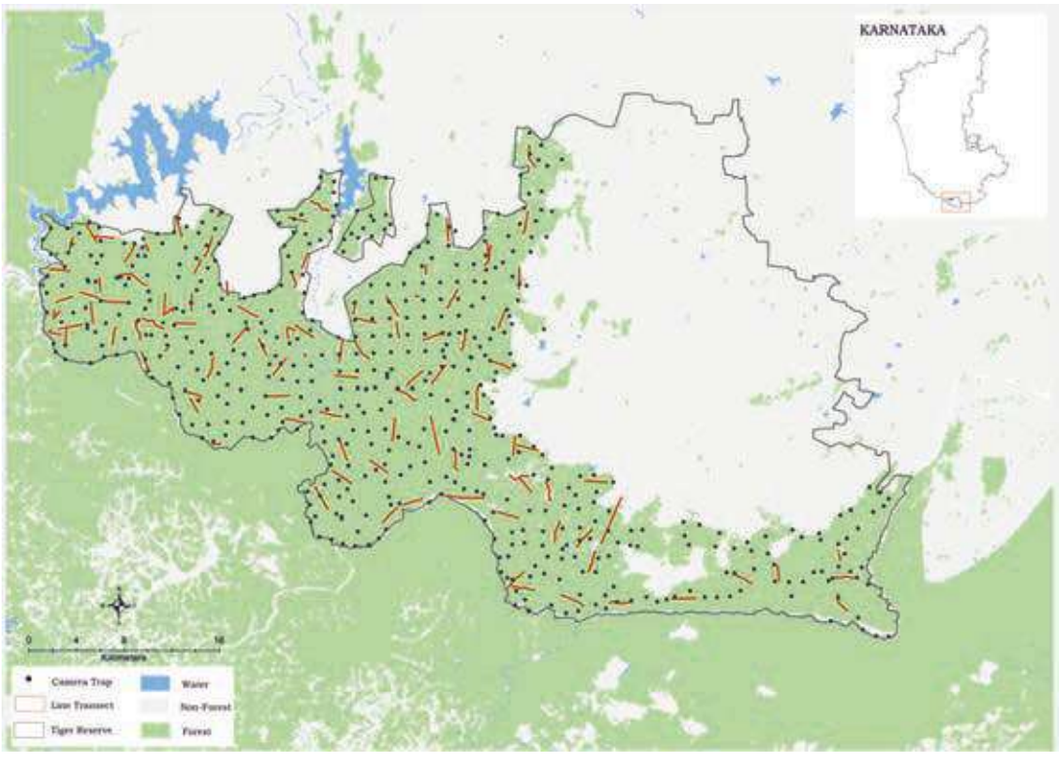


Figure 11.12
Camera trap and transect layout in Bandipur Tiger Reserve, 2018-19

RESULTS

Tiger Density Estimates

A total of 534 camera traps were deployed in Bandipur Tiger Reserve yielding 1,479 tiger detections (including 127 photos of cubs) from which 126 individual tigers were identified. Density of tigers in the Tiger Reserve was estimated to be 7.70 (SE 0.71) per 100 km^2 (Table 11.4). The detection corrected tiger male to female sex ratio in Bandipur was 0.41:0.59 (Table 11.4).

Variables	Estimates
Model space (km^2)	2029.12
Camera points	534
Trap nights (effort)	20512
Unique tigers captured	126
Model	g_0 (sex) σ (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	7.70 (0.71)
σ Female (SE) km	1.70 (0.04)
σ Male (SE) km	2.85 (0.07)
g_0 Female (SE)	0.01 (0.001)
g_0 Male (SE)	0.01 (0.0007)
Pmix Female (SE)	0.59 (0.04)
Pmix Male (SE)	0.41 (0.04)

Table 11.4

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Bandipur Tiger Reserve, 2018-19.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

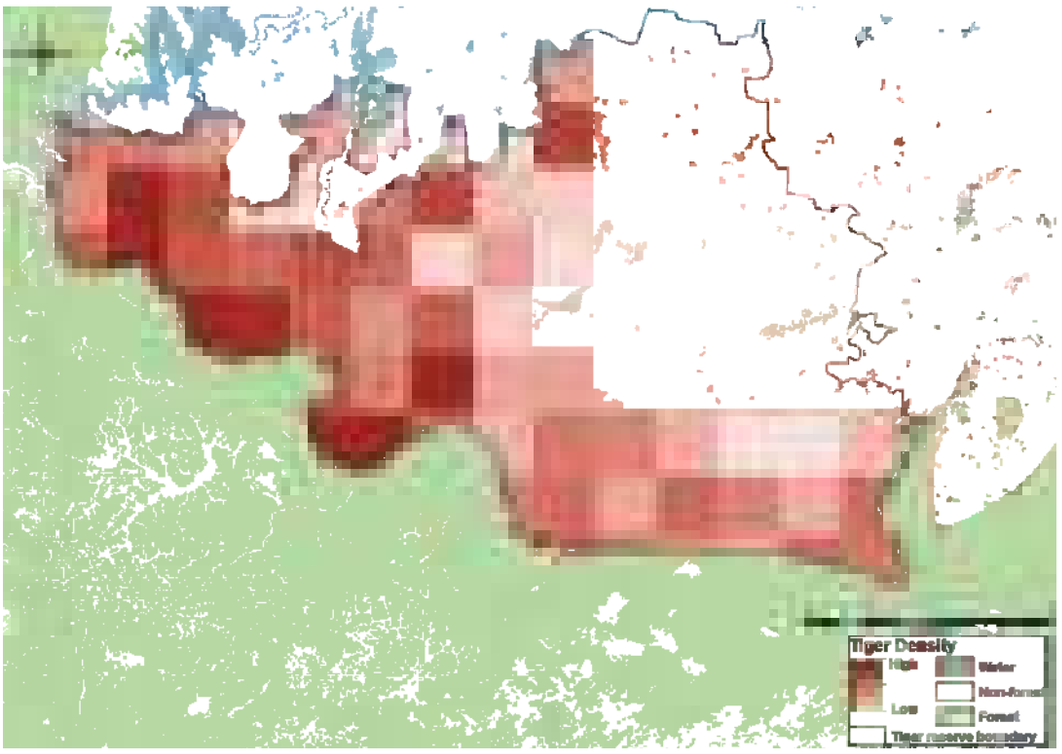


Figure 11.13

Spatial density map of tigers in Bandipur Tiger Reserve, 2018-19

Tigers were more or less evenly distributed within the critical tiger habitat of Bandipur Tiger Reserve. Some high density pockets were seen along the southern and western parts of the Tiger Reserve (Mooleholle, Gundre and N. Begur areas).

Prey Density Estimates

A total of 325 transects were sampled in Bandipur Tiger Reserve which amounted to an effort of 603.53 km. Chital was found to be the most abundant ungulate followed by barking deer and sambar in Bandipur Tiger Reserve (Table 11.5).

Table 11.5

Model statistics and parameter estimates of line transect (n=325, Total effort 603.53 km) based distance sampling for prey species in Bandipur Tiger Reserve, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital	30.67 (0.90)	277	6.9 (0.36)	0.12 (0.004)	0.45	7.48 (1.58)	51.72 (11.25)
Sambar	31.08 (1.22)	147	1.8 (0.06)	0.06 (0.002)	0.24	3.91 (0.81)	7.27 (1.52)
Gaur	33.20 (2.14)	16	2.1 (0.35)	0.11 (0.007)	0.02	0.39 (0.10)	0.84 (0.26)
Elephant	47.62 (2.82)	74	2.2 (0.20)	0.12 (0.007)	0.12	1.28 (0.28)	2.95 (0.71)
Wild pig	27.54 (1.98)	14	4.8 (0.86)	0.09 (0.007)	0.02	0.42 (0.13)	2.04 (0.75)
Barking deer	25.88 (1.33)	96	2.8 (0.21)	0.08 (0.004)	0.15	3.07 (0.56)	8.7 (1.7)

Distribution of Major Mammalian Fauna Found in Bandipur Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Bandipur Tiger Reserve.

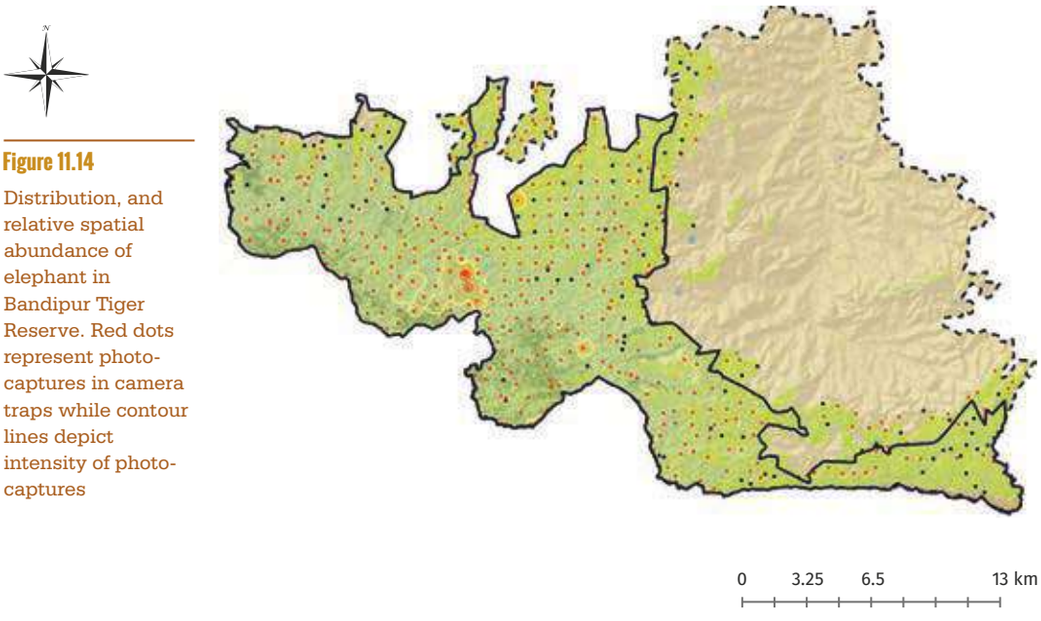


Figure 11.14

Distribution, and relative spatial abundance of elephant in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Elephant was distributed throughout the Tiger Reserve with greater concentration near Ainurmadigudi and Mooleholle.

Gaur was distributed throughout the Tiger Reserve with greater concentration near Ainurmadigudi area.

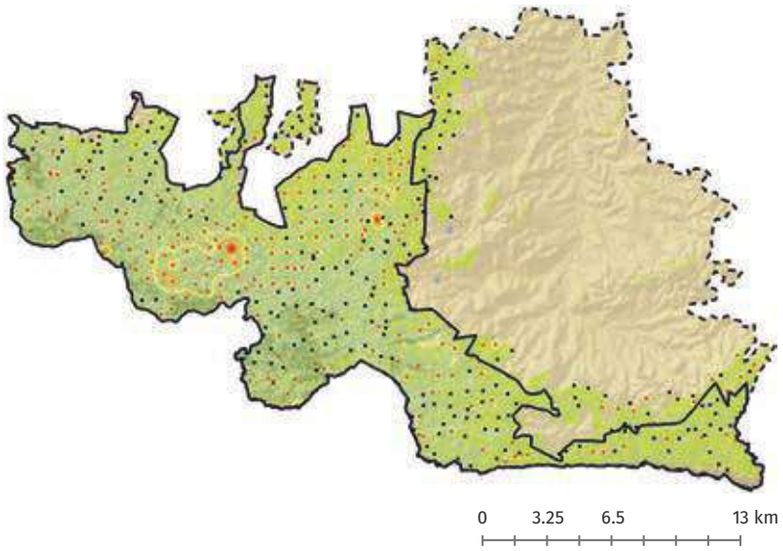


Figure 11.15
Distribution, and relative spatial abundance of gaur in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Chowsingha had a widespread distribution in Bandipur Tiger Reserve with larger concentration of photo-captures from Kundakere (Moyar) area.

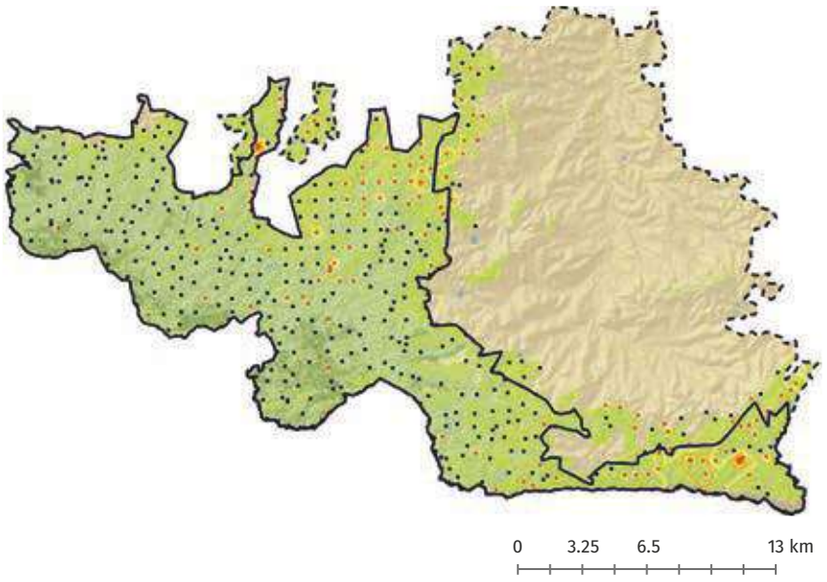


Figure 11.16
Distribution, and relative spatial abundance of chowsingha in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Mouse deer was distributed from throughout the Tiger Reserve with greater concentration of photo-captures from Gopalaswamy Betta area of the tiger reserve.

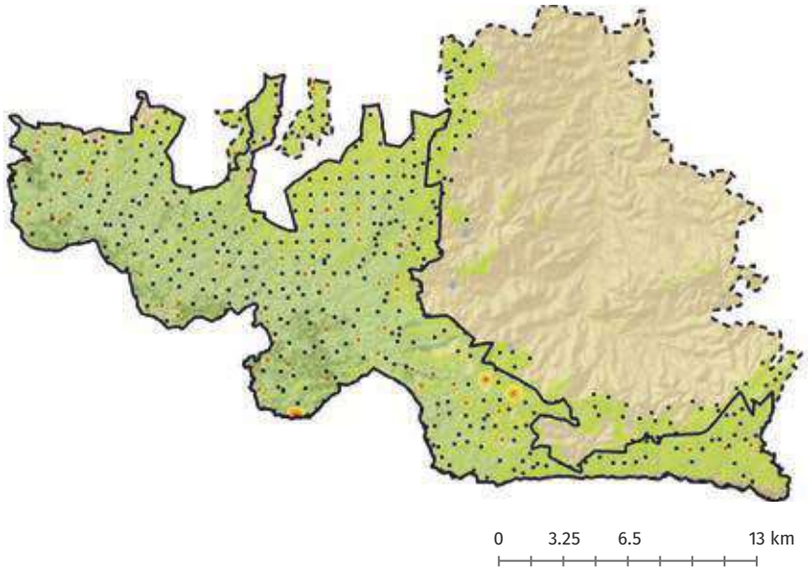


Figure 11.17
Distribution, and relative spatial abundance of mouse deer in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

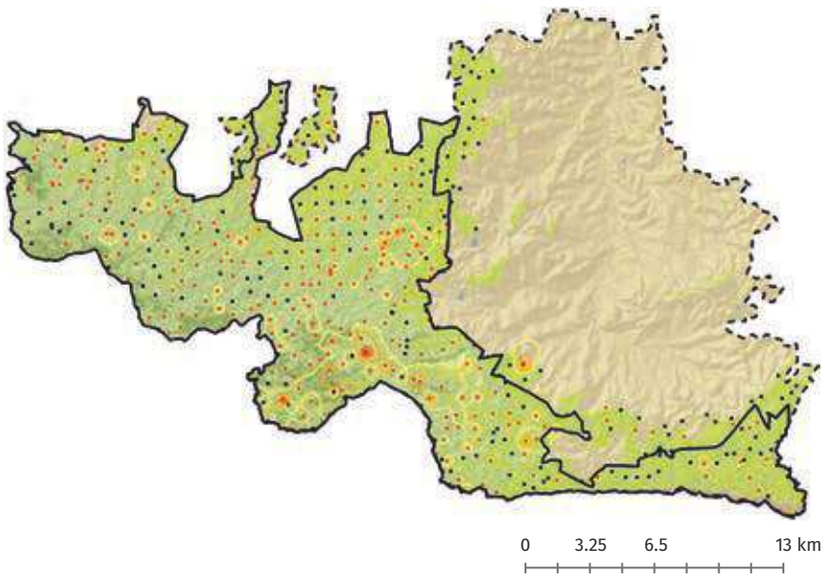


Figure 11.18

Distribution, and relative spatial abundance of leopard in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Leopards were uniformly distributed in the Tiger Reserve with larger concentration towards the periphery of the park.

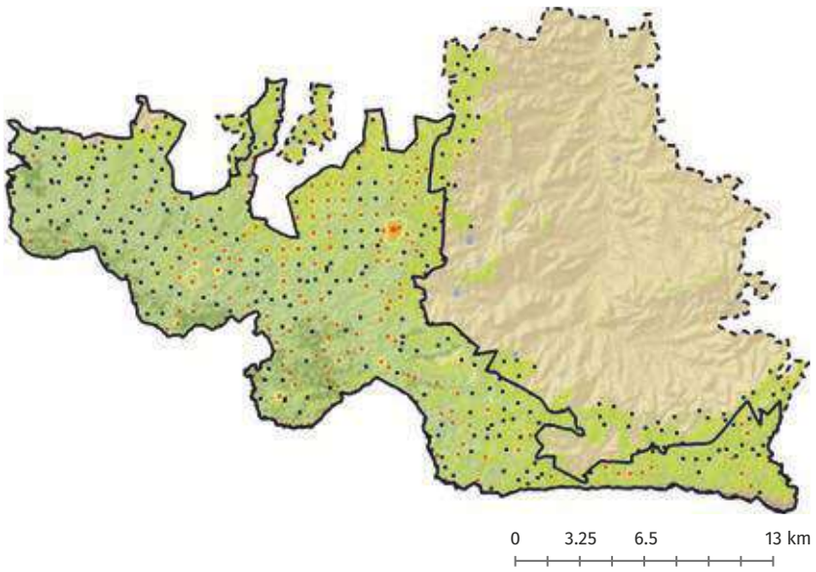


Figure 11.19

Distribution, and relative spatial abundance of dhole in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Dholes were distributed in all areas of the Tiger Reserve.

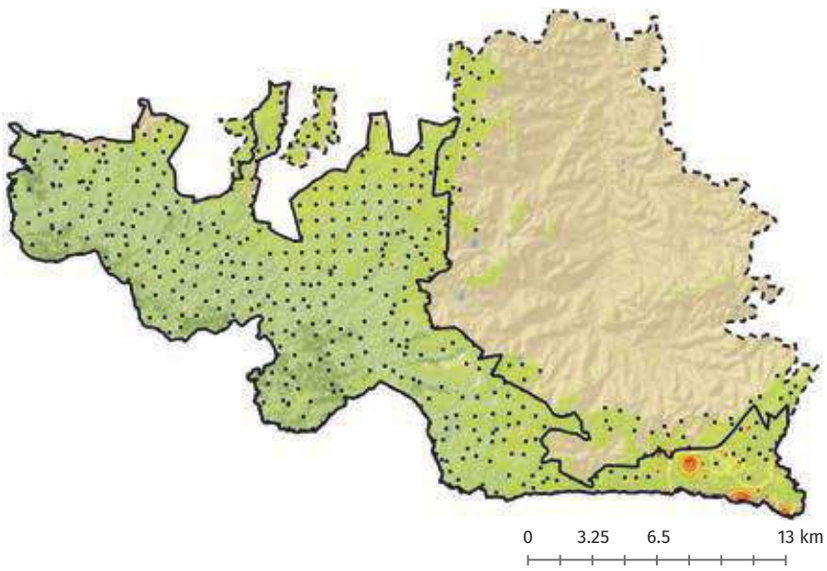


Figure 11.20

Distribution, and relative spatial abundance of hyena in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Hyena had a limited distribution in the Kundekere (Moyar) area of the Tiger Reserve.

Sloth bear photo-captures were maximum from western part of the Tiger Reserve (Gundre, N. Begur, Ainurmarigudi areas).

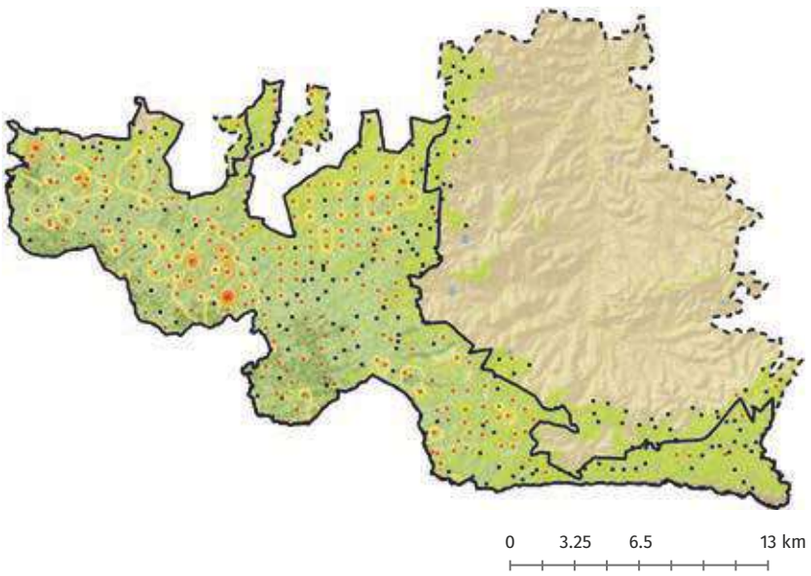


Figure 11.21

Distribution, and relative spatial abundance of sloth bear in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Jungle cats were photo-captured from all areas of the Tiger Reserve including the buffer areas of Gundlupet.

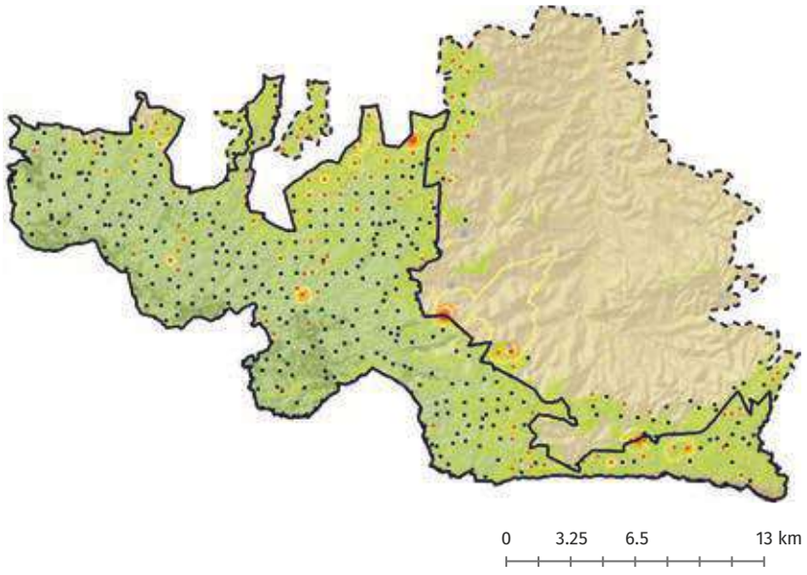


Figure 11.22

Distribution, and relative spatial abundance of jungle cat in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Rusty spotted cats were photo-captured from all parts of the Tiger Reserve.

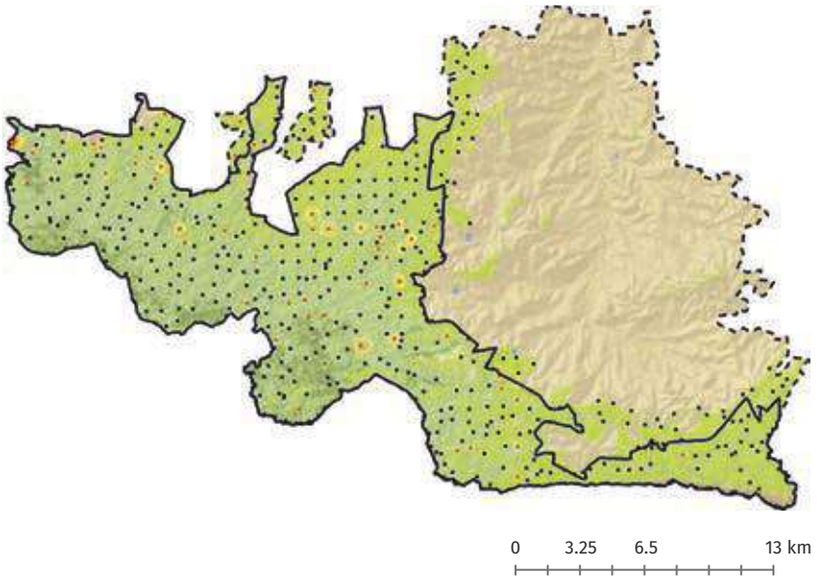


Figure 11.22

Distribution, and relative spatial abundance of rusty spotted cat in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

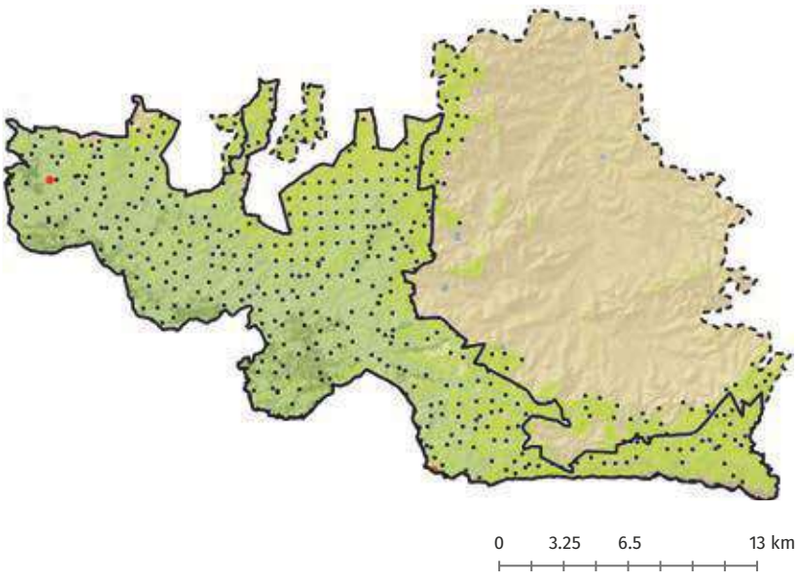


Figure 11.24

Distribution, and relative spatial abundance of leopard cat in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Leopard cat had only one photo-capture from the Tiger Reserve and the reason behind its poor status needs to be investigated.

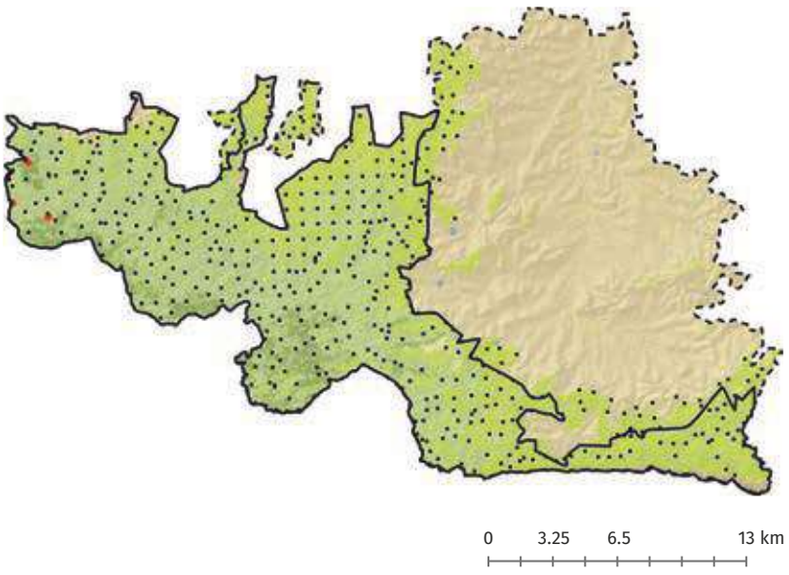


Figure 11.25

Distribution, and relative spatial abundance of golden jackal in Bandipur Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Jackals had only three photo-captures from the Tiger Reserve and the reason behind its poor status and decline needs to be investigated.

Relative Abundance of all Photocaptured Species in Bandipur Tiger Reserve

A total of 36 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Chital was the most commonly photo-captured (Table 11.6). Pangolin was the rarest species photo-captured followed by leopard cat.

Table 11.6

Details of all photocaptured species and their relative abundance index (RAI) in Bandipur Tiger Reserve, 2018-19.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	1.10	91
Blackbuck	0.38	266
Black-naped hare	21.35	5
Bonnet macaque	0.99	101
Brown mongoose	0.18	570
Brown palm civet	0.01	6837
Chital	53.09	2
Common palm civet	2.37	42
Domestic cat	0.08	1282
Domestic dog	0.30	331
Elephant	15.28	7
Four horned antelope	2.92	34
Gaur	6.26	16
Golden jackal	0.01	6837
Grey jungle fowl	1.39	72
Hanuman langur	5.02	20
Indian fox	0.01	6837
Indian grey mongoose	0.76	132
Indian pangolin	0.01	10256
Indian porcupine	5.82	17
Jungle cat	1.54	65
Leopard	5.28	19
Leopard cat	0.01	6837
Livestock	3.01	33
Mouse deer	0.85	118
Peafowl	18.43	5
Ruddy mongoose	0.38	263
Rusty spotted cat	0.45	223
Sambar	14.07	7
Sloth bear	4.10	24
Small Indian civet	3.20	31
Stripe-necked mongoose	0.61	164
Striped hyena	0.09	1080
Tiger	7.21	14
Wild dog	1.84	54
Wild pig	4.72	21

DISCUSSION

Tiger population in Bandipur Tiger Reserve has increased from previous estimates of 2014 primarily due to better protection and habitat management in the area by Karnataka Forest Department. Human pressures on the Park such as livestock grazing and fuel wood collection is high with about 200 villages located within 5 km of the Reserve boundary. Two highways, viz., the Mysore-Ooty highway and Gundulpet-Sultan Bathery highway are a major disturbance to wildlife in the area which need to be appropriately mitigated. Major concern in the Tiger Reserve is the loss of bamboo and large extent invasion by *Lantana*.

BHADRA TIGER RESERVE

INTRODUCTION

Bhadra Tiger Reserve is a protected area covering 492 km^2 in the Western Ghats located at 75° 38' E and 13° 34' N. It was declared as a tiger reserve in the year 1998. The protected area is at an altitude of 670-760 m, with monthly mean temperatures of 10-32 °C, and an annual rainfall ranging between 2000-2540 mm. Vegetation comprises of wet evergreen forests and moist deciduous forests that are dominated by bamboo. Low-lying valleys of the park previously consisted of swampy grasslands occupied by village settlements and rice-agriculture.

Following massive relocation of large number of villages from the park in 2002, large mammal populations are on a gradual increasing trend. The forests of Malenad landscape in the Western Ghats supports large assemblages of carnivores and herbivores: tiger (*Panthera tigris*), leopard (*Panthera pardus*), Asiatic wild dog (*Cuon alpinus*) and sloth bear (*Melursus ursinus*), Asiatic elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), mouse deer (*Moschiola indica*) and hanuman langur (*Semnopithecus entellus*).

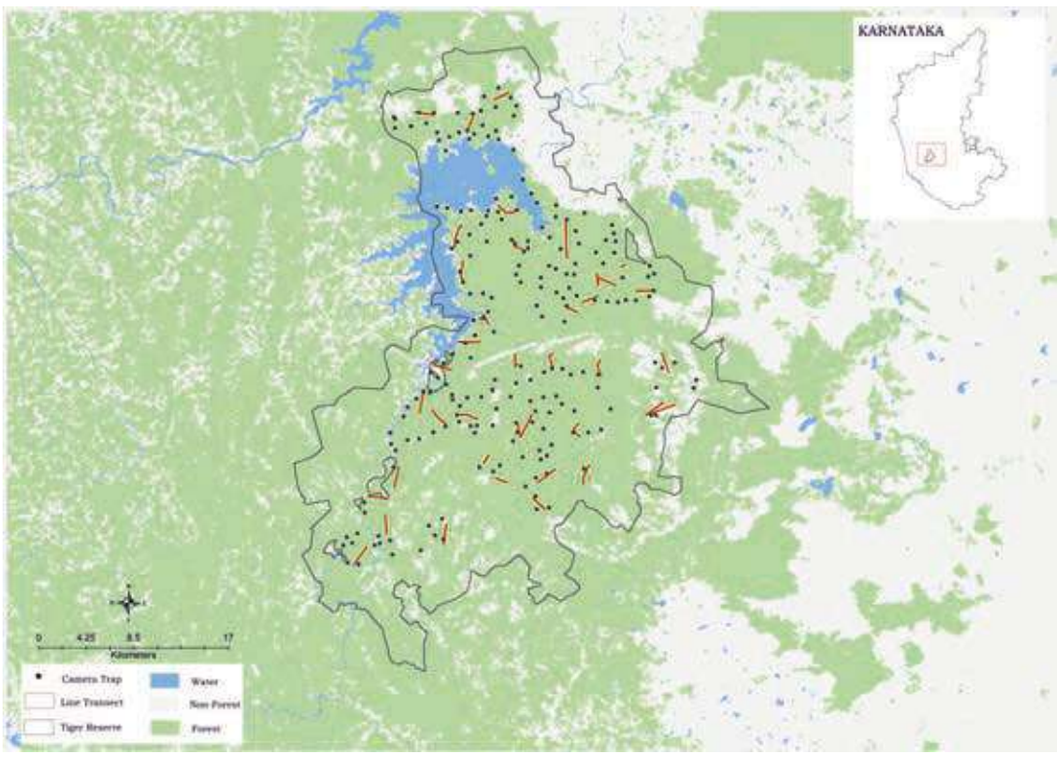


Figure 11.26
Camera trap and transect layout in Bhadra Tiger Reserve, 2018-19

RESULTS

Tiger Density Estimates

A total of 212 camera traps were deployed in Bhadra Tiger Reserve yielding 296 tiger detections (including 48 images of cubs) from which 28 individual tigers were identified. Density of tigers in the Tiger Reserve was estimated to be 2.86 (SE 0.55) per 100 km^2 (Table 11.7). The detection corrected tiger male to female sex ratio in Bhadra was 0.16:0.84 (Table 11.7).

Variables	Estimates
Model space (km^2)	1558.12
Camera points	212
Trap nights (effort)	6653
Unique tigers captured	28
Model	g_0 (sex) σ (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	2.86 (0.55)
σFemale (SE) km	1.99 (0.09)
σMale (SE) km	3.39 (0.35)
g_0 Female (SE)	0.03 (0.003)
g_0 Male (SE)	0.01 (0.004)
Pmix Female (SE)	0.84 (0.06)
Pmix Male (SE)	0.16 (0.06)

Table 11.7

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Bhadra Tiger Reserve, 2018.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

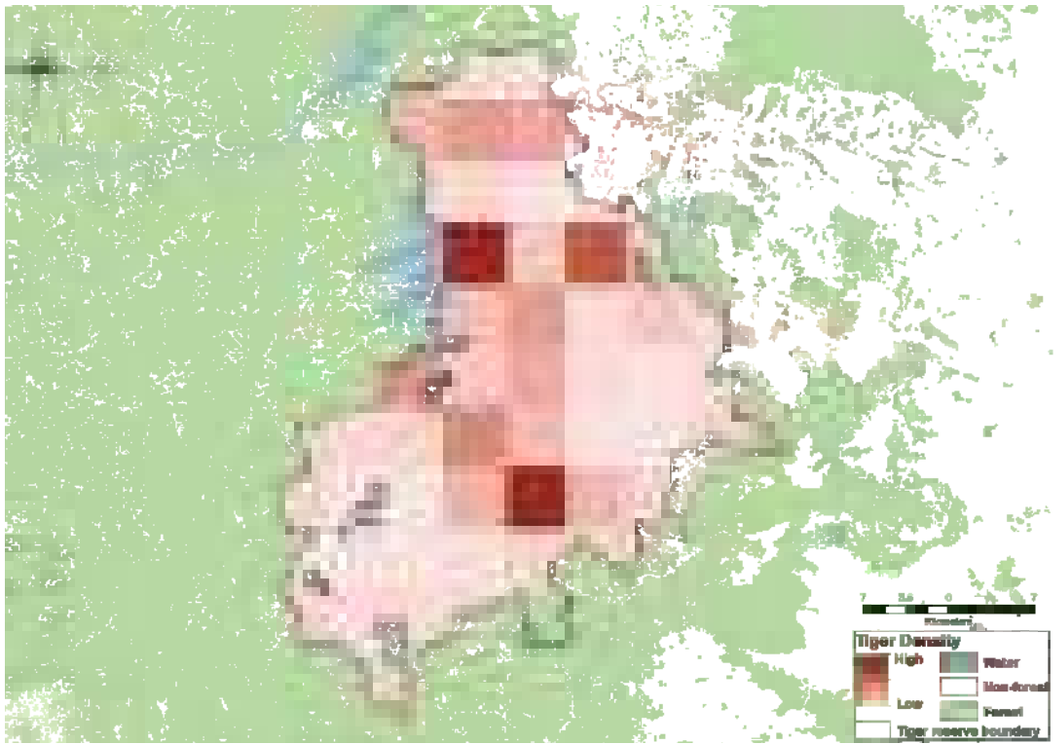


Figure 11.27

Spatial density of tigers in Bhadra Tiger Reserve, 2018-19

Bhadra Tiger Reserve has a low to medium density of tigers consistently across the park. Some high density pockets were seen near the Bhadra reservoir and in Hippala areas of the reserve. The status of tigers and wildlife is on the recovery and can be attributed to good management and protection regime implemented through M-STrIPES in Bhadra.

Prey Density Estimates

A total of 216 transects were sampled in Bhadra Tiger Reserve which amounted to an effort of 418.93 km. Chital was found to be the most abundant ungulate in Bhadra Tiger Reserve (Table 11.8).

Table 11.8

Model statistics and parameter estimates of line transect (n=216, Total effort 418.93 km) based distance sampling for prey species in Bhadra Tiger Reserve, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital	29.8 (1.6)	51	7.0 (0.8)	0.24 (0.01)	0.122	2.04 (0.35)	14.35 (2.9)
Sambar	29.7 (2.0)	106	2.0 (0.2)	0.11 (0.008)	0.253	4.25 (0.45)	8.53 (1.41)
Gaur	24.9 (2.6)	48	1.6 (0.6)	0.19 (0.02)	0.115	2.29 (0.40)	3.71 (1.52)
Barking deer	29.1 (2.1)	43	1.1 (0.08)	0.22 (0.1)	0.103	1.75 (0.27)	2.04 (0.35)
Wild pig	21.9 (1.7)	29	2.9 (0.38)	0.22 (0.1)	0.069	1.57 (0.30)	4.67 (1.09)
Elephant	44.3 (3.7)	22	2.5 (0.43)	0.24 (0.002)	0.053	0.59 (0.13)	1.48 (0.42)

Distribution of Major Mammalian Fauna Found in Bhadra Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Bhadra Tiger Reserve.

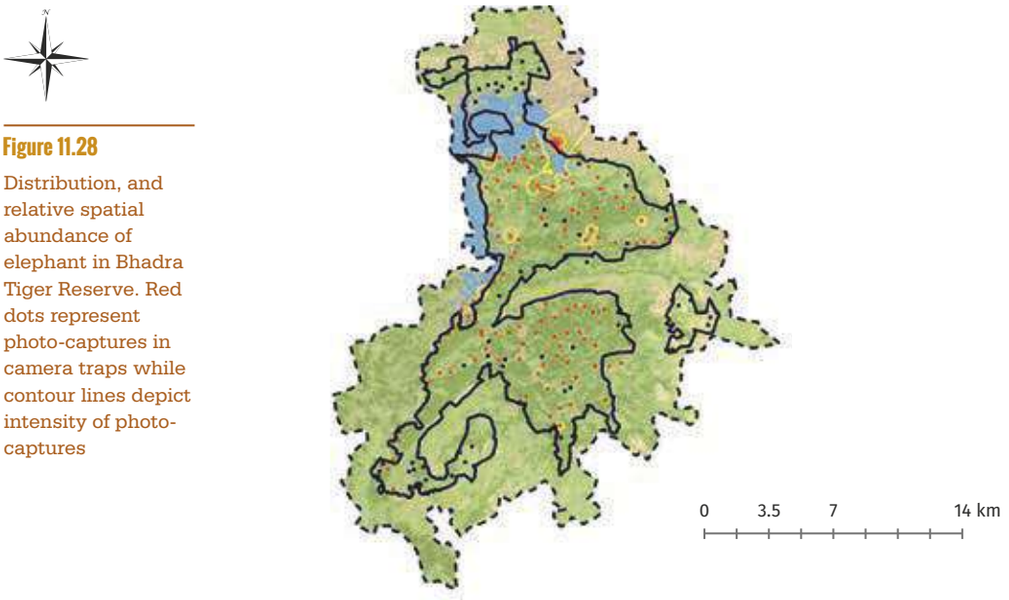


Figure 11.28

Distribution, and relative spatial abundance of elephant in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Elephant photo-capture was from throughout the Tiger Reserve with more concentration was from the northern part of the reserve near the reservoir.

Gaur photo-capture was uniform from all parts of the Tiger Reserve.

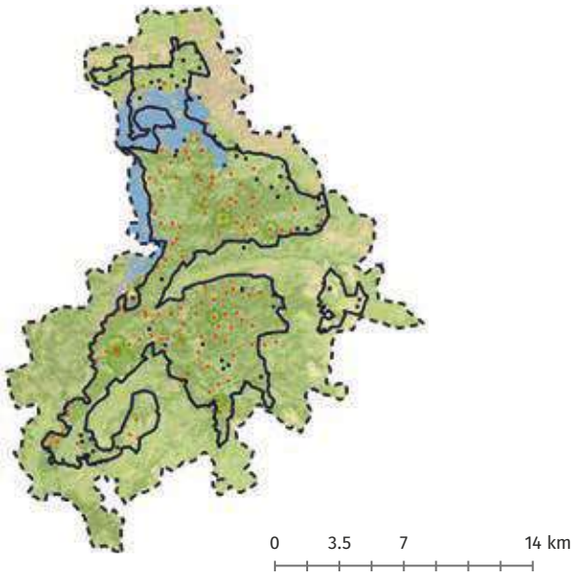


Figure 11.29

Distribution, and relative spatial abundance of gaur in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Mouse deer was distributed uniformly in all parts of the Tiger Reserve.

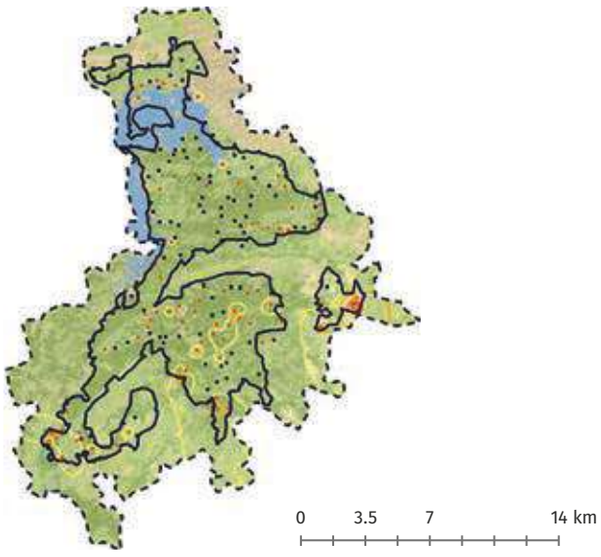


Figure 11.30

Distribution, and relative spatial abundance of mouse deer in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Leopard photo-capture was from throughout the Tiger Reserve.

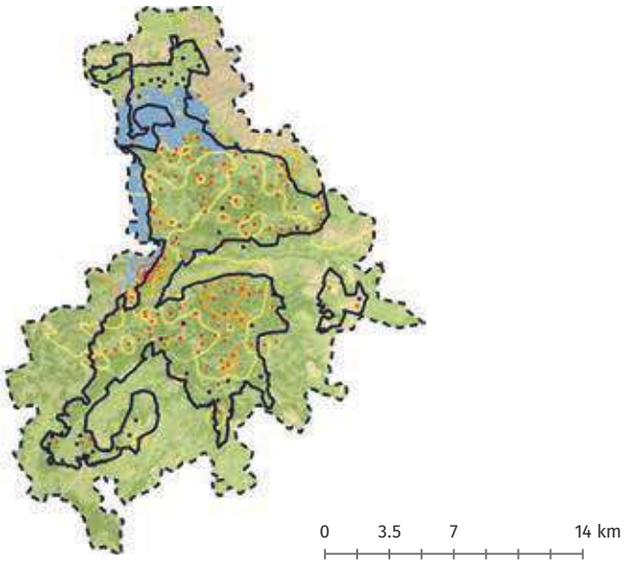


Figure 11.31

Distribution, and relative spatial abundance of leopard in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

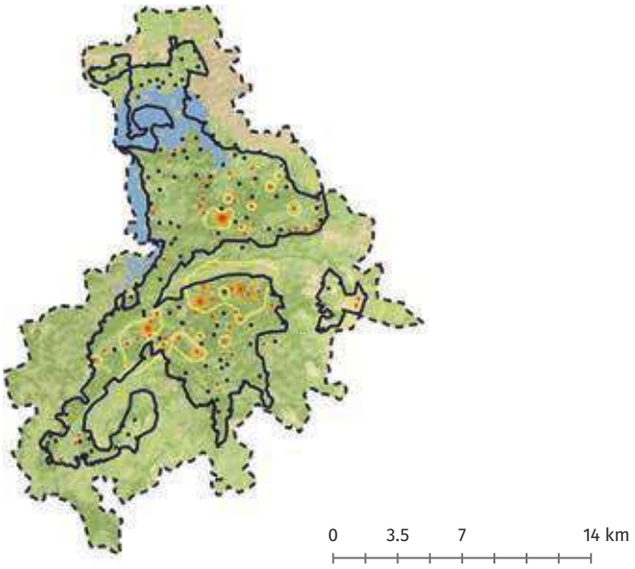


Figure 11.32

Distribution, and relative spatial abundance of dhole in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Dhole was uniformly distributed in Bhadra Tiger Reserve.

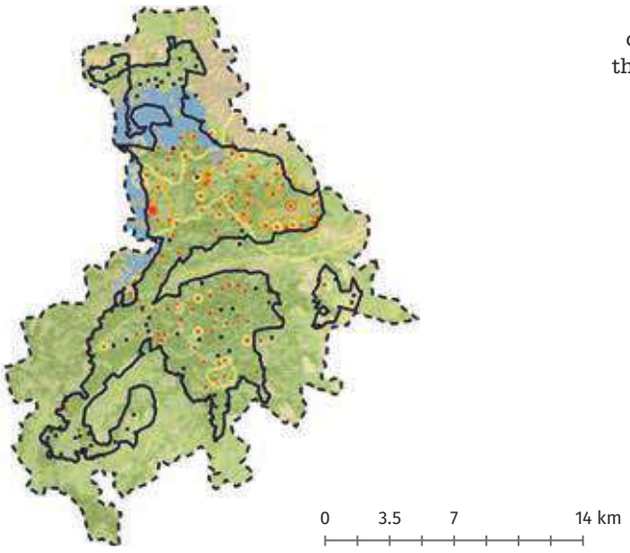


Figure 11.33

Distribution, and relative spatial abundance of sloth bear in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Sloth bear photo-captures were from throughout the Tiger Reserve.

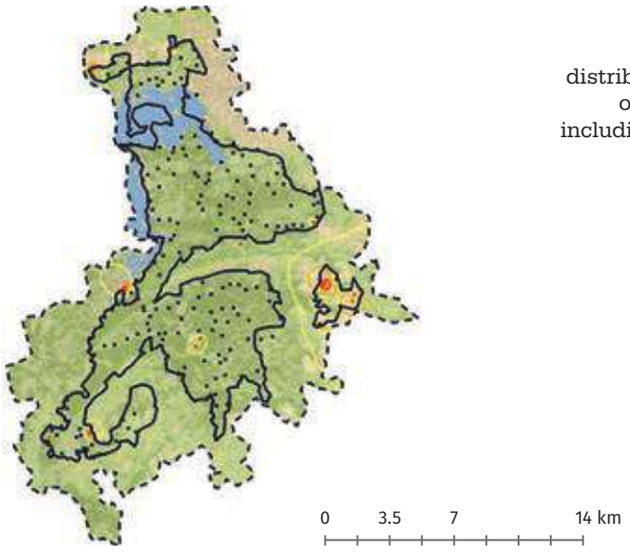


Figure 11.34

Distribution, and relative spatial abundance of jungle cat in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Jungle cat was distributed from all parts of the Tiger Reserve including the buffer zone.

Golden jackal distribution was low and from the peripheries of the Tiger Reserve.

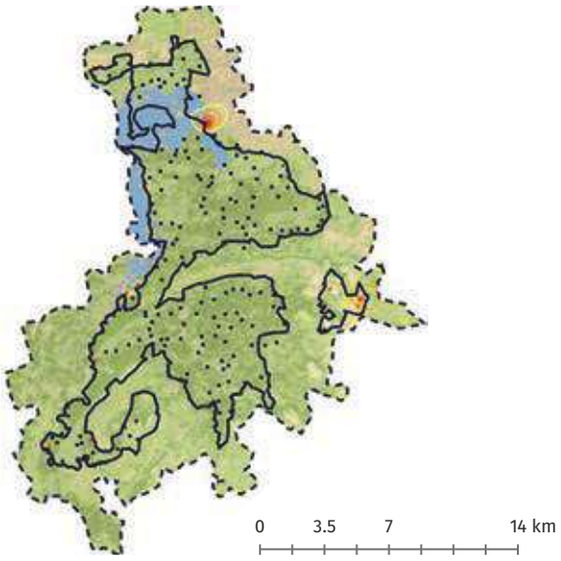


Figure 11.35

Distribution, and relative spatial abundance of golden jackal in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Rusty spotted cat was distributed in the northern periphery of the Tiger Reserve.

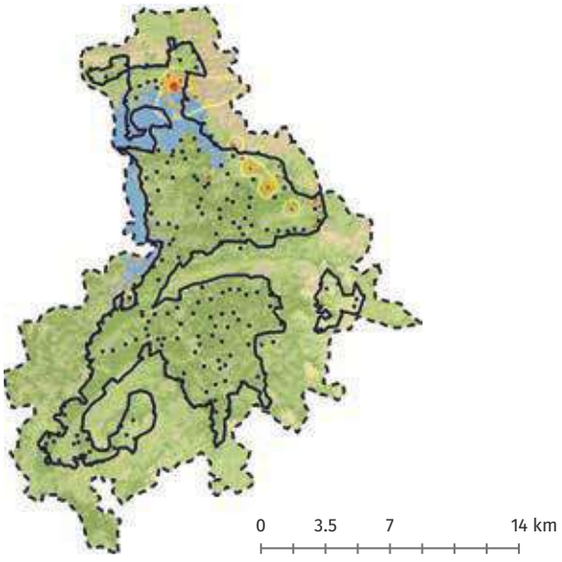


Figure 11.36

Distribution, and relative spatial abundance of rusty spotted cat in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Eurasian otter had a very low photo-capture from the Tiger Reserve.

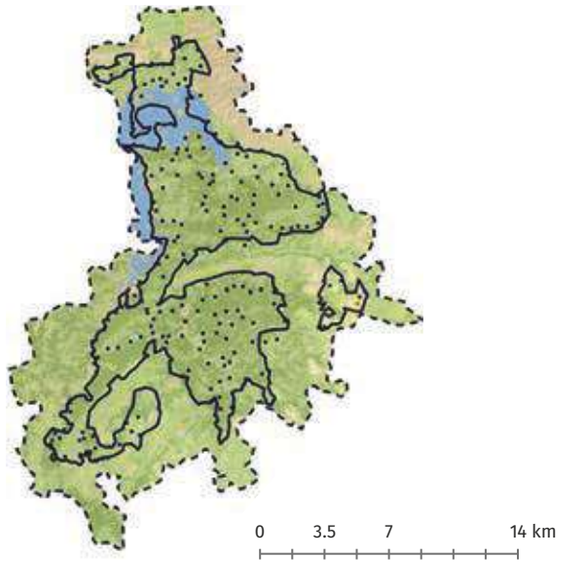


Figure 11.37

Distribution, and relative spatial abundance of Eurasian otter in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

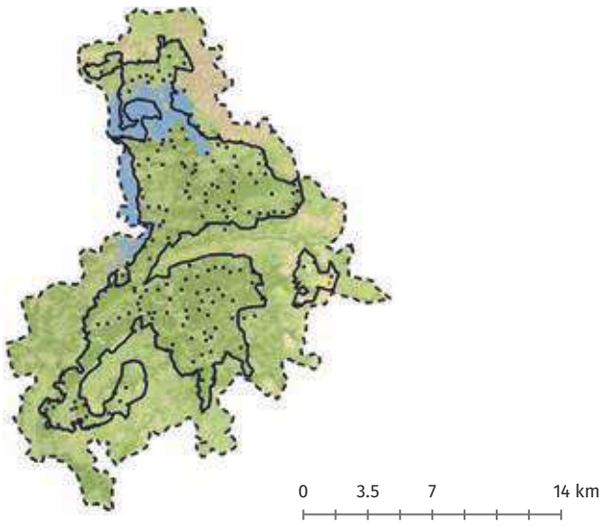


Figure 11.38

Distribution, and relative spatial abundance of smooth coated otter in Bhadra Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Smooth coated otter had a low photo-capture from the Tiger Reserve.

Table 11.9

Details of all photocaptured species and their relative abundance index (RAI) in Bhadra Tiger Reserve, 2018-19.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	4.54	22
Black-naped hare	23.19	4
Bonnet macaque	4.76	21
Brown palm civet	1.08	92
Chital	21.42	5
Common palm civet	0.90	111
Domestic cat	0.11	950
Domestic dog	5.19	19
Elephant	9.11	11
Gaur	11.86	8
Golden jackal	0.29	350
Grey jungle fowl	9.91	10
Hanuman langur	3.08	32
Indian grey mongoose	0.29	350
Indian pangolin	0.12	832
Indian porcupine	12.07	8
Jungle cat	0.48	208
Leopard	9.75	10
Leopard cat	0.62	162
Livestock	5.10	20
Monitor lizard	0.21	475
Mouse deer	4.25	24
Nilgai	0.14	739
Peafowl	25.93	4

Relative Abundance of all Photocaptured Species in Bhadra Tiger Reserve

A total of 34 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Sambar and peafowl were the most commonly photo-captured species (Table 11.9). Smooth coated otter was the rarest to be photo-captured.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Ruddy mongoose	1.19	84
Rusty spotted cat	0.50	202
Sambar	35.29	3
Sloth bear	7.23	14
Small Indian civet	10.49	10
Smooth coated otter	0.03	3327
Stripe-necked mongoose	4.55	22
Tiger	4.45	22
Wild dog	2.03	49
Wild pig	11.05	9

DISCUSSION

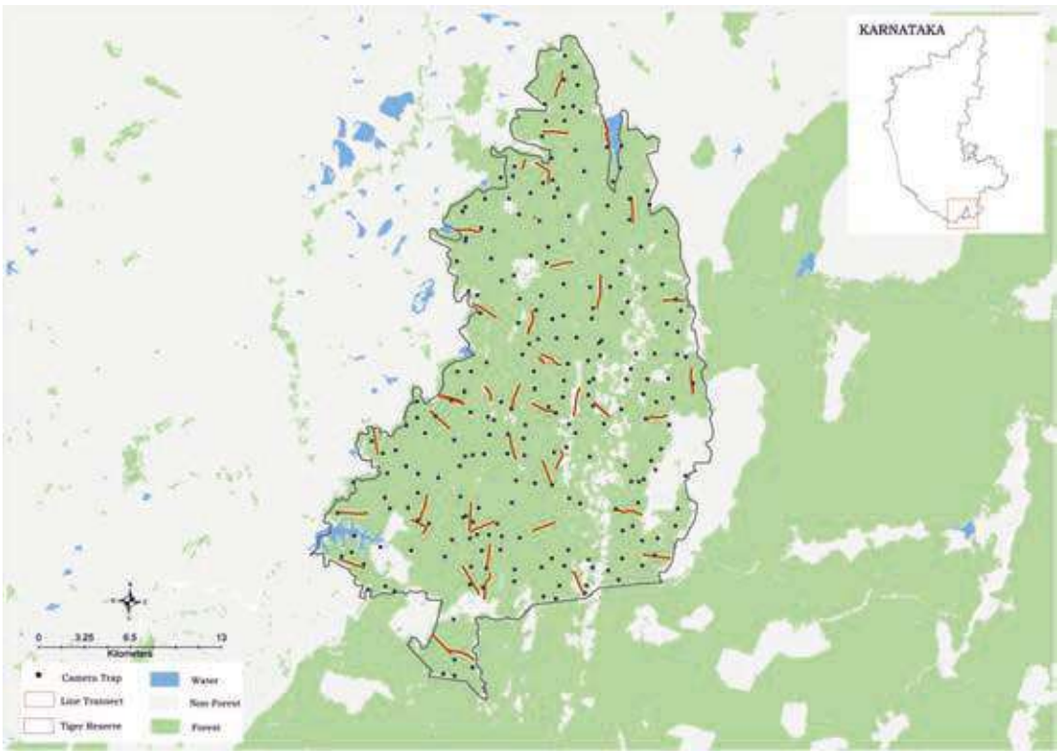
Tiger density in Bhadra Tiger Reserve has been consistently low since the last estimation of 2014. This Tiger Reserve is often cited as the best example of successful 'voluntary relocation' of people from Protected Areas with 11 villages having volunteered to move out of the Reserve by 2003. Presence of magnetite ore in the Baba Budangiri Hills, damming River Somvahini and upcoming upper Bhadra lift irrigation project are some of the major threats to this area which need to be appropriately mitigated.

BILIGIRIRANGANATHA SWAMY TEMPLE (BRT HILLS) TIGER RESERVE

INTRODUCTION

The Biligiriranganatha Hills, commonly called BR Hills, is a hill range situated in south-eastern Karnataka, at its border with Tamil Nadu (Erode District) in South India. The area is called Biligiriranganatha Swamy Temple Wildlife Sanctuary or simply BRT Wildlife Sanctuary. Being at the starting point of the Eastern Ghats and very close to Western Ghats, the sanctuary is home to eco-systems that are unique to both the mountain ranges. The site was declared a tiger reserve in January 2011 by the Karnataka government. The sanctuary, ~35 km long north-south and ~15 km wide east-west is spread over an area of 540 km^2 with a wide variation in mean temperature (9°C to 16°C minimum and 20°C to 38°C maximum) and annual rainfall (600 mm at the base and 3000 mm at the top of the hills) The hill ranges, within the sanctuary raise as high as 1200 m above the basal plateau of 600 m and run north-south in two ridges. The wide range of climatic conditions along with the altitude variations within the small area of the sanctuary have translated it into a highly heterogeneous mosaic of habitats such that we find almost all major forest vegetation types - scrub, deciduous, riparian, evergreen, sholas and grasslands. Major mammalian fauna include tiger (*Panthera tigris*), dhole (*Cuon alpinus*), sloth bear (*Melursus ursinus*), elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*) and barking deer (*Muntiacus vaginalis*).

Figure 11.39
Camera trap and transect layout in BRT Hills Tiger Reserve, 2018-19



RESULTS

Tiger Density Estimates

A total of 240 camera traps were deployed in BRT Hills Tiger Reserve yielding 540 tiger detections (including 6 images of cubs) from which 49 individual tigers were identified. Density of tigers in the Tiger Reserve was estimated to be 4.96 (SE 0.71) per 100 km^2 (Table 11.10). The detection corrected tiger male to female sex ratio in BRT Hills TR was 0.29:0.71 (Table 11.10).

Variables	Estimates
Model space (km^2)	1953.25
Camera points	240
Trap nights (effort)	8028
Unique tigers captured	49
Model	g_0 (sex) σ (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	4.96 (SE 0.71)
σ Female (SE) km	3.4 (0.1)
σ Male (SE) km	7.3 (0.4)
g_0 Female (SE)	0.01 (0.001)
g_0 Male (SE)	0.008 (0.0008)
Pmix Female (SE)	0.71 (0.05)
Pmix Male (SE)	0.29 (0.05)

Table 11.10

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for BRT Hills Tiger Reserve, 2018.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

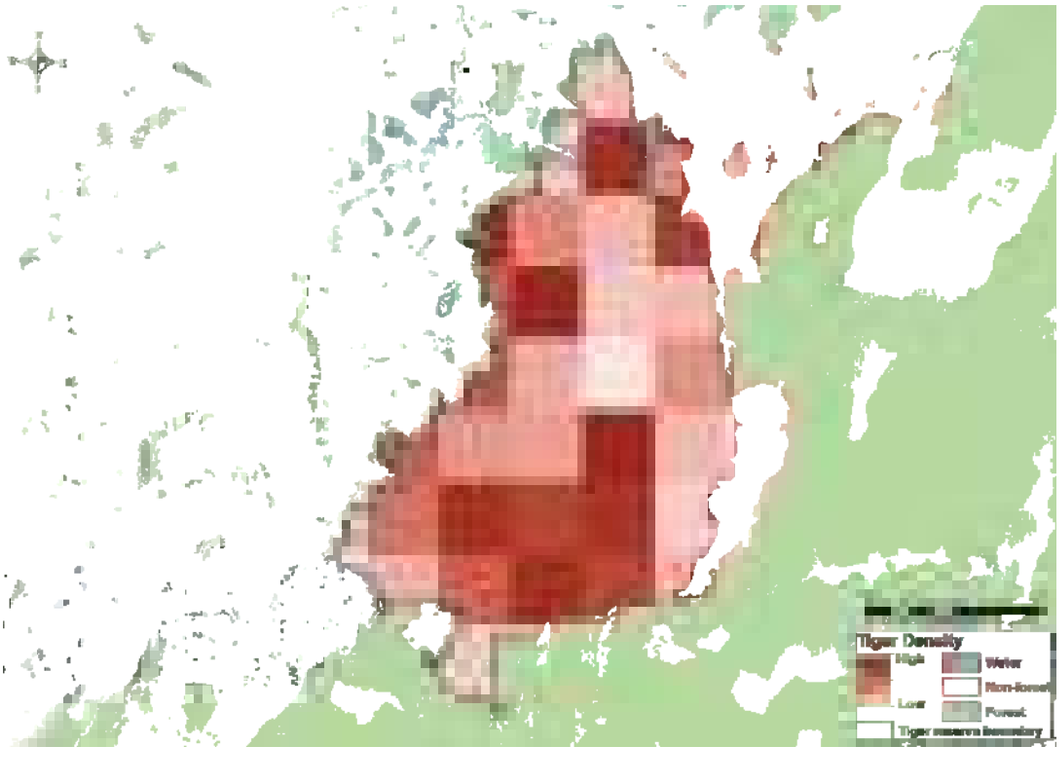


Figure 11.40

Spatial density of tigers in Biligiri Ranganathaswamy Temple Tiger Reserve, 2018-19

BRT Hills Tiger Reserve has medium to high density of tigers consistently across the park. Some high density pockets were seen near the southern part of the tiger reserve in Punjur and Chamrajanagara Ranges.

Prey Density Estimates

A total of 148 transects were sampled in BRT Hills Tiger Reserve which amounted to an effort of 288.59 km. Chital was found to be the most abundant ungulate in BRT Hills Tiger Reserve (Table 11.11).

Table 11.11

Model statistics and parameter estimates of line transect (n=148, Total effort 288.59 km) based distance sampling for prey species in BRT Hills Tiger Reserve, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital	30.67 (0.9)	42	3.5 (0.5)	0.12 (0.004)	0.14	2.37 (0.39)	8.41 (1.8)
Sambar	31.08 (1.2)	44	2.7 (0.4)	0.06 (0.002)	0.15	2.45 (0.40)	6.63 (1.5)
Gaur	33.20 (2.1)	16	1.7 (0.3)	0.11 (0.007)	0.05	0.83 (0.21)	1.46 (0.4)
Elephant	47.62 (2.8)	10	2.0 (0.2)	0.12 (0.007)	0.03	0.36 (0.11)	0.72 (0.2)
Wild pig		6	2.67 (0.8)		0.02		
Barking deer	25.88 (1.3)	25	1.2 (0.1)	0.08 (0.004)	0.08	1.67 (0.32)	2.07 (0.4)

Distribution of Major Mammalian Fauna Found in BRT Hills Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of BRT Hills Tiger Reserve.

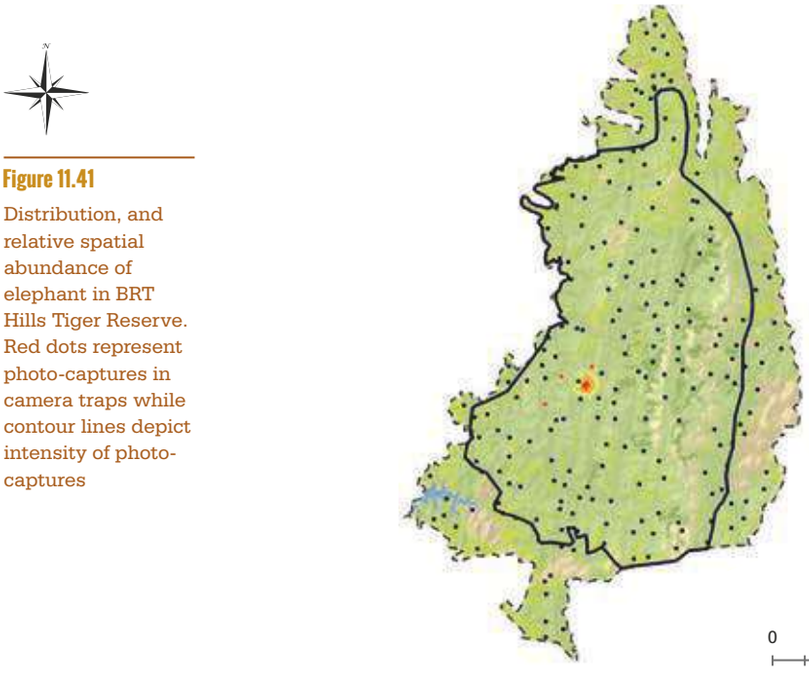


Figure 11.41

Distribution, and relative spatial abundance of elephant in BRT Hills Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Elephant photo-captures were recorded from the central part of the tiger reserve.

Gaur was recorded maximum from the periphery of the core and buffer zone of the tiger reserve.

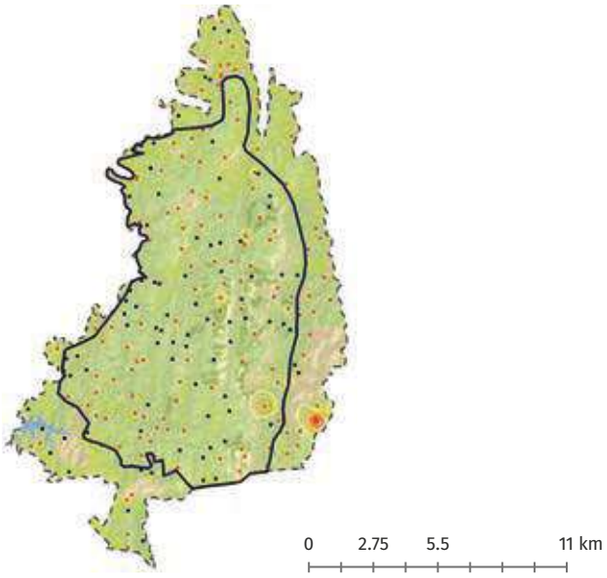


Figure 11.42

Distribution, and relative spatial abundance of gaur in BRT Hills Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Chowsingha was observed from the northern part of the tiger reserve.

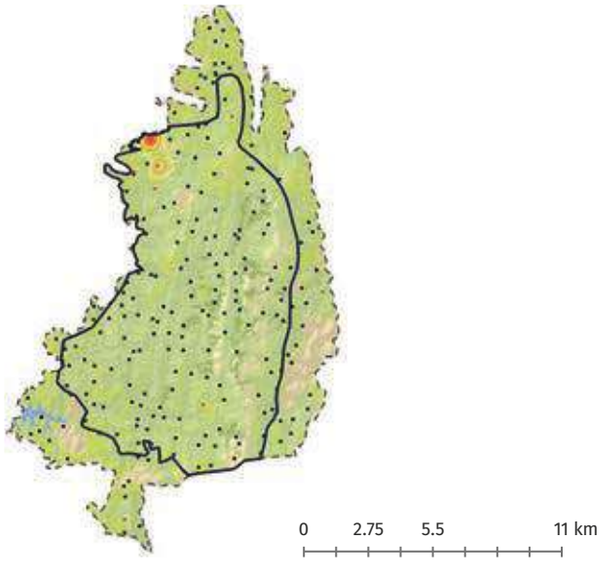


Figure 11.43

Distribution, and relative spatial abundance of chowsingha in BRT Hills Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Mouse deer had a uniform distribution from almost all parts of the tiger reserve.

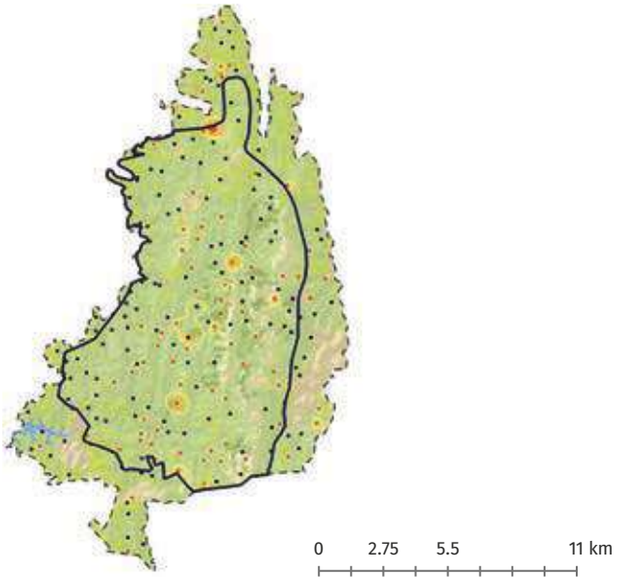


Figure 11.44

Distribution, and relative spatial abundance of mouse deer in BRT Hills Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Figure 11.45

Distribution, and relative spatial abundance of leopard in BRT Hills Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Leopards were distributed from all parts of the tiger reserve and mostly from the peripheries dotted with human habitations.

Figure 11.46

Distribution, and relative spatial abundance of sloth bear in BRT Hills Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Sloth bear captures were from across the Tiger Reserve, with concentration near the southern part.

Figure 11.47

Distribution, and relative spatial abundance of jungle cat in BRT Hills Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Although jungle cat was distributed from all parts of the tiger reserve, concentration of photo-captures was high along the southern boundaries.

Dhole was widespread in distribution from all parts of the tiger reserve.

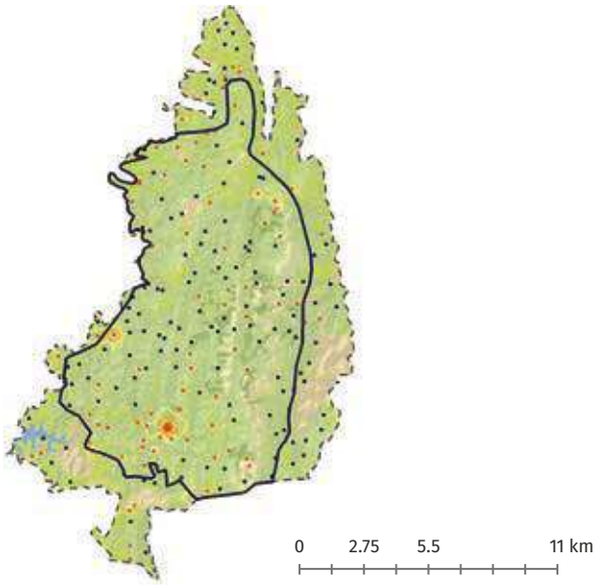


Figure 11.48

Distribution, and relative spatial abundance of dhole in BRT Hills Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Rusty spotted cat was mostly photo-captured from the northern side of the tiger reserve.

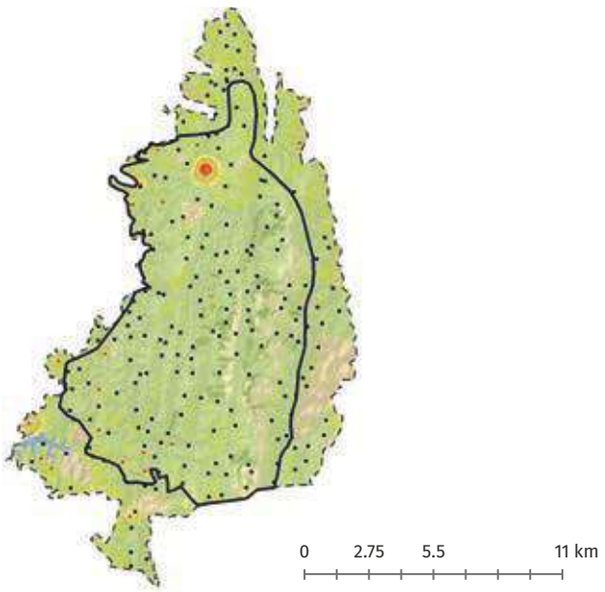


Figure 11.49

Distribution, and relative spatial abundance of rusty spotted cat in BRT Hills Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Leopard cat was photo-captured from most parts of the tiger reserve.

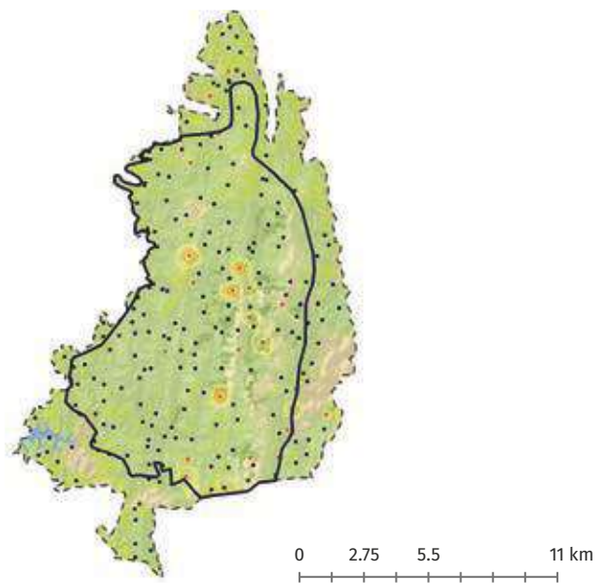


Figure 11.50

Distribution, and relative spatial abundance of leopard cat in BRT Hills Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures

Table 11.12

Details of all photocaptured species and their relative abundance index (RAI) in BRT Hills Tiger Reserve, 2018-19.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	6.94	14
Black-naped hare	12.33	8
Bonnet macaque	0.71	141
Brown mongoose	0.04	2676
Brown palm civet	0.19	535
Chital	28.99	3
Common palm civet	2.75	36
Domestic cat	0.24	423
Domestic dog	1.78	56
Elephant	11.09	9
Four horned antelope	0.36	277
Gaur	12.84	8
Grey jungle fowl	3.79	26
Hanuman langur	1.03	97
Indian grey mongoose	1.01	99
Indian pangolin	0.01	8028
Indian porcupine	13.64	7
Jungle cat	1.48	67
Leopard	1.84	54
Leopard cat	0.50	201
Monitor lizard	0.02	4014
Mouse deer	3.39	30
Peafowl	10.59	9
Ruddy mongoose	1.52	66
Rusty spotted cat	0.61	164
Sambar	21.14	5
Sloth bear	7.72	13
Small Indian civet	2.84	35
Stripe-necked mongoose	2.88	35
Tiger	6.73	15
Wild dog	2.60	38
Wild pig	4.61	22

Relative Abundance of all Photocaptured Species in BRT Hills Tiger Reserve

A total of 32 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Chital was the most commonly photo-captured species were Pangolin was the rarest species to be photo-captured followed by brown mongoose (Table 11.12).

DISCUSSION

The Tiger Reserve currently supports a medium density tiger population and has potential to become one of the source populations in the Western Ghats landscape provided its connectivity with Bandipur-Mudumalai-Nagarhole-Wayanad complex is maintained. There are about 57 tribal settlements in and around the BRT Hills Tiger Reserve including 10 Sholiga tribal settlements inside the core. Efforts should be made to resettle these human habitations outside the Tiger Reserve following NTCA's incentivized voluntary village resettlement package. Two major roads (Sathyamangalam - Chamrajanagar and Kollegal - Hasanur) passing through the tiger reserve need to be appropriately mitigated for unhindered wildlife movement.

NAGARHOLE TIGER RESERVE

INTRODUCTION

Nagarhole, (76° 05' E and 12° 04' N) covering an area of 644 km^2, was constituted as a National Park in 1955. The protected area is at an altitude of 700-960 m, with monthly mean temperatures of 20-27 °C, and with an annual rainfall ranging between 1000 mm in the eastern parts and 1500 mm in the western parts. The vegetation mostly consists of tropical moist-deciduous and tropical dry deciduous forests, with anthropogenic habitat modifications creating a heterogeneous vegetation matrix. The land cover around the protected area includes large tracts of forests, coffee plantations towards the western parts (Kodagu District) and crop mosaic towards the eastern parts. Over 600 families have been relocated from inside of Nagarahole and a few are still living inside the reserve. The park has a good number of streams and rivulets. The Kabini and Taraka reservoirs are large water bodies located towards the west and southeastern parts of the park respectively. Nagarahole is contiguous with Wayanad Wildlife Sanctuary (Kerala) to its south and Bandipur National Park to its southeastern parts. These forests of Malenad landscape in the Western Ghats support large assemblages of carnivores and herbivores: tiger (*Panthera tigris*), leopard (*Panthera pardus*), Asiatic wild dog (*Cuon alpinus*) and sloth bear (*Melursus ursinus*), Asiatic elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), muntjac (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), mouse deer (*Moschiola indica*) and hanuman langur (*Semnopithecus entellus*).

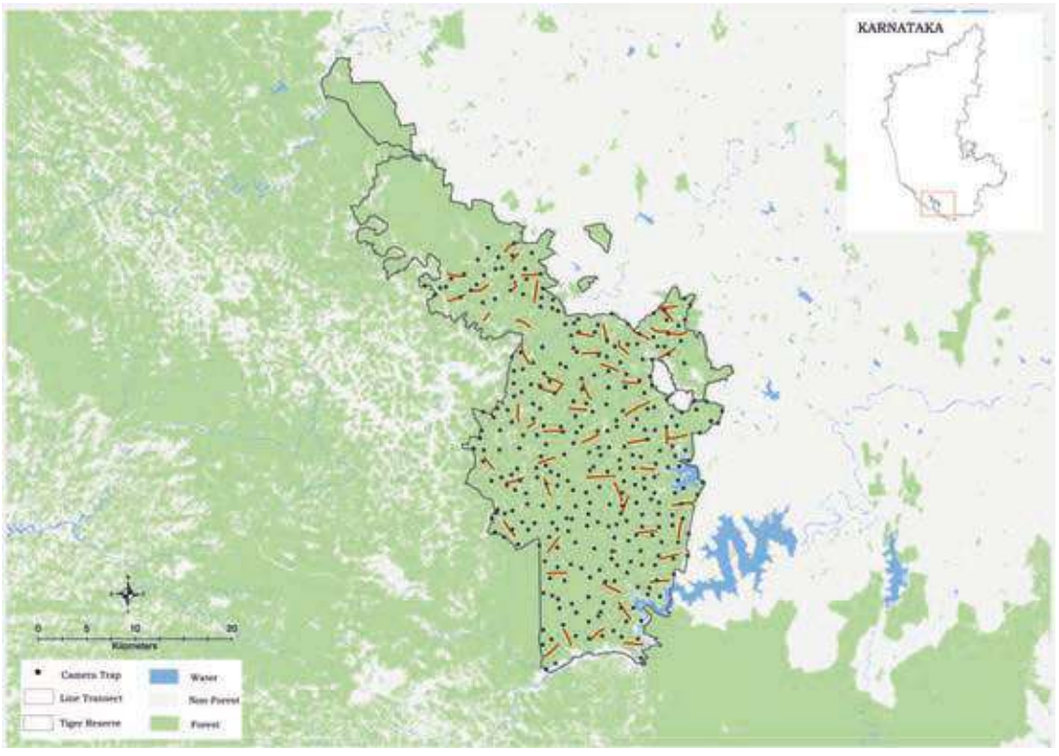


Figure 11.51
Camera trap and transect layout in Nagarhole Tiger Reserve, 2018-19

RESULTS

Tiger Density Estimates

A total of 329 camera traps were deployed in Nagarhole Tiger Reserve yielding 1,571 tiger detections (including 22 images of cubs) from which 125 individual tigers were identified. Density of tigers in the Tiger Reserve was estimated to be 11.82 (SE 1.05) per 100 km^2 (Table 11.13). The detection corrected tiger male to female sex ratio in Nagarhole TR was 0.38:0.62 (Table 11.13).

Table 11.13

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Nagarhole, 2018-19.

Variables	Estimates
Model space (km^2)	1372.87
Camera points	329
Trap nights (effort)	12862
Unique tigers captured	125
Model	g_0 (sex) σ (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	11.82 (1.05)
σFemale (SE) km	1.87 (0.03)
σMale (SE) km	2.88 (0.06)
g_0 Female (SE)	0.02 (0.001)
g_0 Male (SE)	0.01 (0.001)
Pmix Female (SE)	0.62 (0.04)
Pmix Male (SE)	0.38 (0.04)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

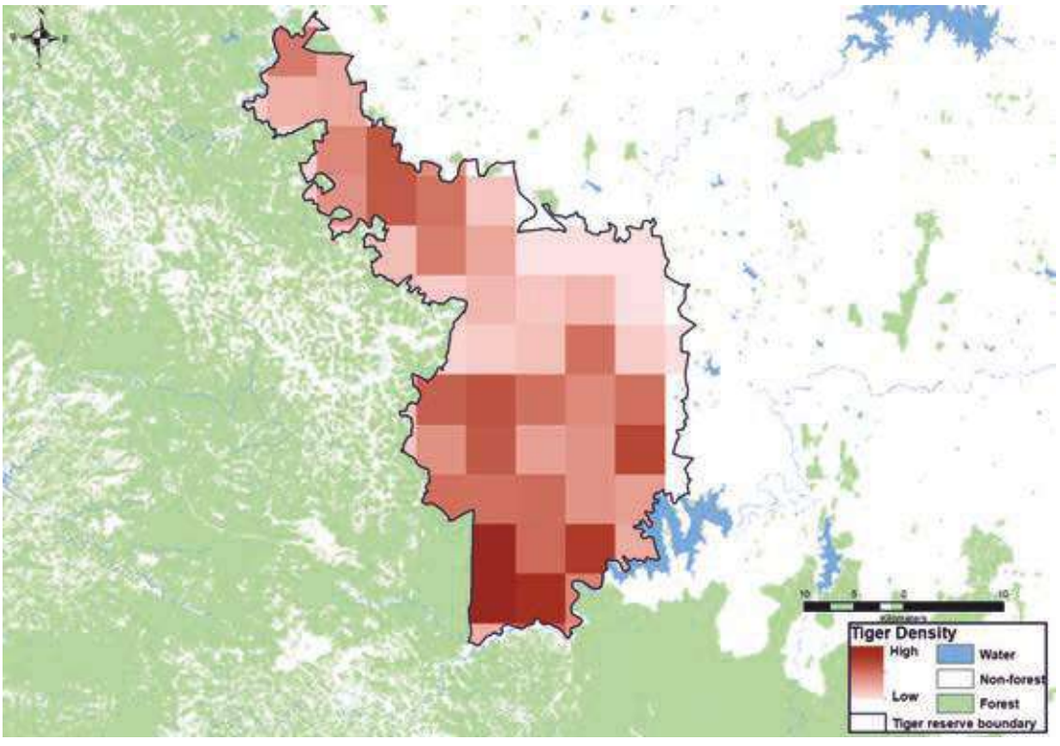
σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Figure 11.52

Spatial density of tigers in Nagarahole Tiger Reserve, 2018-19



Nagarhole Tiger Reserve has high density of tigers. Some high density pockets were seen near the southern part of the tiger reserve adjacent to Wayanad Wildlife Sanctuary of Kerala.

Prey Density Estimates

A total of 183 transects were sampled in Nagarhole which amounted to an effort of 387.8 km. Chital was found to be the most abundant ungulate in Nagarhole TR (Table 11.14).

Table 11.14

Model statistics and parameter estimates of line transect (n=150, Total effort 387.81 km) based distance sampling for prey species in Nagarhole TR, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital	30.67 (0.9)	100	5.74 (0.45)	0.12 (0.004)	0.25	4.20 (0.57)	24.13 (3.79)
Sambar	31.08 (1.22)	39	2.94 (0.51)	0.06 (0.002)	0.10	1.61 (0.27)	4.77 (1.15)
Gaur	33.20 (2.14)	19	2.52 (0.45)	0.11 (0.007)	0.04	0.73 (0.17)	1.86 (0.55)
Elephant	47.62 (2.82)	28	1.60 (0.25)	0.12 (0.007)	0.07	0.75 (0.15)	1.21 (0.31)
Wild pig	27.54 (1.98)	19	3.89 (0.71)	0.09 (0.007)	0.04	0.89 (0.20)	3.46 (1.02)
Barking deer	25.88 (1.33)	53	1.86 (0.25)	0.08 (0.004)	0.13	2.64 (0.50)	4.93 (1.14)

Distribution of Major Mammalian Fauna in Nagarhole Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Nagarhole Tiger Reserve.

Elephants were uniformly photo-captured from all parts of the tiger reserve with higher concentration near Kolavige and Kabini reservoir.

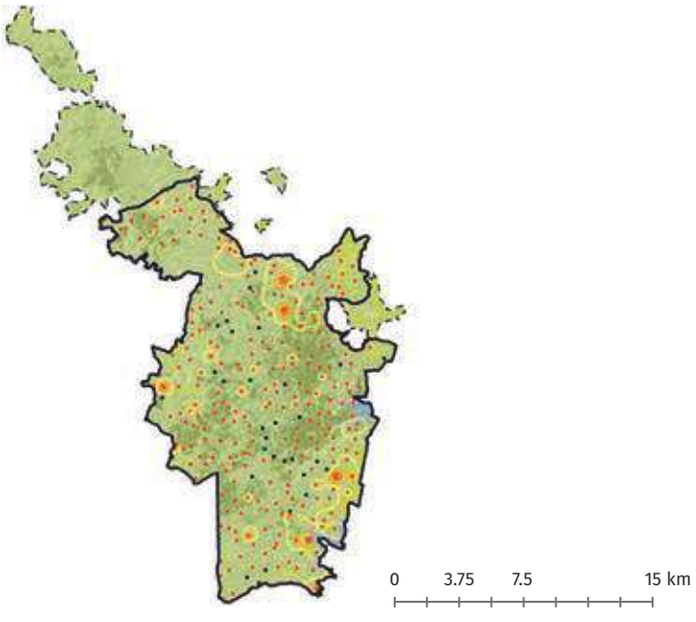


Figure 11.53

Distribution, and relative spatial abundance of elephant in Nagarhole TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

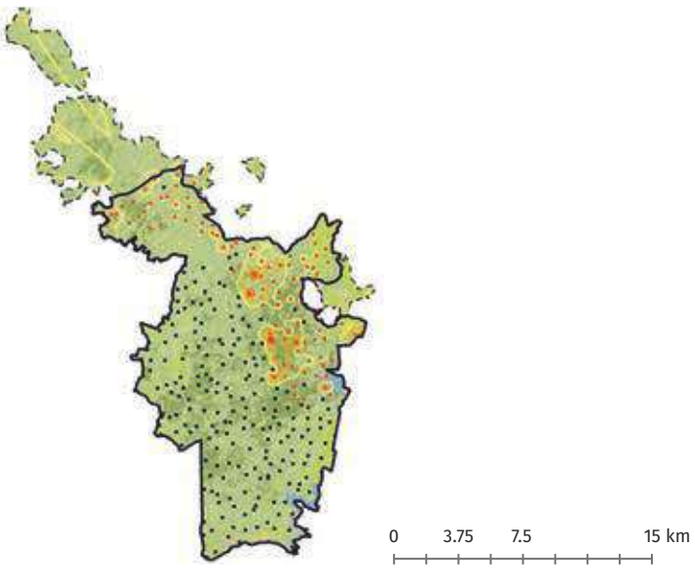


Figure 11.54

Distribution, and relative spatial abundance of gaur in Nagarhole TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Gaur were photo-captured from all parts of the tiger reserve with higher concentration from Kolavige, Taraka reservoir and Ganigadde Hadi.

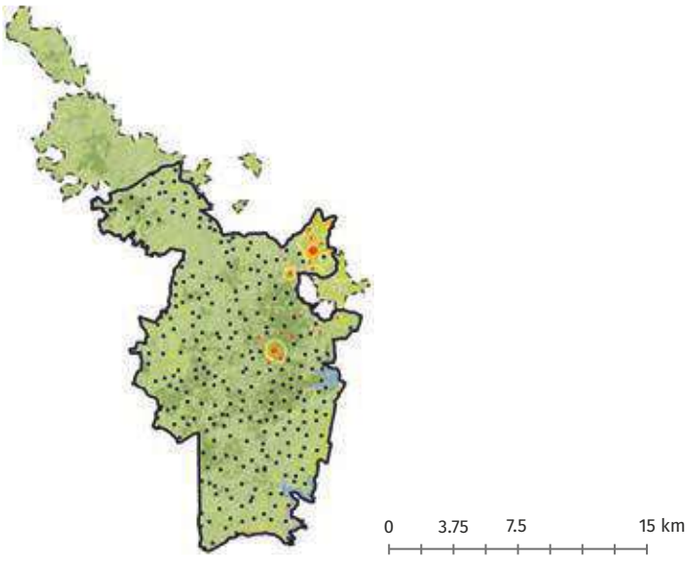


Figure 11.55

Distribution, and relative spatial abundance of chowsingha in Nagarhole TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Chowsingha distribution was found to be restricted mostly on the northern parts of the tiger reserve.

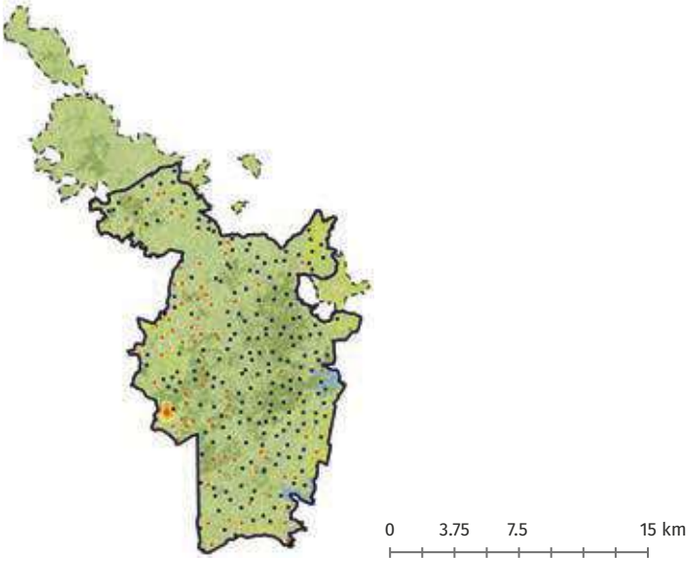


Figure 11.56

Distribution, and relative spatial abundance of mouse deer in Nagarhole TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Mouse deer was photo-captured from all parts of the tiger reserve.

Leopard photo-captures were high and spread across all parts of the park.

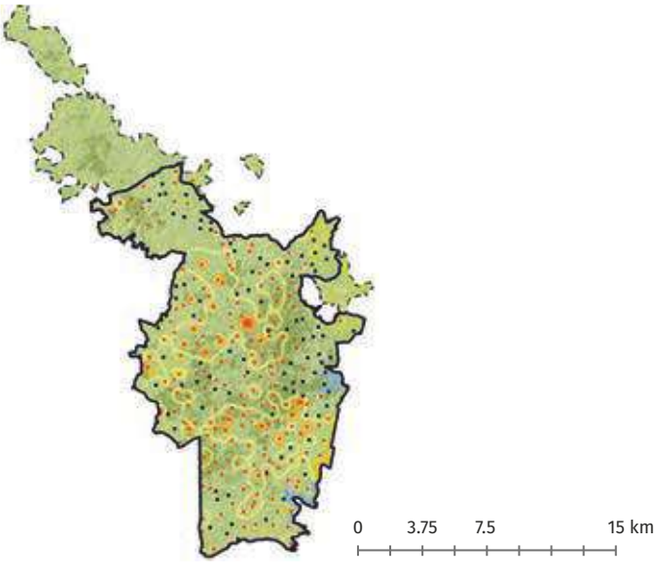


Figure 11.57

Distribution, and relative spatial abundance of leopard in Nagarhole TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Sloth bears were photo-captured from all parts of the tiger reserve.

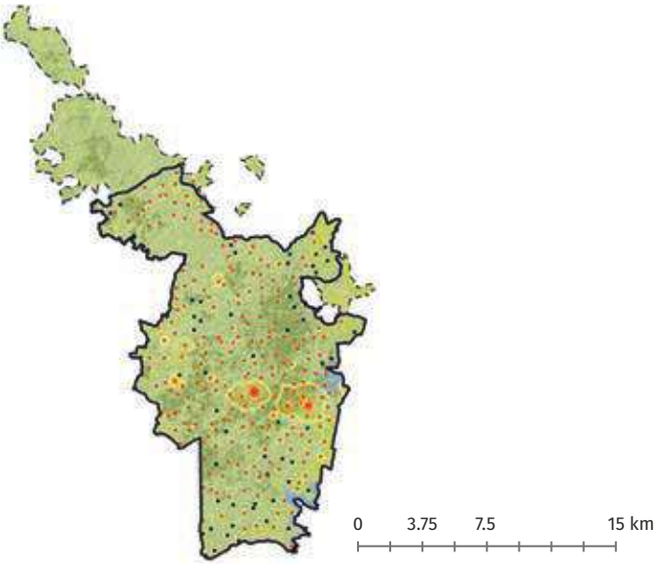


Figure 11.58

Distribution, and relative spatial abundance of sloth bear in Nagarhole TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Dhole photocaptures were uniform across the tiger reserve.

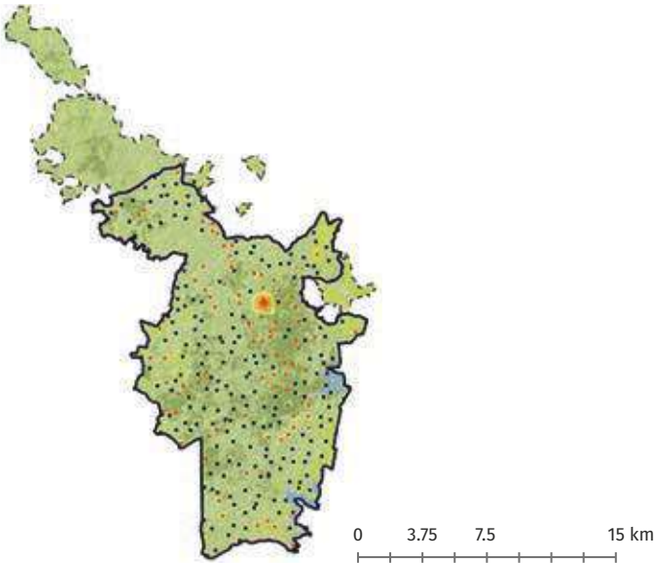


Figure 11.59

Distribution, and relative spatial abundance of dhole in Nagarhole TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

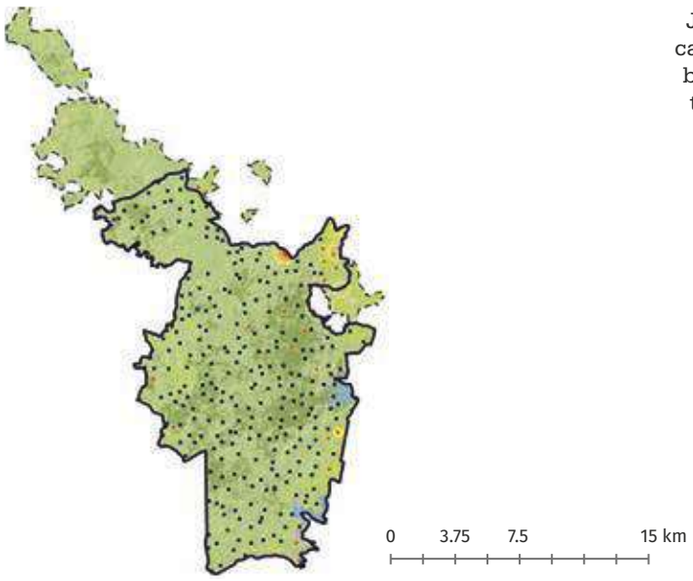


Figure 11.60

Distribution, and relative spatial abundance of jungle cat in Nagarhole TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Jungle cat photo-captures were low but spread across the tiger reserve.

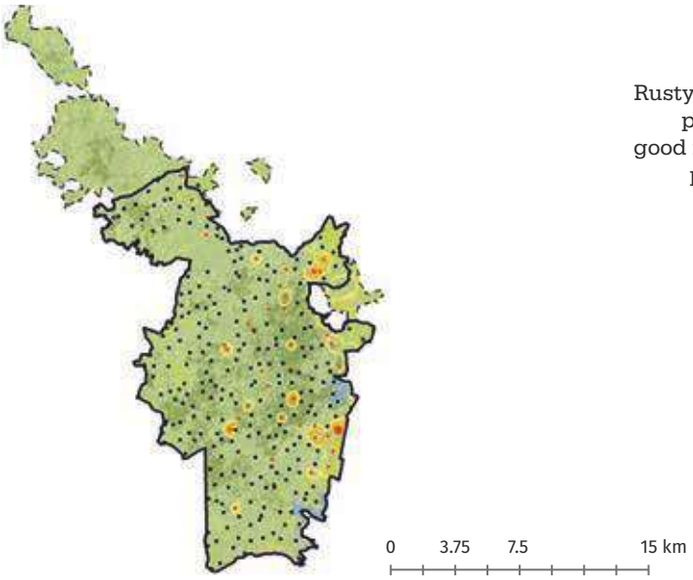


Figure 11.61

Distribution, and relative spatial abundance of rusty spotted cat in Nagarhole TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Rusty spotted cat was photo-captured in good numbers from all parts of the park.

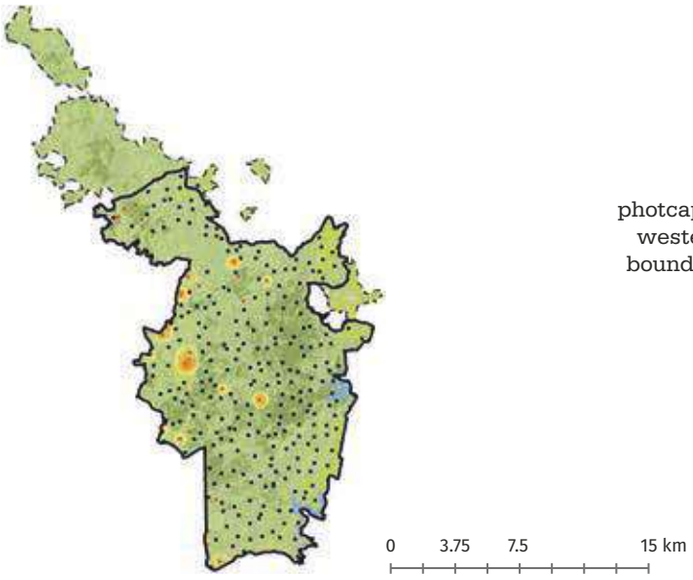


Figure 11.62

Distribution, and relative spatial abundance of leopard cat in Nagarhole TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard cat photcaptures were from western and southern boundaries of the park.

Relative Abundance of all Photocaptured Species in Nagarhole Tiger Reserve

A total of 37 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Chital was the most commonly photo-captured (Table 11.15). Jackal and nilgai were the rarest species to be photo-captured.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	4.46	22
Black-naped hare	20.60	5
Bonnet macaque	4.37	23
Chital	176.66	1
Common palm civet	2.36	42
domestic cat	0.07	1429
domestic dog	0.81	124
Elephant	16.19	6
Four horned antelope	0.38	262
Gaur	11.91	8
Golden jackal	0.01	12862
Grey jungle fowl	2.74	37
Hanuman langur	12.25	8
Indian giant squirrel	0.04	2572
Indian grey mongoose	0.56	179
Indian pangolin	0.04	2572
Indian porcupine	10.45	10
Jungle cat	0.48	207
Leopard	4.46	22
Leopard cat	0.28	357
Livestock	1.19	84
Monitor lizard	0.22	459
Mouse deer	2.37	42
Nilgai	0.01	12862
Peafowl	25.40	4
Ruddy mongoose	1.54	65
Rusty spotted cat	0.61	163
Sambar	14.42	7
Sloth bear	7.83	13
Small Indian civet	9.98	10
Stripe necked mongoose	1.53	65
Tiger	12.21	8
Wild dog	1.44	70
Wild pig	9.42	11

Table 11.15
Details of all photocaptured species and their relative abundance index (RAI) in Nagarhole Tiger Reserve, 2018-19.

DISCUSSION

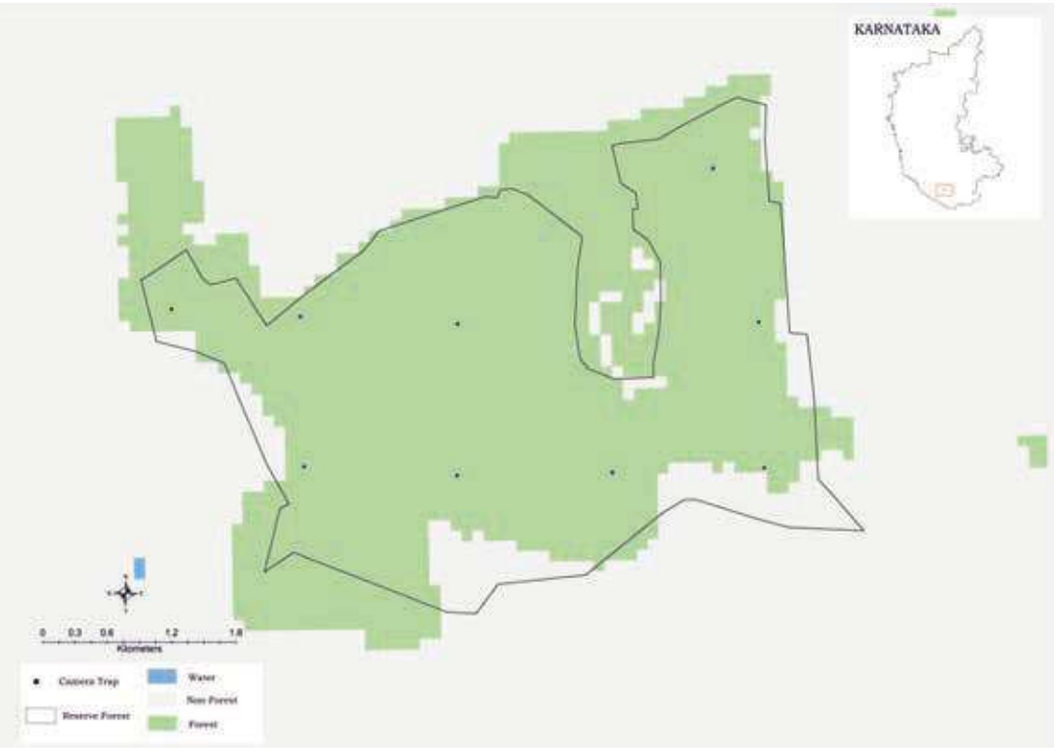
Nagarhole Tiger Reserve continues to be one of the high density Tiger Reserves and major source population for the Western Ghats landscape compared to previous cycle of estimation (Jhala et al. 2015). There are about 33 tribal settlements inside the core area of the Tiger Reserve which need to be resettled outside. State highways passing through the core critical habitat of the Tiger Reserve need to be appropriately mitigated so as to allow unhindered animal movement.

ARABITHITTU WILDLIFE SANCTUARY

INTRODUCTION

Arabithittu Wildlife Sanctuary comprises of Arabithittu State Forest located in Hunsur Taluk of Mysore district of Karnataka State. It lies between latitudinal range 12° 17' 16" to 12° 20' 41" North and longitudinal range 76° 22' 43" to 76° 28' 51" East. Total extent of the sanctuary is 13.5 km^2. All sides of the sanctuary are surrounded by private agricultural land except in the north east portion which belongs to the Ministry of Defense. Formerly, when this area was under the territorial jurisdiction, *Eucalyptus* plantations were raised in parts of the sanctuary. Until the construction of chain link fence all around the forest area, it was subjected to heavy grazing, firewood and timber extraction ultimately leading to degradation and soil erosion. The sanctuary harbours several mammals like leopard (*Panthera pardus*), chital (*Axis axis*), wild pig (*Sus scrofa*), Indian porcupine (*Hystrix indica*), common mongoose (*Herpestes edwardsi*), fox (*Vulpes bengalensis*) etc.

Figure 11.63
Camera trap layout in Arabithittu Wildlife Sanctuary, 2018-19



RESULTS

Camera Trap Results

Camera trapping was done in Arabithittu Wildlife Sanctuary, but no tiger image was recorded (Table 11.16).

Table 11.16
Sampling details of camera trapping exercise for Arabithittu Wildlife Sanctuary, 2018-19.

Variables	Estimates
Camera points	09
Trap nights (effort)	164
Unique tigers captured	0

DISCUSSION

The forests serve as sink habitat for dispersing tigers from the adjacent tiger reserves.

BANNERGHATTA NATIONAL PARK

INTRODUCTION

Bannerghatta National Park, near Bangalore, Karnataka, was declared as a national park in 1974. In 2002 a portion of the park, became a biological reserve, the Bannerghatta Biological Park. The 260.51 km^2 national park is located about 22 km south of Bangalore in the hills of the Anekal range with an elevation of 1,245 - 1,634m. The park has a hilly terrain of granite sheets under moist deciduous forest valleys and scrubland on higher areas. Sixteen villages border the park. The park is part of a wildlife corridor for elephants which connects the BR Hills and the Sathyamangalam forest. The park is contiguous with Talli reserve forest in the southeast and Bilikal forest in the south. The park is threatened by multiple granite quarries operating around the national park. These quarries are located alarmingly close to critical elephant corridors inside the national park such as Kardikal - Madeswara corridor.

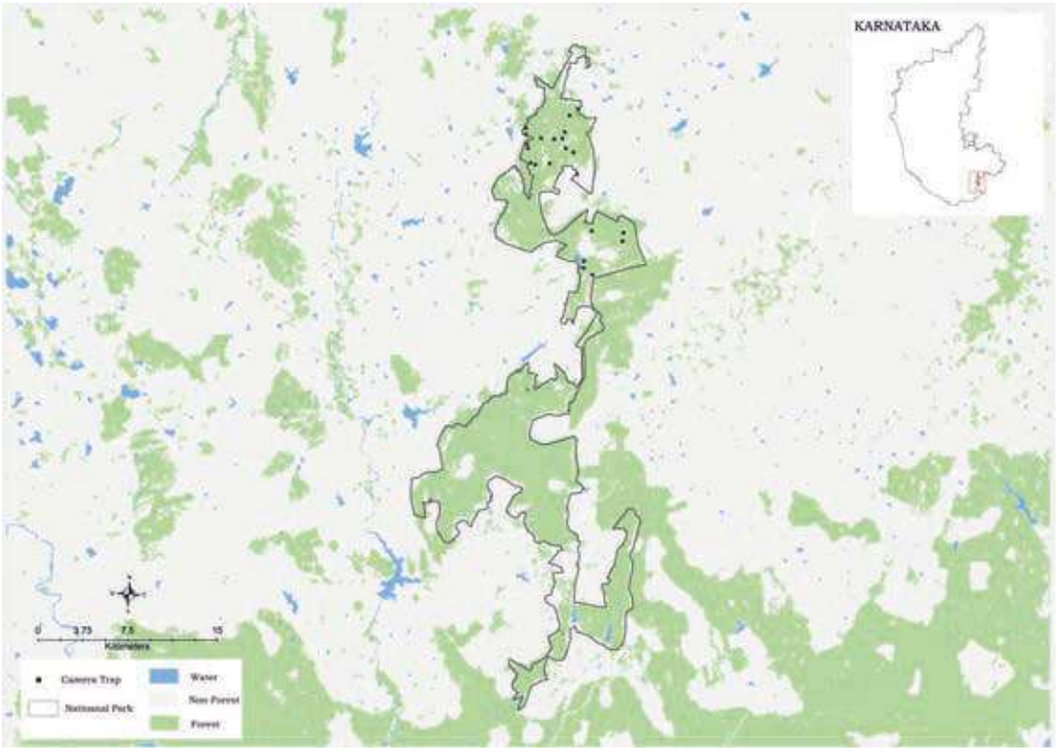


Figure 11.64
Camera trap layout in Bannerghatta National Park, 2018-19

RESULTS

Camera Trap Results

A total of 22 camera traps were deployed in Bannerghatta National Park yielding 10 tiger images from which one individual tiger was identified (Table 11.17).

Sampling details	Count
Camera points	22
Trap nights (effort)	1004
Unique tigers captured	1

Table 11.17
Sampling details of camera trapping exercise for Bannerghatta National Park, 2018-19.

DISCUSSION

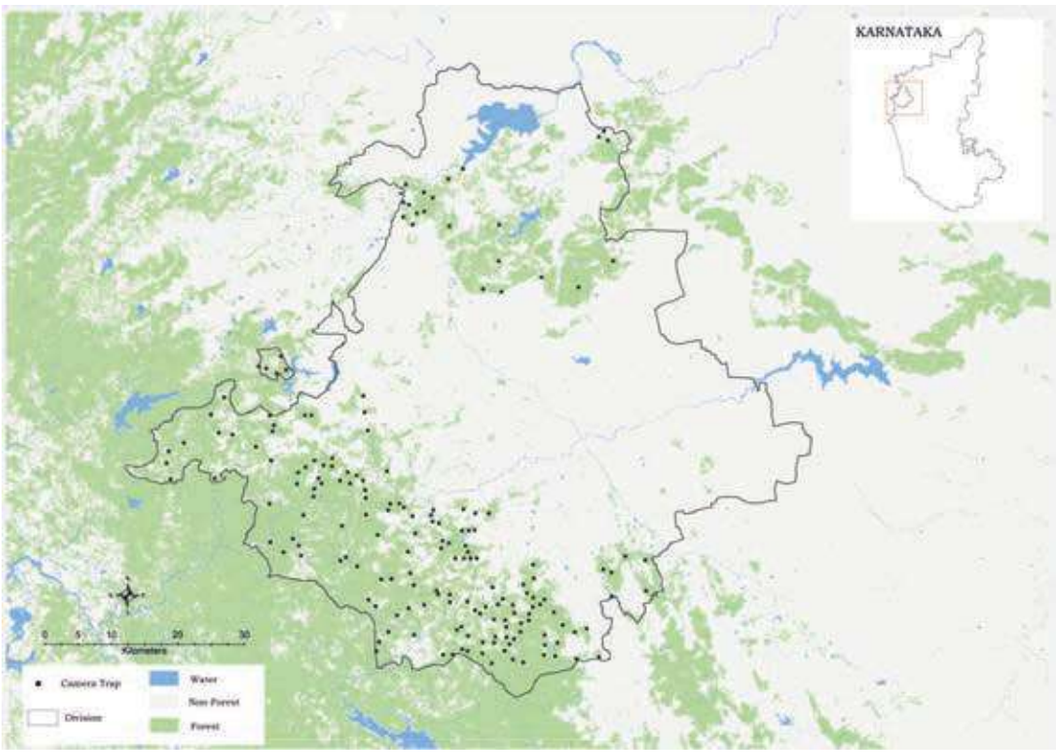
Even though only one tiger was detected, this detection validates the importance of Bannerghatta National Park as a stepping stone patch for maintaining the meta-population of tigers in this landscape.

BELAGAVI FOREST DIVISION

INTRODUCTION

Belagavi forest division is located in the north western part of Karnataka state bordering the states of Goa and Maharashtra. The division occupies a portion of Belagavi district, the remaining part being in Ghataprabha (Gokak) forest division. The total notified forest area of the division is 1,230 km^2 which constitute about 27.25% of the geographical area of the division (4,515.52 km^2). The division has three sub-divisions, namely, Nagargali, Khanapur and Belagavi sub-divisions, and consists of ten ranges, namely, Belagavi, Golihalli, Gujanal, Kakathi, Kanakumbi, Khanapura, Londa, Nagaragali, Nesargi and Bhimgad Wildlife ranges. There is one Wildlife Sanctuary in the division, namely, Bhimgad Wildlife Sanctuary (190 km^2). It is situated in Khanapur taluk, and primarily comprises evergreen and semi-evergreen forests of Hemmadga and Jamboti. Wildlife found in the Sanctuary includes tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*) etc. The Bhimgad forests are notable for the Barapede caves, breeding area of the Wroughton's free-tailed bat (Otomops wroughtoni).

Figure 11.65
Camera trap layout in Belagavi Forest Division, 2018-19



RESULTS

Camera Trap Results

Camera trapping in Belagavi Division yielding 16 tiger detections from which five individual tigers were identified (Table 11.18).

Table 11.18
Sampling details of camera trapping exercise for Belagavi Forest Division, 2018-19.

Sampling Details	Counts
Camera points	183
Trap nights (effort)	4642
Unique tigers captured	5

DISCUSSION

Belagavi Forest Division forms an important habitat corridor for tigers dispersing between Anshi Dandeli Tiger Reserve and Protected Areas of Goa and any developmental project in the area should be appropriately mitigated.

BHADRAVATHI FOREST DIVISION

INTRODUCTION

Bhadravarthi division is situated on the eastern part of Shivamogga circle. It covers parts of Shivamogga, Davanagere and Chikkamagaluru districts of Karnataka. The concerned taluks are Bhadravathi and Shivamogga (part) from Shivamogga district, Channagiri and Honnali (part) from Davanagere district, and Tarikere (part) from Chikkamagaluru district, respectively. The extent of notified forest area of the division is about 891.3 km^2. The division has two sub-divisions, namely, Channagiri and Tarikere sub-divisions, and consists of seven ranges, namely, Bhadravathi, Umblebyle, Lakavalli, Tarikere, Ajjampura, Channagiri and Shantisagar ranges. Forests of Bhadravathi division are primarily of dry deciduous and scrub type. Patches of moist deciduous forest are found in the Kukwada Ubrani and Antharagange state forests of Channagiri range and Chornedehalli and Kakanahosudi state forests of Umblebyle range. The forests of the division in the eastern part and nearer to habitation are highly degraded tending to thorny scrub type.

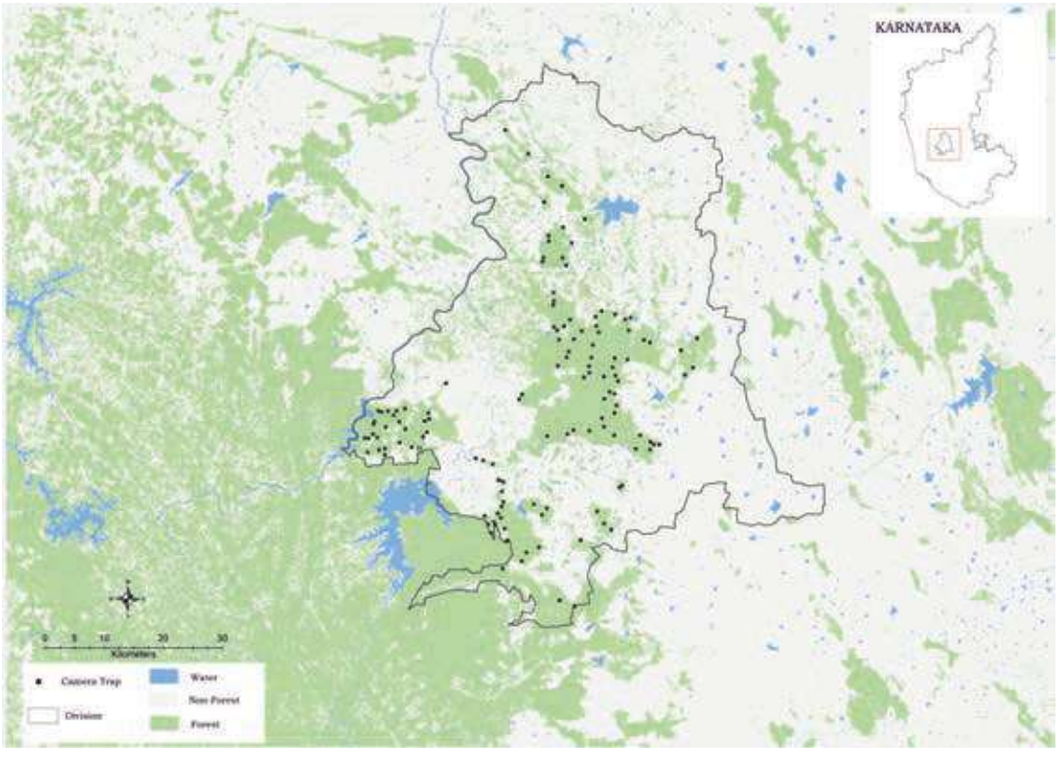


Figure 11.66 Camera trap layout in Bhadravathi Forest Division, 2018

RESULTS

Camera Trap Results

A total of 133 camera traps were deployed in Bhadravathi Division yielding 13 tiger detections from which four individual tigers were identified (Table 11.19).

Sampling details	Counts
Camera points	133
Trap nights (effort)	2468
Unique tigers captured	4

Table 11.19 Sampling details of camera trapping exercise for Bhadravathi Forest Division, 2018-19.

DISCUSSION

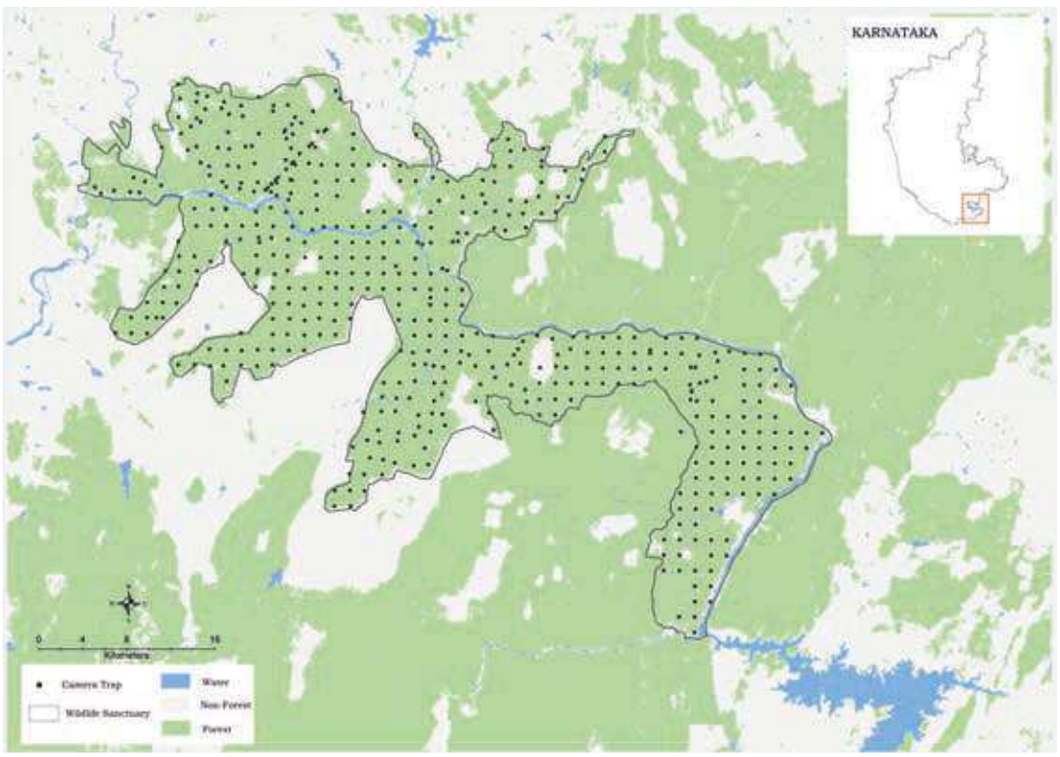
The forests serve as sink habitat for dispersing tigers from the adjacent tiger reserves.

CAUVERY WILDLIFE SANCTUARY

INTRODUCTION

Cauvery Wildlife Sanctuary is a protected area located in the Mandya, Chamarajanagar and Ramanagar districts of Karnataka. The Cauvery River passes through its midst. An area of 510.52 km^2 was established as Cauvery Wildlife Sanctuary in 1987. The sanctuary was expanded to its current area of 1027.53 km^2 in 2013. On its east, it adjoins Dharmapuri forest division of Tamil Nadu state. It lies within an elevation range of 125-1,514 metres. The sanctuary has a semi-arid climate, where the average temperatures are a minimum of 5 °C and maximum of 38 °C. The rainfall varies between 750 mm and 800 mm. The sanctuary mainly consists of dry deciduous forest, southern tropical dry thorn and riverine forests. It is home to mammals like tiger (*Panthera tigris*), elephant (*Elephas maximus*), wild pig (*Sus scrofa*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), spotted deer (*Axis axis*), barking deer (*Muntiacus vagionalis*), sambar (*Rusa unicolor*), four-horned antelope (*Tetracerus quadricornis*), mouse deer (*Moschiola indica*), common langur (*Semnopithecus entellus*), bonnet macaque (*Macaca radiata*), honey badger (*Mellivora capensis*), malabar giant squirrel (*Ratufa indica*), grizzled giant squirrel (*Ratufa macroura*) and smooth-coated otter (*Lutrogale perspicillata*).

Figure 11.67
Camera trap layout in Cauvery WLS, 2018



RESULTS

Camera Trap Results

A total of 502 camera traps were deployed in Cauvery Wildlife Sanctuary yielding five tiger detections from which two individual tigers were identified (Table 11.20).

Table 11.20
Sampling details of camera trapping exercise for Cauvery Wildlife Sanctuary, 2018.

Sampling Details	Counts
Camera points	502
Trap nights (effort)	16924
Unique tigers captured	2

DISCUSSION

Cauvery Wildlife Sanctuary is an important sink habitat for maintaining the metapopulation dynamics of tigers in the landscape. Feasibility of the upcoming Mekedatu dam within the sanctuary (inundating about 50 km^2 of forests) should be critically examined.

HALIYAL FOREST DIVISION

INTRODUCTION

Haliyal Forest Division comprises of Haliyal and part of Joida talukas of Uttar Kannada district of Karnataka but excludes the reserve forest areas of wildlife division Dandeli. The erstwhile Haliyal division, comprised of Haliyal, Bhagawati, Sambrani, Dandeli, Virnoli, Kulgi, Barchi, Jagalbet, Tinaighat and Gund Ranges. In 1997-1998, after the formation of wildlife division with head quarter at Dandeli, the ranges namely Gund, Kulgi and Virnoli (part) of Haliyal division were attached to wildlife. The division is situated between the north latitude 15° 5' 00" to 15° 29' 00" and east longitude between 74 ° 20' 21" to 74° 54' 40". The average altitude is 600 m above mean sea level. The important rivers in the tract are Kali, Pandri, Duski, Karka, Tattihalla and Nagzari. The total geographical area of division is 1,194 km^2. The climate is mostly humid round the year in the Ghat regions of Tinaighat. In eastern side, it is dry except during south-west monsoon. The highest rainfall is about 5000 mm at Joida taluk and lowest being 1000 mm in parts of Haliyal. The minimum temp is 15 °C in winter and maximum up to 35 °C in summer. Wild mammals seen in the tract are leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), tiger (*Panthera tigris*), elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), jackal (*Canis aureus*), barking deer (*Muntiacus vaginalis*), wild pig (*Sus scrofa*), sloth bear (*Melursus ursinus*), common langur (*Semnopithecus entellus*), malabar giant squirrel (*Ratufa indica*) etc. All four native species of hornbills (Great Pied/Indian Hornbill, Malabar Pied Hornbill, Indian Grey Hornbill and Malabar Grey Hornbill) are found in Hornbill Conservation Reserve and in surrounding areas of Haliyal and Dandeli - Anshi Tiger Reserve.

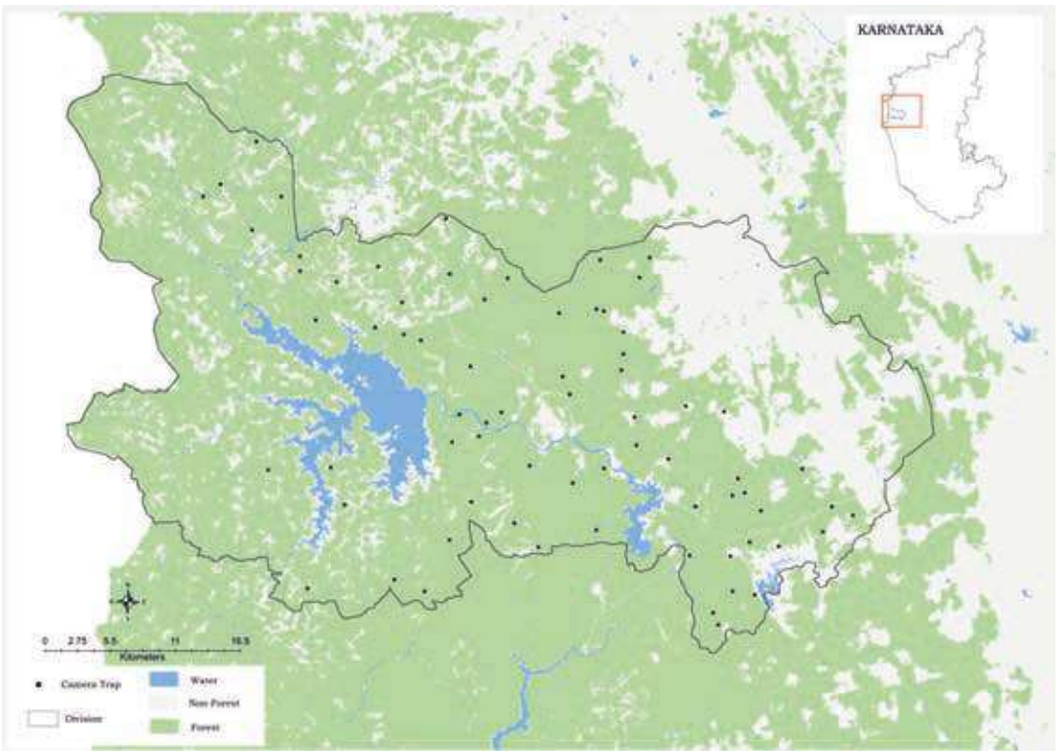


Figure 11.68
Camera trap layout in Haliyal Forest Division, 2018

RESULTS

A total of 71 camera traps were deployed in Haliyal Forest Division yielding 14 tiger detections from which 2 individual tigers were identified (Table 11.21).

Table 11.21

Sampling details of camera trapping exercise for Haliyal Forest Division, 2018-19.

Sampling details	Count
Camera points	71
Trap nights (effort)	1851
Unique tigers captured	2

DISCUSSION

Haliyal Forest Division is an important sink habitat for tigers from Anshi-Dandeli landscape.

HONAVAR TERRITORIAL DIVISION

INTRODUCTION

Honavar Forest Division is situated in the west coast in Uttara Kannada district of Karnataka. The division includes entire Bhatkal, Honavar and Kumta taluks and part of Ankola taluk. The total extent of forest areas of the division is 1,409 km^2 comprising 71% of the geographical area of the division (1,925 km^2). The division comprises both coastal areas and Ghat areas. Sharavati, Aghanashini and Gangavali are the three major rivers which run through the division and drain in to Arabian Sea. The division receives average rainfall of 3,500 mm to 4,000 mm per annum. It has three sub-divisions, namely, Honavar, Bhatkal and Kumta sub-divisions, and consists of seven ranges, namely, Bhatkal, Manki, Honnavar, Gersoppa, Kumta, Katgal and Hiregutti ranges. The division has 28 sections and 79 beats. There are two timber depots, at Honavar and Katgal. Honavar division primarily consists of semi-evergreen, evergreen and secondary moist deciduous forests. There are some mangrove forests in the coastal areas.

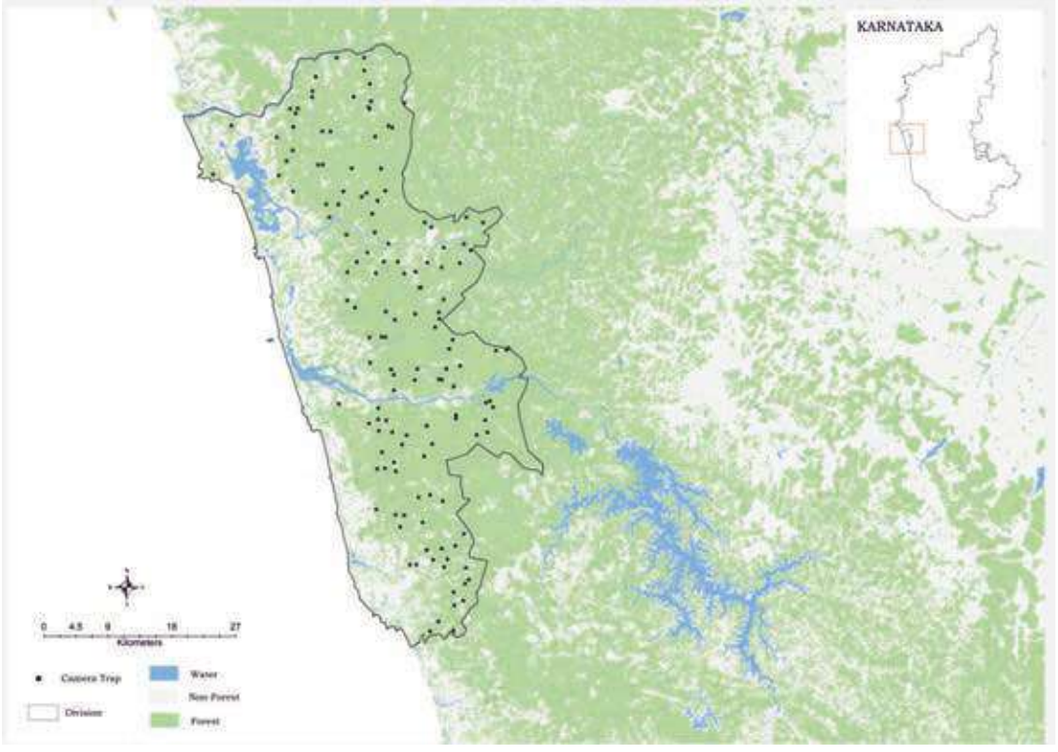


Figure 11.69 Camera trap layout in Honavar Forest Division, 2018-19

RESULTS

Camera Trap Results

A total of 144 camera traps were deployed in Honavar Division yielding no tiger image (Table 11.22).

Sampling details	Counts
Camera points	144
Trap nights (effort)	4184
Unique tigers captured	0

Table 11.22 Sampling details of camera trapping exercise in Honavar Forest Division, 2018-19.

DISCUSSION

The forests serve as sink habitat for dispersing tigers from the adjacent tiger reserve in the landscape (Kali Tiger Reserve).

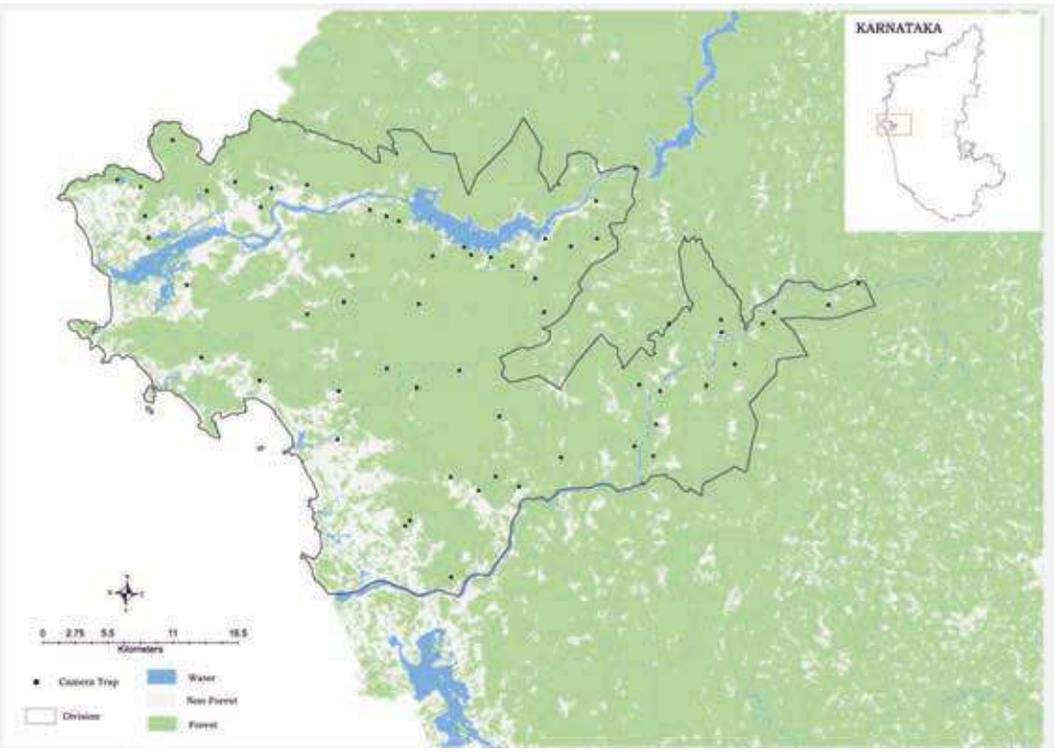
KARWAR FOREST DIVISION

INTRODUCTION

Karwar Forest Division is situated in the west coast in Uttara Kannada district of Karnataka, bordering the state of Goa in the north. The division includes the entire Karwar taluk and parts of Ankola and Joida taluks. The total extent of forest areas of the division is 1,179 km^2 comprising 71.75 % of the geographical area of the division (1,642.81 km^2). The Division comprises both coastal areas and Ghat areas. Kali and Gangavali are the major rivers which run through the division and drain into Arabian Sea. It has two sub-divisions, namely, Karwar and Ankola sub-divisions, and consists of seven ranges, namely, Karwar, Gopsitta, Kadra, Joida, Ankola, Mastikatta and Ramanguli ranges. The division has 28 sections and 79 beats. There are two timber depots, at Hattikeri and Kadra. Karwar division primarily consists of moist deciduous, semi-evergreen and evergreen forests, besides some mangrove in the coastal areas.

Figure 11.70

Camera trap layout in Karwar Forest Division, 2018-19



RESULTS

Camera Trap Results

A total of 63 camera traps were deployed in Karwar Forest Division; no tigers were photo-captured during this exercise (Table 11.23).

Table 11.23

Sampling details of camera trapping exercise for Karwar Forest Division, 2018-19.

Sampling Details	Counts
Camera points	60
Trap nights (effort)	1500
Unique tigers captured	0

DISCUSSION

The division would benefit with enhanced protection and reduction of human impacts to improve its biodiversity values.

KOPPA WILDLIFE DIVISION

INTRODUCTION

Koppa forest division is situated in the south-western part of Karnataka state. The division covers the revenue taluks of Narasimharajpura (N.R. Pura), Koppa and Sringeri. It comprises 892 km^2 of forest land which constitute about 44.58% of the geographical area of the division (2,000 km^2). The division has two sub-divisions, namely, Koppa and Balehonnur, and consists of six ranges, namely, Balehonnur, Chikkagrahara, Kalasa, Koppa, Narasimharajpura (N.R. Pura) and Sringeri ranges. The division has a timber depot at N.R. Pura. Forests of Koppa division are principally of semi-evergreen and moist deciduous types with some excellent patches of evergreen forests in Kalasa and Sringeri ranges. In the higher reaches of the evergreen forests, shola vegetation surrounded by grassy blanks is also encountered in the areas adjoining to Kudremukh National Park.

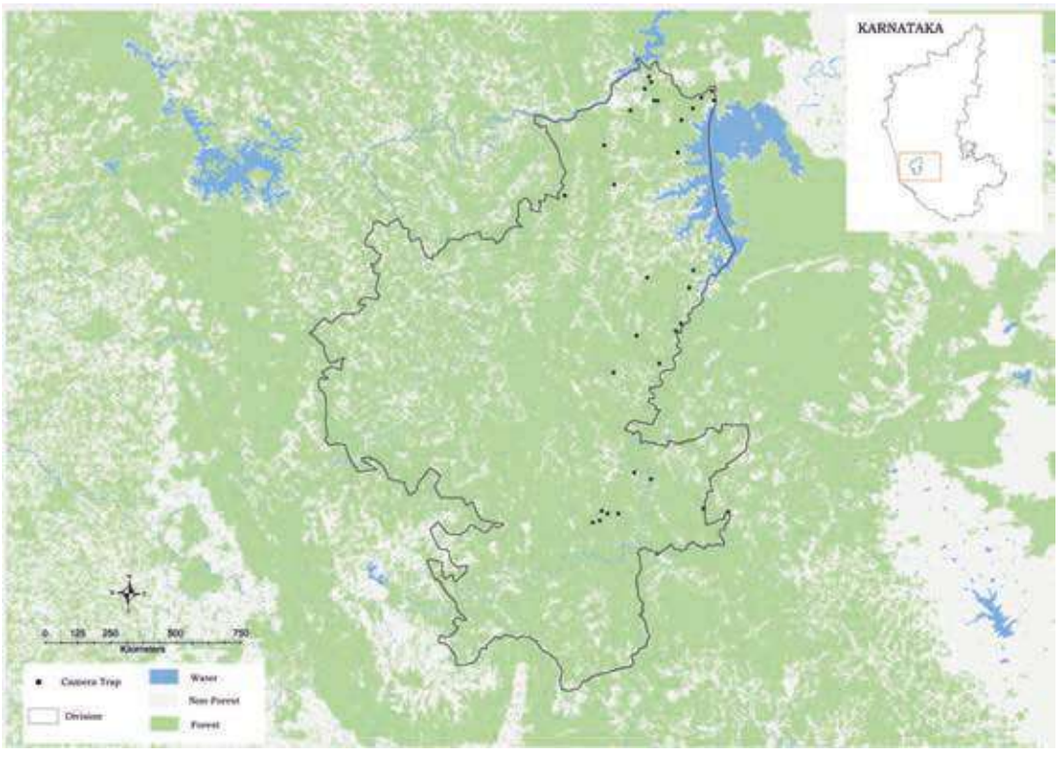


Figure 11.71 Camera trap layout in Koppa Wildlife Division, 2018-19

RESULTS

Camera Trap Results

A total of 32 camera traps were deployed in Koppa Forest Division yielding 3 tiger detections from which three individual tigers were identified (Table 11.24).

Sampling details	Counts
Camera points	32
Trap nights (effort)	902
Unique tigers captured	3

Table 11.24 Sampling details of camera trapping exercise for Koppa Forest Division, 2018.

DISCUSSION

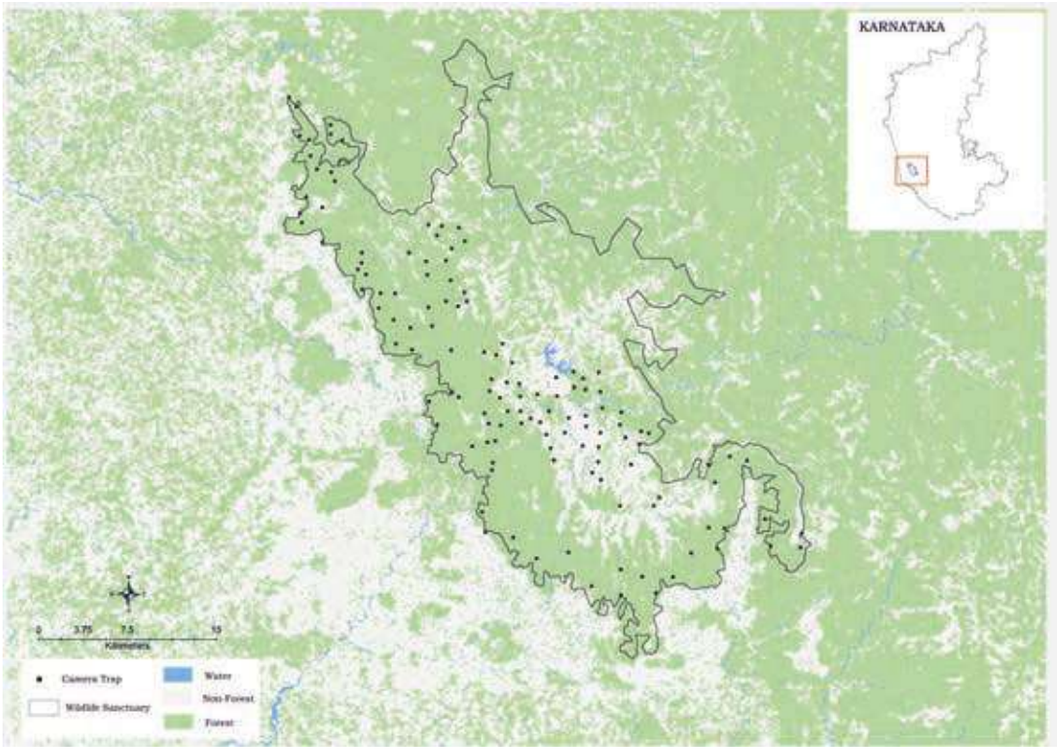
The division is currently under human pressures in terms of extraction of forest resources which need to be minimized so as to improve its biodiversity values.

KUDREMUKH NATIONAL PARK

INTRODUCTION

Kudremukh National Park is spread over an area of 600.32 km^2 thick hilly forests near the coastal plains on the western portion and the shola vegetation on the Western Ghats uplands, covering parts of three districts, viz., Chickmagalur, Udupi and Dakshina Kannada in the state of Karnataka. The Kudremukh peak, by which the national park derives its name, is the highest spot at 1892 meters. The hills, which bear the brunt of the severe monsoon winds, preclude any tree growth. Added to that the region is known for its rich low grade magnetite soil which primarily inhibits tree growth. As a result, the landscape is covered with grass. The valleys which are tucked in, have reasonable protection from wind and a deep soil profile, as a result of which stunted evergreen forests exist creating a unique microclimate, rich with mosses, orchids, etc. The whole scenery of grassland interspersed with narrow strips of forests provides a fantastic vista. Three important rivers, the Tunga, the Bhadra, and the Nethravathi are said to have their origins here. Major mammalian fauna found in the park include malabar civet (*Viverra civettina*), tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), sambar (*Rusa unicolor*) and chital (*Axis axis*).

Figure 11.72
Camera trap layout in Kudremukh National Park, 2018-19



RESULTS

Camera Trap Results

A total of 130 camera traps were deployed in Kudremukh National Park yielding eight tiger detections from which one individual tiger was identified (Table 11.25).

Table 11.25
Sampling details of camera trapping exercise in Kudremukh National Park, 2018.

Sampling Details	Counts
Camera points	130
Trap nights (effort)	3389
Unique tigers captured	1

DISCUSSION

Kudremukh National Park is not only a part of an important tiger landscape, but it also supports rich biodiversity and endemism. Habitat fragmentation and mining are major threats for this park which need to be regulated so that the conservation value of the park is not compromised.

MADIKERI TERRITORIAL DIVISION

INTRODUCTION

Madikeri Forest Division (also known as Mercara) is situated on the northern part of Kodagu circle in the state of Karnataka. The total extent of reserved forests of Madikeri division is 369 km^2. However, besides Reserved Forests, there are other tree-clad areas covered under the working plan of Madikeri division which come under various categories such as Protected Forests, Devarakadus, Paisaries, Section-4 notified areas, unredeemed lands and Bane lands, etc. The total extent of such lands including the Reserved Forests of the division is 1,157 km^2. Madikeri division comprises of two forest sub-divisions, namely, Madikeri and Somavarpet sub-divisions, and consists of six ranges, namely, Bhagamandala, Madikeri, Sampaje, Kushalnagar, Shanivarasanthe and Somavarpete. These areas come within Madikeri and Somavarpete taluks of Kodagu district. Forests of Madikeri division are primarily evergreen, semi-evergreen and moist deciduous. Bhagamandala and Sampaje ranges have some excellent patches of evergreen forests in the Reserved Forests of Padinalknad, Pattighat and Kadamkal. Madikeri range has some good evergreen and semi-evergreen forests. The remaining ranges of the division, namely, Kushalnagar, Somavarpet and Shanivarasanthe have moist deciduous forests with semi-evergreen patches in moister localities. A large portion of the division is under coffee estates, which complement the green landscape, giving an impression as if the entire division is forested.

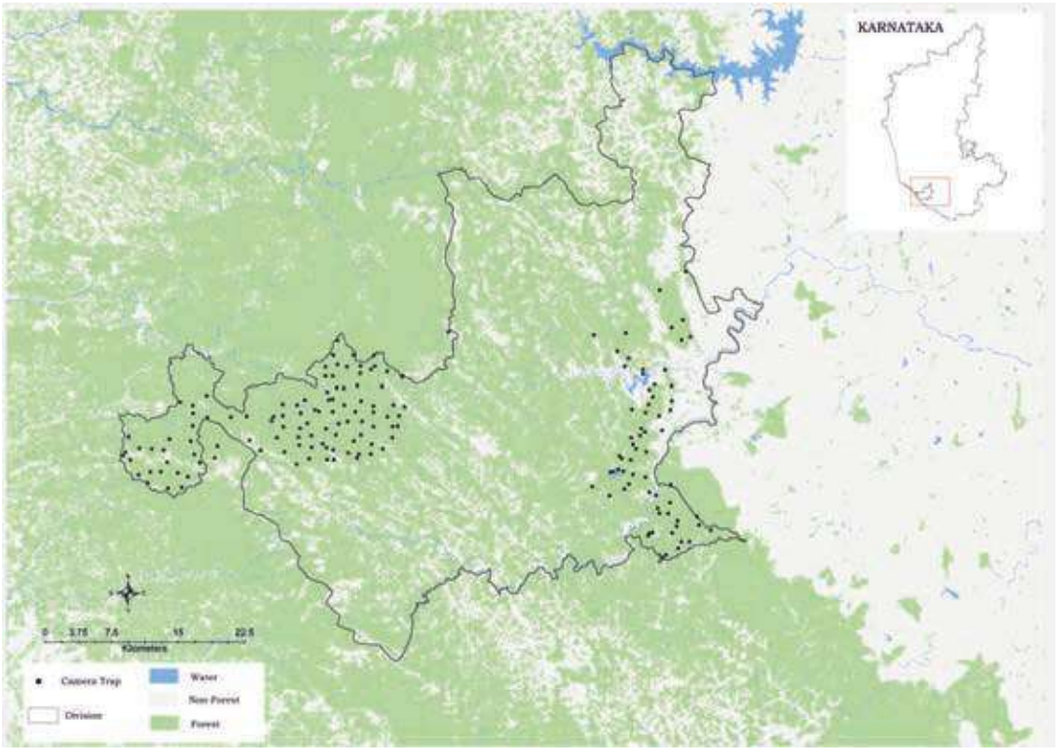


Figure 11.73 Camera trap layout in Madikeri Territorial Division, 2018-19

RESULTS

Tiger Density Estimates

A total of 169 camera traps were deployed in Madikeri Territorial Division yielding 64 tiger detections from which 10 individual tigers were identified. Density of tigers in Madikeri Territorial Division was estimated to be 1.45 (SE 0.46) per 100 km^2 (Table 11.26). The male to female sex ratio (model inferred) in Madikeri Territorial Division was 0.33:0.67 (Table 11.26).

Table 11.26

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Madikeri Territorial Division, 2018.

Variables	Estimates
Model space (km^2)	1531.37
Camera points	169
Trap nights (effort)	2871
Unique tigers captured	10
Model	g_0 (.) σ (.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.45 (0.46)
σ (SE) km	2.51 (0.33)
g_0 (SE)	0.004 (0.001)
Pmix Female (SE)	0.67 (0.27)
Pmix Male (SE)	0.33 (0.27)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

The division has more tigers and a higher tiger density compared to many Tiger Reserves. It acts as an important sink for the adjacent Nagarhole Tiger Reserve. Minimizing further habitat fragmentations and mitigating human-wildlife conflict in the Division would be essential for fostering long term viability of tigers in this multiple use landscape.

MADIKERI WILDLIFE DIVISION

INTRODUCTION

Madikeri wildlife division comprises of three wildlife sanctuaries, namely, Brahmagiri Wildlife Sanctuary (181.29 km²), Pushpagiri Wildlife Sanctuary (102.92 km²) and Talacauvery Wildlife Sanctuary (105.59 km²) in the state of Karnataka. Madikeri Wildlife Division consists of one sub-division, namely, Madikeri wildlife sub-division, and consists of four wildlife ranges, namely, Makutta, Virajpet, Srimangala and Talacauvery Wildlife Ranges. Brahmagiri Sanctuary is located in Virajpet Taluk. It adjoins the forests of the Wyanad district of Kerala state. It covers Brahmagiri and Urti Reserved Forests. The Sanctuary is named after its highest point (peak) known as Brahmagiri (1,607 m). Pushpagiri sanctuary is located in Somwarpet taluk. The sanctuary covers a part of Kadamakkal Reserved Forest. The highest point (peak) of the Sanctuary is Pushpagiri (Kumara Parvata) (1,712 m). The Sanctuary adjoins the Bisle Ghat Forests of Hassan division and the Kukke Subramanya forests of Mangalore division. Talacauvery Sanctuary is located in Madikeri taluk. It adjoins the forests of Kasarkode district of Kerala state. The Sanctuary covers part of Padinalknad Reserve Forest. The Sanctuary is named after Talacauvery, the origin of the Cauvery River which lies on the eastern edge of the Sanctuary. The forests of all the three Wildlife Sanctuaries of Madikeri Wildlife Division are evergreen or semi-evergreen. Major mammals found in the sanctuaries are tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), Nilgiri marten (*Martes gwatkinsii*), elephant (*Elephas maximus*), gaur (*Bos gaurus*), sloth bear (*Melursus ursinus*), Lion-tailed macaque (*Macaca silenus*), common langur (*Semnopithecus entellus*), sambar (Rusa unicolor), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), Malabar giant squirrel (*Ratufa indica*), giant flying squirrel (*Petaurista philippensis*), wild pig (*Sus scrofa*) etc.

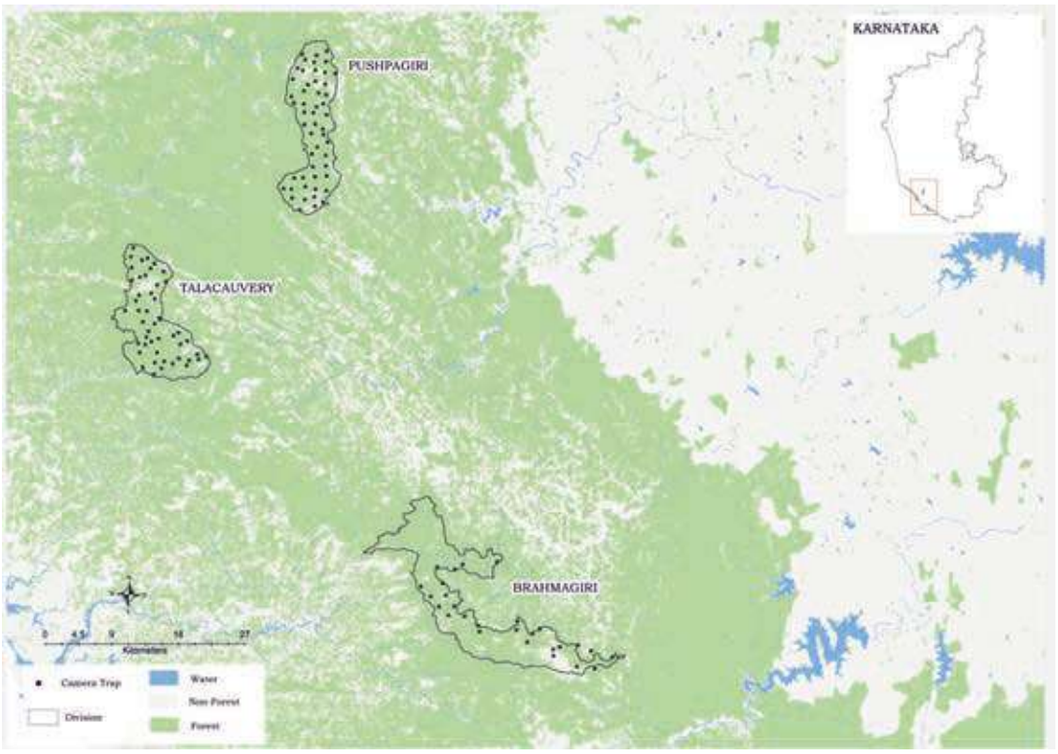


Figure 11.74 Camera trap layout in Madikeri Wildlife Division, 2018

RESULTS

Tiger Density Estimates

A total of 140 camera traps were deployed in Madikeri Wildlife Division yielding 14 tiger detections(including one image of cub) from which 10 individual tigers were identified. Density of tigers in Madikeri Wildlife Division was estimated to be 1.89 (SE 1.33) per 100 km^2 (Table 11.27). The model inferred tiger male to female sex ratio in Madikeri Wildlife Division was 0.57:0.43 (Table 11.27).

Table 11.27

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Madikeri Wildlife Division, 2018. Variables Estimates

Variables	Estimates
Model space (km^2)	1899.75
Camera points	140
Trap nights (effort)	3696
Unique tigers captured	10
Model	g_0 (.) σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.89 (1.33)
σ (SE) km	2.09 (0.97)
g_0 (SE)	0.002 (0.002)
Pmix Female (SE)	0.43 (0.18)
Pmix Male (SE)	0.57 (0.18)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

The division has more tigers and a higher tiger density compared to many Tiger Reserves. It acts as an important sink for the adjacent Nagarhole Tiger Reserve. Mitigating human-wildlife conflict in the Division would be essential for fostering long term viability of tigers in this landscape.

MALE MAHADESHWARA HILLS WILDLIFE SANCTUARY (MM HILLS)

INTRODUCTION

Male Mahadeshwara Wildlife Sanctuary is located in the state of Karnataka in India. It is named after the presiding deity "Lord Male Mahadeshwara" of the famed Male Mahadeshwara Hills Temple located within the sanctuary. The sanctuary lies in the Chamarajanagar district of Karnataka. The sanctuary was established in 2013 with an area of 906.187 km^2 and is proposed to be designated as a tiger reserve. The sanctuary has Cauvery Wildlife Sanctuary (Karnataka) to its North and East, Sathyamangalam Tiger Reserve (Tamil Nadu) to its South and Biligirirangaswamy Temple Tiger Reserve (Karnataka) to its West. The predominant forest type of the sanctuary is dry and moist deciduous forests. The sanctuary supports major mammalian fauna like tiger (*Panthera tigris*), elephant (*Elephas maximus*), gaur (*Bos gaurus*), wild pig (*Sus scrofa*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), sambar (*Rusa unicolor*), four-horned antelope (*Tetracerus quadricornis*), mouse deer (*Moschiola indica*), common langur (*Semnopithecus entellus*), bonnet macaque (*Macaca radiata*), honey badger (*Mellivora capensis*) etc.

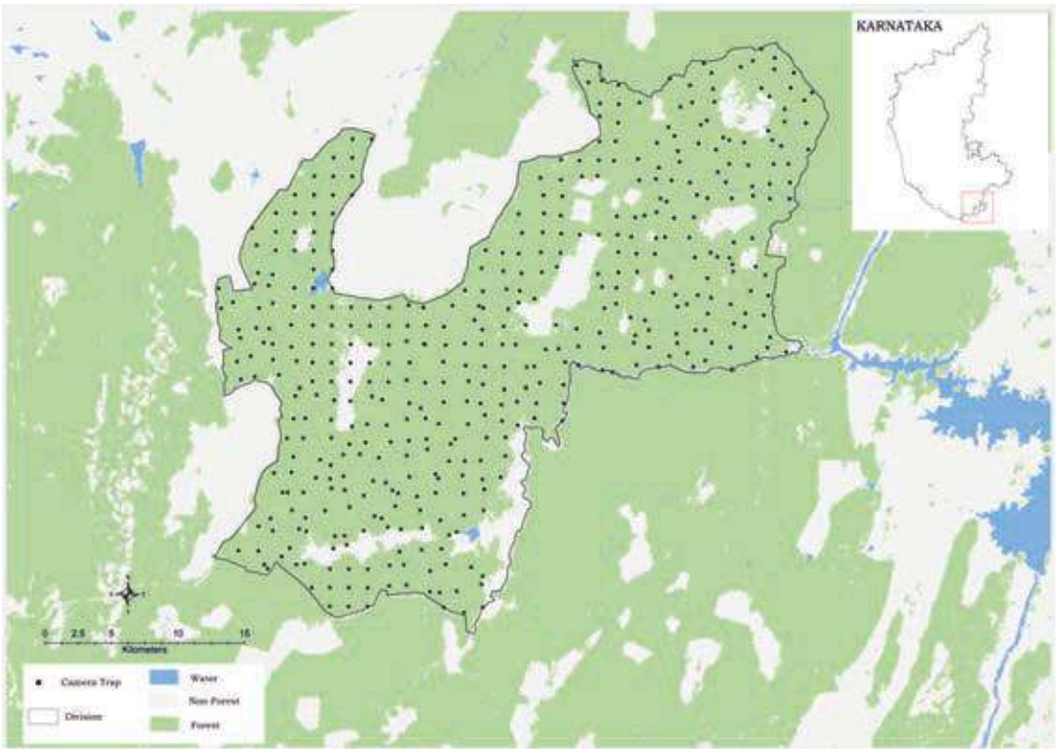


Figure 11.75
Camera trap layout in MM Hills Wildlife Sanctuary, 2018-19

RESULTS

Tiger Density Estimates

A total of 447 camera traps were deployed in MM Hills WLS yielding 118 tiger detections from which eight individual tigers were identified. Density of tigers in MM Hills WLS was estimated to be 0.32 (SE 0.12) per 100 km^2 (Table 28). The model inferred tiger male to female sex ratio in MM Hills WLS was 0.20:0.80 (Table 28).

Table 11.28

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for MM Hills WLS, 2018. Variables Estimates

Variables	Estimates
Model space (km^2)	3154.62
Camera points	447
Trap nights (effort)	9808
Unique tigers captured	8
Model	g_0 (.)σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.32 (0.12)
σ (SE) km	4.05 (0.22)
g_0 (SE)	0.002 (0.002)
Pmix Female (SE)	0.80 (0.17)
Pmix Male (SE)	0.20 (0.17)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

It would be advantageous to declare Male Mahadeshwara Wildlife Sanctuary as a tiger reserve as this would increase resource allocation for incentivized voluntary relocation of human settlements, and assist in prey and tiger recovery adding space for dispersing and colonizing tigers in this landscape of global conservation importance. The Sanctuary is strategically located to connect major tiger reserves.

MOOKAMBIKA WILDLIFE SANCTUARY

INTRODUCTION

Mookambika Wildlife Sanctuary is a protected area in the state of Karnataka. The sanctuary lies in the Western Ghats in Udupi district of Karnataka. The sanctuary consists of an area of 274 km^2 which was notified in the year 1974. The expanded sanctuary comprises the Abbigudde, Baregundi, Chakra, Chittor, Gunduberu, Harmannupare, Hulikal, Hulimurdibare, Jannalane, Kilandur, Kodachadri, Korakoppadahola, Korathikalbare, Madibare, Meganivalley, Metkalgudda, Mudgalpare, Murkodihola, Naganakalbare, Nujinane, Talburane reserve forests. The Mookambika Wildlife Sanctuary has west coast tropical evergreen forests, west coast semi evergreen forests, southern secondary moist mixed deciduous forests and dry grasslands in its ranges. The sanctuary has fauna like tiger (*Panthera tigris*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), jackal (*Canis aureus*), sloth bear (*Melursus ursinus*), wild pig (*Sus scrofa*), Indian porcupine (*Hystrix indica*), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*), gaur (*Bos gaurus*), black naped hare (*Lepus nigricollis*), lion tailed macaque (*Macaca Silenus*), bonnet macaque (*Macaca radiata*), common langur (*Semnopithecus entellus*), giant flying squirrel (*Petaurista philippensis*) etc.

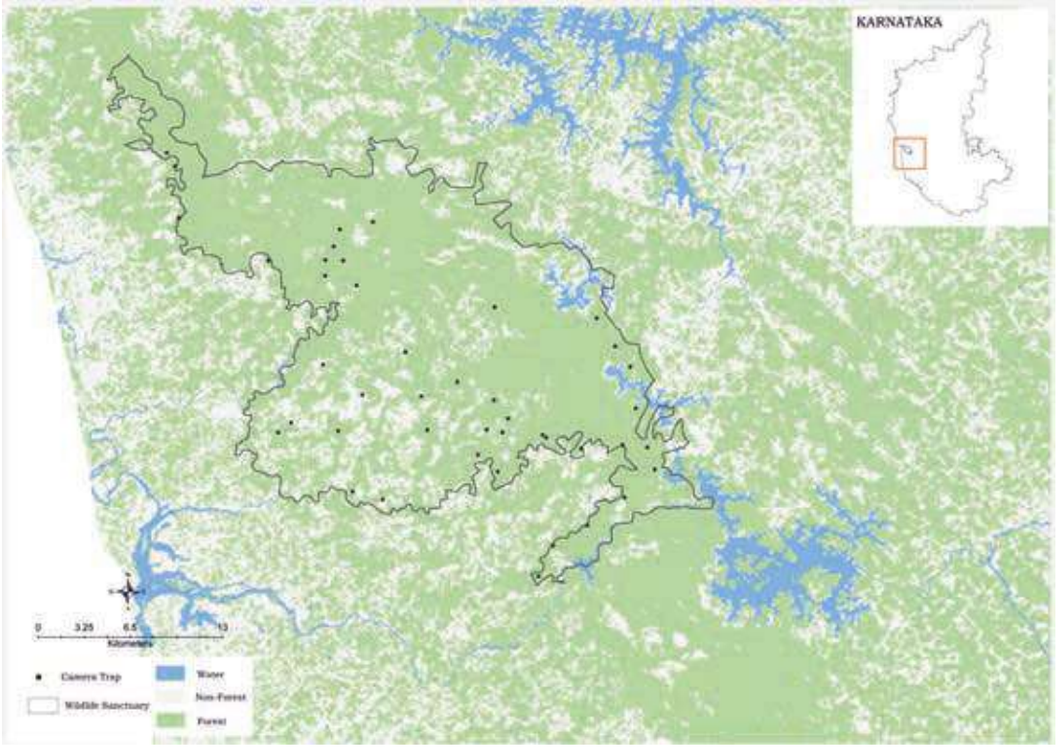


Figure 11.76 Camera trap layout in Mookambika Wildlife Sanctuary, 2018-19

RESULTS

Camera Trap Results

A total of 43 camera traps were deployed in Mookambika WLS yielding no tiger image (Table 11.29).

Sampling details	Counts
Camera points	43
Trap nights (effort)	1037
Unique tigers captured	0

Table 11.29 Sampling details of camera trapping exercise for Mookambika Wildlife Sanctuary, 2018-19.

DISCUSSION

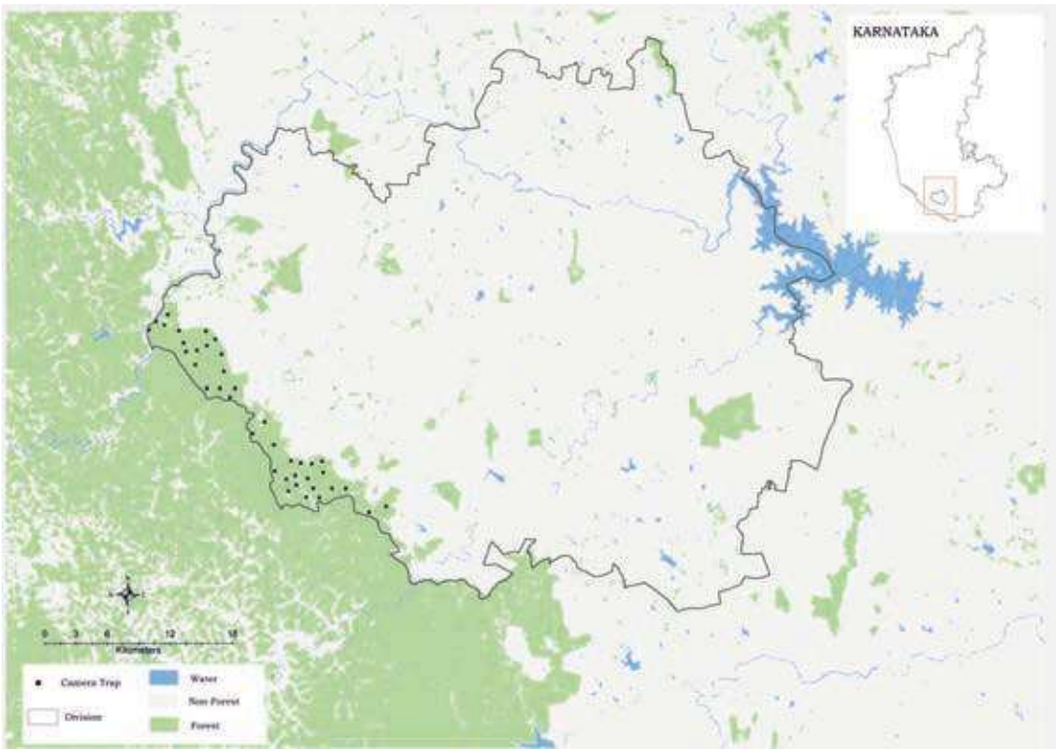
Although no tiger was captured during the exercise, but Mookambika Wildlife Sanctuary acts as an important sink for the tigers from the adjacent tiger reserves.

PERIYAPATNA (HUNSUR DIVISION)

INTRODUCTION

Hunsur division is situated in the western part of Mysuru district, Karnataka. The division is bounded on the north by Hassan forest division, on the east by Mysuru forest division, on the south by the Nagarahole Tiger Reserve and on the west by Madikeri and Virajpet forest divisions. The extent of notified forests of Hunsur division is 136 km^2 which constitutes about 5.6% of the geographical area of the division (2,432.91 km^2). The division has one sub-division, namely, Hunsur sub-division, and comprises of three ranges, namely, Hunsur, Periyapatna and K.R. Nagar ranges. All these ranges come under Mysore district except for a portion of Mattadakaval State forest of K.R. Nagar range, which falls in Hassan and Mandya districts. The forests of Hunsur division are fringe forests abutting the Western Ghats and most of its biodiversity elements are similar to those found in the forests of the Western Ghats. These forests are quite rich in their floristic and faunal diversity and great variability at species and ecosystem levels having different types of vegetation like evergreen, moist deciduous, dry deciduous, scrub and swamps (locally known as hadlus). As Hunsur forest division in adjacent to the Rajiv Gandhi National Park (Nagarahole tiger reserve), most of the animals found in the park are also found in the forests of Hunsur division especially in the Doddaharve, Anechowkur and Muddanahalli state forests.

Figure 11.77
Camera trap layout in Hunsur Division, 2018-19



RESULTS

Tiger Density Estimates

A total of 39 camera traps were deployed in Hunsur Division yielding 46 tiger detections from which 11 individual tigers were identified. Density of tigers in Hunsur Division was estimated to be 3.07 (SE 1.02) per 100 km^2 (Table 11.30). The model inferred tiger male to female sex ratio in Hunsur Division was 0.67:0.33 (Table 11.30).

Table 11.30

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Hunsur Division, 2018-19.

Variables	Estimates
Model space (km^2)	414.75
Camera points	39
Trap nights (effort)	980
Unique tigers captured	11
Model	g_0 (.) σ (.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	3.07 (1.02)
σ (SE) km	4.02 (0.6)
g_0 (SE)	0.02 (0.005)
Pmix Female (SE)	0.33 (0.19)
Pmix Male (SE)	0.67 (0.19)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

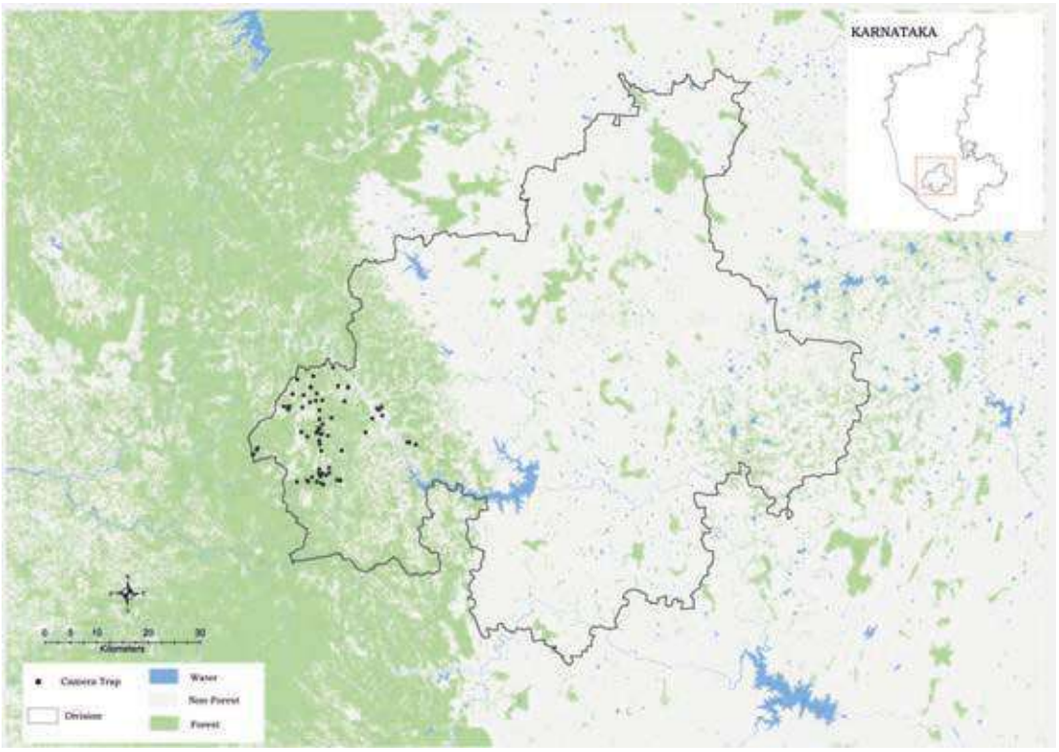
Hunsur Division is an important sink for tigers from Bandipur and Nagarhole Tiger Reserves and is crucial for maintaining the metapopulation dynamics of tigers in the landscape. Removal of anthropogenic pressures, better protection and mitigating human wildlife conflict are some of the key recipes for future conservation of this Division.

SAKLESHPURA (HASSAN FOREST DIVISION)

INTRODUCTION

Hassan Forest Division is situated in the south western sector of Karnataka. The limits of Hassan division are the same as those of Hassan district. The total extent of forest land in the division is 881 km^2 which constitutes about 12.92% of the geographical area of the division (6,814 km^2). Hassan division has three sub-divisions, namely, Hassan, Sakaleshpura and Channarayapatna sub-divisions, and consists of nine ranges, namely, Alur, Arkalgud, Arsikere, Belur, Channarayapatna, Hassan, Holenarsipura, Sakaleshpur and Yeslur ranges. Sakleshpur and Yeslur ranges have primarily evergreen and semi-evergreen forests interspersed with moist deciduous forests. There are some shola forest patches surrounded by grasslands at higher altitudes (above 1,000 m). There are extensive coffee plantations in these two ranges in the semi-evergreen / moist deciduous zone. The remaining forest ranges of the division primarily have dry deciduous and scrub forests.

Figure 11.78
Camera trap layout in Sakleshpura, 2018-19



RESULTS

Camera Trap Results

A total of 66 camera traps were deployed in Sakleshpura, no tiger photocaptures were recorded (11.31).

Table 11.31
Sampling details of camera trapping exercise for Sakleshpura 2018-19.

Sampling Details	Counts
Camera points	66
Trap nights (effort)	1380
Unique tigers captured	0

DISCUSSION

Although no tiger was captured during the exercise, but Sakleshpura acts as an important sink for the tigers from the adjacent tiger reserves (Bandipur and Nagarhole).

SHIVAMOGGA WILDLIFE DIVISION

INTRODUCTION

Shivamogga Wildlife Division is situated in the central part of Shivamogga circle of Karnataka. It covers forest areas from Shivamogga, Thirthahalli, Sagar and Hosanagara taluks. The division is in charge of three Wildlife Sanctuaries, namely, Shettihalli Wildlife Sanctuary (395.60 km^2), Sharavathi Wildlife Sanctuary (431.23 km^2) and Gudavi Bird Sanctuary (0.73 km^2). Gudavi Bird Sanctuary is situated in Soraba taluk. Shivamogga Wildlife Division has two sub-divisions, namely, Shivamogga wildlife and Kargal wildlife sub-divisions, and consists of four ranges, namely, Hanagere, Kargal, Shivamogga and Sakrebyle ranges. Forests of Sharavathi wildlife sanctuary are primarily of evergreen and semi-evergreen types. Forests of Shettihalli Wildlife Sanctuary are primarily of moist deciduous and semi-evergreen types. The forests towards the eastern part of the Sanctuary such as Anesara and Purdal are of dry deciduous type. The forests of the Sanctuary nearer to Shivamogga city are fairly degraded due to biotic interferences. Wildlife found in the Shettihalli and Sharavathi Sanctuaries includes tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), gaur (*Bos gaurus*), elephant (occasional), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), sloth bear (*Melursus ursinus*), wild pig (*Sus scrofa*), jackal (*Canis aureus*), bonnet macaque (*Macaca radiata*), common langur (*Semnopithecus entellus*) and varieties of reptiles and birds.

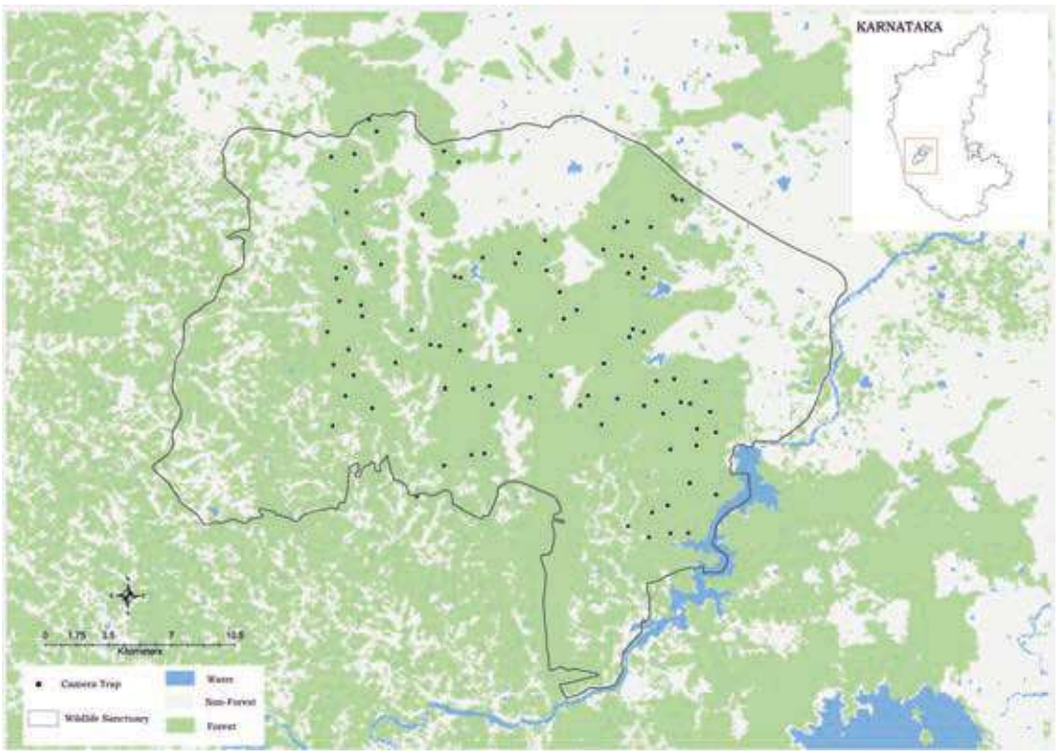


Figure 11.79 Camera trap and layout in Shettihalli Wildlife Sanctuary, 2018-19

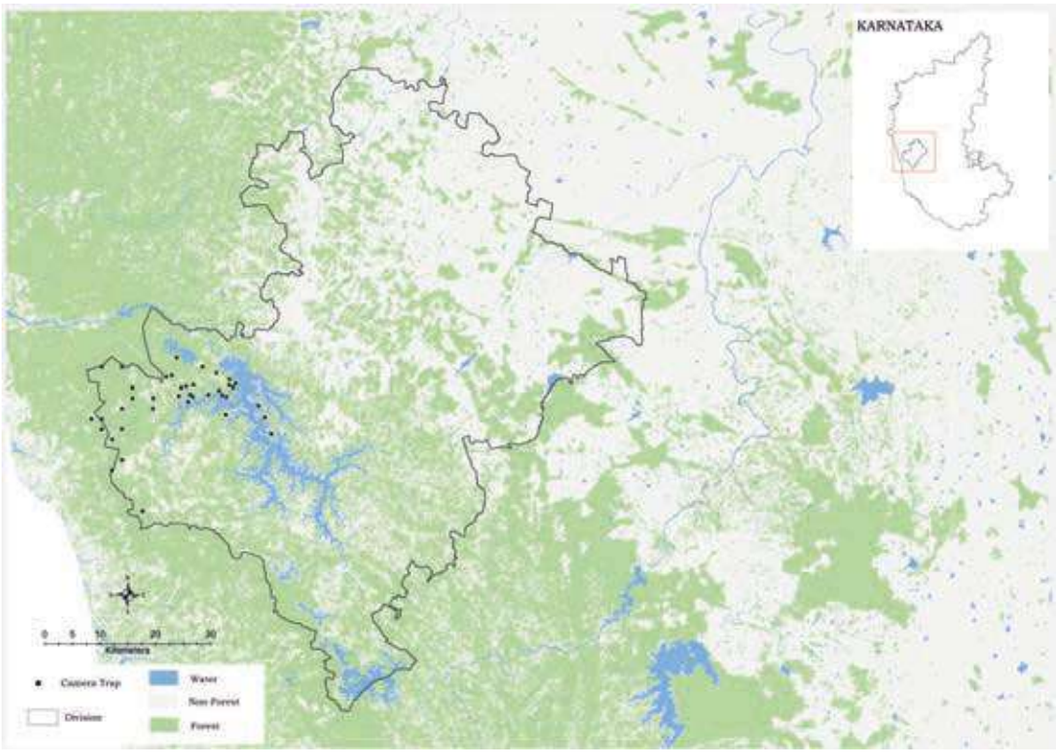


Figure 11.80
Camera trap layout in Sharavathi Wildlife Sanctuary, 2018-19

RESULTS

Camera Trap Results

A total of 134 camera traps were deployed in Shivamogga Wildlife Division yielding 33 tiger detections from which four individual tigers were identified (Table 11.32).

Table 11.32
Sampling details of camera trapping exercise Shivamogga Wildlife Division, 2018-19.

Sampling Details	Counts
Camera points	134
Trap nights (effort)	2718
Unique tigers captured	4

DISCUSSION

The division would benefit with enhanced protection and reduction of human impacts to improve its biodiversity values.

SIRSI TERRITORIAL DIVISION

INTRODUCTION

Sirsi forest division is situated in the south-western part of Uttara Kannada district bordering Shivamogga district in the west. It covers Sirsi and Siddapur taluks and a small part of Mundgod taluk. The total forest area of the division including Betta lands (protected forest) is 1,718 km^2 which constitute 79.04% of the total geographical area of the division (2,173.90 km^2). The major rivers draining the division are Aghanashini, Sharavathi, Varada, Sonda, Dharma and Bedti. Dharma and Varada rivers drain towards the east and eventually join the Tunga-Bhadra River. The other rivers are west-flowing and join the Arabian Sea. Bedti is known as Gangavali in the downstream areas. Sirsi division has three sub-divisions, namely, Sirsi, Janmane and Siddapur sub-divisions, and consists of six ranges, namely, Sirsi, Hulekal, Banavasi, Janmane, Siddapur and Kyadgi ranges. There are 22 sections and 78 beats in the division. There are two timber depots, at Chipgi and Manmane. Sirsi division primarily harbors semi-evergreen and moist deciduous forests with pockets of wet evergreen forests in the valleys. Portions of the forests of the division towards the east tend to be scrubby.

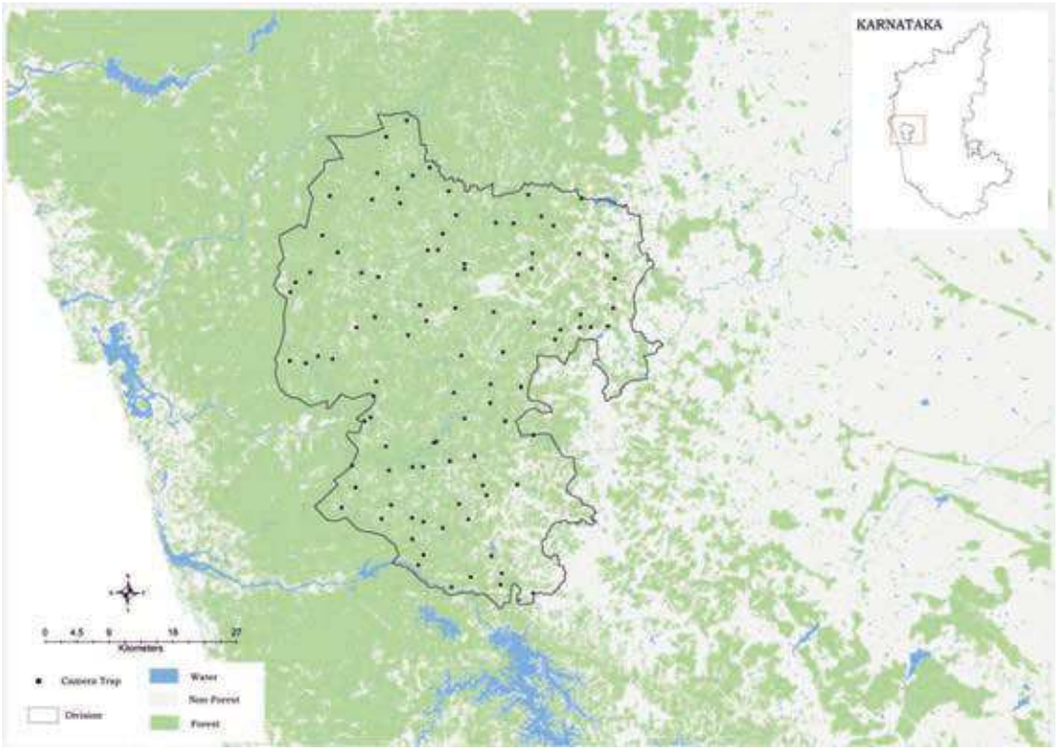


Figure 11.81
Camera trap layout in Sirsi Territorial Division, 2018-19

RESULTS

Camera Trap Results

A total of 114 camera traps were deployed in Sirsi Territorial Division yielding 1 tiger image from which 1 individual tiger was identified (Table 11.33).

Sampling details	Counts
Camera points	114
Trap nights (effort)	3220
Unique tigers captured	1

Table 11.33
Sampling details of camera trapping exercise for Sirsi Forest Division, 2018-19.

DISCUSSION

Even though only one tiger was detected, this detection validates the importance of Sirsi Forest Division as a stepping stone patch (important sink for adjacent tiger reserves) for maintaining the meta-population of tigers in this landscape.

SOMESHWARA WILDLIFE SANCTUARY

INTRODUCTION

Situated in the Western Ghats, the Someshwara Wildlife Sanctuary covers an area of 88.4 km^2 in Udupi District, Karnataka. The sanctuary lies in Udupi and Shivamogga districts of Karnataka, below Agumbe. It was declared a Wildlife Sanctuary in 1974. It was subsequently expanded to 314.25 km^2 in the year 2011. Post expansion the sanctuary spans across Udupi, Kundapura, Karkala, Thirthahalli taluks of Udupi and Shivamoga districts. The sanctuary was expanded by adding Balehalli Reserve Forest, Agumbe State Forest, Someshwara Reserve Forest and Tombatlu Reserve Forest areas, to the existing sanctuary. The expanded sanctuary forms a contiguous stretch of protected area that includes Mookambika Wildlife Sanctuary, Sharavathi Wildlife Sanctuary and Kudremukh National Park. The Someshwara Wildlife Sanctuary has tropical wet evergreen forests, west coast semi evergreen forests and southern secondary moist mixed deciduous forests in its ranges. The sanctuary has fauna like tiger (*Panthera tigris*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), jackal (*Canis aureus*), palm civet (*Paradoxurus hermaphroditus*), jungle cat (*Felis chaus*), wild pig (*Sus scrofa*), Indian porcupine (*Hystrix indica*), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*), gaur (*Bos gaurus*), black naped hare (*Lepus nigricollis*), lion tailed macaque (*Macaca Silenus*), bonnet macaque (*Macaca radiata*), common langur (*Semnopithecus entellus*), giant flying squirrel (*Petaurista philippensis*) etc.

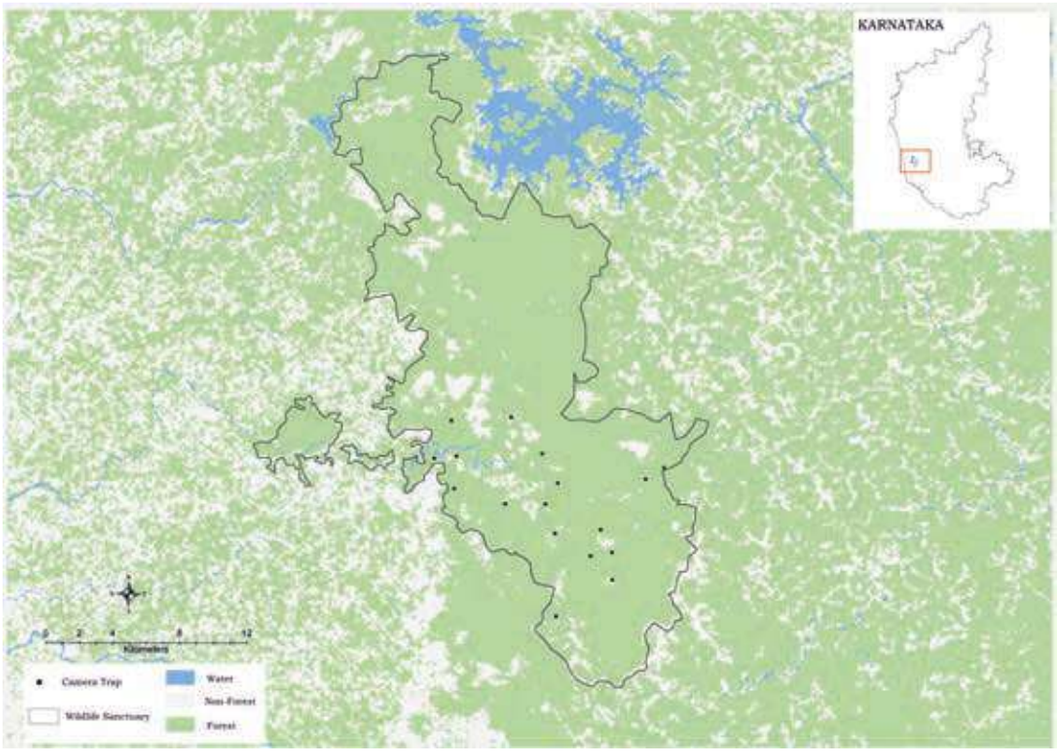


Figure 11.82
Camera trap layout in Someshwara Wildlife Sanctuary, 2018-19

RESULTS

Camera Trap Results

A total of 17 camera traps were deployed in Someshwara Wildlife Sanctuary yielding 1 tiger image from which one individual tiger was identified (Table 11.34).

Table 11.34
Sampling details of camera trapping exercise for Someshwara Wildlife Sanctuary, 2018-19.

Sampling Details	Counts
Camera points	17
Trap nights (effort)	420
Unique tigers captured	1

DISCUSSION

The Sanctuary is strategically located to connect major tiger reserves and tiger bearing Protected Areas and Forest Divisions. Thus it acts as an important stepping stone for maintaining tiger metapopulation dynamics in the landscape.

VIRAJPET TERRITORIAL DIVISION

INTRODUCTION

Virajpet Forest Division occupies the southern part of Kodagu circle. The total extent of Reserve Forests of Virajpet division is 303 km^2. In addition to the Reserve Forests, there are tree covered areas in the division in the form of Protected Forests, Devarakadus, Paisaries, Section-4 notified areas, unredeemed lands and Bane lands, etc. Virajpet division comprises of two sub-divisions, namely, Virajpet and Thithimathi sub-divisions, and consists of three ranges namely, Munrote, Makutta and Thithimathi ranges. Forests of Virajpet division are primarily evergreen, semi-evergreen and moist deciduous. Evergreen and semi-evergreen forests are found in Padinalknad and Kerti Reserve Forests. Moist deciduous forests occur in Mavukal and Devamachi Reserve Forests. There are extensive coffee estates in the division.

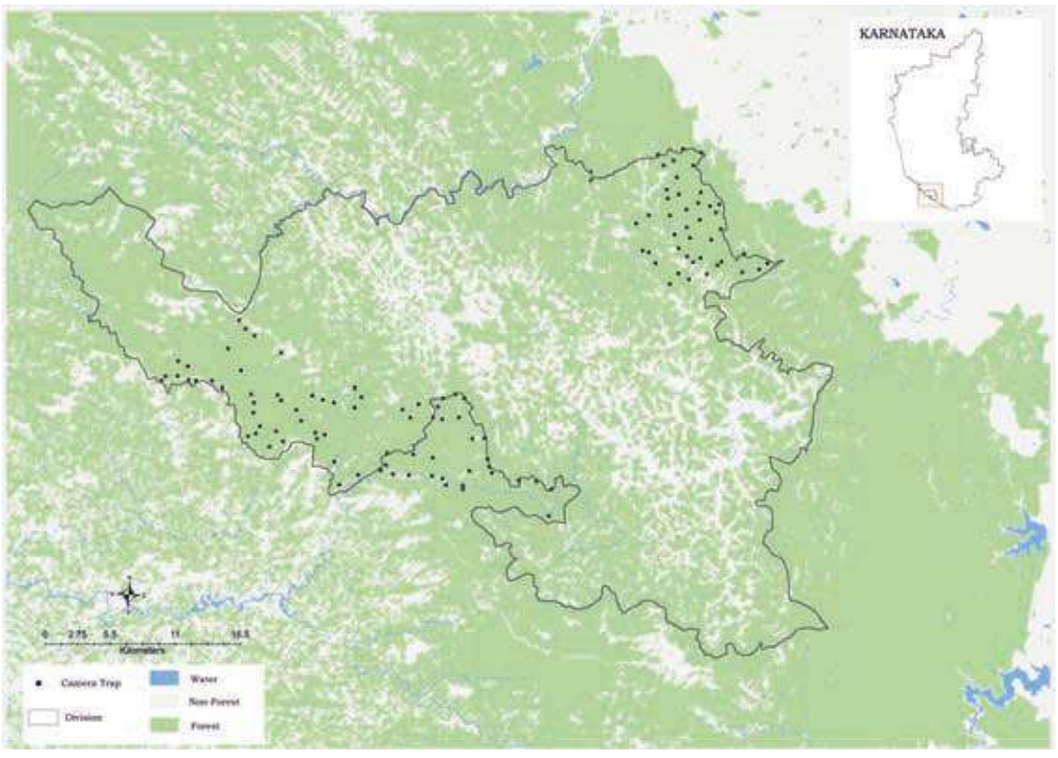


Figure 11.83
Camera trap layout in Virajpet Territorial Division, 2018-19

RESULTS

Tiger Density Estimates

A total of 114 camera traps were deployed in Virajpet Division yielding 68 tiger detections from which nine individual tigers were identified. Density of tigers in Virajpet Division was estimated to be 1.41 (SE 0.49) per 100 km^2 (Table 11.35). The model inferred tiger male to female sex ratio in Virajpet Division was 0.44:0.56 (Table 11.35).

Table 11.35

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Virajpet Territorial Division, 2018.

Variables	Estimates
Model space (km^2)	1341
Camera points	114
Trap nights (effort)	2856
Unique tigers captured	9
Model	g_0 (.) σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.41 (0.49)
σ (SE) km	1.95 (0.18)
g_0 (SE)	0.01 (0.002)
Pmix Female (SE)	0.56 (0.16)
Pmix Male (SE)	0.44 (0.16)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Being located adjacent to Nagarhole Tiger Reserve and Wayanad-Bandipur-Mudumalai complex, Virajpet division acts as an important stepping stone for maintaining tiger metapopulation dynamics in the landscape. Removal of anthropogenic pressures, better protection and mitigating human wildlife conflict are some of the key recipes for future conservation of this Division.

YELLAPURA FOREST DIVISION

INTRODUCTION

Yellapura Forest Division is situated in the eastern part of Uttara Kannada district with Dharwar and Haveri districts in the east. The division is spread over two taluks, viz., Yellapura and Mundgod. The total forest area of the division including Betta lands (protected forest) is 1,689 km^2 which constitutes 86.97% of the geographical area of the division (1,902.28 km^2). The division is drained by a number of rivers such as Kali, Bedti, Dharma, Tattihalla, etc. Out of the above, Dharma is east-flowing the others are west flowing. Yellapur division has three sub-divisions, namely, Yellapura, Manchikeri and Mundgod, and consists of six ranges, namely, Yellapur, Kirwatti, Manchikeri, Idagunji, Mundgod and Katur ranges. It has 28 sections and 76 beats. There are two timber depots, at Kirwatti and Mundgod. Yellapura division has dry deciduous forests in its eastern part, moist deciduous forest in the central part, and semi-evergreen forests in the western part which, in very favourable localities, tend to wet evergreen forests.

Figure 11.84 Camera trap layout in Yellapura Forest Division, 2018-19

RESULTS

Camera Trap Results

A total of 27 camera traps were deployed in Yellapura Division, no tiger images were recorded (Table 11.36).

Sampling details	Counts
Camera points	27
Trap nights (effort)	495
Unique tigers captured	0

Table 11.36 Sampling details of camera trapping exercise for Yellapura Forest Division, 2018.

DISCUSSION

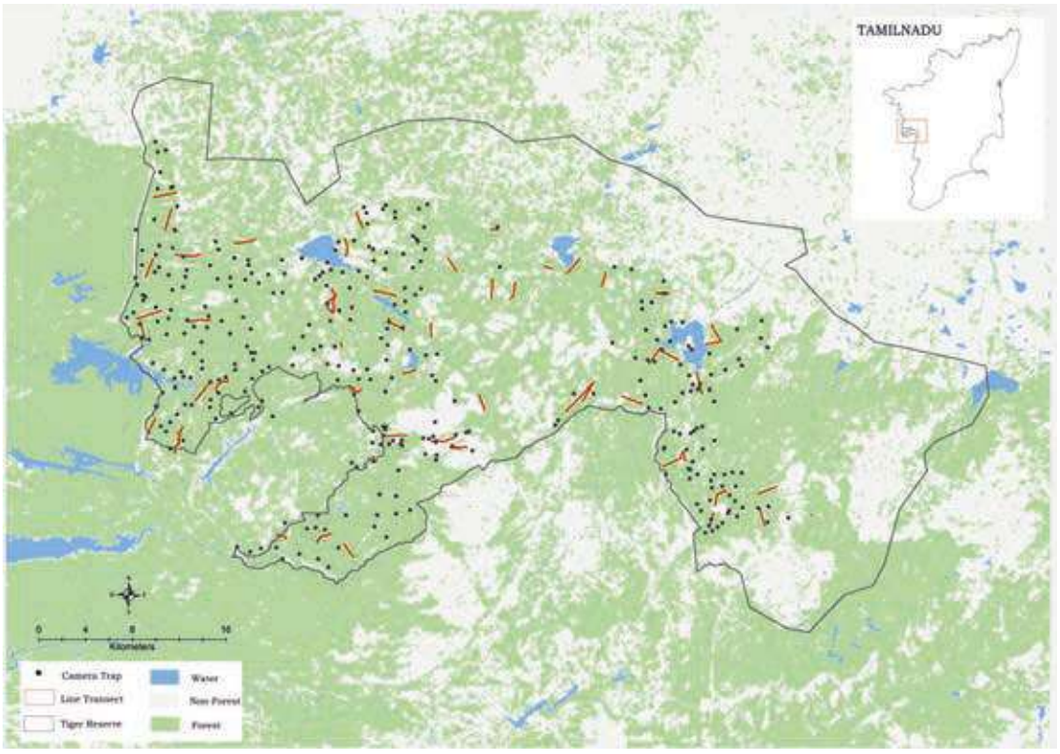
Yellapura Forest Division did not have any tiger recorded during the exercise; but it is an important habitat permitting movement of tigers and elephants from Kali Tiger Reserve.

ANAMALAI TIGER RESERVE

INTRODUCTION

Anamalai Tiger Reserve (ATR) located in Tamil Nadu is one of the larger tiger reserves in India. It is situated in the Southern Western Ghats landscape south of the Palghat gap. It is located between 10° 12' N to 10° 35' N and 76° 49' E to 77° 24' E. Total area of the tiger reserve comprises of 958.59 km^2 of core habitat and a buffer area of 521.28 km^2, totaling to an area of 1479.87 km^2. This reserve has diverse forest types which range from dry thorn forest to shola patches, grass land, dry deciduous, moist deciduous, evergreen, semi evergreen and teak plantations. Considerable extent of man-made teak plantations, exotics like eucalyptus, wattle, pines and deep fresh water ecosystem created by the construction of Parambikulam Aliyar Project dams add to the diversity of the place. The endemism of the vegetation is high in the Tiger Reserve. Several endangered and threatened species of plants (~ 39) are found in the Tiger Reserve. The Tiger Reserve supports populations of several endangered wild animals (fishes ~ 70 species, amphibians ~ 70 species, reptiles ~ 120 species, birds ~ 300 species, and mammals ~ 80 species. The major carnivores found here are tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), leopard cat (*Prionailurus bengalensis*), jungle cat (*Felis chaus*), brown palm civet (*Paradoxurus jerdoni*) and small Indian civet (*Viverricula indica*). Major ungulates are elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*) and nilgiri tahr (*Nilgiritragus hylocrius*). Anamalai is worthy of being designated as an 'Anthropological Reserve' as it is home to six indigenous tribal communities viz. Malasar, Malai malasars, Kadars, Eravallars, Pulayars and Muduvars.

Figure 11.85
Camera trap and line transect layout in Anamalai Tiger Reserve, 2018-19



RESULTS

Tiger Density Estimates

A total of 332 camera traps were deployed in Anamalai Tiger Reserve yielding 197 tiger detections (no image of cubs were obtained) from which 20 individual tigers were identified. Density of tigers in the Tiger Reserve was estimated to be 1.11 (SE 0.26) per 100 km^2 (Table 11.37). The detection corrected tiger male to female sex ratio in Anamalai was 0.38:0.62 (Table 11.37).

Variables	Estimates
Model space (km^2)	2238.25
Camera points	332
Trap nights (effort)	11023
Unique tigers captured	20
Model	g_0 (sex) σ (sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.11 (0.26)
σ Female (SE) km	3.59 (0.24)
σ Male (SE) km	4.67 (0.40)
g_0 Female (SE)	0.006 (0.0009)
g_0 Male (SE)	0.003 (0.0007)
Pmix Female (SE)	0.62 (0.11)
Pmix Male (SE)	0.38 (0.11)

Table 11.37

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Anamalai Tiger Reserve, 2018-19.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

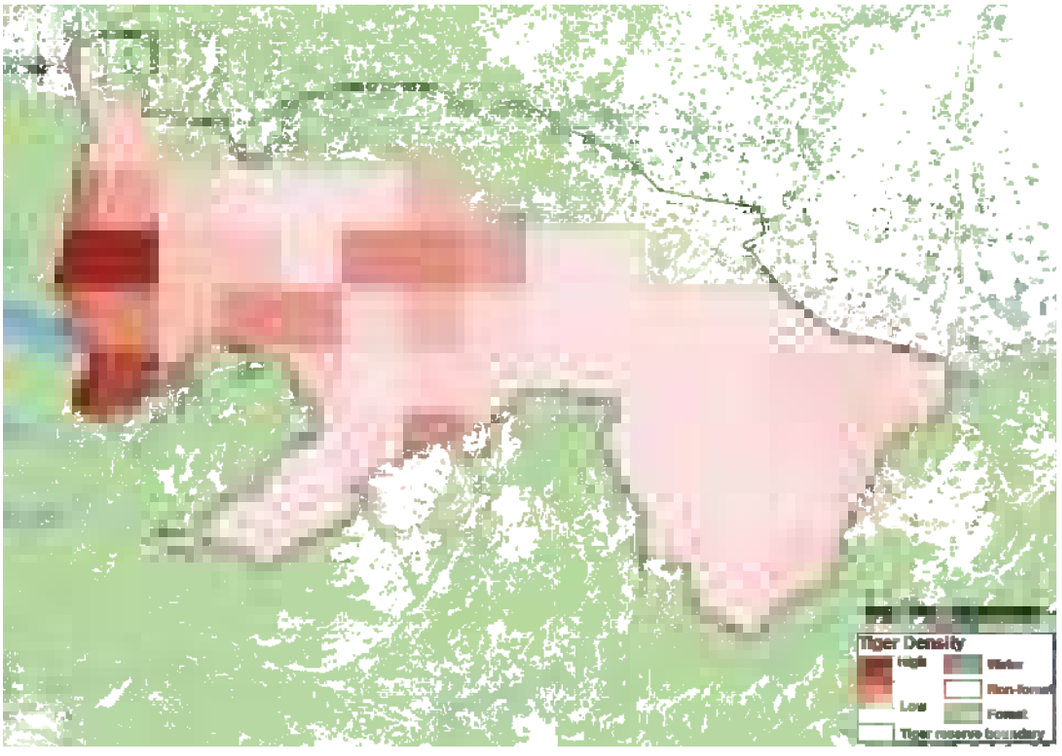


Figure 11.86

Spatial density map of tigers in Anamalai Tiger Reserve, 2018-19

Tigers were more or less evenly distributed in low to medium density within Anamalai Tiger Reserve. Some high density pockets were seen along the western part of the Tiger Reserve (mostly contiguous with Parambikulam Tiger Reserve).

Prey Density Estimates

A total of 227 transects were sampled in Anamalai Tiger Reserve which amounted to an effort of 442.36 km. Chital was found to be the most abundant ungulate in Anamalai Tiger Reserve (Table 11.38).

Table 11.38

Model statistics and parameter estimates of line transect (n=227, Total effort 442.36 km) based distance sampling for prey species in Anamalai Tiger Reserve, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Sambar	32.46 (3.34)	25	1.77 (0.38)	0.09 (0.01)	0.06	0.94 (0.21)	1.67 (0.52)
Gaur	37.67 (2.6)	34	4.55 (0.74)	0.10 (0.007)	0.07	0.01 (0.002)	0.04 (0.01)
Elephant	49.39 (4.45)	23	3.08 (0.66)	0.16 (0.01)	0.05	0.005 (0.001)	0.01 (0.005)
Chital	30.9 (1.9)	14	6 (1.19)	0.24 (0.01)	0.03	0.51 (0.18)	3.06 (1.24)

Distribution of Major Mammalian Fauna Found in Anamalai Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Anamalai Tiger Reserve.

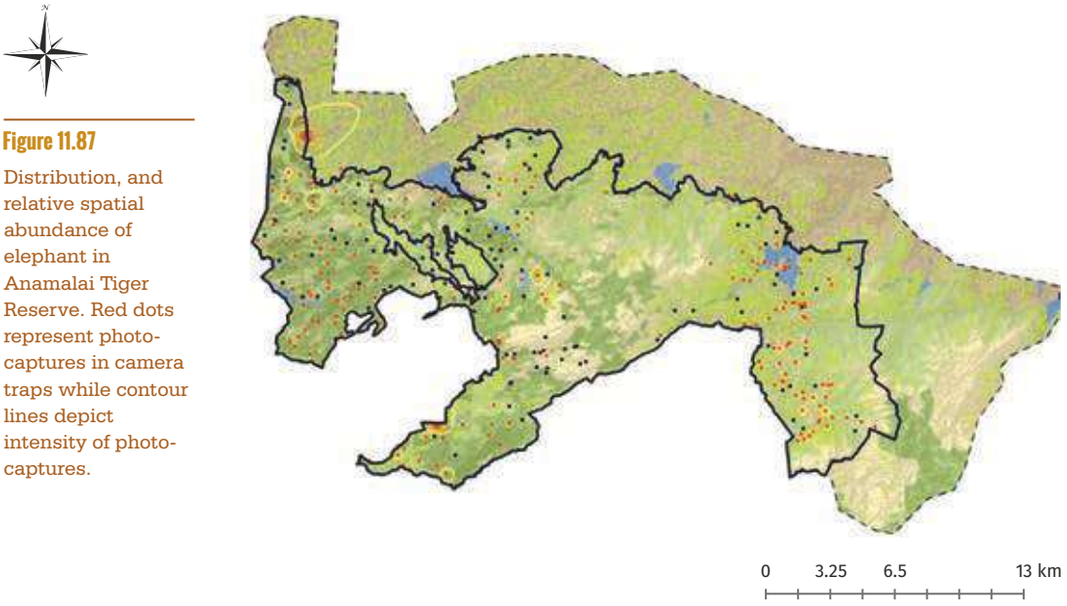


Figure 11.87

Distribution, and relative spatial abundance of elephant in Anamalai Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Elephants were distributed throughout the tiger reserve with higher concentration of photo-captures in Valparai plateau and areas adjoining Parambikulam Tiger Reserve.

Gaur was distributed throughout the tiger reserve with higher concentration of photo-captures near Thirumoorthy Dam located northern side of Valparai plateau.

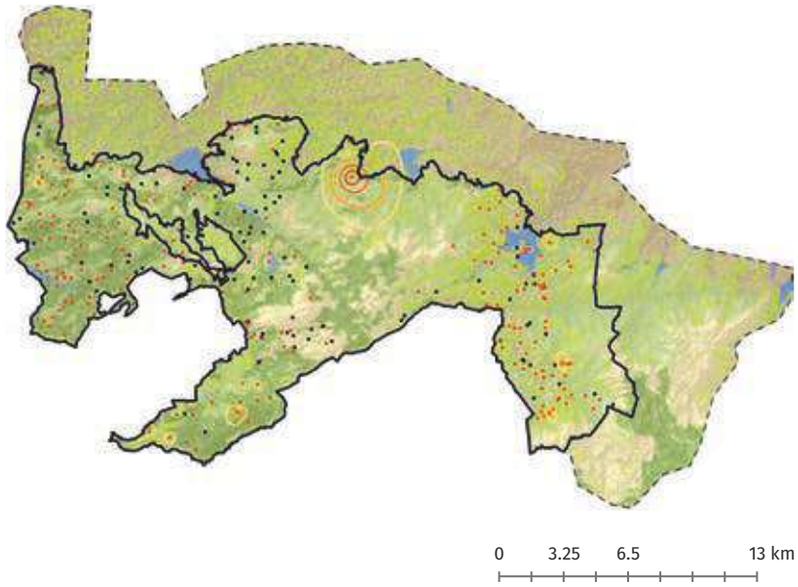


Figure 11.88

Distribution, and relative spatial abundance of gaur in Anamalai Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Mouse deer was mostly concentrated near Valparai plateau of Anamalai Tiger Reserve.

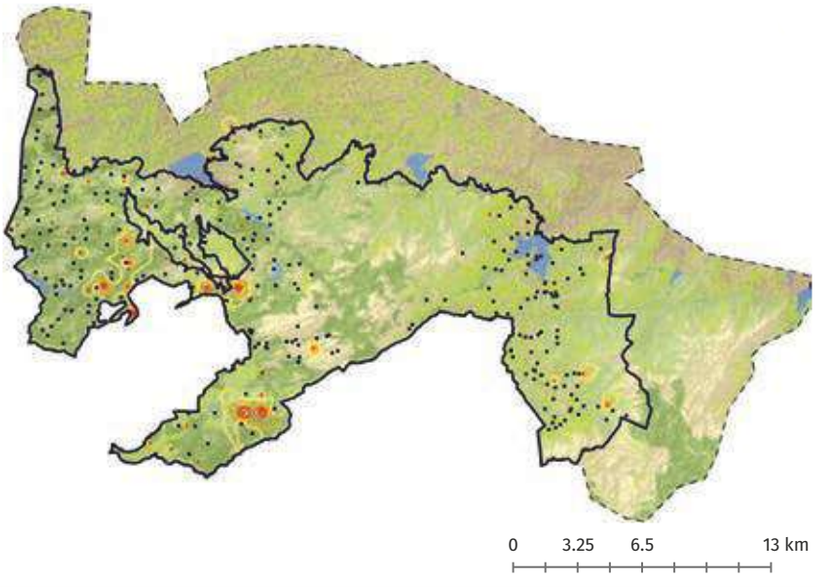


Figure 11.89

Distribution, and relative spatial abundance of mouse deer in Anamalai Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Leopards were distributed throughout the tiger reserve with higher concentration of photo-captures in Valparai plateau and areas adjoining Parambikulam Tiger Reserve and Chinnar WLS.

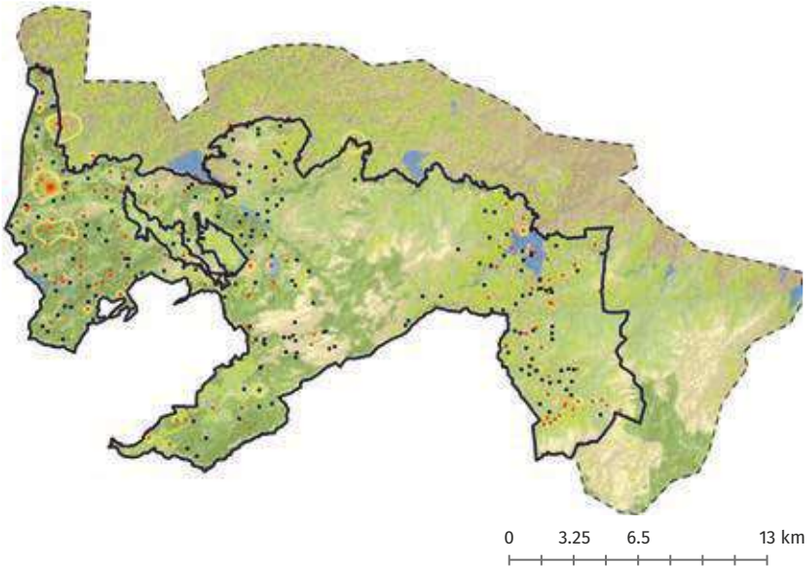


Figure 11.90

Distribution, and relative spatial abundance of leopard in Anamalai Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

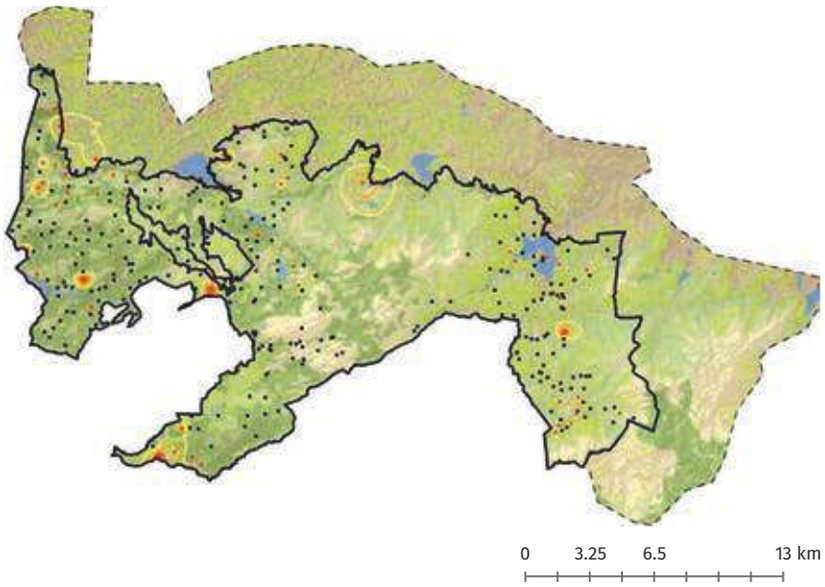


Figure 11.91

Distribution, and relative spatial abundance of dhole in Anamalai Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Dholes were distributed throughout the tiger reserve with higher concentration of photo-captures in Valparai plateau and areas adjoining Parambikulam Tiger Reserve.

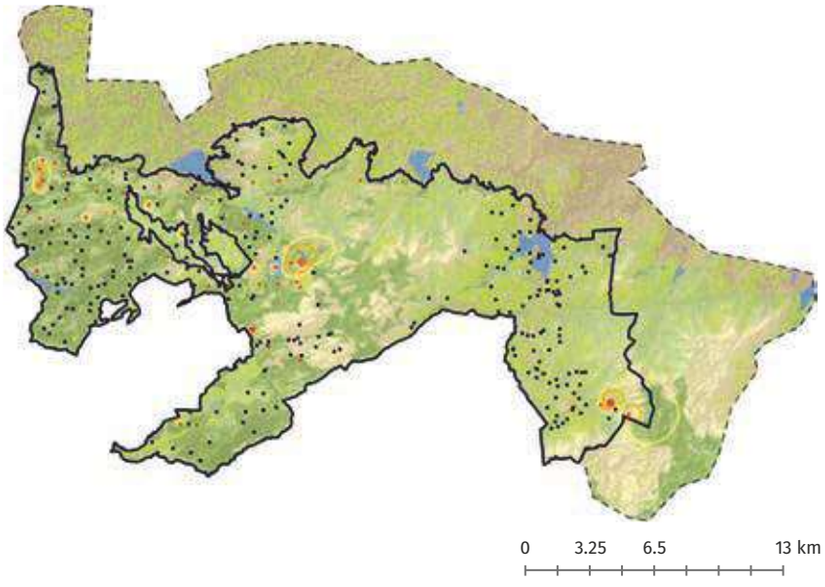


Figure 11.92

Distribution, and relative spatial abundance of sloth bear in Anamalai Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Sloth bears were distributed throughout the tiger reserve with higher concentration of photo-captures in Valparai plateau and areas adjoining Parambikulam Tiger Reserve and Chinnar WLS.

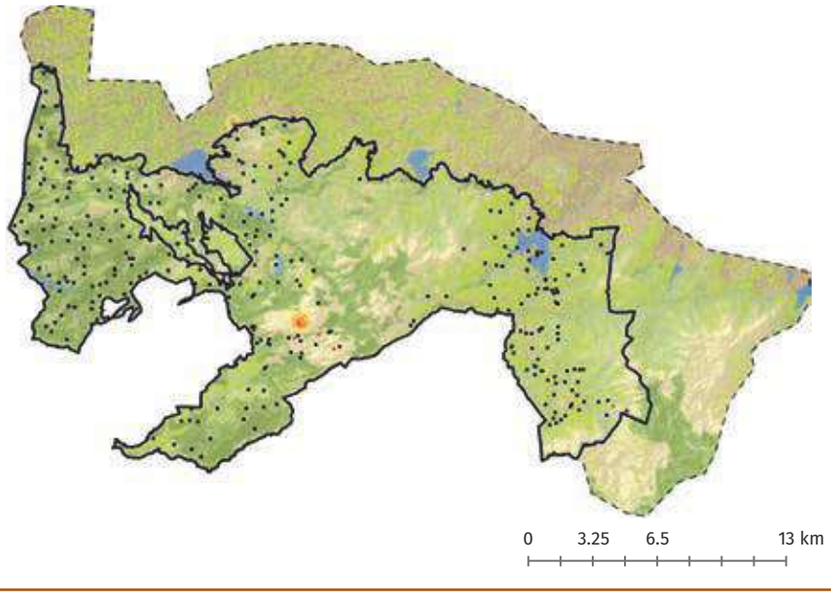


Figure 11.93

Distribution, and relative spatial abundance of jungle cat in Anamalai Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Jungle cat had a very limited distribution from the northern part of Valparai plateau.

Rusty spotted cat had a very low photo captures from the Tiger Reserve.

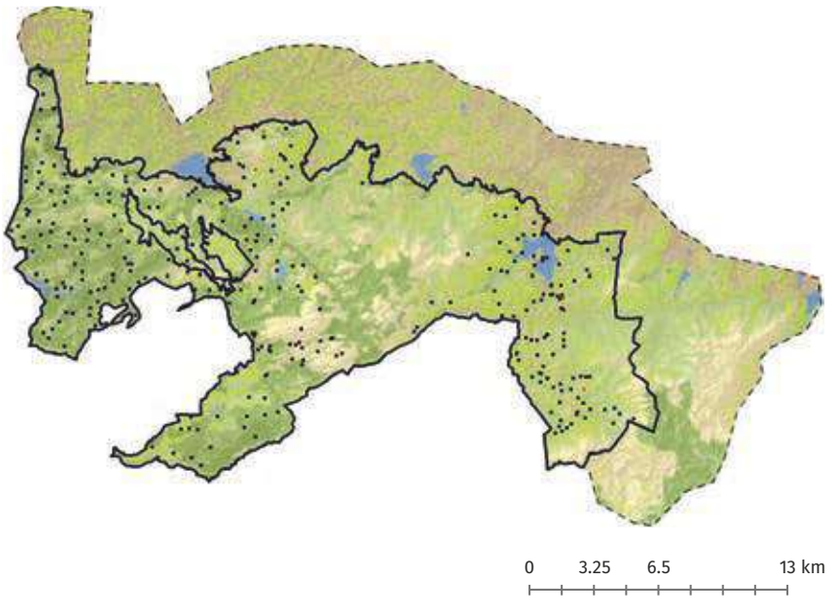


Figure 11.94

Distribution, and relative spatial abundance of rusty spotted cat in Anamalai Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Leopard cat had limited distribution from Valparai plateau of Anamalai Tiger Reserve.

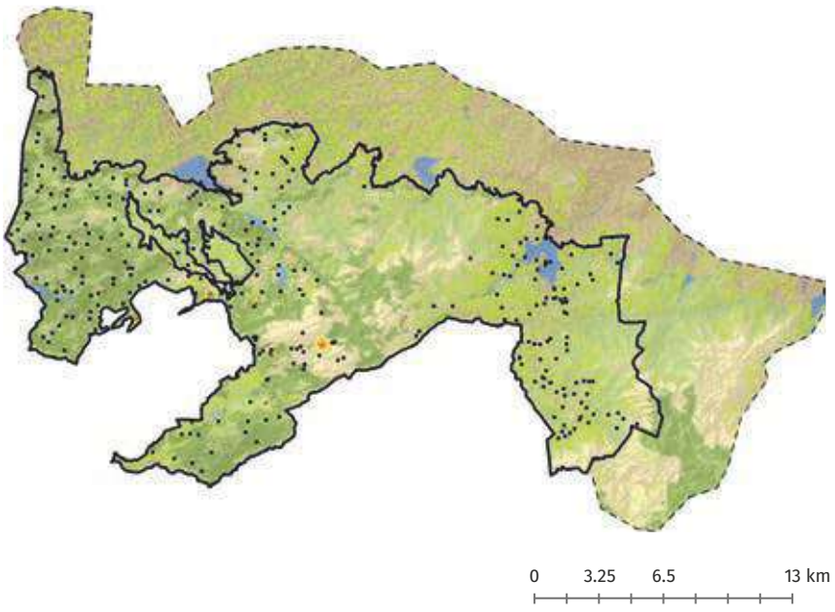


Figure 11.95

Distribution, and relative spatial abundance of leopard cat in Anamalai Tiger Reserve. Red dots represent photo-captures in camera traps while contour lines depict intensity of photo-captures.

Table 11.39

Details of all photocaptured species and their relative abundance index (RAI) in Anamalai Tiger Reserve, 2018-19.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	6.34	16
Black-naped hare	0.59	170
Bonnet macaque	0.29	344
Brown palm civet	0.54	187
Chital	3.10	32
Common palm civet	0.54	184
Elephant	9.07	11
Gaur	15.79	6
Grey jungle fowl	1.22	82
Hanuman langur	0.43	235
Indian grey mongoose	0.06	1575
Indian pangolin	0.01	11023
Indian porcupine	3.52	28
Jungle cat	0.08	1225
Leopard	3.09	32
Leopard cat	0.16	612
Livestock	4.38	23
Monitor lizard	0.01	11023
Mouse deer	0.80	125
Nilgiri langur	0.15	648
Nilgiri marten	0.05	1837
Peafowl	1.42	70
Ruddy mongoose	0.30	334
Rusty spotted cat	0.05	1837
Sambar	19.40	5
Sloth bear	0.90	111
Small Indian civet	0.45	220
Stripe-necked mongoose	0.56	178
Tiger	1.79	56
Wild dog	0.98	102
Wild pig	5.11	20

Relative Abundance of all Photocaptured Species in Anamalai Tiger Reserve

A total of 35 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Sambar, Gaur and Elephant were the most commonly photo-captured species (Table 11.39). Pangolin was the rarest species to be photo-captured followed by Rusty spotted cat.

DISCUSSION

Anamalai Tiger Reserve continues to be a low density tiger reserve as compared to 2014 estimates [1.18 (SE 0.46) tigers / 100 km^2; Jhala et al. 2015]. Among the two administrative units namely Pollachi and Tirupur forest divisions, the Pollachi forest division holds a better carnivore and herbivore population. The faunal diversity is lower in Thirupur forest division due to high anthropogenic pressure. There is a need for more intervention to work on community related issues in the Thirupur forest division. Proper management interventions and protection can ensure that the region can sustain good tiger population.

KALAKAD MUNDANTHURAI TIGER RESERVE (KMTR)

INTRODUCTION

Kalakkad Mundanthurai Tiger Reserve (KMTR) is located at 8° 41' 0" N, 77° 19' 0" in the Southern Western Ghats. It also forms part of the interstate Agasthiyamalai Biosphere Reserve. It was declared as a Tiger Reserve in 1988. This includes two contiguous Sanctuaries namely Kalakad Sanctuary and Mundanthurai Sanctuary and a part of Kanyakumari Sanctuary. The total area of the Tiger Reserve is 895 km^2. Major Forest types found in KMTR are southern hilltop evergreen forests, west coast tropical wet evergreen forests, Tirunelveli semi evergreen forests, southern moist mixed deciduous forests, tropical riparian fringing forests, dry teak forests, southern dry mixed deciduous forests, carnatic umbrella thorn forests, ochlandra reeds and southern montane wet grassland (Champion and Seth 1968). KMTR has 77 mammals, 33 fish, 37 amphibians, 81 reptiles and 273 birds. The flagship species are tiger (*Panthera tigris*), elephant (*Elephas maximus*) and lion tailed macaque (*Macaca Silenus*). Co-predators of tiger include dhole (*Cuon alpinus*) and leopard (*Panthera pardus*). Major ungulates are wild pig (*Sus scrofa*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*), gaur (*Bos gaurus*), chital (*Axis axis*), sambar (*Rusa unicolor*) and nilgiri tahr (*Nilgiritragus hylocrius*).

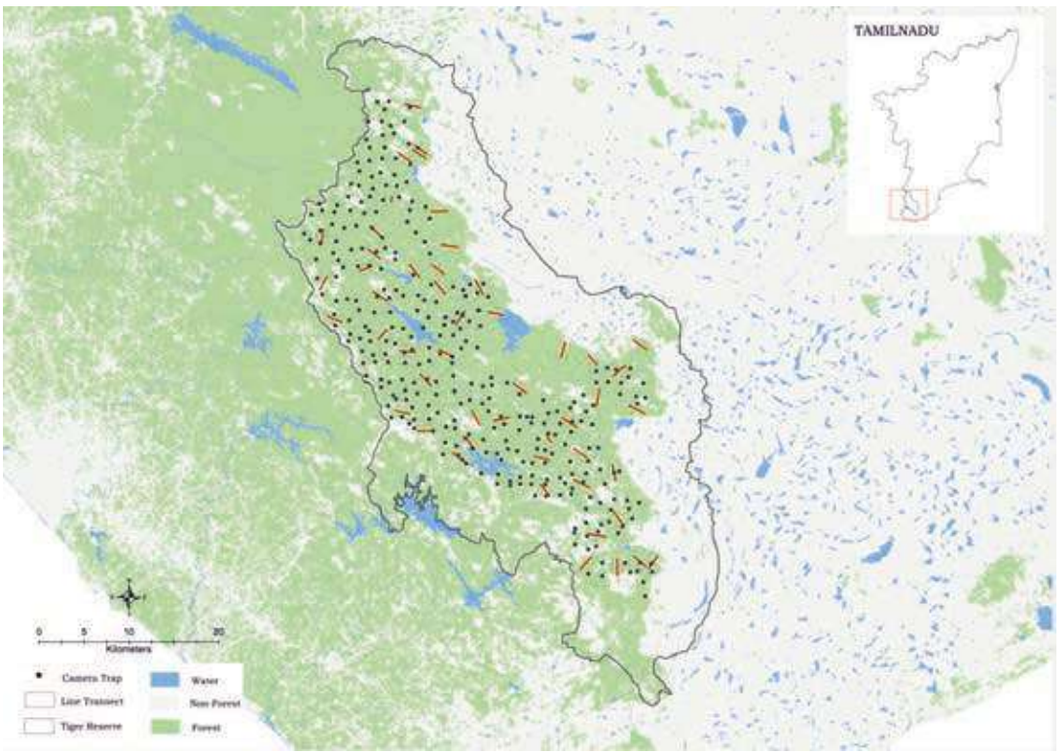


Figure 11.96
Camera trap and transect layout in KMTR, 2018-19

RESULTS

Tiger Density Estimates

A total of 316 camera traps were deployed in KMTR yielding 62 tiger detections (no image for tiger cubs) from which 7 individual tigers were identified. Density of tigers in the Tiger Reserve was estimated to be 0.43 (SE 0.17) per 100 km^2 (Table 11.40). The model inferred tiger male to female sex ratio in KMTR was 0.5:0.5 (Table 11.40).

Table 11.40

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for KMTR, 2018.

Variables	Estimates
Model space (km^2)	1949.12
Camera points	316
Trap nights (effort)	12014
Unique tigers captured	7
Model	g_0 (.) σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.43 (0.17)
σ (SE) km	5.1 (0.4)
g_0 (SE)	0.007 (0.002)
Pmix Female (SE)	0.50 (0.20)
Pmix Male (SE)	0.50 (0.20)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

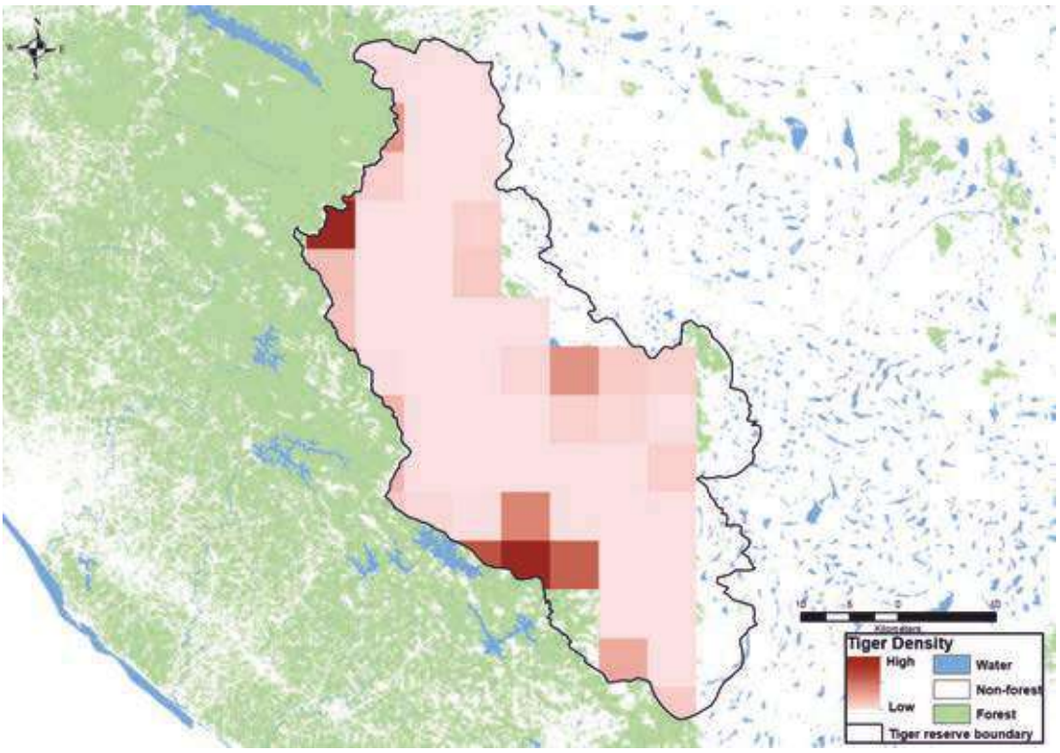
σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix - Detection corrected estimate of proportion of males and females

Figure 11.97

Spatial density of tigers in Kalakad Mundanthurai Tiger Reserve, 2018-19



Tigers were more or less evenly distributed in low to medium density within Kalakad Mundanthurai Tiger Reserve. Some high density pockets were seen along western and southern parts of the Tiger Reserve in Papanasm and Virapuli RFs.

Prey Density Estimates

A total of 150 transects were sampled in KMTR which amounted to an effort of 283.81 km. Sambar was found to be the most abundant ungulate in KMTR (Table 11.41).

Table 11.41

Model statistics and parameter estimates of line transect (n=150, Total effort 283.81 km) based distance sampling for prey species in KMTR, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital		6	2.83 (0.65)		0.02		
Sambar	32.46 (3.3)	50	1.68 (0.12)	0.09 (0.01)	0.17	2.71 (0.45)	4.55 (0.83)
Gaur	37.67 (2.6)	24	2.41 (0.31)	0.10 (0.007)	0.08	0.01 (0.002)	0.02 (0.006)
Elephant		13	1.22 (0.41)		0.04		
Wild pig	37.79 (6.1)	20	4.60 (0.79)	0.09 (0.01)	0.07	0.93 (0.24)	4.28 (1.35)
Barking deer		4			0.01		

Distribution of Major Mammalian Fauna in Kalakad Mundanthurai Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Kalakad Mundanthurai Tiger Reserve.

Elephant distribution was throughout with maximum photo-captures from Papanasam RF.

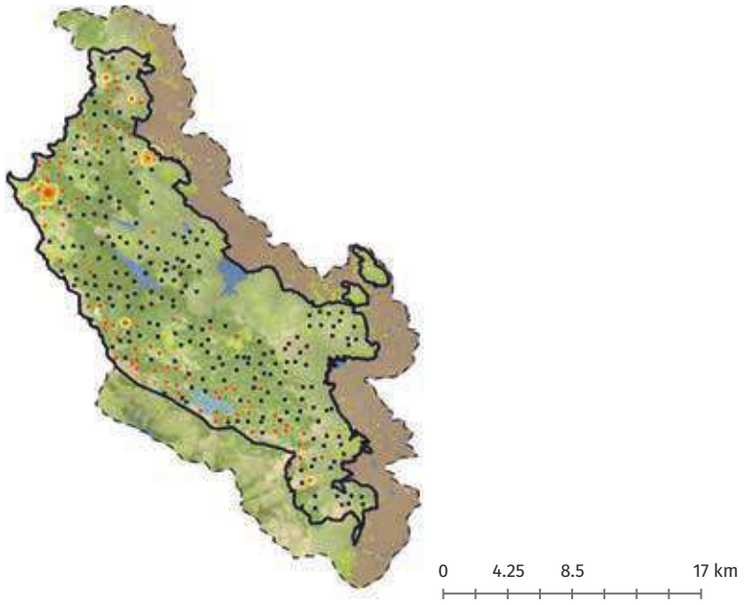


Figure 11.98

Distribution, and relative spatial abundance of elephant in KMTR. Red dots represent photo-captures in camera traps while contour lines depict intensity

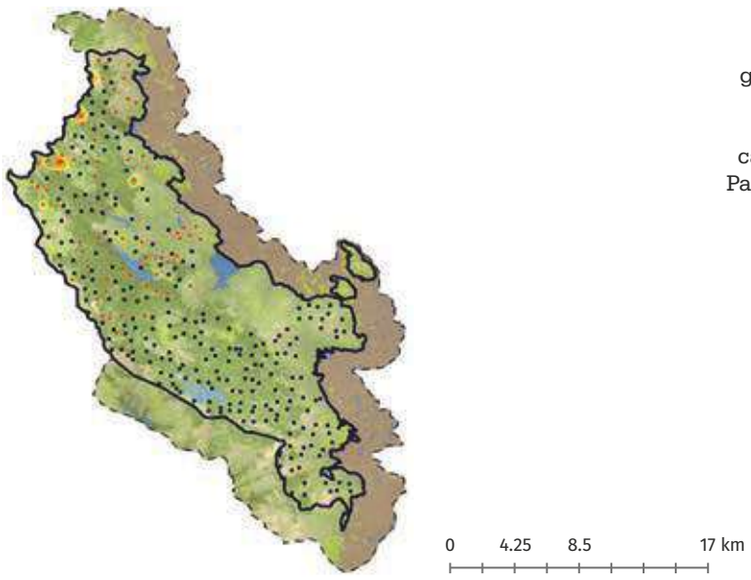


Figure 11.99

Distribution, and relative spatial abundance of gaur in KMTR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Like elephants, gaur also had maximum photo-captures from Papanasam RF of the tiger reserve.

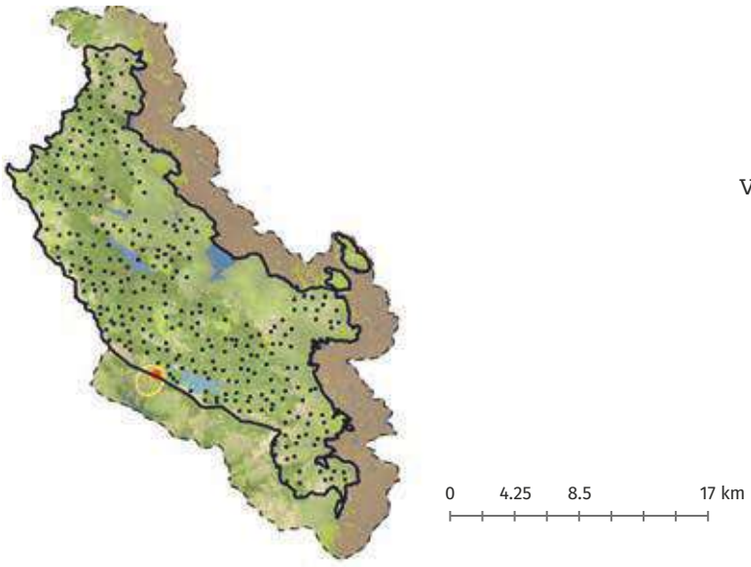


Figure 11.100

Distribution, and relative spatial abundance of nilgiri tahr in KMTR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Photo-captures of nilgiri tahr were from Virapuli RF of the tiger reserve.

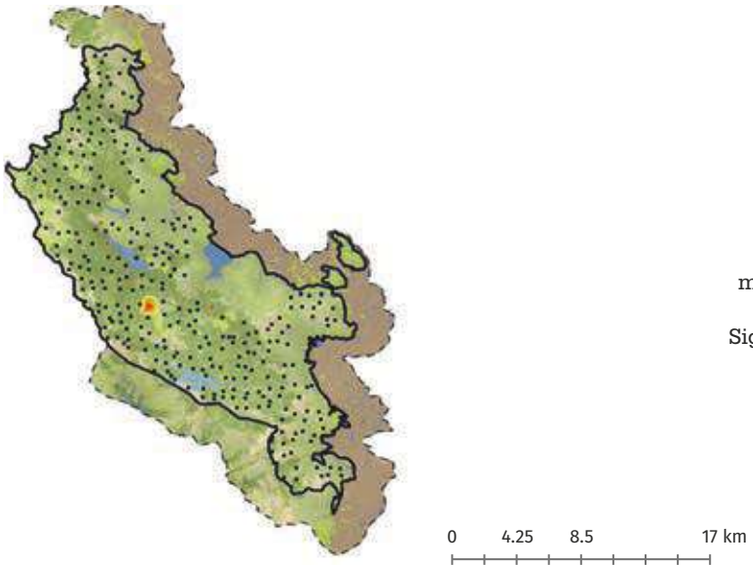


Figure 11.101

Distribution, and relative spatial abundance of lion tailed macaque in KMTR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Maximum photo-captures of lion tailed macaque was from Sigampatty RF of the tiger reserve.

Mouse deer distribution was from throughout the tiger reserve.

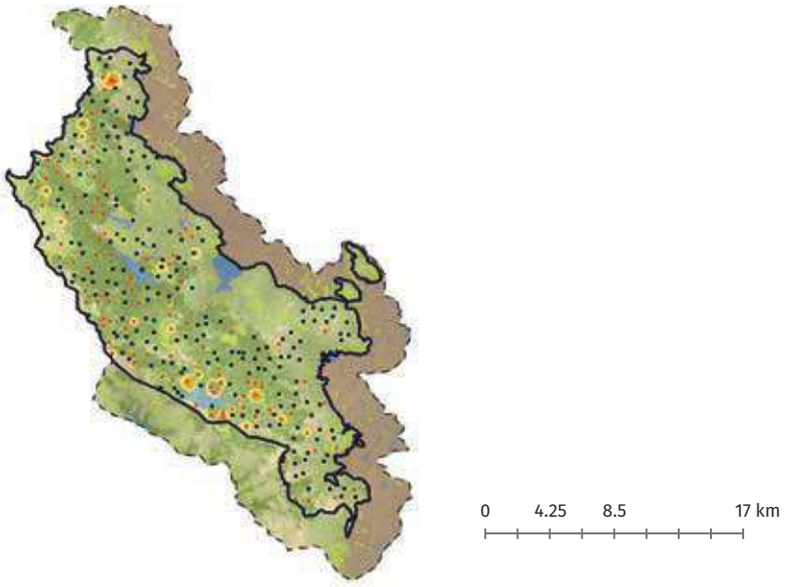


Figure 11.102

Distribution, and relative spatial abundance of mouse deer in KMTR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard was distributed in all parts of the tiger reserve.

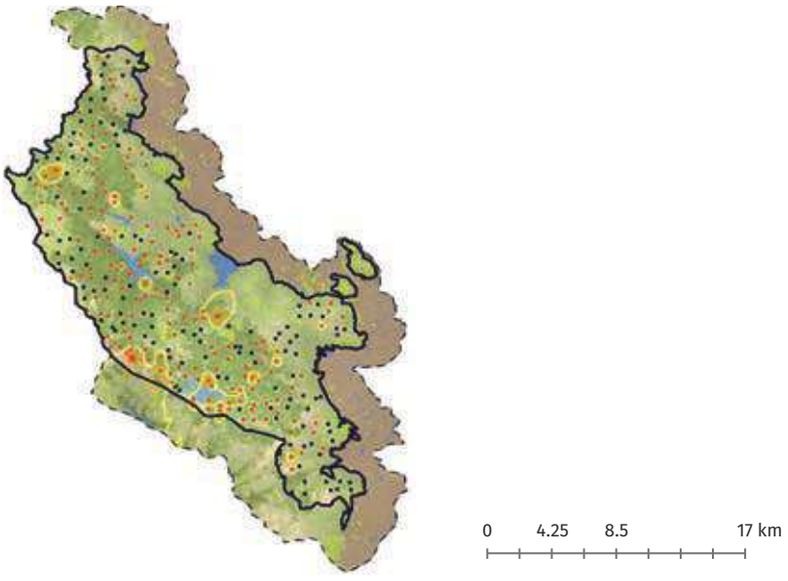


Figure 11.103

Distribution, and relative spatial abundance of leopard in KMTR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Distributed all across the tiger reserve, sloth bear had maximum photo-captures from Papanasam RF of the tiger reserve.

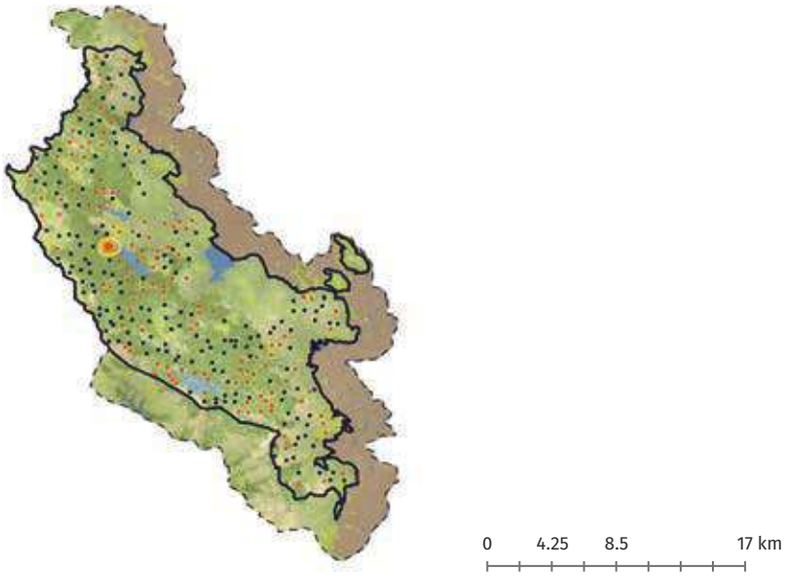


Figure 11.104

Distribution, and relative spatial abundance of sloth bear in KMTR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Figure 11.105

Distribution, and relative spatial abundance of dhole in KMTR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Maximum concentration of dhole photo-captures was along the southern boundaries of the tiger reserve in Kalamali and Virapuli Rfs.

Figure 11.106

Distribution, and relative spatial abundance of rusty spotted cat in KMTR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Rusty spotted cat was photo-captured from eastern part of the tiger reserve.

Figure 11.107

Distribution, and relative spatial abundance of leopard cat in KMTR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard cat distribution was uniform from across the tiger reserve.

Relative Abundance of all Photocaptured Species in KMTR

A total of 32 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Sambar and gaur were the most commonly photo-captured species (Table 11.42). Domestic dog and bonnet macaque was the rarest species photo-captured.

Table 11.42

Details of all photocaptured species and their relative abundance index (RAI) in Kalakad Mundanthurai Tiger Reserve, 2018-19.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	0.26	388
Black-naped hare	0.09	1092
Bonnet macaque	0.01	12014
Brown palm civet	1.73	58
Chital	0.16	632
Common palm civet	1.51	66
Domestic dog	0.01	12014
Elephant	1.98	50
Gaur	8.07	12
Giant squirrel	0.03	3004
Grey jungle fowl	3.20	31
Hanuman langur	0.02	4005
Indian grey mongoose	0.96	104
Indian pangolin	0.07	1502
Indian porcupine	2.95	34
Leopard	4.69	21
Leopard cat	0.37	267
Livestock	0.39	256
Monitor lizard	0.11	924
Mouse deer	3.19	31
Nilgiri langur	0.16	632
Nilgiri marten	0.07	1502
Nilgiri tahr	0.13	751
Peafowl	1.86	54
Rusty spotted cat	0.04	2403
Sambar	8.75	11
Sloth bear	2.30	44
Small Indian civet	3.30	30
Stripe-necked mongoose	0.18	546
Tiger	0.52	194
Wild dog	0.83	120
Wild pig	3.20	31

DISCUSSION

KMTR continues to be a low density tiger reserve as compared to 2014 estimates [0.88 (SE 0.39) tigers / 100 km^2; Jhala et al. 2015]. Proper management interventions and protection can ensure that the region can sustain good tiger population. The tribal settlements inside the core of the Tiger Reserve need to be resettled outside following NTCA's scheme. Feasibility of the upcoming highway in between Papanasam and Trivandrum passing through the Tiger Reserve should be critically examined in terms of its impacts on tiger population dynamics and other biodiversity in the region with appropriate realignment and mitigation measures in place. The Southern Western Ghat Tiger population has been identified as a conservation priority population (Kolipakam et al 2019).

MUDUMALAI TIGER RESERVE

INTRODUCTION

Mudumalai Tiger Reserve (MTR) is located at 11° 35' 0" N, 76° 33' 0" E. Mudumalai is situated at the tri-junction of Tamil Nadu, Karnataka and Kerala states. It is contiguous with Wayanad wildlife Sanctuary on the north west, Bandipur Tiger Reserve on the north, the Singara and Sigur Reserved Forests which form the remaining boundary of Nilgiri North Division. Mudumalai also forms part of the Nilgiri Biosphere Reserve. The core area of the reserve is 321 km^2, with a buffer of 367.59 km^2 the total area of the tiger reserve is approximately 688.59 km^2.

There are three main types of forest in the sanctuary: tropical moist deciduous occur in the western Benne Block, where rainfall is higher than in other blocks. Tropical dry deciduous forest occurs in the central part and southern tropical dry thorn forests occur in the east. In addition, there are patches of tropical semi-evergreen forest in the southwest and western part of Mudumalai. The protected area is home to several endangered and vulnerable species including elephant (*Elephas maximus*), tiger (*Panthera tigris*), gaur (*Bos gaurus*) and leopard (*Panthera pardus*). Other carnivores found here are wild dog (*Cuon alpinus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyena hyena*), jackal (*Canis aureus*), jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*) and leopard cat (*Prionailurus bengalensis*). Major ungulate species include chowsingha (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*), gaur (*Bos gaurus*), chital (*Axis axis*), sambar (*Rusa unicolor*) and blackbuck (*Antilope cervicapra*).

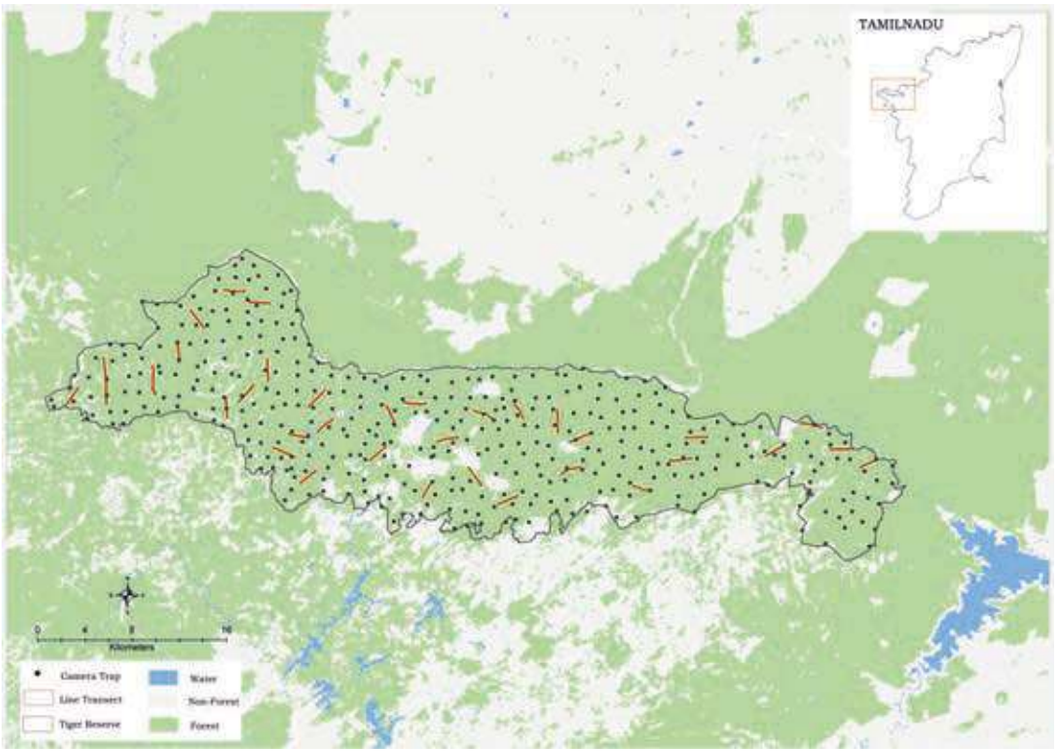


Figure 11.108
Camera trap and transect layout in Mudumalai Tiger Reserve, 2018-19

RESULTS

Tiger Density Estimates

A total of 391 camera traps were deployed in Mudumalai TR yielding 1,081 tiger detections (including 31 images of cubs) from which 103 individual adult tigers were identified. Density of tigers in the Tiger Reserve was estimated to be 6.19 (SE 0.64) per 100 km^2 (Table 43). The detection corrected tiger male to female sex ratio in Mudumalai TR was 0.32:0.68 (Table 11.43).

Variables	Estimates
Model space (km^2)	2716.20
Camera points	391
Trap nights (effort)	12482
Unique tigers captured	103
Model	g_0 (sex) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	6.19 (0.64)
σ Female (SE) km	1.9 (0.04)
σ Male (SE) km	4.6 (0.14)
g_0 Female (SE)	0.03 (0.002)
g_0 Male (SE)	0.01 (0.001)
Pmix Female (SE)	0.68 (0.04)
Pmix Male (SE)	0.32 (0.04)

Table 11.43

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Mudumalai Tiger Reserve, 2018-19.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

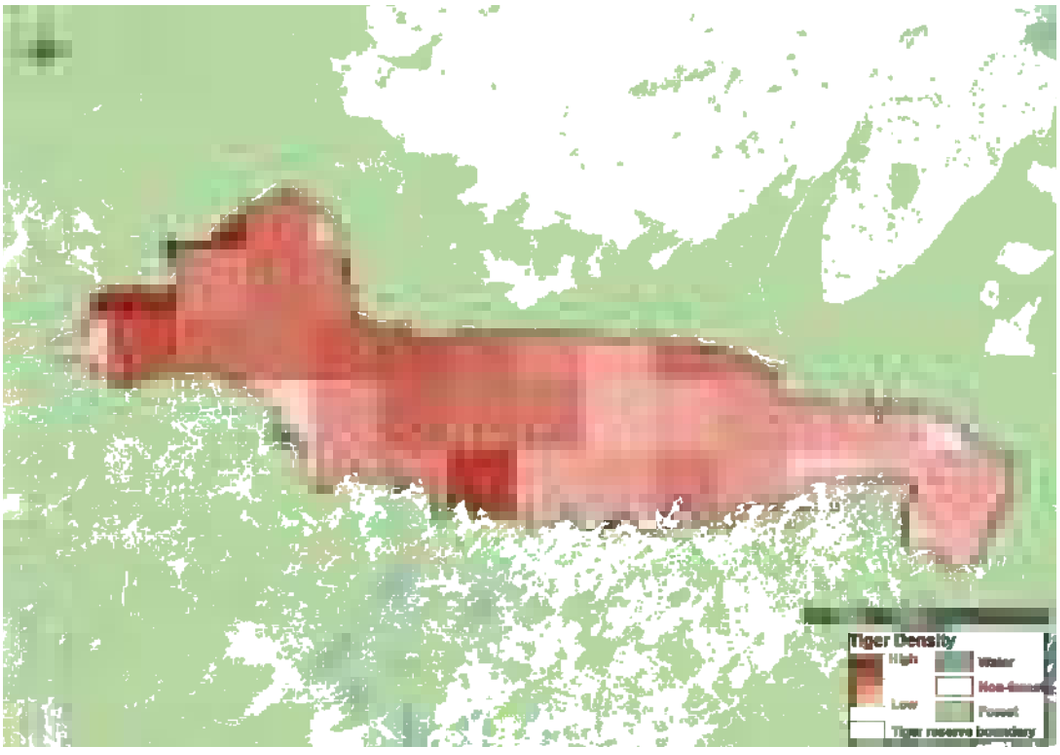


Figure 11.109

Spatial density of tigers in Mudumalai Tiger Reserve, 2018-19

Tigers were more or less evenly distributed in medium to high density within Mudumalai Tiger Reserve. Some high density pockets were seen along western border of the Tiger Reserve adjoining Bandipur Tiger Reserve.

Prey Density Estimates

A total of 365 transects were sampled in Mudumalai which amounted to an effort of 720.89 km. Chital was found to be the most abundant ungulate in Mudumalai TR (Table 11.44).

Table 11.44

Model statistics and parameter estimates of line transect (n=150, Total effort 283.81 km) based distance sampling for prey species in Mudumalai TR, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital	30.67 (0.90)	303	7.49 (0.53)	0.12 (0.004)	0.42	6.20 (0.62)	46.49 (5.74)
Sambar	31.08 (1.22)	86	2.01 (0.23)	0.06 (0.002)	0.11	1.59 (0.31)	3.21 (0.74)
Gaur	33.20 (2.14)	73	3.30 (0.42)	0.11 (0.007)	0.10	0.79 (0.11)	2.61 (0.49)
Elephant	47.62 (2.82)	60	2.31 (0.27)	0.12 (0.007)	0.08	0.80 (0.17)	1.87 (0.46)
Wild pig		6	1.5 (0.22)		0.008		

Distribution of Major Mammalian Fauna Found in Mudumalai Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Mudumalai Tiger Reserve.

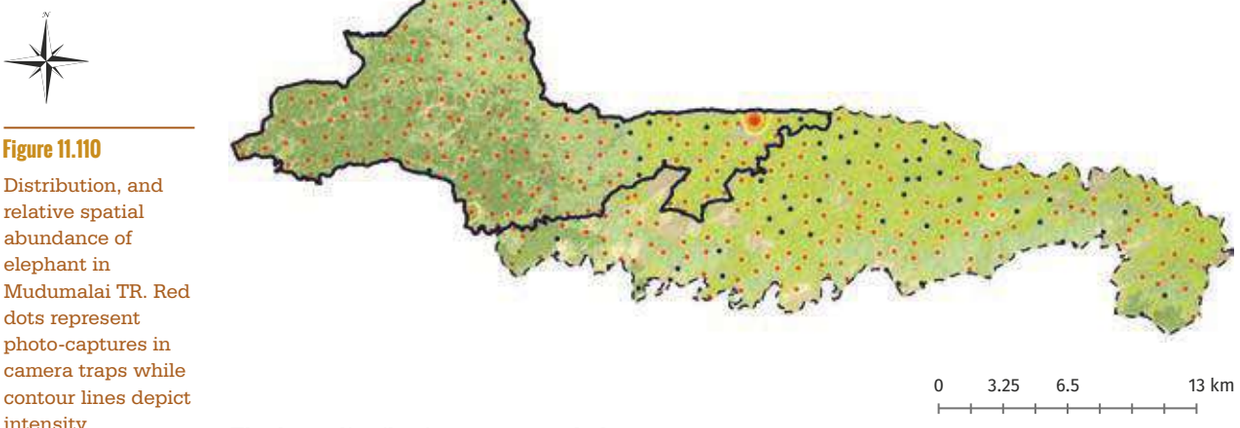
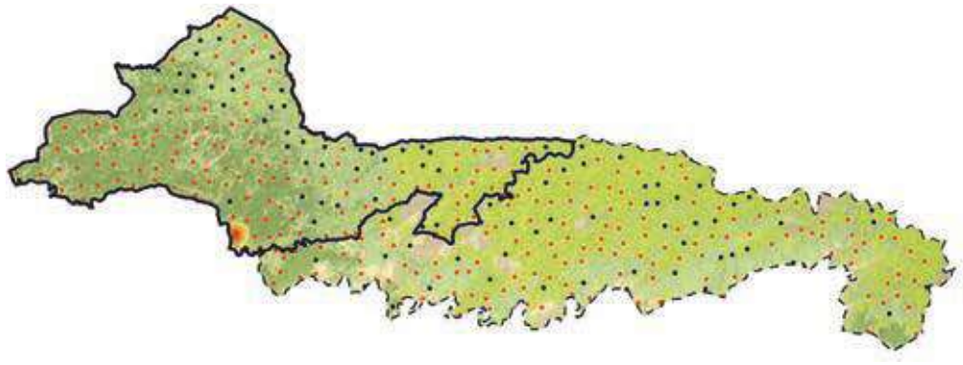


Figure 11.110

Distribution, and relative spatial abundance of elephant in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Elephant distribution was recorded from entire tiger reserve with maximum concentration from the areas bordering Bandipur Tiger Reserve.

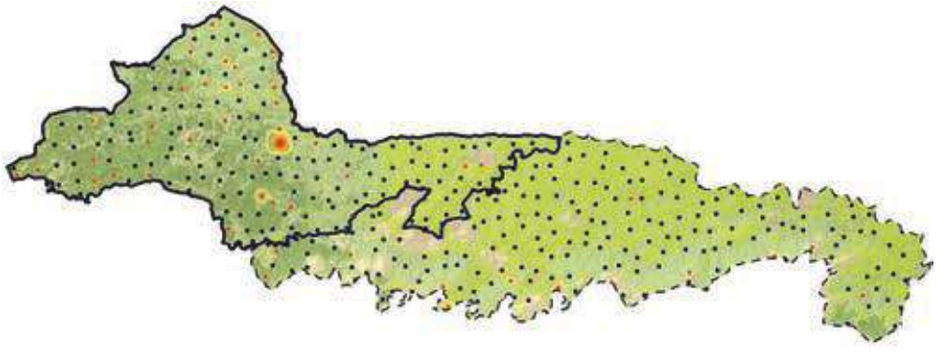


Gaur distribution was uniform across the tiger reserve.

0 3.25 6.5 13 km

Figure 11.111

Distribution, and relative spatial abundance of gaur in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

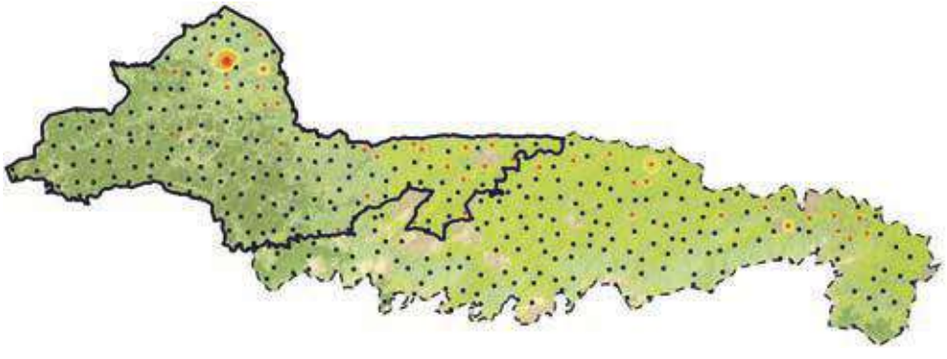


Mouse deer was common with no particular distribution pattern in Mudumalai tiger reserve.

0 3.25 6.5 13 km

Figure 11.112

Distribution, and relative spatial abundance of mouse deer in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity



Chowsingha distribution was from all parts of the tiger reserve with maximum concentration from Gudalur area.

0 3.25 6.5 13 km

Figure 11.113

Distribution, and relative spatial abundance of chowsingha in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

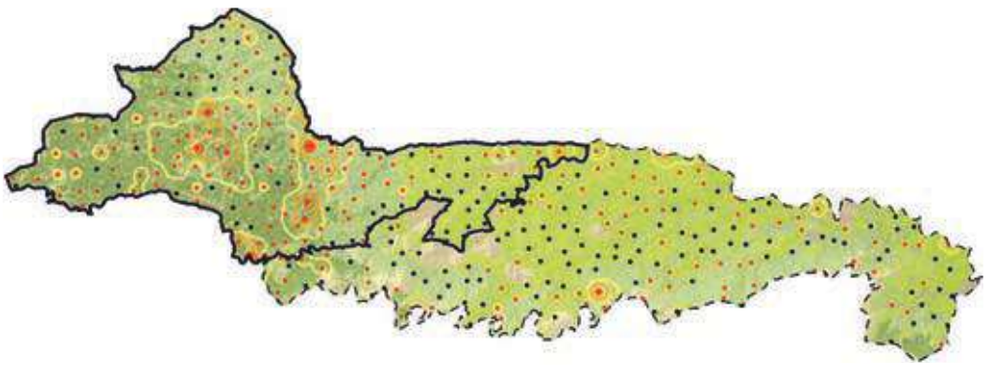


Figure 11.114

Distribution, and relative spatial abundance of leopard in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard distribution was uniform from the tiger reserve with maximum concentration from Gudalur and Pandalur areas.

0 3.25 6.5 13 km

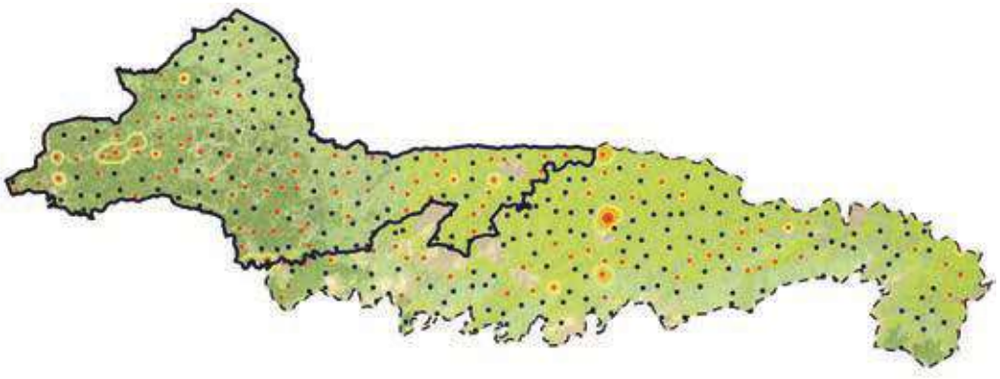


Figure 11.115

Distribution, and relative spatial abundance of dhole in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Dhole photo-captures were from all across the tiger reserve.

0 3.25 6.5 13 km

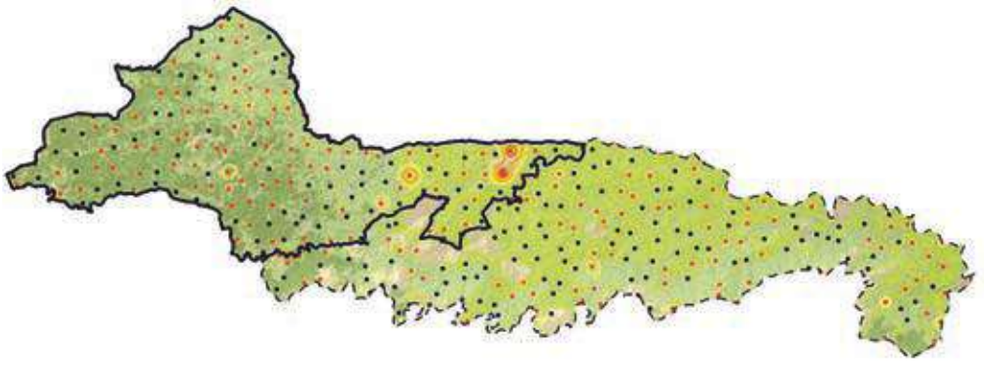
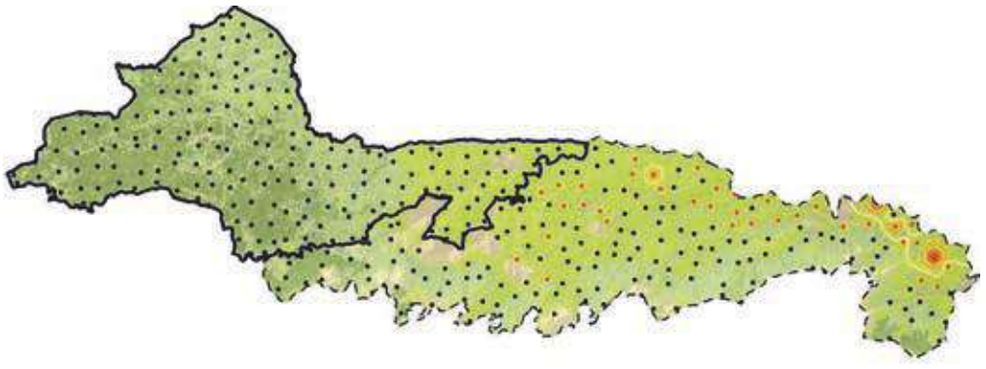


Figure 11.116

Distribution, and relative spatial abundance of sloth bear in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Sloth bear photocaptures were high in areas bordering Bandipur Tiger Reserve.

0 3.25 6.5 13 km

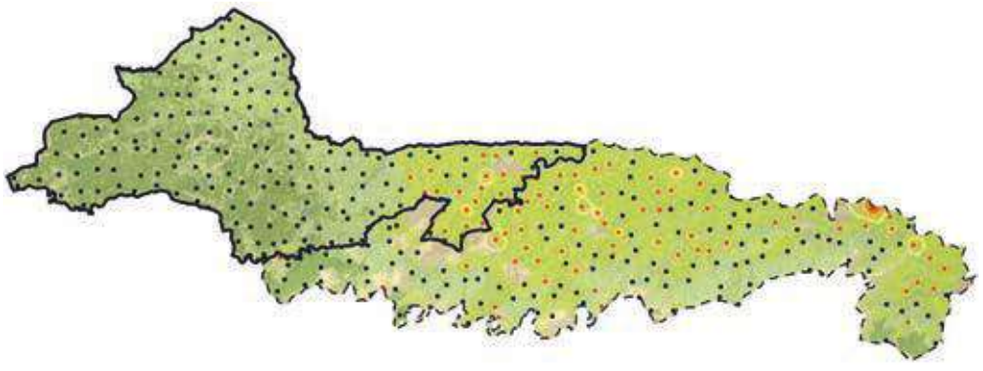


Hyena distribution was recorded maximum from the buffer areas of the tiger reserve.

0 3.25 6.5 13 km

Figure 11.117

Distribution, and relative spatial abundance of hyena in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

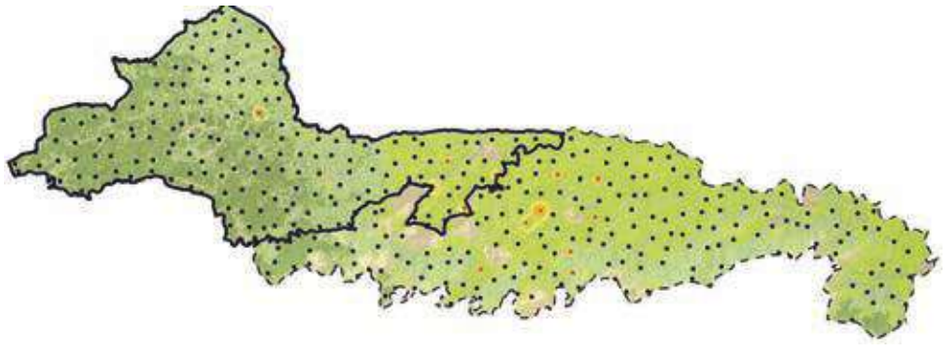


Jungle cat was distributed across the Tiger Reserve with higher photocaptures from the buffer zone.

0 3.25 6.5 13 km

Figure 11.118

Distribution, and relative spatial abundance of jungle cat in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity



Rusty spotted cat was photo-captured at low rates from the central part of the tiger reserve.

0 3.25 6.5 13 km

Figure 11.119

Distribution, and relative spatial abundance of rusty spotted cat in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

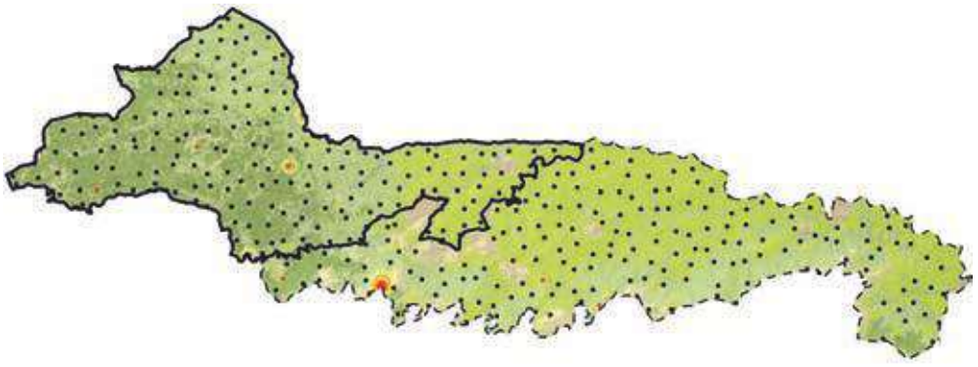


Figure 11.120
Distribution, and relative spatial abundance of leopard cat in Mudumalai TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard cat was photo-captured at low rates from the buffer zone of the tiger reserve.

0 3.25 6.5 13 km

Table 11.45
Details of all photocaptured species and their relative abundance index (RAI) in Mudumalai Tiger Reserve, 2018-19.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	4.09	24
Black buck	0.88	113
Black-naped hare	15.81	6
Bonnet macaque	0.95	106
Brown palm civet	0.36	277
Chital	78.33	1
Common palm civet	1.12	89
Domestic cat	0.03	3121
Domestic dog	1.85	54
Elephant	22.82	4
Four horned antelope	0.74	136
Gaur	13.09	8
Hanuman langur	6.18	16
Indian grey mongoose	0.68	147
Indian pangolin	0.04	2496
Indian porcupine	11.42	9
Jungle cat	2.81	36
Leopard	5.24	19
Leopard cat	0.13	780
Livestock	6.06	17
Monitor lizard	0.07	1387

Relative Abundance of all Photocaptured Species in Mudumalai Tiger Reserve

A total of 35 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Chital was the most commonly photo-captured species (Table 11.45). Nilgiri marten was the rarest species photo-captured followed by domestic cat.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Mouse deer	1.25	80
Nilgiri langur	0.05	2080
Nilgiri marten	0.01	12482
Peafowl	3.53	28
Ruddy mongoose	2.35	43
Rusty spotted cat	0.17	594
Sambar	30.15	3
Sloth bear	3.36	30
Small Indian civet	1.77	56
Stripe-necked mongoose	1.09	92
Striped hyena	1.43	70
Tiger	8.66	12
Wild dog	2.70	37
Wild pig	6.27	16

DISCUSSION

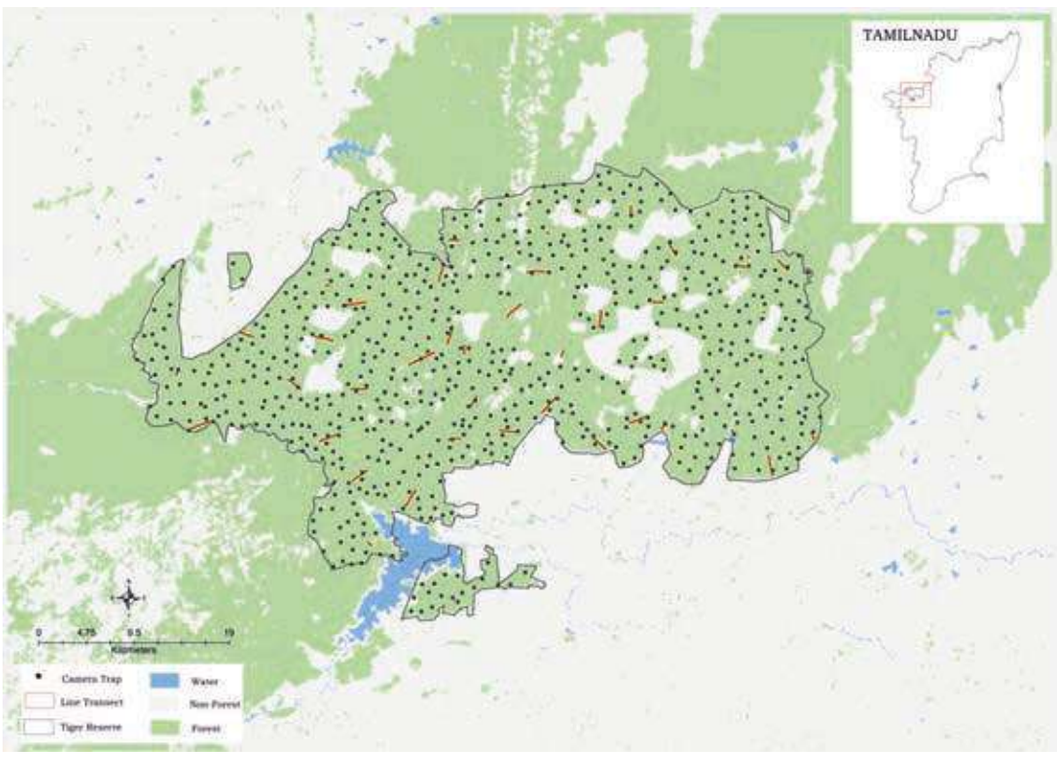
Along with Bandipur, Nagarhole, Wayanad and Sathyamangalam; Mudumalai Tiger Reserves supports the largest population of wild tigers and elephants in the world. However, the tiger reserve is currently under biotic pressures from the villages situated inside which need to be resettled urgently. Ooty-Mysuru highway passing through the Tiger Reserve needs to be appropriately mitigated so as to permit unhindered animal movement.

SATHYAMANGALAM TIGER RESERVE

INTRODUCTION

Sathyamangalam Tiger Reserve (SMTR) is located at 11° 38' 24" N, 77° 13' 34" E and covers an area of 1,411.6 km^2. Sathyamangalam forest range is an important wildlife corridor in the Nilgiri Biosphere Reserve between the Western Ghats and the rest of the Eastern Ghats. It forms a genetic link between the four other protected areas which it adjoins, the Billigiri Ranganatha Swamy Temple Wildlife Sanctuary, Sigur Plateau, Mudumalai National Park and Bandipur National Park. The Sathyamangalam forest is mostly tropical dry forest and is part of the South Deccan Plateau dry deciduous forests ecoregion. There are five distinct forest types: tropical evergreen (Shola), semi-evergreen, mixed-deciduous, dry deciduous and thorn forests. Major carnivores found here are tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*) and striped hyena (*Hyena hyena*). Some of the major herbivores found here are elephant (*Elephas maximus*), gaur (*Bos gaurus*), chital (*Axis axis*), blackbuck (*Antilope cervicapra*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), four-horned antelope *Tetracerus quadricornis*) and wild pig (*Sus scrofa*).

Figure 11.121
Camera trap and transect layout in Sathyamangalam Tiger Reserve, 2018-19



RESULTS

Tiger Density Estimates

A total of 707 camera traps were deployed in Sathyamangalam Tiger Reserve yielding 709 tiger detections (including 35 detections of cubs) from which 83 individual tigers were identified. Density of tigers in the Tiger Reserve was estimated to be 3.75 (SE 0.43) per 100 km^2 (Table 11.46). The detection corrected tiger male to female sex ratio in Sathyamangalam Tiger Reserve was 0.38:0.62 (Table 11.46).

Variables	Estimates
Model space (km^2)	2951.00
Camera points	707
Trap nights (effort)	22806
Unique tigers captured	83
Model	g_0 (sex) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	3.75 (0.43)
σ Female (SE) (km)	2.08 (0.06)
σ Male (SE) (km)	4.63 (0.17)
g_0 Female (SE)	0.01 (0.001)
g_0 Male (SE)	0.005 (0.0005)
Pmix Female (SE)	0.62 (0.05)
Pmix Male (SE)	0.38 (0.05)

Table 11.46

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Sathyamangalam Tiger Reserve, 2018.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

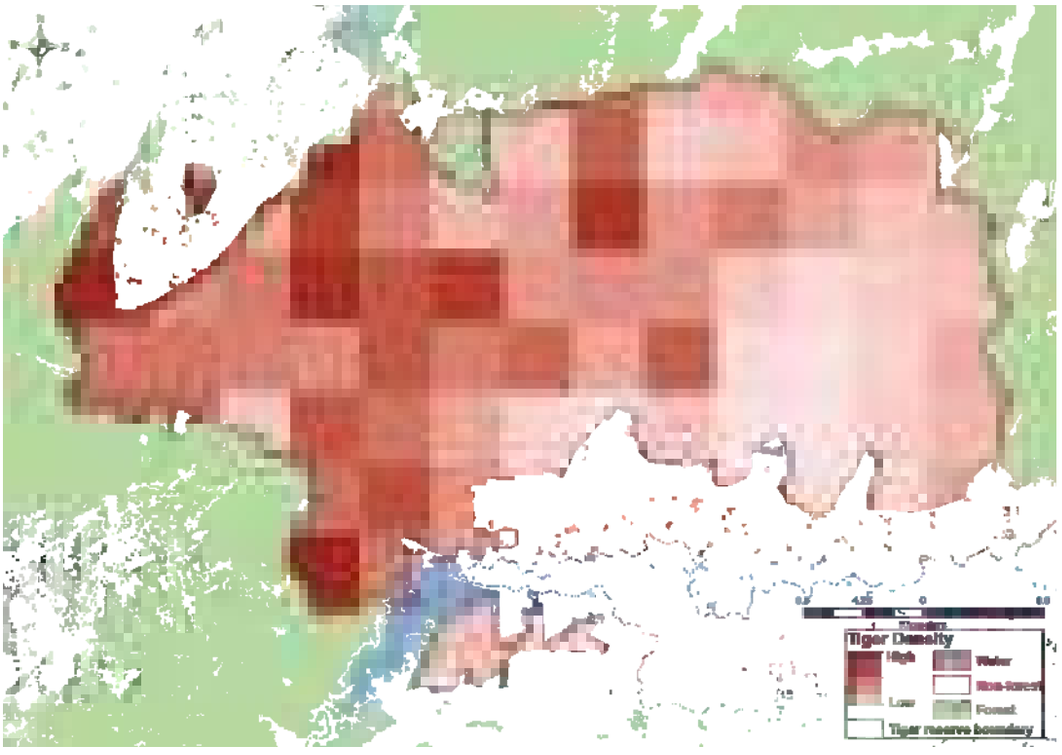


Figure 11.122

Spatial density of tigers in Sathyamangalam Tiger Reserve, 2018-19

Tigers were uniformly distributed in the Tiger Reserve with medium to high density. Some high density pockets were seen near the Moyar valley adjoining Bandipur Tiger Reserve.

Prey Density Estimates

A total of 147 transects were sampled in Sathyamangalam which amounted to an effort of 223.99 km. Chital was found to be the most abundant ungulate in Sathyamangalam TR (Table 11.47).

Table 11.47

Model statistics and parameter estimates of line transect (n=147, Total effort 223.99 km) based distance sampling for prey species in Sathyamangalam TR, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital	30.67 (0.90)	122	4.46 (0.46)	0.12 (0.004)	0.54	8.88 (0.78)	39.66 (5.39)
Sambar	31.08 (1.22)	69	1.81 (0.12)	0.06 (0.002)	0.30	4.95 (0.55)	8.97 (1.19)
Gaur	33.20 (2.14)	58	2.51 (0.34)	0.11 (0.007)	0.25	3.90 (0.58)	9.81 (1.99)
Elephant	47.62 (2.82)	38	1.94 (0.19)	0.12 (0.007)	0.17	1.78 (0.31)	3.46 (0.70)
Wild pig	27.54 (1.98)	15	5.20 (0.88)	0.09 (0.007)	0.06	1.21 (0.31)	6.32 (1.95)
Barking deer		7	1.42 (0.42)		0.03		

Distribution of Major Mammalian Fauna Found in Sathyamangalam Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Sathyamangalam Tiger Reserve.

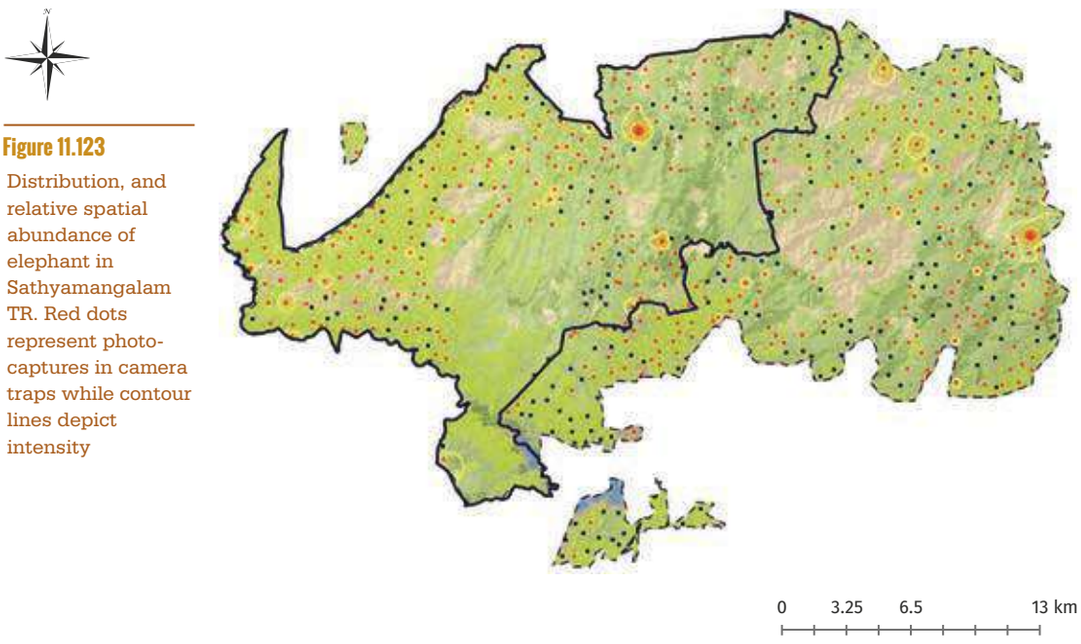
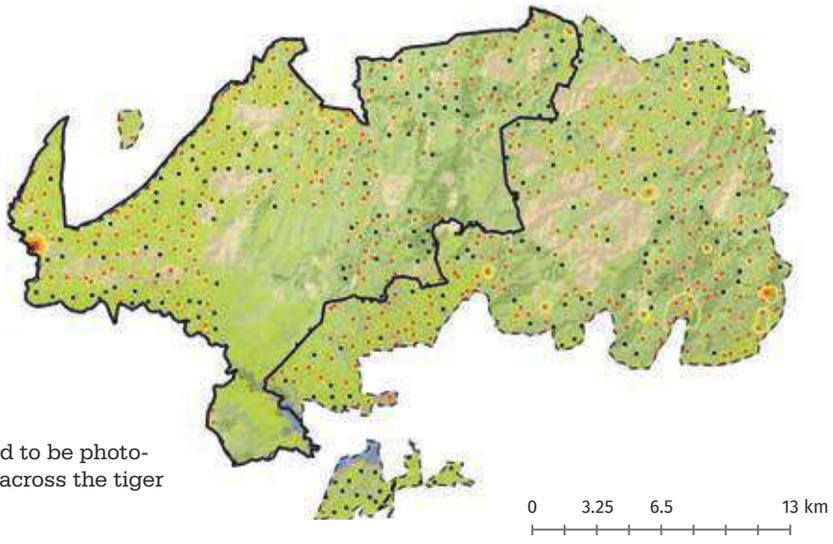


Figure 11.123

Distribution, and relative spatial abundance of elephant in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

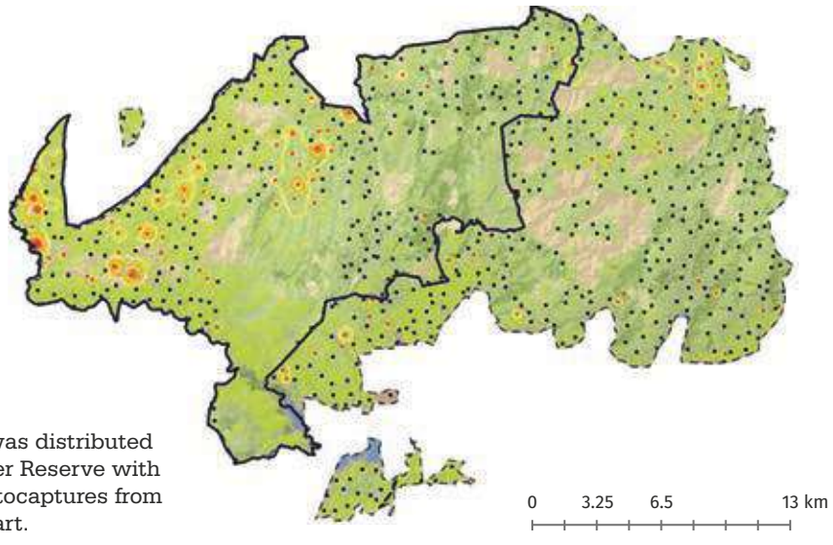
Elephants were photo-captured from all areas of the tiger reserve.



Gaur was found to be photo-captured from across the tiger reserve.

Figure 11.124

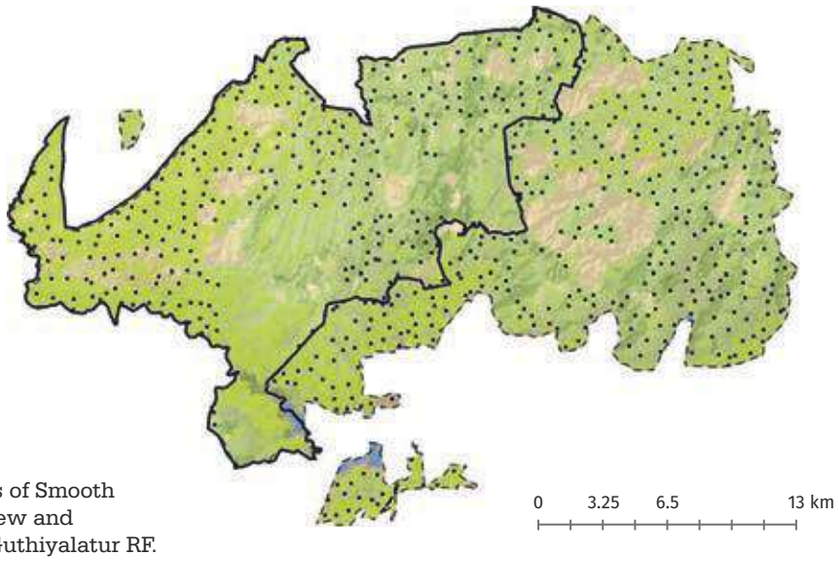
Distribution, and relative spatial abundance of gaur in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity



Chowsingha was distributed across the Tiger Reserve with maximum photocaptures from the western part.

Figure 11.125

Distribution, and relative spatial abundance of chowsingha in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity



Photocaptures of Smooth coated were few and restricted to Guthiyalatur RF.

Figure 11.126

Distribution, and relative spatial abundance of smooth coated otter in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

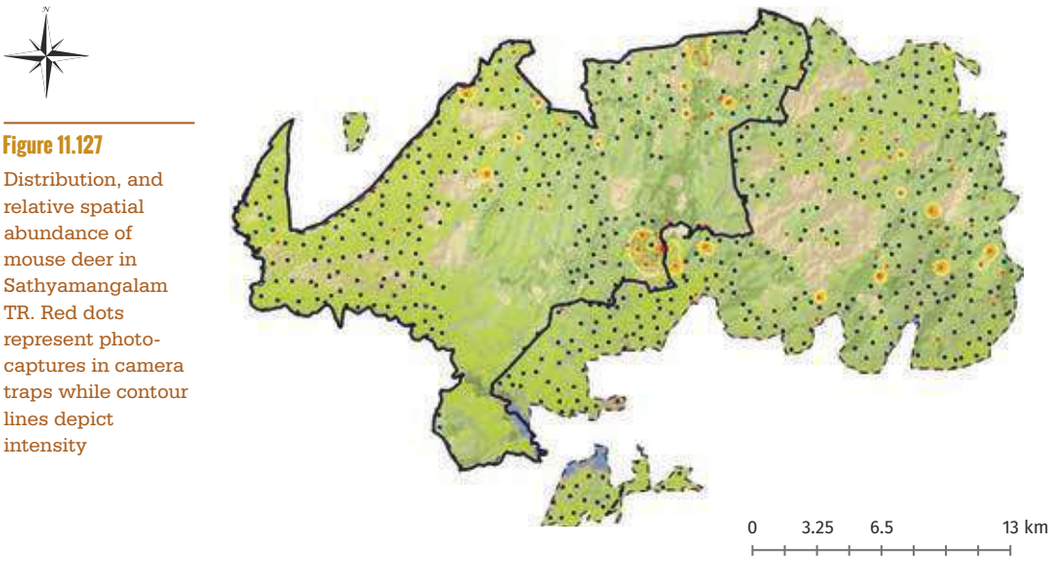


Figure 11.127

Distribution, and relative spatial abundance of mouse deer in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Mouse deer were photo-captured from all areas of the tiger reserve.

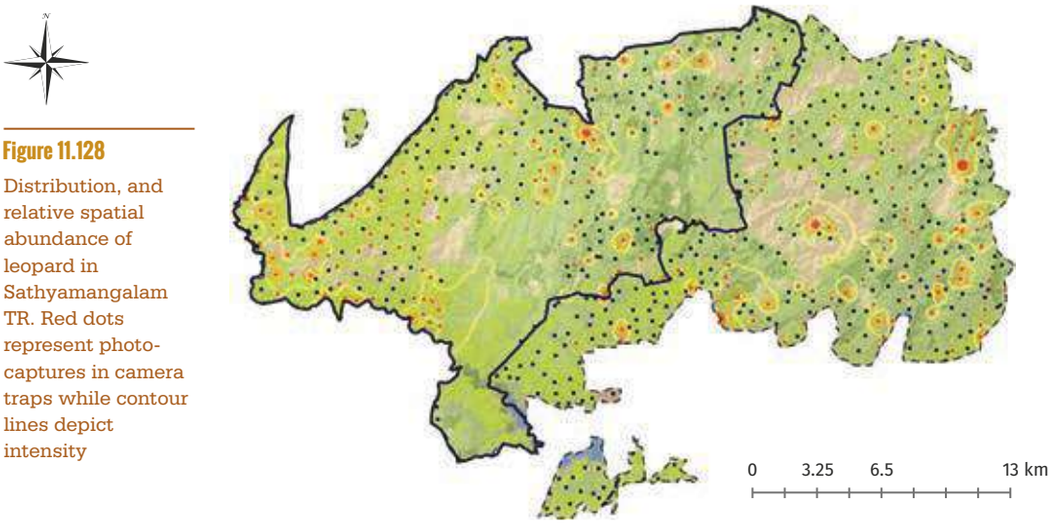


Figure 11.128

Distribution, and relative spatial abundance of leopard in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard were photo-captured from throughout the park at high rates.

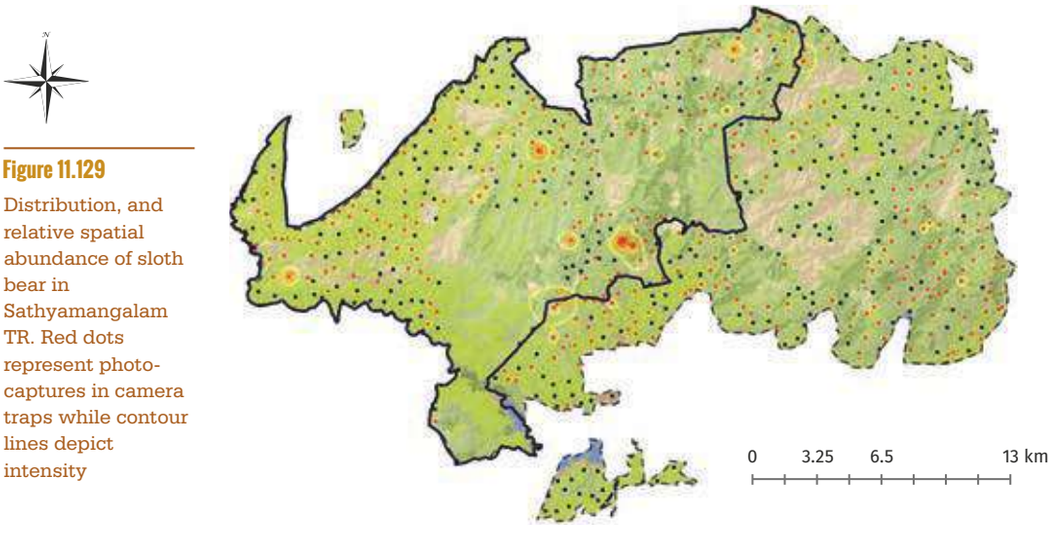
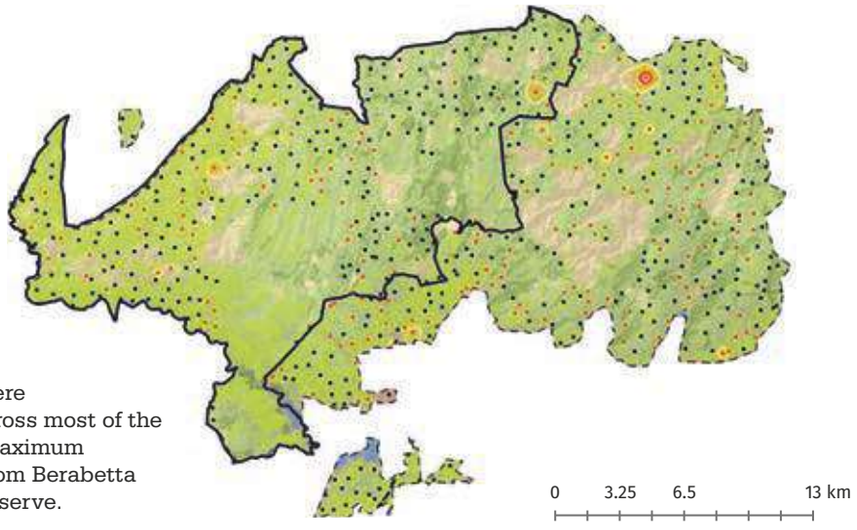


Figure 11.129

Distribution, and relative spatial abundance of sloth bear in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

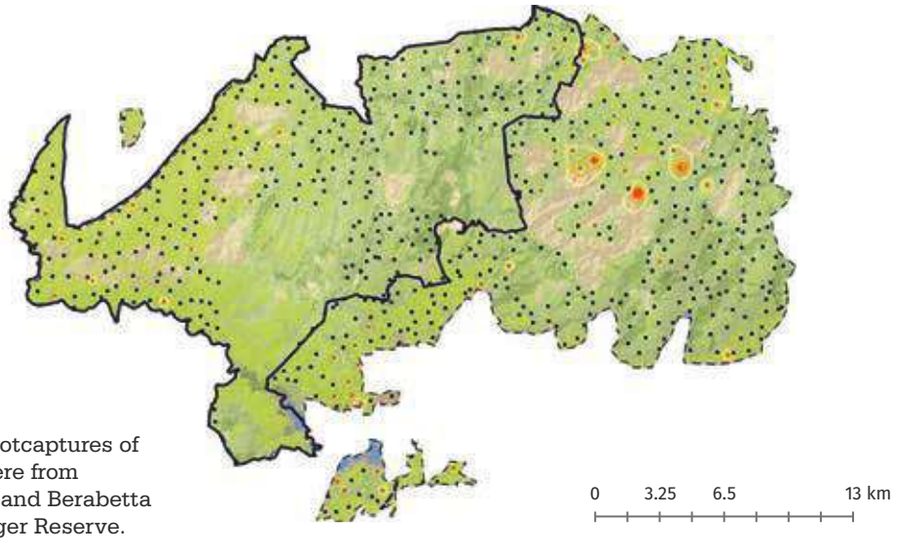
Sloth bear captures were from all areas of the tiger reserve.



Though dhole were photcaptured across most of the Tiger Reserve, maximum captures were from Berabetta RF of the tiger reserve.

Figure 11.130

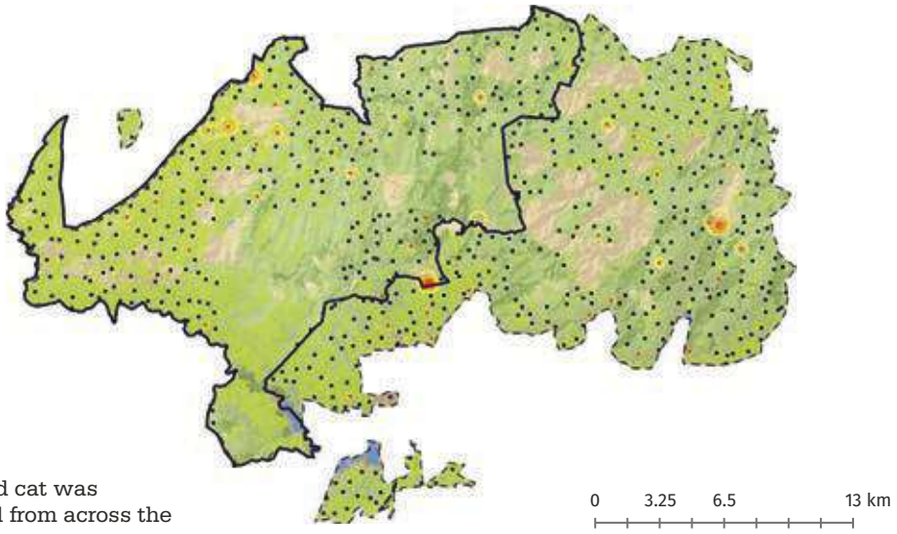
Distribution, and relative spatial abundance of dhole in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity



Maximum photcaptures of jungle cat were from Guthiyalatur and Berabetta RFs of the Tiger Reserve.

Figure 11.131

Distribution, and relative spatial abundance of jungle cat in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity



Rusty spotted cat was photcaptured from across the tiger reserve.

Figure 11.132

Distribution, and relative spatial abundance of rusty spotted cat in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

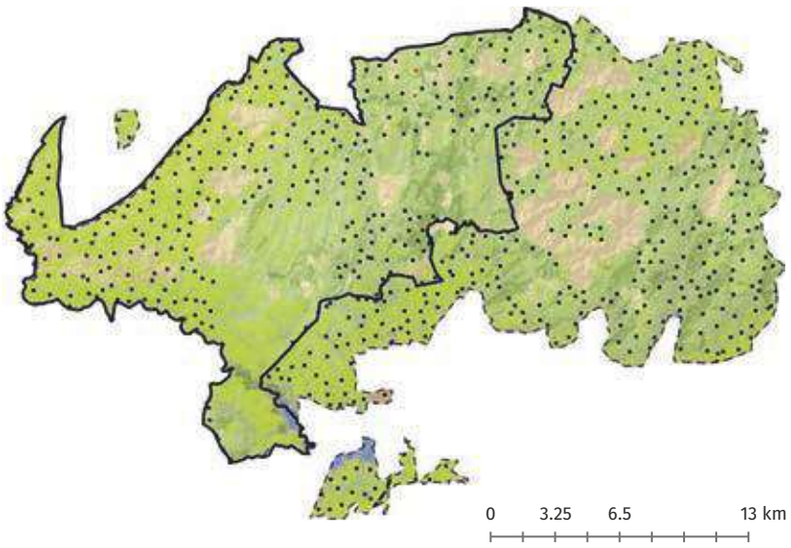


Figure 11.133

Distribution, and relative spatial abundance of leopard cat in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Few leopard cat photo-captures were obtained from Guthiyalatur RF of the tiger reserve.

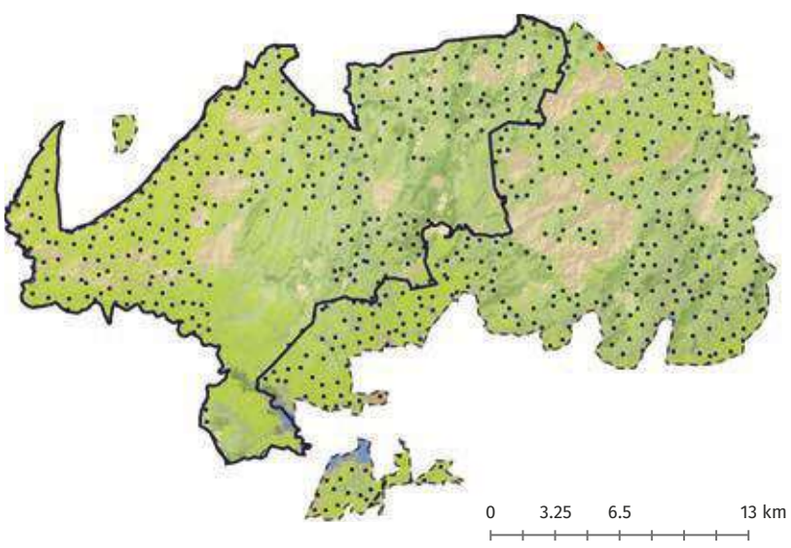


Figure 11.134

Distribution, and relative spatial abundance of jackal in Sathyamangalam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Very few photo-captures of golden jackal were from areas adjacent to Kollegal Forest Division of Karnataka

Relative Abundance of all Photocaptured Species in Sathyamangalam Tiger Reserve

A total of 35 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Livestock and chital were the most commonly photo-captured species (Table 11.48). Smooth coated otter was the rarest species photo-captured followed by jackal.

Table 11.48

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Sathyamangalam Tiger Reserve, 2018-19.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	2.94	34
Black buck	0.19	530
Black-naped hare	6.96	14
Bonnet macaque	0.35	285
Chital	13.54	7
Common palm civet	0.44	228
Domestic cat	0.01	7602
Domestic dog	3.67	27
Elephant	6.56	15
Four horned antelope	0.60	168
Gaur	10.41	10
Golden jackal	0.01	7602
Hanuman langur	0.35	285
Indian giant squirrel	<0.01	22806
Indian grey mongoose	0.43	233
Indian pangolin	0.01	7602
Indian porcupine	4.56	22
Jungle cat	0.40	248
Leopard	1.24	81
Leopard cat	0.02	5702
Livestock	18.77	5
Mouse deer	0.53	188
Peafowl	4.96	20
Ratel	0.01	7602
Ruddy mongoose	0.93	108
Rusty spotted cat	0.21	485
Sambar	7.82	13
Sloth bear	3.24	31
Small Indian civet	0.78	128
Smooth coated otter	<0.01	22806
Stripe-necked mongoose	0.25	407
Striped hyena	0.42	240
Tiger	1.63	61
Wild dog	1.36	74
Wild pig	5.47	18

DISCUSSION

Tiger number and density in Sathyamangalam Tiger Reserve has increased compared to the previous estimation [2.98 (SE 0.38); Jhala et al. 2015] and the tiger reserve acts as an important source population in the landscape. However, a lot of developmental projects and mining are prevalent in the Sathyamangalam landscape which need to be mitigated appropriately so that the source value of the Tiger Reserve is not compromised. The Tiger Reserve is pocketed with human settlements that are legally excluded from within the reserve but ecologically impact biodiversity values. Community support and incentivized voluntary relocation is required to reduce human impacts especially from the village Tengumarahada which is in the vitan habitat of Moyar river valley connecting Sathyamangalam to Mudumalai and Bandipur Tiger Reserves.

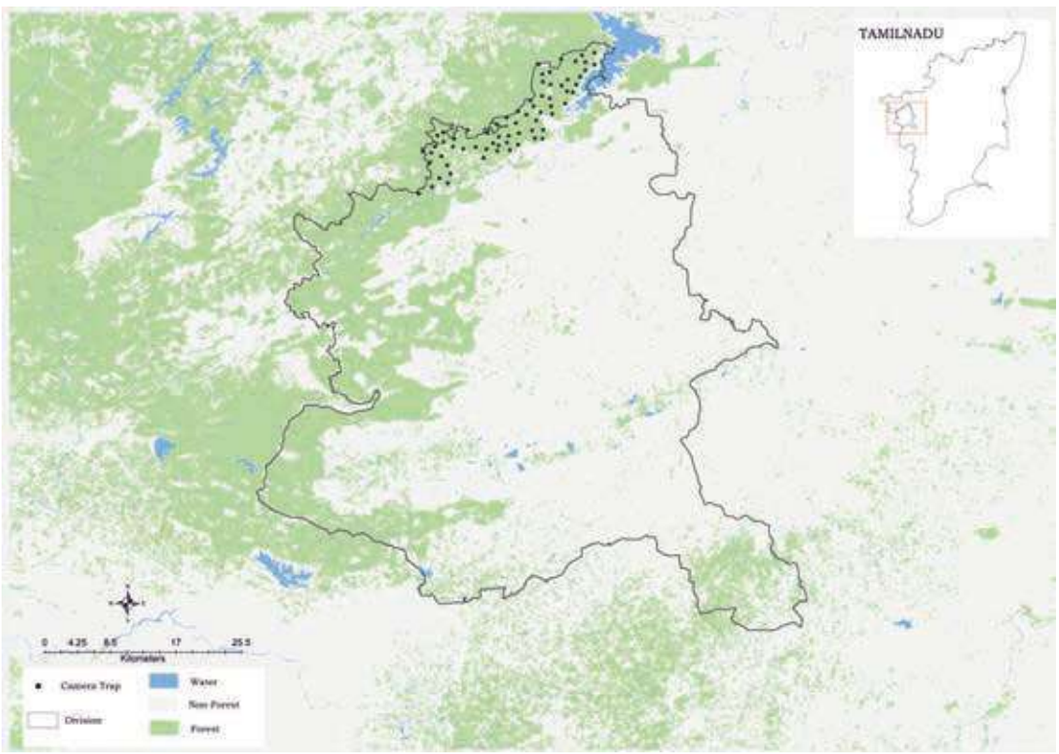
COIMBATORE WILDLIFE DIVISION

INTRODUCTION

Coimbatore district is richly endowed with hills, forests, rivers and wildlife. The Western Ghats of the district are the home of rivers such as Bhavani, Noyyal River, Aliyar, Siruvani which provide the drinking water and irrigation water for the people and farmers of Coimbatore. The forests of Coimbatore district spread over an area of 693.48 km^2 against district area of 7433.72 km^2. The forests are responsible for the cool weather, the green landscape and clean air of the district. The forest tract falls between 10°37' and 11°31' North latitudes and 76°39' and 77°5' East longitudes. The greater part of the Coimbatore forest division is situated in southward extending Western Gnats, with the North-western parts forming the lower Ranges of the Nilgiris. The Coimbatore forest division is part of the Nilgiri Biosphere Reserve (NBR) and also forms part of the Core Zone of the NBR. The forest of Coimbatore is administered by two forest divisions. South of Palghat Gap lies the Anamalai Wildlife Sanctuary, which has been designated as Tiger Reserve during 2008. North of Palghat lies the Coimbatore forest division. This division is bounded on the North and North West by Sathyamangalam, Erode, Nilgiris North and Nilgiris South Forest Divisions, and on the west and South-west by Palghat Forest division of Kerala State.

Figure 11.135

Camera trap layout in Coimbatore Wildlife Division, 2018-19



RESULTS

Tiger Density Estimates

A total of 67 camera traps were deployed in Coimbatore Wildlife Division yielding 128 tiger detections (no image for tiger cub) from which 11 individual tigers were identified. Density of tigers in Coimbatore Forest Division was estimated to be 1.70 (SE 0.54) per 100 km^2 (Table 49). The detection corrected tiger male to female sex ratio in Coimbatore Forest Division was 0.31:0.69 (Table 11.49).

Variables	Estimates
Model space (km^2)	855.62
Camera points	67
Trap nights (effort)	2709
Unique tigers captured	11
Model	g_0 (.)σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.70 (0.54)
σFemale (SE) km	4.02 (0.36)
σMale (SE) km	6.23 (0.6)
g_0 (SE)	0.03 (0.004)
Pmix Female (SE)	0.69 (0.13)
Pmix Male (SE)	0.31 (0.13)

Table 11.49

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Coimbatore Forest Division, 2018.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

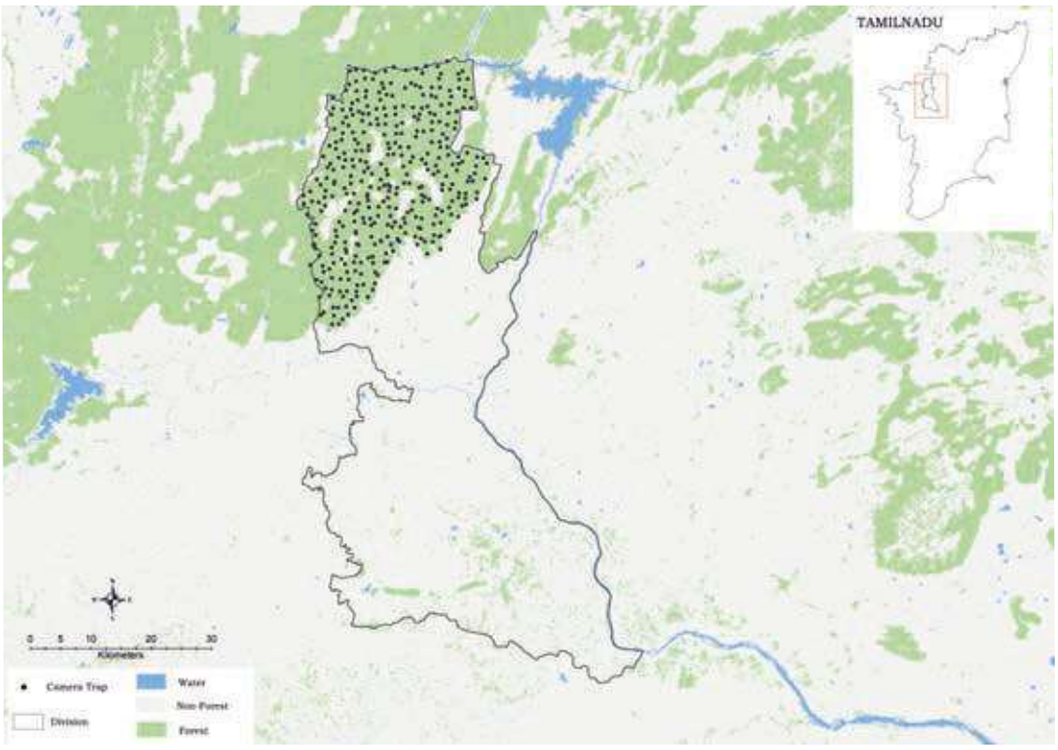
Coimbatore Division being strategically located connecting many Tiger Reserves is an important tiger habitat maintaining the metapopulation dynamics for the species in the landscape. Better protection, minimizing human-wildlife conflict and mitigating developmental projects are some of the key recipes for conservation of this Division.

ERODE WILDLIFE DIVISION

INTRODUCTION

Erode Forest Division (821.4 km^2) forms buffer of Sathyamangalam Tiger Reserve and is surrounded by Kollegal Forest Division of Karnataka State on the northern side, Salem, Namakkal Districts on eastern side, Sathyamangalam Division on western side and Tiruppur District on southern side. This forest tract supports major fauna like elephant (*Elephas maximus*), tiger (*Panthera tigris*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), wild pig (*Sus scrofa*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*) etc. The prominent forest types of Erode District are Tropical dry thorn forest, Tropical dry mixed deciduous forest, Tropical semi evergreen, Sub-tropical hill forests, Riparian forest and phoenix savannah forests.

Figure 11.136
Camera trap layout in Erode Wildlife Division, 2018



RESULTS

Tiger Density Estimates

A total of 366 camera traps were deployed in Erode Wildlife Division yielding 84 tiger detections (no image of tiger cub) from which 10 individual tigers were identified. Density of tigers in Erode Forest Division was estimated to be 0.85 (SE 0.28) per 100 km^2 (Table 11.50). The detection corrected tiger male to female sex ratio in Erode Forest Division was 0.26:0.74 (Table 11.50).

Variables	Estimates
Model space (km^2)	1943.62
Camera points	366
Trap nights (effort)	10866
Unique tigers captured	10
Model	g_0 (.)σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.85 (0.28)
σFemale (SE) km	2.8 (0.2)
σMale (SE) km	4.1 (0.5)
g_0 (SE)	0.01 (0.003)
Pmix Female (SE)	0.74 (0.13)
Pmix Male (SE)	0.26 (0.13)

Table 11.50

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Erode Wildlife Division, 2018.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Erode division is already under the buffer zone of Sathyamangalam Tiger Reserve. The division would benefit with enhanced protection and reduction of human impacts to improve its biodiversity values.

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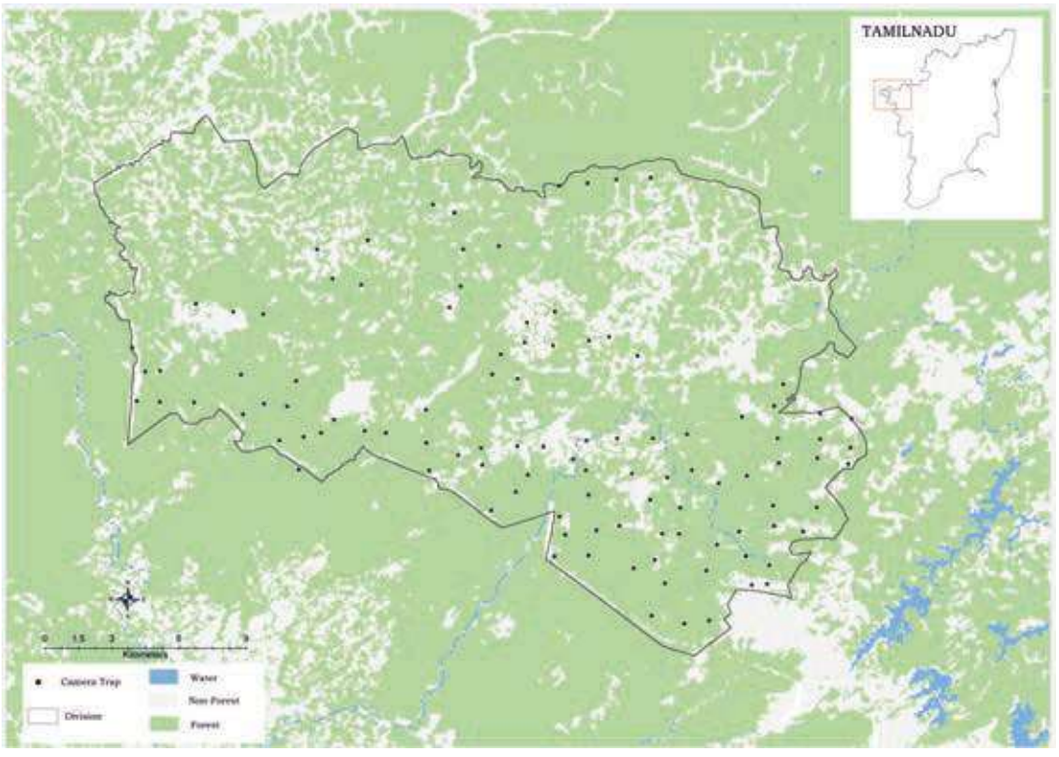
GUDALUR WILDLIFE DIVISION

INTRODUCTION

Gudalur Forest Division is situated in the Nilgiris-Wyanad tract of Tamil Nadu in southern Western Ghats. This Division lies west of the Nilgiris plateau and is bound on the North by Benne Reserved Forest of Mudumalai Wildlife Sanctuary on the East by the hills of Kundah and South East, west and North-west by forests of Kerala state. The Gudalur Forest Division is represented by several forest types such as west-coast tropical evergreen, southern moist deciduous, southern montane wet temperate, southern montane tropical semi-evergreen and southern dry deciduous forests.

Figure 11.137
Camera trap layout in Gudalur Wildlife Division, 2018-19



RESULTS

Tiger Density Estimates

A total of 106 camera traps were deployed in Gudalur Wildlife Division yielding 45 tiger detections (no image of tiger cub) from which 11 individual tigers were identified. Density of tigers in Gudalur Forest Division was estimated to be 1.81 (SE 0.58) per 100 km^2 (Table 11.51). The model inferred tiger male to female sex ratio in Gudalur Forest Division was 0.50:0.50 (Table 11.51).

Variables	Estimates
Model space (km^2)	1047
Camera points	106
Trap nights (effort)	3699
Unique tigers captured	11
Model	g_0 (.) σ (.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.81 (0.58)
σ (SE) km	1.78 (0.2)
g_0 (SE)	0.04 (0.01)
Pmix Female (SE)	0.50 (0.15)
Pmix Male (SE)	0.50 (0.15)

Table 11.51

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Gudalur Wildlife Division, 2018-19.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

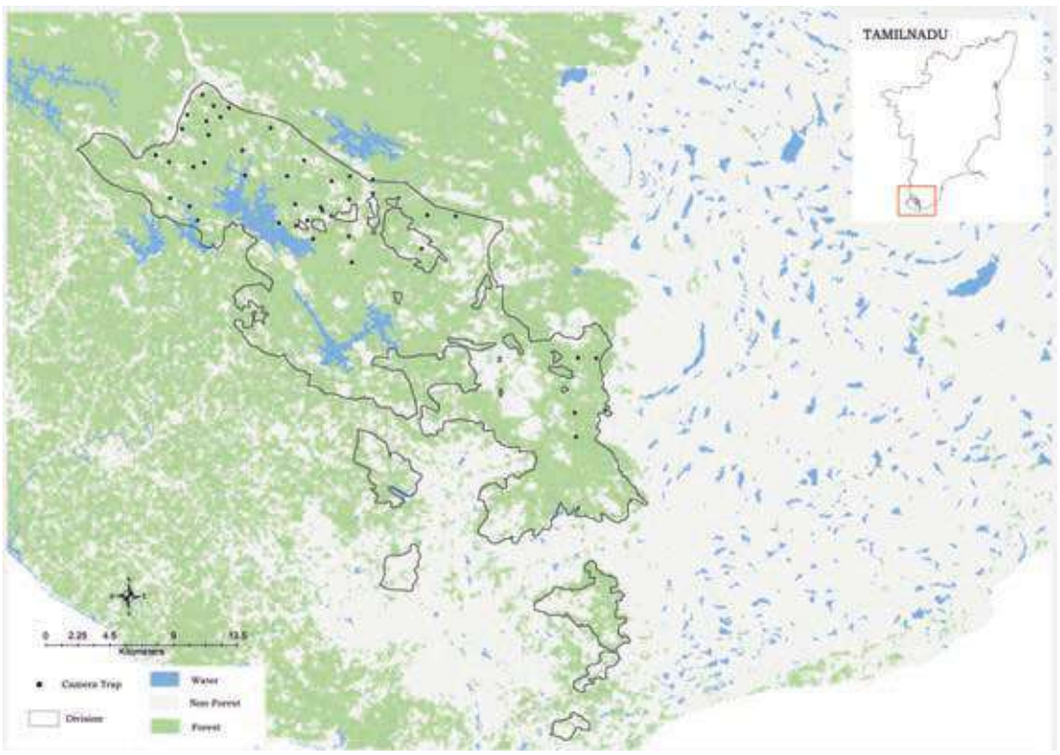
Gudalur division is already part of buffer of Mudumalai Tiger Reserve. The division would benefit with enhanced protection and reduction of human impacts to improve its biodiversity values.

KANYAKUMARI WILDLIFE SANCTUARY

INTRODUCTION

Kanyakumari Wildlife Sanctuary is a 402.4 km^2 protected area in Kanyakumari district, Tamil Nadu declared in February 2008. Seven rivers originate in the forest including the Thamirabarani River and Pahrali River. The region is one of the most diverse wildlife forest location in southern India. Several new species of plants, amphibians and insects discovered here are found nowhere else, making it an endemic region. The area is a wildlife corridor with high biodiversity, and in addition to tigers, is home to the threatened species: gaur (*Bos gaurus*), elephant (*Elephas maximus*), lion-tailed macaque (*Macaca silenus*), mouse deer (*Moschiola indica*), Nilgiri tahr (*Nilgiritragus hylocrius*) and sambar (*Rusa unicolor*).

Figure 11.138
Camera trap layout in Kanyakumari Wildlife Sanctuary, 2018-19



RESULTS

Camera Trap Results

A total of 43 camera traps were deployed in Kanyakumari Wildlife Sanctuary yielding two tiger detections from which one individual tiger was identified (Table 11.52).

Table 11.52
Sampling details of camera trapping exercise for Kanyakumari Wildlife Sanctuary, 2018.

Sampling Details	Counts
Camera points	43
Trap nights (effort)	1417
Unique tigers captured	1

DISCUSSION

This sanctuary is the southernmost limit of tiger distribution in India.

KODAIKANAL WILDLIFE SANCTUARY

INTRODUCTION

In 2013, the Tamil Nadu Government officially declared 609 km^2 of the Palani Hills protected as the Kodaikanal Wildlife Sanctuary. The Palani Hills are an eastern offshoot of the Western Ghats, radiating from the "Cardamom Hills" south of the Palghat Gap. This spur is aligned on an east-west axis with a length of 65 km and a maximum north-south width of 40 km. The park is located between latitude 10°7' - 10°28' N and longitude 77°16' - 77°46' E. The whole of the Palanis fall within the western border of Tamil Nadu State in southern India. From the plains of Tamil Nadu, these hills rise in steep escarpments to a high undulating plateau, much of which lies above 2,000 m. The total area of the Palanis is 2,068 km^2. The Palani Hills can be divided into two distinct geographical zones-the Lower Palanis (up to 1500 m altitude), and the Upper Palanis (above 1500 m. altitude). A deep ravine (at its highest point called the Neutral Saddle) running north-south separates the Lower Palanis (area 1,683 km^2) in the east from the Upper Palanis (area 385 km^2). Climate varies over the range, but much of the plateau receives an average of more than 1500 mm. of rainfall annually, with no more than four dry months. In the higher areas mean day temperatures in the coolest months are below 17°C. The foothills from 400 to 800 m consist mostly of Deccan thorn scrub forests and South Deccan Plateau dry deciduous forests. Between 800 to 1,600 m is dominated by South Western Ghats moist deciduous forests accompanied by shrub savannah. From 1,600 to 2,000 m are upper montane slopes characterized by shola-grassland mosaic. Peaks rising to over 2,500 m consist mostly of montane grasslands interspersed with sholas. Major mammalian species in the park include tiger (*Panthera tigris*), elephant (*Elephas maximus*), leopard (*Panthera pardus*), gaur (*Bos gaurus*), Nilgiri tahr (*Nilgiritragus hylocrius*) and grizzled giant squirrel (*Ratufa macroura*).

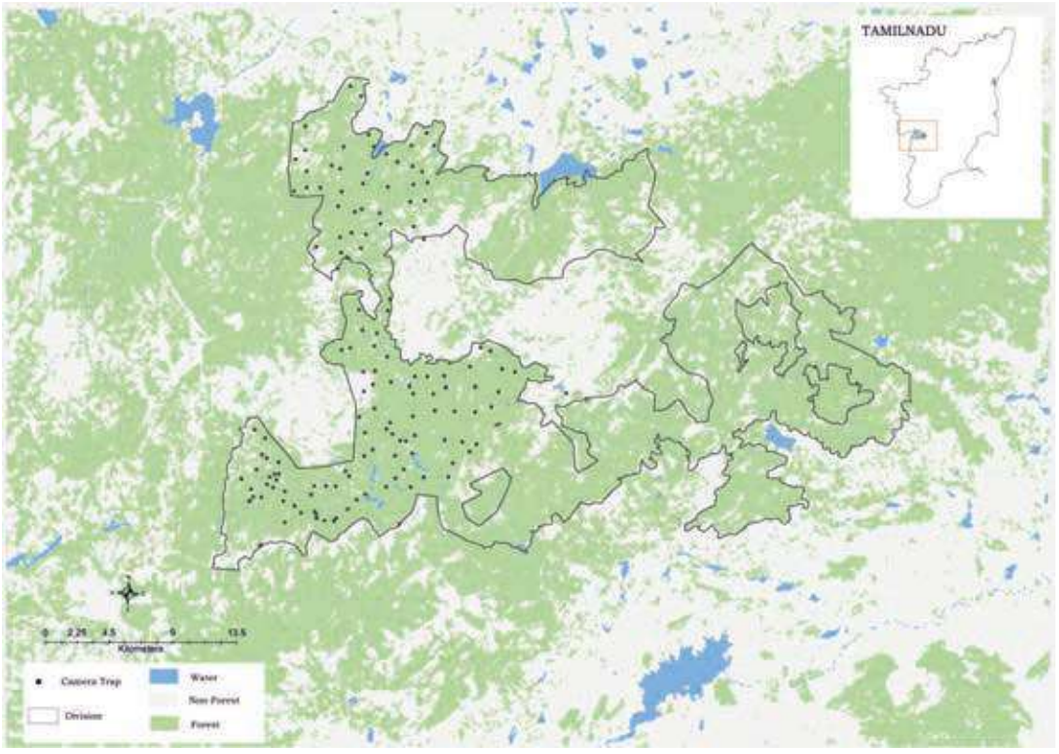


Figure 11.139 Camera trap layout in Kodaikanal Wildlife Sanctuary, 2018-19

RESULTS

Camera Trap Results

A total of 152 camera traps were deployed in Kodaikanal Wildlife Sanctuary yielding 22 tiger detections from which four individual tigers were identified (Table 11.53).

Table 11.53

Sampling details of camera trapping exercise for Kodaikanal Wildlife Sanctuary, 2018-19.

Sampling Details	Counts
Camera points	152
Trap nights (effort)	2788
Unique tigers captured	4

DISCUSSION

Kodaikanal Wildlife Sanctuary does not only have tigers but also supports a rich assemblage of flora and fauna and unique shola habitats. A participatory approach to its conservation with community involvement and alternative sustainable livelihoods is the best long-term solution.

MEGAMALAI WILDLIFE SANCTUARY

INTRODUCTION

The Megamalai Wildlife Sanctuary (269.1 km^2) situated in Theni and Madurai districts of Tamil Nadu is an excellent buffer to the Periyar Tiger Reserve and Grizzled Squirrel Wildlife Sanctuary and can immensely strengthen conservation in the southern Western Ghats, the range of hills south of the Palakkad Gap. Vegetation ranges from scrub forests at the foothills, up to ubiquitous expanses of tea and coffee estates, to spice (pepper, cardamom, cinnamon) plantations and finally to the dense evergreen forests at the top. Megamalai forest area hosts a variety of birds, mammals, reptiles and butterflies. Resident and migratory elephants are common. Other animals sighted are tiger (*Panthera tigris*), leopard (*Panthera pardus*), Nilgiri tahr (*Nilgiritragus hylocrius*), gaur (*Bos gaurus*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), sambar (*Rusa unicolor*), wild pig (*Sus scrofa*), Nilgiri langur (*Semnopithecus johnii*), lion-tailed macaque (*Macaca silenus*), common langur (*Semnopithecus entellus*), bonnet macaque (*Macaca radiata*), sloth bear (*Melursus ursinus*).

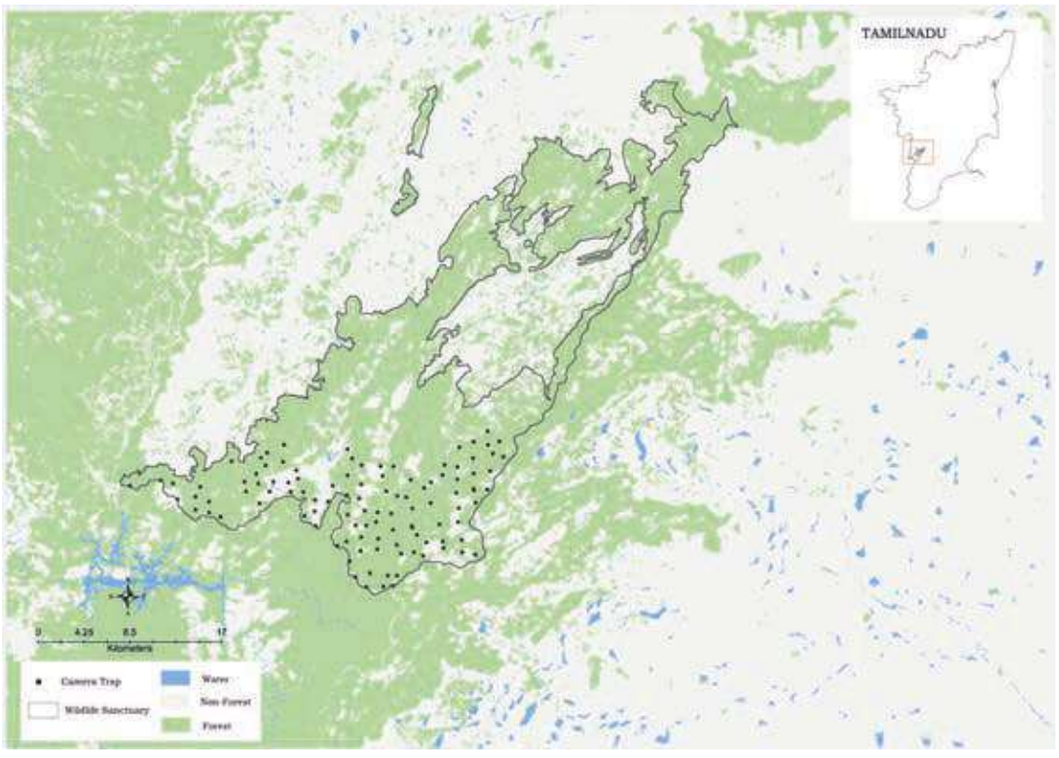


Figure 11.140 Camera trap layout in Megamalai Wildlife Sanctuary, 2018-19

RESULTS

Camera Trap Results

A total of 109 camera traps were deployed in Megamalai Wildlife Sanctuary yielding 19 tiger detections from which four individual tigers were identified (Table 11.54).

Sampling details	Counts
Camera points	109
Trap nights (effort)	2402
Unique tigers captured	4

Table 11.54 Sampling details of camera trapping exercise for Megamalai Wildlife Sanctuary, 2018-19.

DISCUSSION

Given the proximity of the Sanctuary to tiger reserves and with its good prey base, tiger density is likely to increase in the future.

MUKURTHI NATIONAL PARK

INTRODUCTION

Mukurthi National Park (MNP) is a 78.46 km^2 protected area located in the western corner of the Nilgiris Plateau west of Ootacamund hill station in the northwest corner of Tamil Nadu state in the Western Ghats mountain range of South India. The park was created to protect its flagship species, the Nilgiri tahr. The park is characterized by montane grasslands and shrublands interspersed with sholas in a high altitude area of high rainfall, near-freezing temperatures and high winds. Mukurthi National Park has an elongated crescent shape facing to the west between 11°10' to 11°22' N and 76°26' to 76°34' E. It is bordered on the west by Nilambur South Forest Division in Kerala, to the northwest by Gudalur Forest Division, to the northeast, east and southeast by Nilgiri South Forest Division and to the south by Mannarghat Forest Division, Kerala. At its southwest tip the peaks of this park straddle the northeast corner of Silent Valley National Park of Kerala. Major mammalian fauna include: Nilgiri tahr (*Nilgiritragus hylocrius*), elephant (*Elephas maximus*), tiger (*Panthera tigris*), Nilgiri marten (*Martes gwatkinsii*), Nilgiri langur (*Semnopithecus johnii*), Bonhote's mouse (*Mus famulus*), leopard (*Panthera pardus*), bonnet macaque (*Macaca radiata*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*), jungle cat (*Felis chaus*), small Indian civet (*Viverricula indica*), wild dog (*Cuon alpinus*), jackal (*Canis aureus*), black naped hare (*Lepus nigricollis*) and Malabar spiny dormouse (*Platacanthomys lasiurus*).

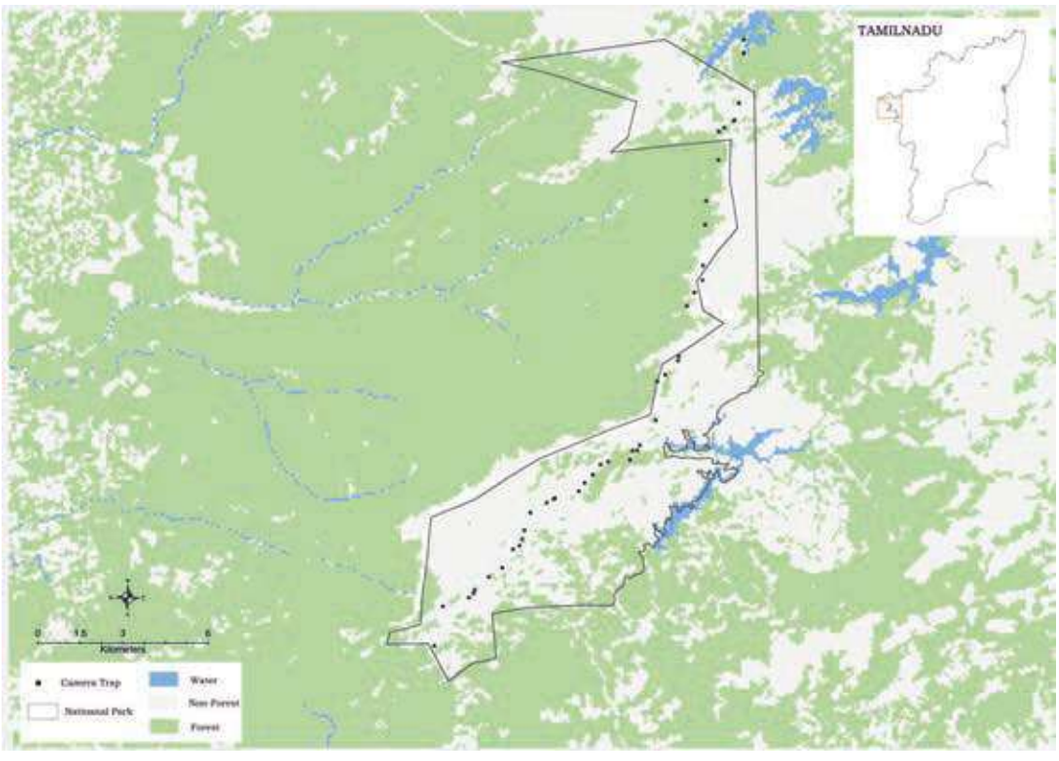


Figure 11.141
Camera trap layout in Mukurthi National Park, 2018-19

RESULTS

Tiger Density Estimates

A total of 44 camera traps were deployed in Mukurthi National Park yielding 66 tiger detections (including 5 images of cubs) from which six individual tigers were identified. Though the camera deployment was not as per the experimental design, density estimation of tigers in Mukurthi National Park was attempted. Tiger density was estimated to be 0.83 (SE 0.36) per 100 km^2 (Table 11.55). The model inferred tiger male to female sex ratio in Mukurthi National Park was 0.50:0.50 (Table 11.55).

Table 11.55

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Mukurthi National Park, 2018.

Variables	Estimates
Model space (km^2)	778.37
Camera points	44
Trap nights (effort)	1452
Unique tigers captured	6
Model	g_0 (.) σ (.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.83 (0.36)
σ (SE) km	4.5 (0.5)
g_0 (SE)	0.03 (0.008)
Pmix Female (SE)	0.50 (0.20)
Pmix Male (SE)	0.50 (0.20)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Mukurthi National Park not only has tigers but also supports a rich assemblage of flora and fauna and endemism. Conserving its unique mountain biodiversity in light of climate change and human impacts will be a challenge.

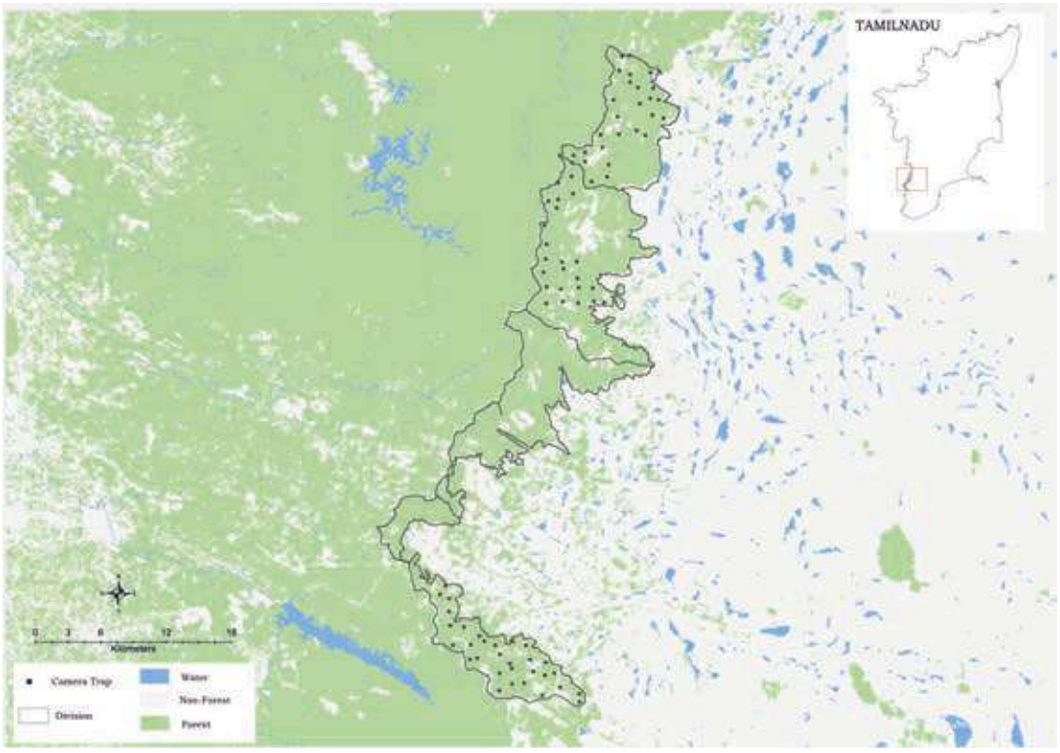
NELLAI WILDIFE SANCTUARY

INTRODUCTION

Nellai Wildlife Sanctuary spread over an area of 356.73 km^2 is located in Shenkottai, Kadayanallur, and Sivagiri taluk of Tirunelveli District in Tamil Nadu. The sanctuary is famous for migratory birds and is an important habitat corridor in Agasthyamalai landscape adjoining Kalakad Mundanthurai Tiger Reserve with the Periyar population.

Figure 11.142

Camera trap layout in Nellai Wildlife Sanctuary, 2018-19



RESULTS

Camera Trap Results

A total of 81 camera traps were deployed in Nellai WLS yielding 3 tiger images from which two individual tigers were identified (Table 11.56).

Table 11.56

Sampling details of camera trapping exercise for Nellai Wildlife Sanctuary, 2018.

Sampling Details	Counts
Camera points	81
Trap nights (effort)	1876
Unique tigers captured	2

DISCUSSION

Even though only two tigers were photocaptured, this detection validates the importance of Nellai WLS as a vital corridor joining the Periyar population with the southern population of KMTR and Kanyakumari for maintaining the meta-population of tigers in this landscape.

NILGIRI FOREST DIVISION

INTRODUCTION

This division comprises of forest ranges of Sigur, Singara, North Eastern Slopes (NES), Kothagiri, Coonoor, Kattabettu and Ooty North. Sigur Plateau is located adjoining the Bandipur National Park to the northwest, Wayanad Wildlife Sanctuary to the west, andSathyamangalam Wildlife Sanctuary and Nilgiris East ranges to the east. As it is insulated by protected areas on all sides, it is less disturbed with diverse vegetation types from Evergreen to Thorn forest and therefore this diversity of habitat supports a variety of fauna. Elevation of the plateau lies between 600m to 2600m. The average annual rainfall varies from 40cm to 200cm. Vegetation type varies in accordance with elevation and rainfall gradient in this area. The presence of Riparian forest along the Moyar River and arid thorn forest on the hills with open grass and sparsely distributed trees supports a variety of large herbivores. Some of the mammal species found in this division include elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), black-naped hare (*Lepus nigricollis*), common langur (*Semnopithecus entellus*), bonnet macaque (*Macaca radiata*). The division supports carnivores like tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), striped hyena (*Hyena hyena*) and sloth bear (*Melursus ursinus*).

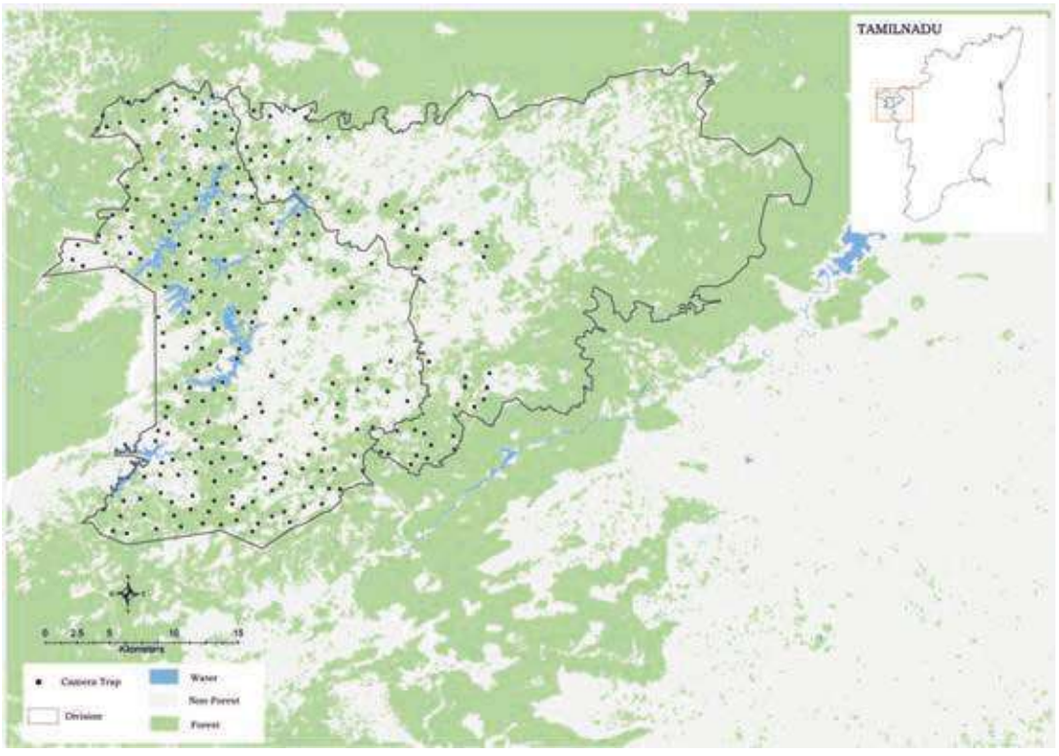


Figure 11.143
Camera trap layout in Nilgiri Forest Division, 2018-19

RESULTS

Tiger Density Estimates

A total of 273 camera traps were deployed in Nilgiri Forest Division yielding 243 tiger detections (including 4 images of cubs) from which 34 individual tigers were identified. Density of tigers in Nilgiri Forest Division was estimated to be 3.04 (SE 0.52) per 100 km^2 (Table 11.57). The detection corrected tiger male to female sex ratio in Nilgiri Forest Division was 0.35:0.65 (Table 11.57).

Table 11.57

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Nilgiri Forest Division, 2018.

Variables		Estimates
Model space (km^2)		1880
Camera points		273
Trap nights (effort)		10731
Unique tigers captured		34
Model	g_0 (sex)	(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)		3.04 (0.52)
σFemale (SE) km		2.31 (0.12)
σMale (SE) km		3.49 (0.27)
g_0 Female (SE)		0.019 (0.002)
g_0 Male (SE)		0.01(0.008)
Pmix Female (SE)		0.65 (0.09)
Pmix Male (SE)		0.35 (0.09)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Nilgiri Forest Division provides habitat heterogeneity with an elevational gradient to harbour varied biodiversity in this landscape. Being strategically located connecting many Tiger Reserves this forest division is an important tiger habitat maintaining the metapopulation dynamics for the species in the landscape. Better protection, minimizing human-wildlife conflict and controlling/mitigating developmental activities that can act as barriers to wildlife movement and encroach on critical habitats needs to be implemented.

SRIVILLIPUTHUR GRIZZLED SQUIRREL WILDLIFE SANCTUARY

INTRODUCTION

The Grizzled Squirrel Wildlife Sanctuary (GSWS), also known as Srivilliputhur Wildlife Sanctuary, was established in 1988 to protect the vulnerable grizzled giant squirrel (*Ratufa macroura*). Occupying an area of 485.2 km^2, it is bordered on the southwest by the Periyar Tiger Reserve and is one of the forests with high biodiversity south of the Palghat Gap. The Grizzled Squirrel Wildlife Sanctuary is located from 9° 21' to 9° 48' N and 77°21' to 77°46' E. The sanctuary lies mostly in Virudhunagar district especially in Srivilliputtur and partly in Madurai district. The sanctuary is bounded to the north by the Andipatti hills, south by Tirunelveli District, east by Srivilliputhur and Rajapalayam towns and west by Theni town and Theni District. It is the eastern boundary for the Periyar river watershed. This sanctuary is contiguous to Periyar Tiger Reserve on the south western side and the Megamalai Reserve Forest on the north western side and Its southern limit is contiguous with the Sivagiri Reserved Forest of Tirunelveli Forest Division. The sanctuary is a mix of tropical evergreen forests and semi-evergreen forests, dry deciduous forests and moist mixed deciduous forests, grassland and cultivated lands. In addition to grizzled giant squirrels (*Ratufa macroura*), other mammals seen here are tiger (*Panthera tigris*), common langur (*Semnopithecus entellus*), bonnet macaque (*Macaca radiata*), elephant (*Elephas maximus*), gaur (*Bos gaurus*), Indian giant squirrel (*Ratufa indica*), leopard (*Panthera pardus*), lion-tailed macaque (*Macaca silenus*), mouse deer (*Moschiola indica*), Nilgiri langur (*Semnopithecus johnii*), Nilgiri Tahr (*Nilgiritragus hylocrius*), sambar (*Rusa unicolor*), slender loris (*Loris lydekkerianus*), sloth bear (*Melursus ursinus*), chital (*Axis axis*), wild pig (*Sus scrofa*) and jungle cat (*Felis chaus*).

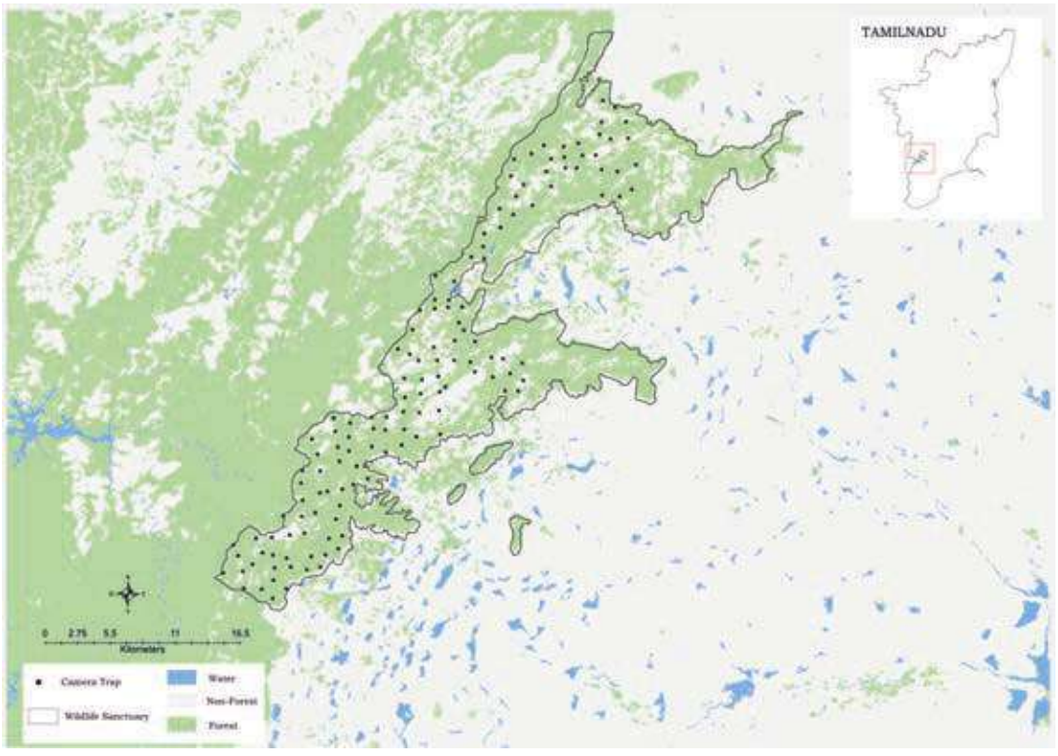


Figure 11.144 Camera trap layout in Srivilliputhur Wildlife Sanctuary, 2018-19

RESULTS

Camera Trap Results

A total of 136 camera traps were deployed in Srivilliputhur Wildlife Sanctuary yielding four tiger detections from which two individual tigers were identified (Table 11.58).

Table 11.58

Sampling details of camera trapping exercise for Srivilliputhur Wildlife Sanctuary, 2018.

Sampling details	Counts
Camera points	136
Trap nights (effort)	3342
Unique tigers captured	2

DISCUSSION

Grizzled Squirrel Wildlife Sanctuary being strategically located in the proximity to Periyar Tiger Reserve acts as a sink habitat as well as dispersal corridor for tigers to maintain the metapopulation dynamics for the species in the landscape.

PARAMBIKULAM TIGER RESERVE

INTRODUCTION

Parambikulam Tiger Reserve is located at 10° 23' 0" N, 76° 42' 30" E, between the Nelliampathy Hills of Kerala and the Anamalai Range of Tamil Nadu within a cluster of Protected Areas. It is located in the Palakkad District of Kerala. It is one of the biodiversity hot spots, with diverse habitat types and high endemism. It was declared as a Tiger Reserve during 2009, with total area of 643.66 km^2, which includes core area of 390.89 km^2 and 252.77 km^2 of buffer. The Reserve has six settlements of indigenous tribes such as the Kadar, Malasar, Muduvar and Malamalasars, living within the tiger reserve. There is also a human settlement in the Reserve which came up in the 1950's and 60's during the construction of the Parambikulam Aliyar Dam Project. The sanctuary has a variety of trees noteworthy being teak, neem, sandalwood and rosewood. The oldest teak tree, Kannimara Teak is found here. It is estimated to be about 450 years old and has a girth of 6.8 meters and a height of 49.5 meters. Major carnivores are tiger (*Panthera tigris*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*) and sloth bear (*Melursus ursinus*). Major ungulates are Nilgiri tahr (*Nilgiritragus hylocrius*), gaur (*Bos gaurus*), elephant (*Elephas maximus*), sambar (*Rusa unicolor*) and wild pig (*Sus scrofa*).

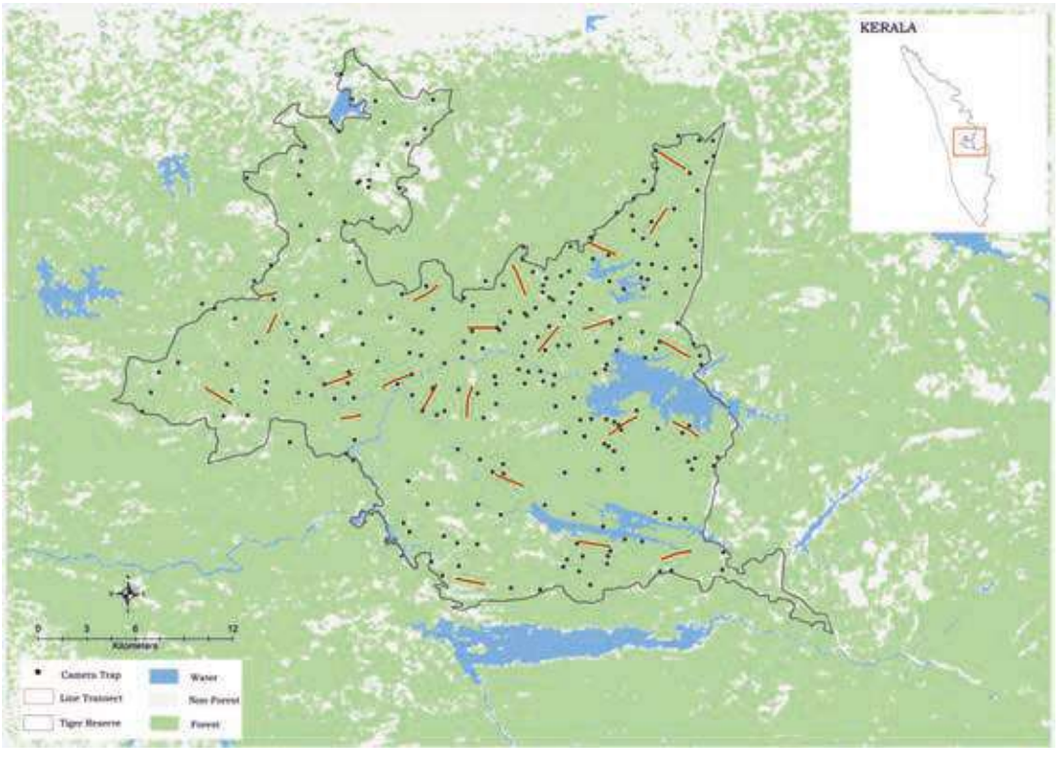


Figure 11.145
Camera trap and transect layout in Parambikulam Tiger Reserve, 2018-19

RESULTS

Tiger Density Estimates

A total of 254 camera traps were deployed in Parambikulam TR yielding 468 tiger detections (including 10 images of cubs) from which 27 individual tigers were identified. Density of tigers in the Tiger Reserve was estimated to be 1.95 (SE 0.39) per 100 km^2 (Table 11.59). The detection corrected tiger male to female sex ratio in Parambikulam TR was 0.47:0.53 (Table 11.59).

Table 11.59

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Parambikulam Tiger Reserve, 2018-19.

Variables	Estimates
Model space (km^2)	1832.12
Camera points	254
Trap nights (effort)	9823
Unique tigers captured	27
Model	g_0 (.)σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.95 (0.39)
σ Female (SE) (km)	2.70 (0.1)
σ Male (SE) (km)	3.27 (0.1)
g_0	0.01 (0.001)
Pmix Female (SE)	0.53 (0.09)
Pmix Male (SE)	0.47 (0.09)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

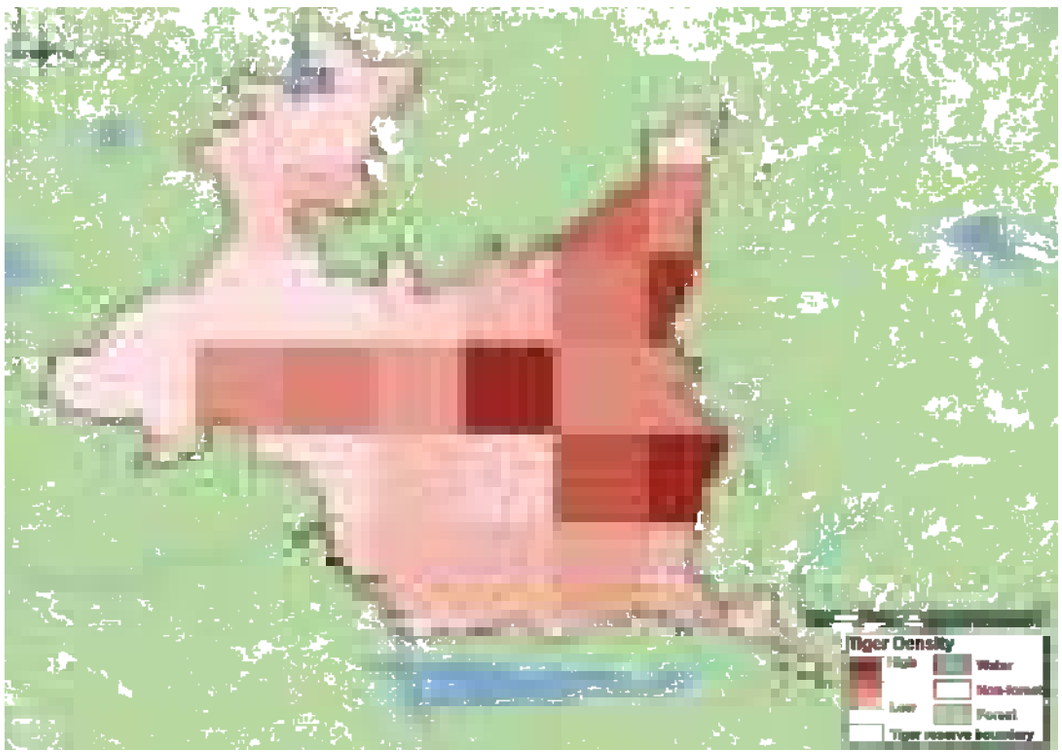
σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

Figure 11.146

Spatial density of tigers in Parambikulam Tiger Reserve, 2018-19



Tigers were uniformly distributed in the Tiger Reserve with low to medium density. Some high density pockets were seen near the reservoir in Sungam, Karimala and Parambikulam Ranges.

Prey Density Estimates

A total of 84 transects were sampled in Parambikulam which amounted to an effort of 164 km. Sambar was found to be the most abundant ungulate in Parambikulam TR (Table 11.60).

Table 11.60

Model statistics and parameter estimates of line transect (n=84, Total effort 164.31 km) based distance sampling for prey species in Parambikulam TR, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital		4			0.02		
Sambar	32.46 (3.34)	33	2.12 (0.26)	0.09 (0.01)	0.20	3.09 (0.69)	6.56 (1.68)
Gaur	37.67 (2.60)	26	2.19 (0.31)	0.10 (0.007)	0.15	0.02 (0.005)	0.04 (0.01)
Elephant	49.39 (4.45)	21	2.85 (0.46)	0.16 (0.01)	0.12	0.01 (0.003)	0.03 (0.01)
Wild pig		2			0.01		
Barking deer		5			0.03		

Distribution of Major Mammalian Fauna in Parambikulam Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Parambikulam Tiger Reserve.

Elephants were photo-captured from all parts of the tiger reserve with concentration in Karimala, Parambikulam and Sungam ranges.

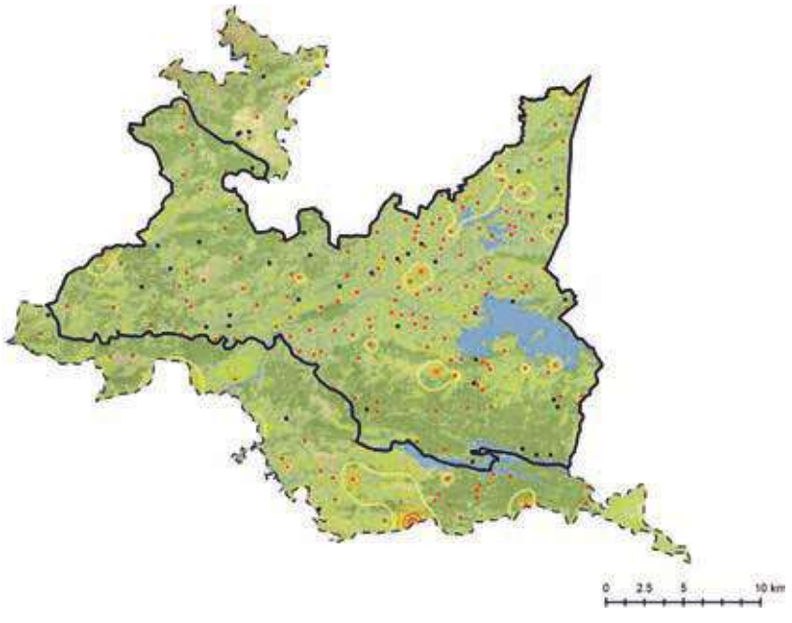


Figure 11.147

Distribution, and relative spatial abundance of elephant in Parambikulam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity.

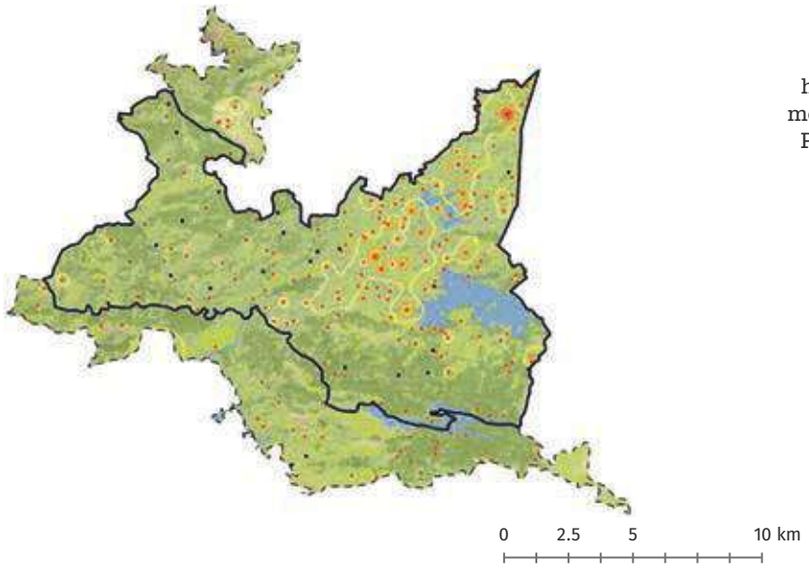


Figure 11.148

Distribution, and relative spatial abundance of gaur in Parambikulam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Gaur photo-capture hotspots were mostly near the Parambikulam Aliyar reservoir.

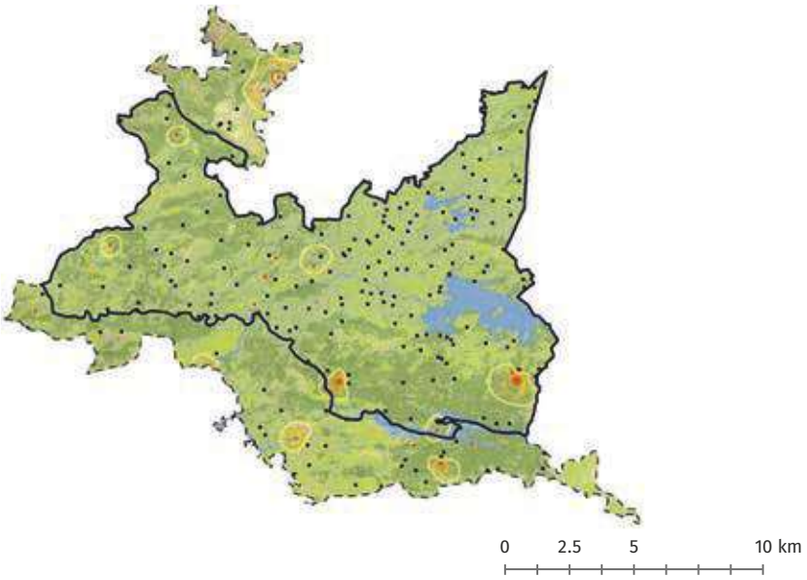


Figure 11.149

Distribution, and relative spatial abundance of lion tailed macaque in Parambikulam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity.

Lion tailed macaque was photo-captured from all Ranges of the tiger reserve.

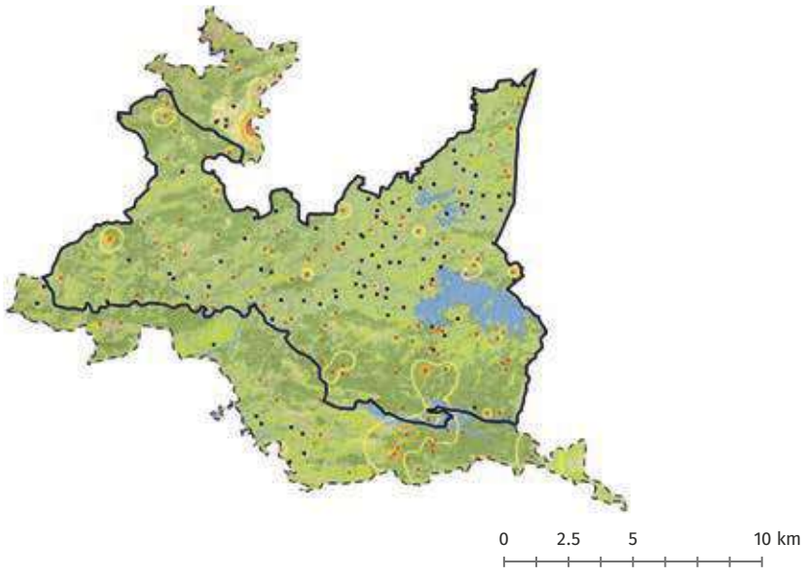
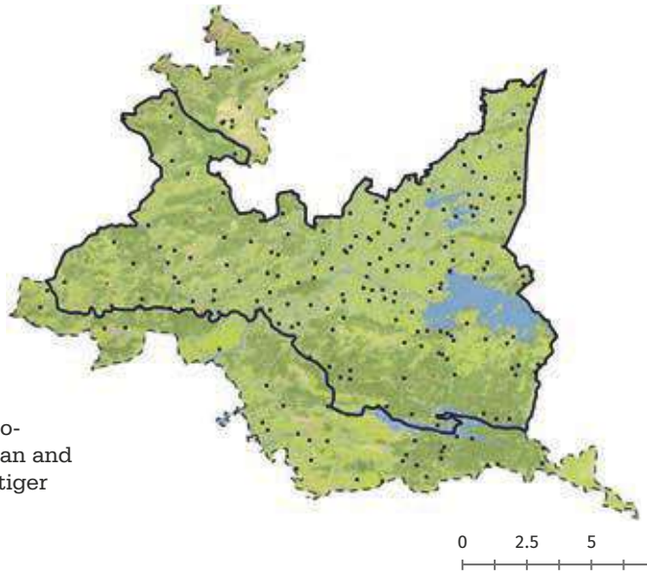


Figure 11.150

Distribution, and relative spatial abundance of mouse deer in Parambikulam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

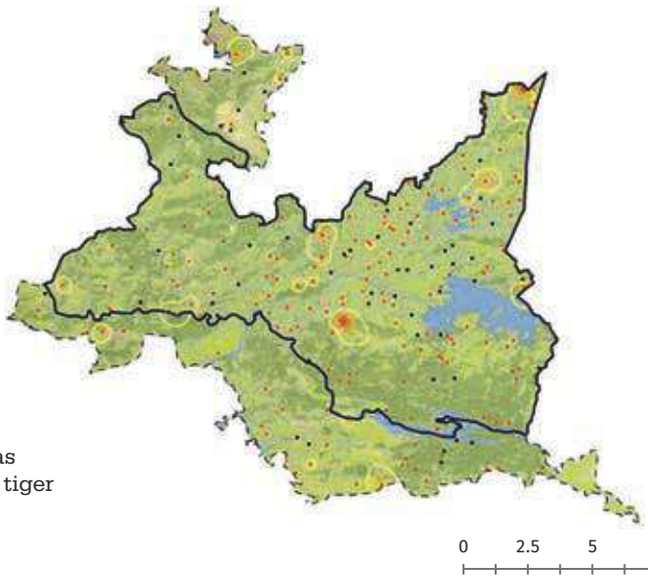
Mouse deer was photo-captured from all parts of the tiger reserve.



Nilgiri marten was photo-captured from Orukomban and Karimala Ranges of the tiger reserve.

Figure 11.151

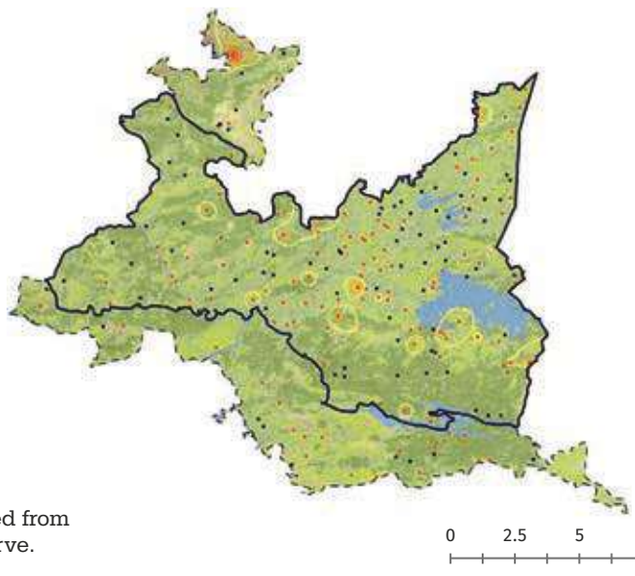
Distribution, and relative spatial abundance of Nilgiri marten in Parambikulam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity



Leopard distribution was uniform from across the tiger reserve.

Figure 11.152

Distribution, and relative spatial abundance of leopard in Parambikulam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity



Dhole was photo-captured from all parts of the tiger reserve.

Figure 11.153

Distribution, and relative spatial abundance of dhole in Parambikulam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

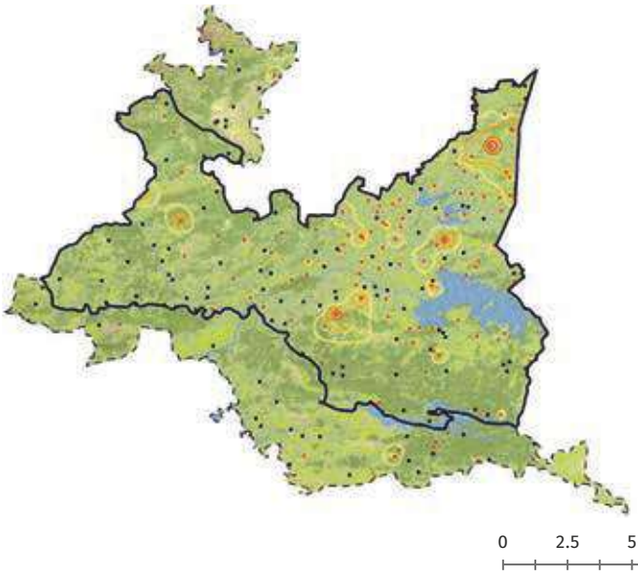


Figure 11.154

Distribution, and relative spatial abundance of sloth bear in Parambikulam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Sloth bear photo-captures were from across the tiger reserve.

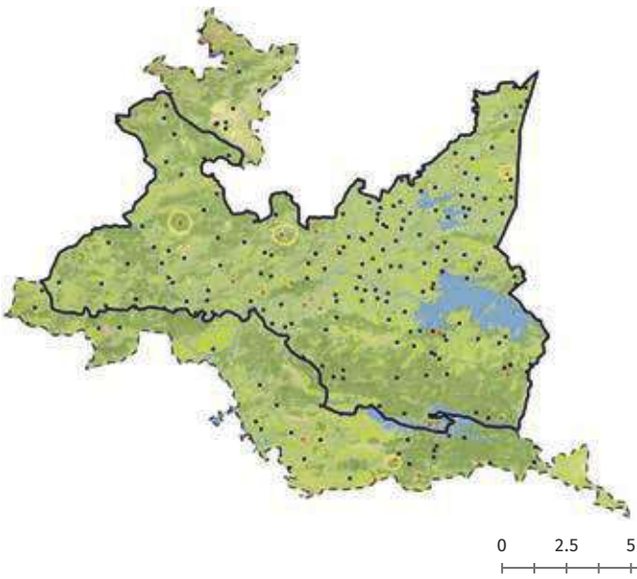


Figure 11.155

Distribution, and relative spatial abundance of leopard cat in Parambikulam TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard cat was photo-captured from all parts of the tiger reserve.

Relative Abundance of all Photocaptured Species in Parambikulam Tiger Reserve

A total of 29 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Gaur was the most commonly photo-captured (Table 11.61). Nilgiri marten was the rarest species to be photo-captured followed by livestock.

Table 11.61
Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Parambikulam Tiger Reserve,2018-19

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	7.82	13
Black-naped hare	1.38	72
Bonnet macaque	0.32	317
Brown palm civet	2.74	37
Chital	11.88	8
Common palm civet	0.44	228
Domestic dog	2.13	47
Elephant	10.63	9
Gaur	29.80	3
Indian giant squirrel	0.01	9823
Indian pangolin	0.20	491
Indian porcupine	9.82	10
Leopard	6.79	15
Leopard cat	0.32	317
Lion-tailed macaque	0.22	447
Livestock	0.12	819
Monitor lizard	0.40	252
Mouse deer	7.02	14
Nilgiri langur	0.48	209
Nilgiri marten	0.05	1965
Peafowl	3.25	31
Ruddy mongoose	0.23	427
Sambar	21.00	5
Sloth bear	2.63	38
Small Indian civet	4.79	21
Stripe-necked mongoose	2.90	34
Tiger	4.76	21
Wild dog	4.14	24
Wild pig	5.78	17

DISCUSSION

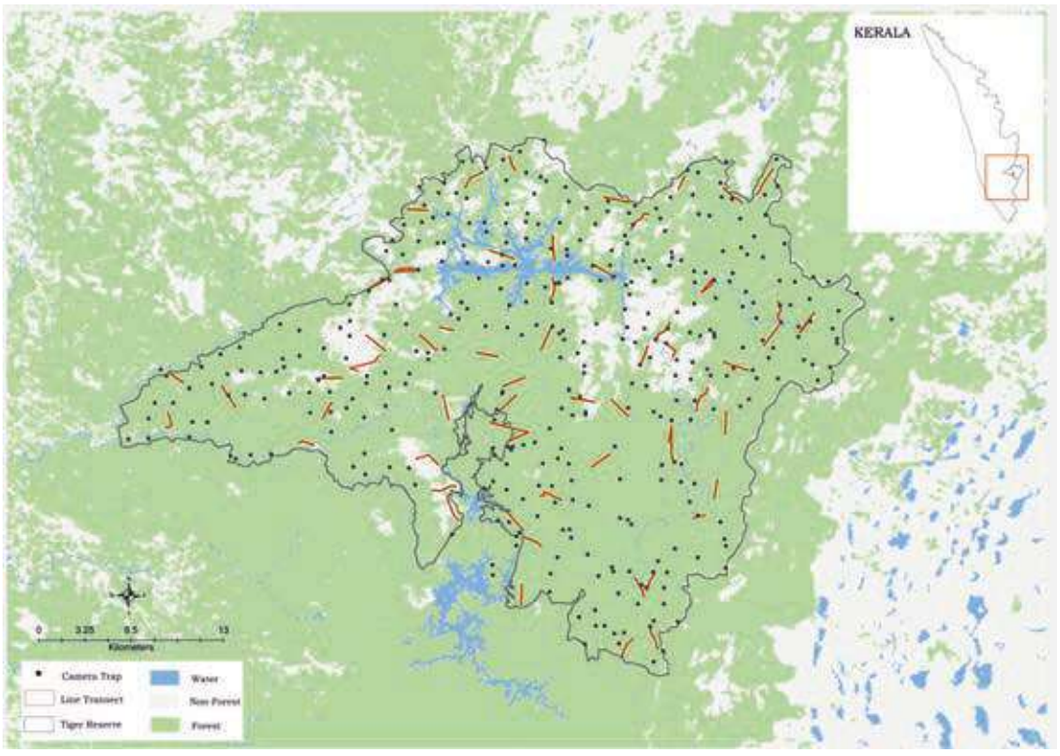
Tiger density in Parambikulam Tiger Reserve has declined in comparison to the previous cycle of estimation [2.33 (SE 0.63); Jhala et al. 2015]. However, photocapture of young tigers is an encouraging sign. This Southern Western Ghats population of tigers is considered a conservation priority due to its genetic uniqueness and poor status. Proper management interventions, especially protection to increase prey density would be helpful.

PERIYAR TIGER RESERVE

INTRODUCTION

Periyar Tiger Reserve, Thekkady, located at 9° 28' 0" N, 77° 10' 0" E is also designated as an elephant reserve. It covers an area of 925 km^2 within Idukki and Pathanamthitta district. To the east of the Reserve are the Srivilliputhur Grizzled Giant Squirrel Wildlife Sanctuary and Thirunelveli Forest Division of Tamil Nadu. The Mullaperiyar dam constructed in 1895 resulted in a lake which covers 26 km^2 of the Reserve. Over five million pilgrims visit the Sabrimala Temple in the Reserve each year; most of these pilgrims reach the temple through Rani Forest Division by road, disturbing the habitat severely and polluting River Pamba. Only four small settlements exist within the Park at Labbakkandam near Kumily, Mannakudy, Paliyakudi and Vanchivayal. The vegetation in the Periyar Tiger Reserve includes evergreen, semi-evergreen and moist deciduous forests, grasslands, an aquatic eco-system and eucalyptus groves. There are 1966 varieties of flowering plants. There are about 171 grass species and 140 species of orchids in the region. Apart from tigers (*Panthera tigris*), a variety of mammals such as leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), wild pig (*Sus scrofa*), sloth bear (*Melursus ursinus*), nilgiri langur (*Semnopithecus johnii*), small Travancore flying squirrel (*Petinomys fuscocapillu*) and stripe-necked mongoose (*Herpestes vitticollis*) are also found here.

Figure 11.156
Camera trap and transect layout in Periyar Tiger Reserve, 2018-19



RESULTS

Tiger Density Estimates

A total of 390 camera traps were deployed in Periyar Tiger Reserve yielding 498 tiger detections (including one image of cub) from which 26 individual tigers were identified. Density of tigers in the Tiger Reserve was estimated to be 1.38 (SE 0.29) per 100 km^2 (Table 11.62). The detection corrected tiger male to female sex ratio in Periyar TR was 0.33:0.67 (Table 11.62).

Variables	Estimates
Model space (km^2)	2861
Camera points	390
Trap nights (effort)	14080
Unique tigers captured	26
Model	g_0 (.) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.38 (0.29)
σFemale (SE) km	3.62 (0.29)
σMale (SE) km	6.7 (0.38)
g_0 (SE)	0.003 (0.0003)
Pmix Female (SE)	0.67 (0.1)
Pmix Male (SE)	0.33 (0.1)

Table 11.62

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Periyar Tiger Reserve, 2018-19.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

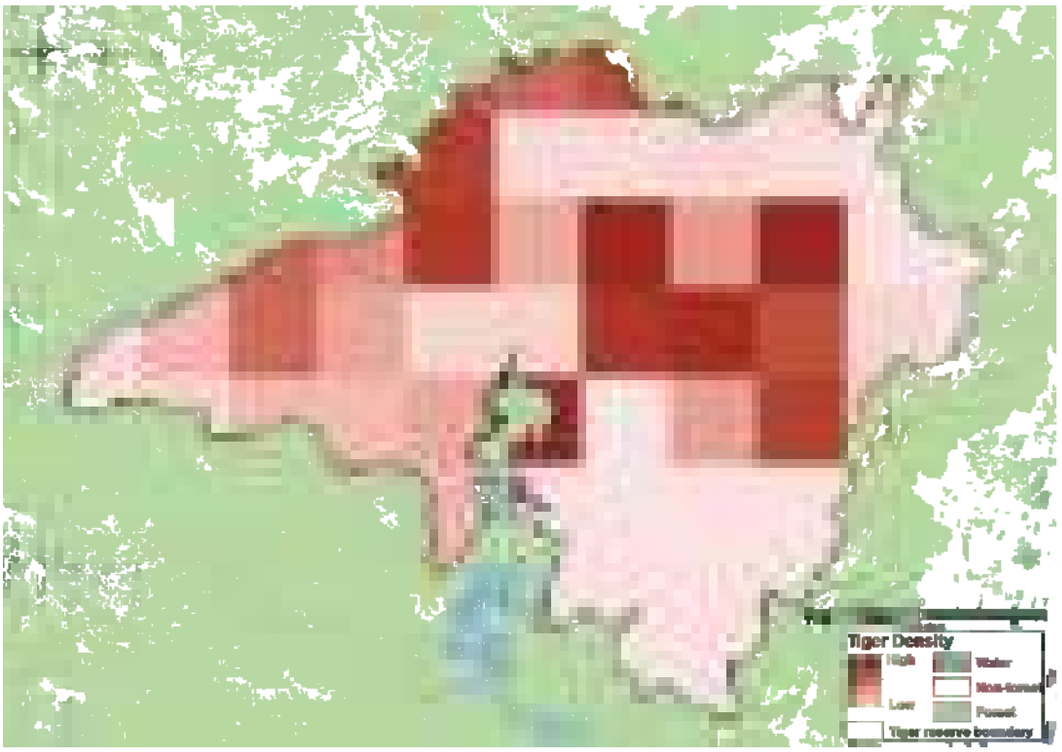


Figure 11.157

Spatial density of tigers in Periyar Tiger Reserve, 2018-19

Tigers were uniformly distributed with medium to high density in all over the Tiger Reserve. Some high density pockets were found in Vallakkadavu and Periyar Ranges of Periyar East Division.

Prey Density Estimates

A total of 170 transects were sampled in Periyar which amounted to an effort of 318.68 km. Sambar was found to be the most abundant ungulate in Periyar TR (Table 11.63).

Table 11.63

Model statistics and parameter estimates of line transect (n=84, Total effort 318.68 km) based distance sampling for prey species in Periyar TR, 2018-19

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate(SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Sambar	32.46 (3.34)	42	2.50 (0.4)	0.09 (0.01)	0.13	2.03 (0.48)	5.07 (1.45)
Gaur	37.67 (2.67)	35	6.829 (1.81)	0.10 (0.007)	0.11	0.01 (0.003)	0.10 (0.03)
Elephant		14	3.35 (0.56)		0.04		
Wild pig		8	4.00 (1.67)		0.02		
Barking deer		7	1.33 (0.21)		0.02		

Distribution of Major Mammalian Fauna Found in Periyar Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Periyar Tiger Reserve.

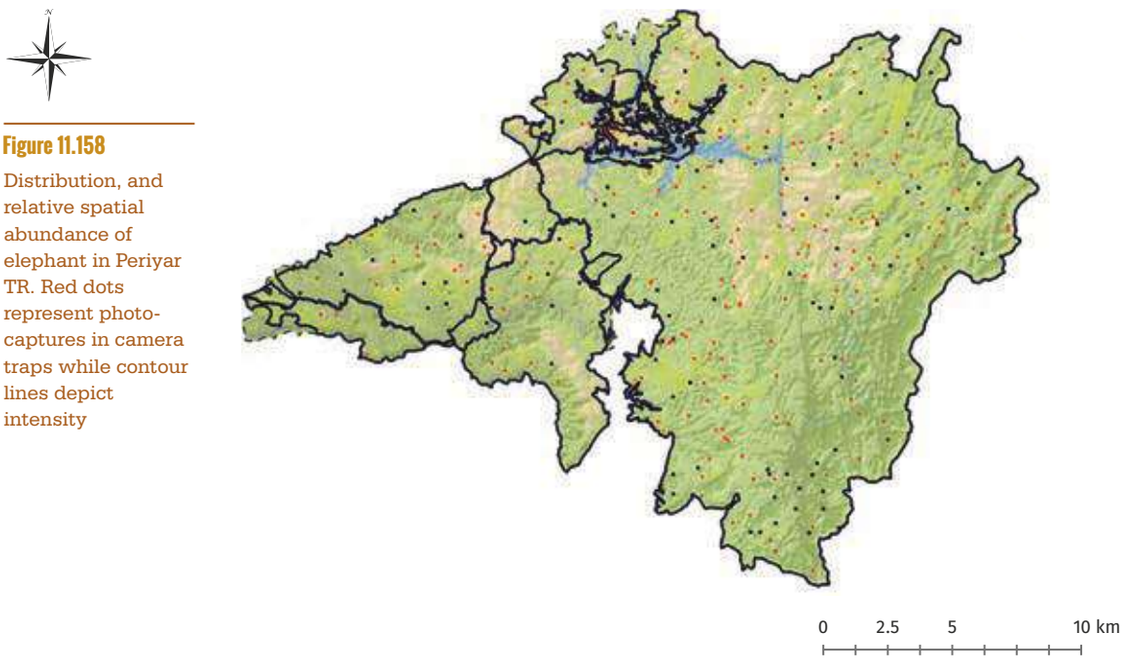


Figure 11.158

Distribution, and relative spatial abundance of elephant in Periyar TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Elephants were photocaptured from all parts of the tiger reserve.

Gaur were uniformly photo-captured from all parts of the tiger reserve.

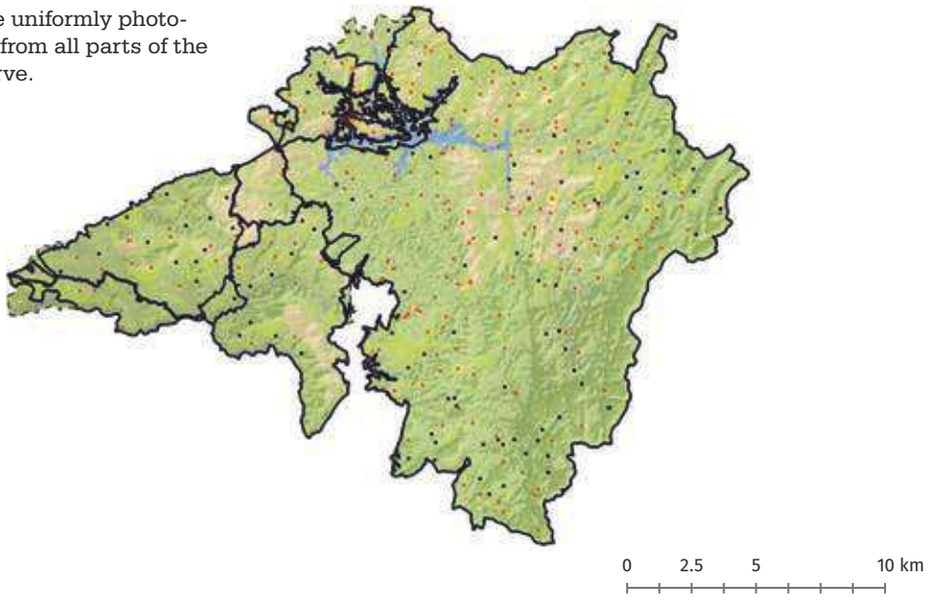


Figure 11.159

Distribution, and relative spatial abundance of gaur in Periyar TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Mouse deer were photo-captured from across the reserve but more records were from Periyar Range adjoining Theni Forest Division.

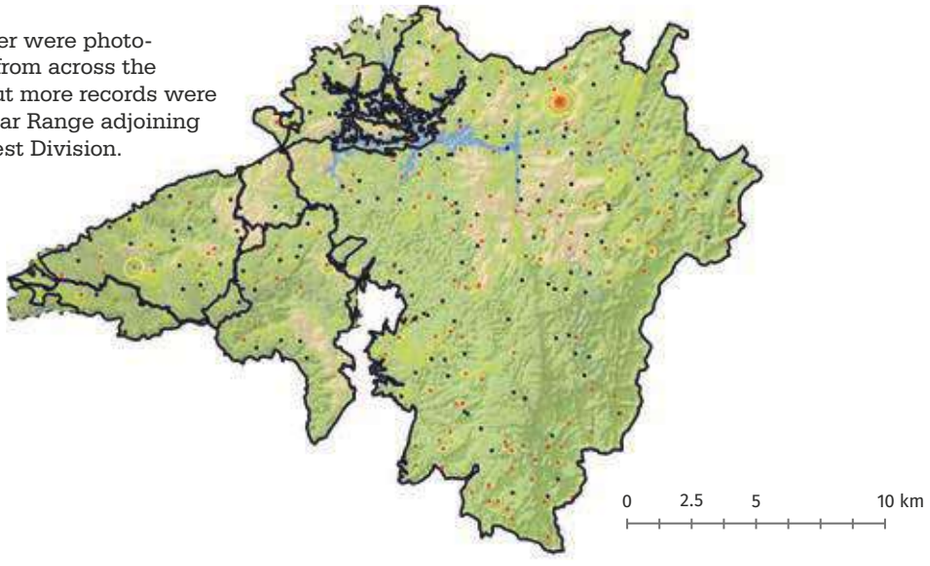


Figure 11.125

Distribution, and relative spatial abundance of mouse deer in Periyar TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard distribution was uniform across the tiger reserve.

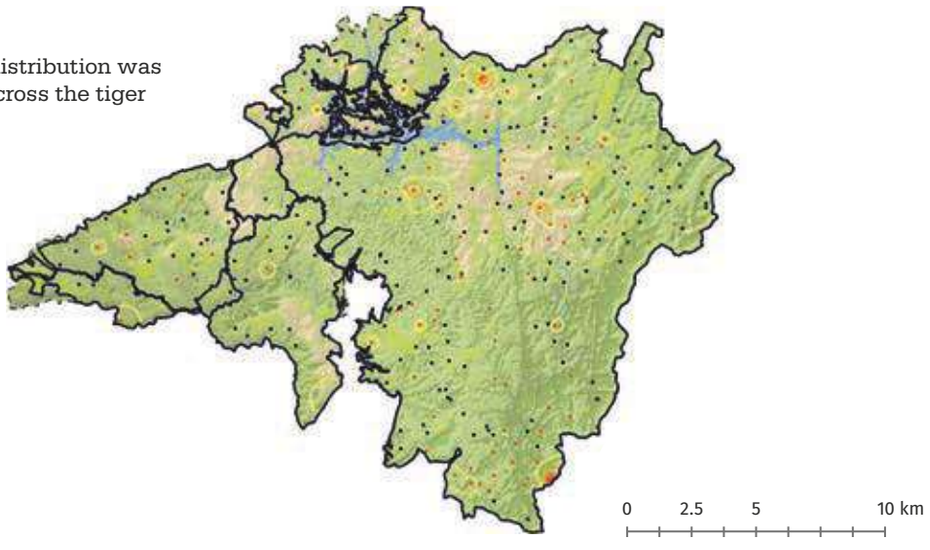


Figure 11.126

Distribution, and relative spatial abundance of leopard in Periyar TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

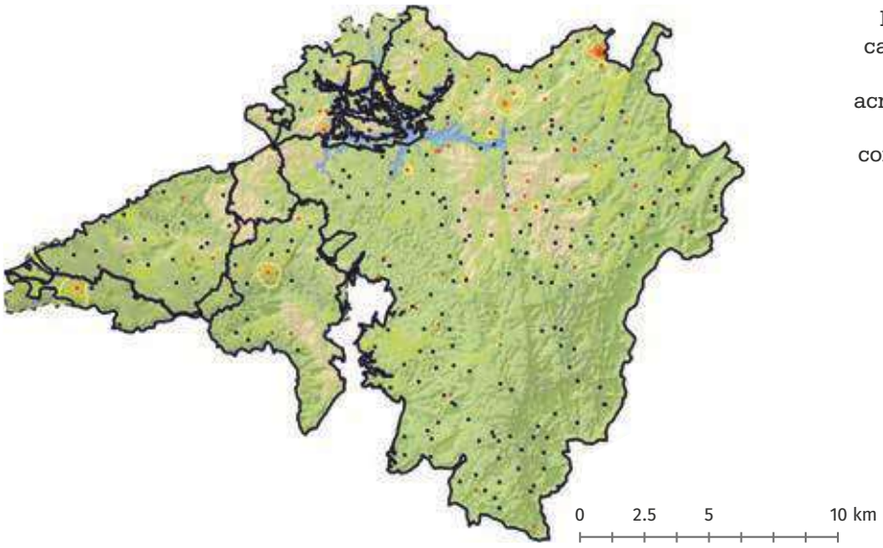


Figure 11.162

Distribution, and relative spatial abundance of dhole in Periyar TR. Red dots represent photo-captures in camera traps while contour lines depict intensity.

Dhole photo-captures were scattered across the park with concentrations from Pamba and Periyar Ranges.

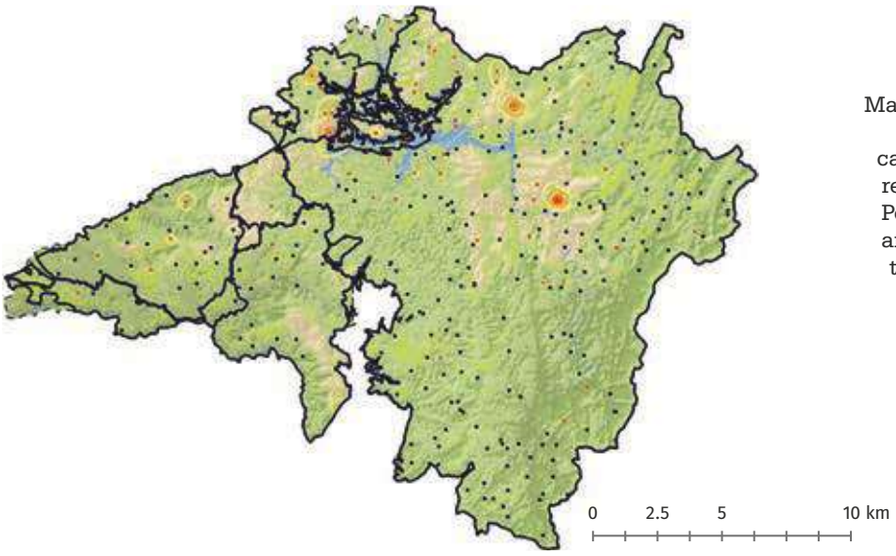


Figure 11.163

Distribution, and relative spatial abundance of sloth bear in Periyar TR. Red dots represent photo-captures in camera traps while contour lines depict intensity.

Maximum sloth bear photo-captures were recorded from Periyar Range and from near the reservoir.

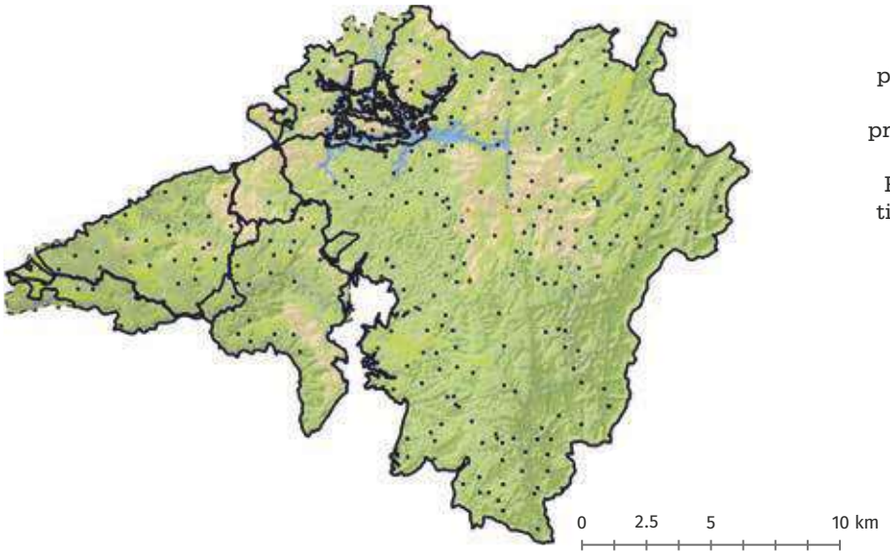


Figure 11.164

Distribution, and relative spatial abundance of jungle cat in Periyar TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Jungle cat photcaptures were low, primarily from Vallakadvu Range of the tiger reserve.

Smooth coated otter was photcaptured from near the reservoir.

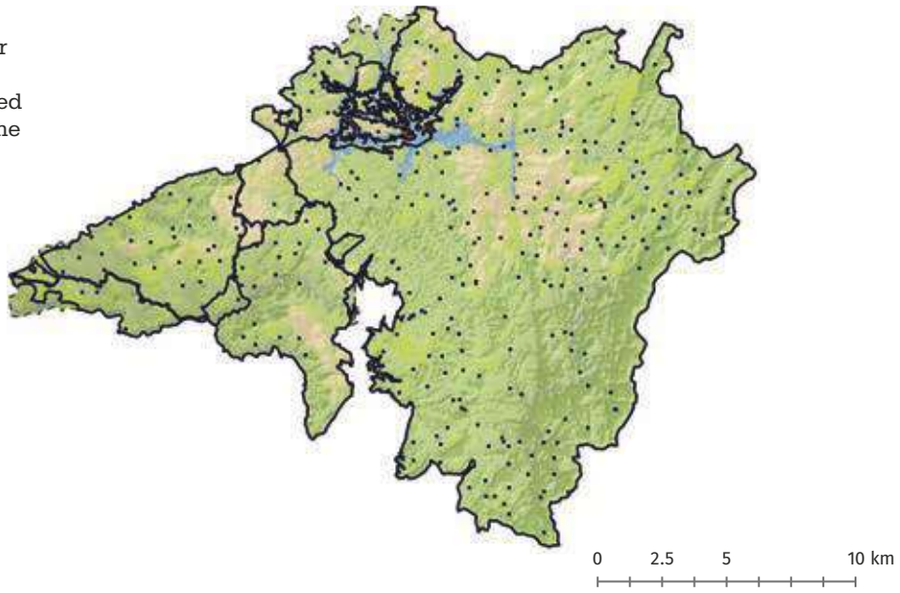


Figure 11.165

Distribution, and relative spatial abundance of smooth coated otter in Periyar TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Leopard cat was distributed across the tiger reserve with maximum records from Periyar East Division.

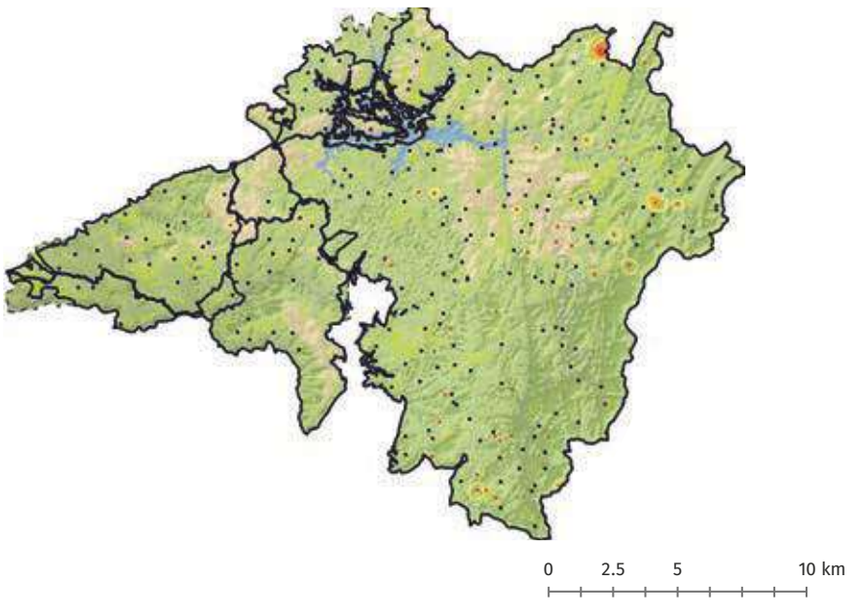


Figure 11.166

Distribution, and relative spatial abundance of leopard cat in Periyar TR. Red dots represent photo-captures in camera traps while contour lines depict intensity

Table 11.64

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Periyar Tiger Reserve,2018-19

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	3.13	32
Black-naped hare	0.06	1564
Bonnet macaque	0.11	939
Brown palm civet	0.99	101
Common palm civet	0.13	741
Domestic dog	0.03	3520
Elephant	7.07	14
Gaur	12.28	8
Grey jungle fowl	1.81	55
Grey jungle fowl	0.47	213
Indian grey mongoose	0.18	542
Indian pangolin	0.04	2816
Indian porcupine	3.16	32
Jungle cat	0.06	1760
Leopard	1.64	61
Leopard cat	0.67	150
Lion-tailed macaque	0.04	2816
Livestock	0.66	151
Monitor lizard	0.05	2011
Mouse deer	5.82	17
Nilgiri langur	0.25	402
Nilgiri marten	0.07	1408
Peafowl	0.18	542
Ruddy mongoose	0.55	181
Sambar	3.92	26
Sloth bear	0.70	142
Small Indian civet	1.01	99
Tiger	2.12	47
Wild dog	0.72	138
Wild pig	5.34	19

Relative Abundance of all Photocaptured Species in Periyar Tiger Reserve

A total of 30 species of ungulates, carnivores, domestic animals, omnivores, and galliformes were photo-captured in the tiger reserve. Gaur, elephant and mouse deer were the most commonly photo-captured species (Table 11.64). Domestic dog was the rarest species to be photo-captured followed by lion tailed macaque.

DISCUSSION

Tiger density remains low in Periyar Tiger Reserve and is probably a function of low prey density in these forests. Improvement in protection regime through the implementation of foot patrolling with M-STrIPES should help control poaching. However, Periyar has high biodiversity values and management focus should not only be tiger centric, besides maintaining viable population of tigers in the landscape for the long-term.

MALAYATOOR WILDLIFE DIVISION

INTRODUCTION

Malayattoor is part of the Malayattoor-Neeleeswaram Panchayat of Ernakulam District of Kerala. Malayattoor Forest Division, an important Forest Division under Central Forest Circle is headquartered here. The division was established in the year 1914, much before the Ernakulam District came into existence. The jurisdiction of this division covers the greater part of Ernakulam district including the urban-suburban area and adjoining forests up to boundary of Tamil Nadu.

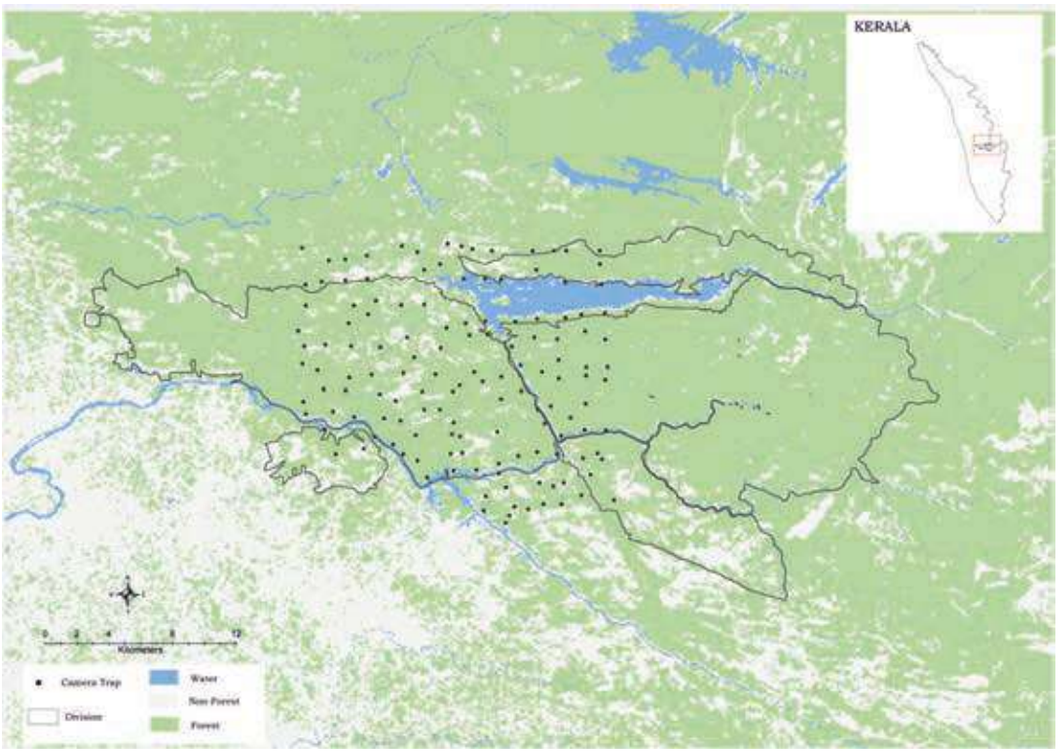


Figure 11.167
Camera trap layout in Malayatoor Wildlife Division, 2018-19

RESULTS

Tiger Density Estimates

A total of 139 camera traps were deployed in Malayatoor Wildlife Division yielding 59 tiger detections (including 3 images of tiger cubs) from which 7 individual tigers were identified. Density of tigers in Malayatoor Wildlife Division was estimated to be 0.88 (SE 0.35) per 100 km^2 (Table 11.65). The model inferred tiger male to female sex ratio in Malayatoor Wildlife Division was 0.71:0.29 (Table 11.65).

Table 11.65

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Malayatoor Wildlife Division, 2018-19.

Variables	Estimates
Model space (km^2)	1044.62
Camera points	139
Trap nights (effort)	3640
Unique tigers captured	7
Model	g_0 (.) σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	0.88 (0.35)
σ (SE) km	4.33 (0.49)
g_0 (SE)	0.02 (0.005)
Pmix Female (SE)	0.29 (0.17)
Pmix Male (SE)	0.71 (0.17)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Malayatoor Wildlife Division being strategically located connecting many Tiger Reserves and Protected Areas is an important tiger habitat maintaining the metapopulation dynamics for the species in the landscape. Better protection, minimizing human-wildlife conflict and mitigating developmental projects are some of the key recipes for conservation of this Division.

RANNI WILDLIFE DIVISION

INTRODUCTION

The Ranni Forest Division (1,059 km^2) in Kerala, India, was constituted on 7 July 1958, comprising of the Ranni, Vadasserikkara, and Goodrical ranges, with its headquarters at Ranni. It covers the parts of Konni reserve forest and the reserves of Ranni, Goodrical, Rajampara, Karimkulam, Kumaramperoor, Valiyakavu, and Schettakkal. The forests in the Ranni range can be classified into the following categories: West coast tropical evergreen forests, West coast semi-evergreen forests, Southern moist mixed deciduous forests, Southern sub-tropical wet hill forests, Southern montane wet temperate forests, grasslands and plantations. Ranni supports about 51 species of fishes, 43 species of amphibians, 59 species of reptiles, 34 species of mammals and 196 species of birds. Ranni Forest Division forms a crucial habitat linkage between Periyar Tiger Reserve and Agasthyamalai landscapes of the Western Ghats.

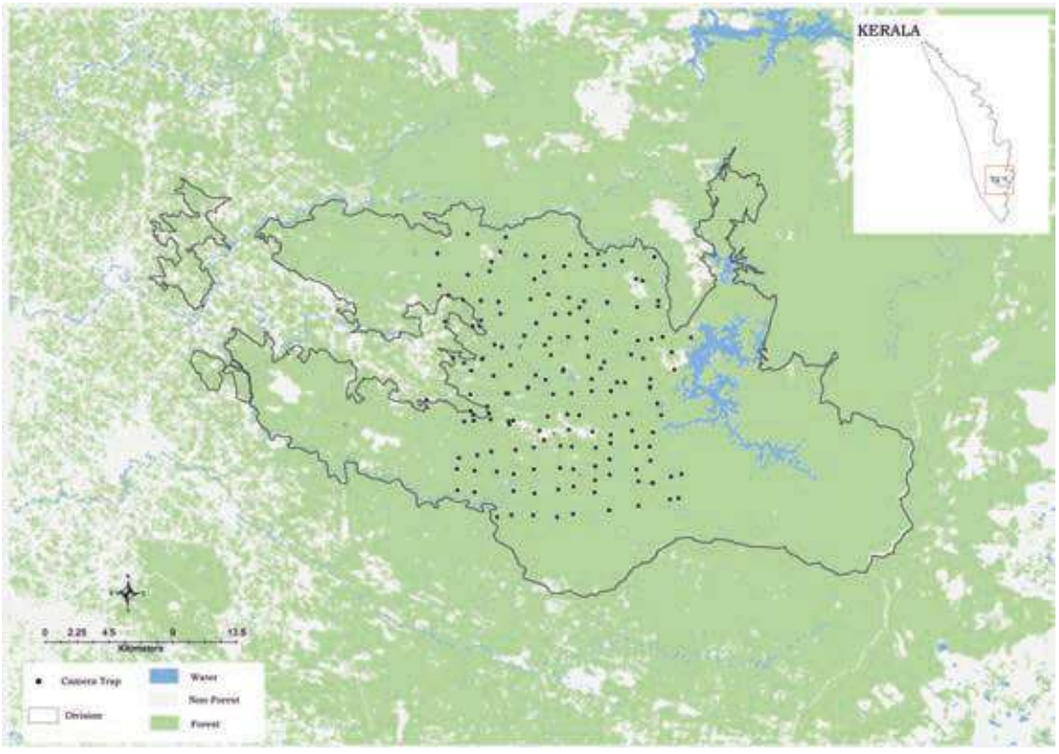


Figure 11.168
Camera trap layout in Ranni Wildlife Division, 2018-19

RESULTS

Camera Trap Results

A total of 159 camera traps were deployed in Ranni Wildlife Division yielding three tiger detections from which one individual tiger was identified (Table 11.66).

Sampling details	Counts
Camera points	159
Trap nights (effort)	3808
Unique tigers captured	1

Table 11.66
Sampling details of camera trapping exercise for Ranni Wildlife Division, 2018.

DISCUSSION

The importance of these forests as connecting habitat for metapopulation structure of tigers and elephants is vital.

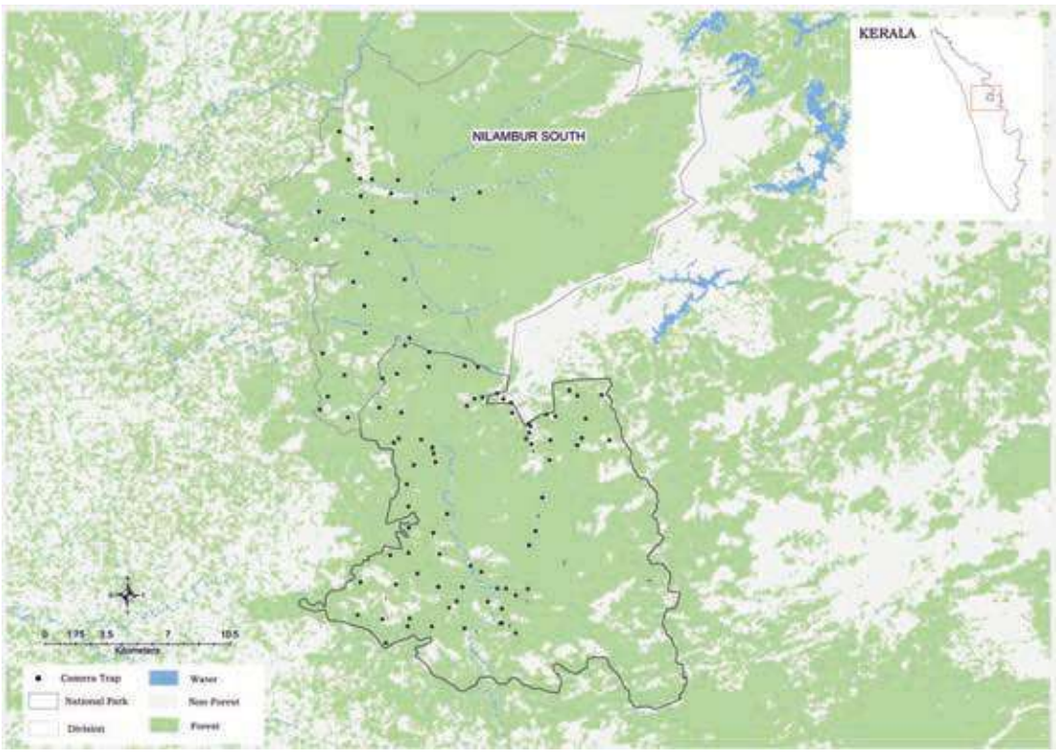
SILENT VALLEY NATIONAL PARK

INTRODUCTION

Silent Valley National Park, located in the Nilgiri hills of Kerala, has a core area of 89.52 km^2, which is surrounded by a buffer zone of 148 km^2. The national park is one of the last undisturbed tracts of South Western Ghats mountain rain forests and tropical moist evergreen forest in India. Contiguous with the proposed Karimpuzha National Park (225 km^2) to the north and Mukurthi National Park (78.46 km^2) to the north-east, it is the core of the Nilgiri Biosphere Reserve (1,455.4 km^2), and is part of the Nilgiri Sub-Cluster (>6,000 km^2), Western Ghats World Heritage Site, recognized by UNESCO in 2007. Plans for a hydroelectric project that threatened the park's biodiversity stimulated an environmentalist social movement in the 1970s, known as the Save Silent Valley movement, which resulted in cancelling the project and creating the park in 1980. The valley areas of the park are in a Tropical and subtropical moist broadleaf forests Ecoregion. Hilly areas above 1,000 m are in the South Western Ghats montane rain forests region. Above 1,500 m, the evergreen forests begin to give way to stunted forests, interspersed with open grassland, called sholas. There are at least 34 species of mammals residing within Silent Valley including the threatened lion-tailed macaque (*Macaca silenus*), Niligiri langur (*Semnopithecus johnii*), Malabar giant squirrel (*Ratufa indica*), Nilgiri tahr (*Nilgiritragus hylocrius*) and hairy-winged bat (*Harpiocephalus harpia*).

Figure 11.169

Camera trap layout in Silent Valley National Park, 2018-19



RESULTS

Tiger Density Estimates

A total of 103 camera traps were deployed in Silent Valley NP yielding 48 tiger detections from which seven individual tigers were identified. Density of tigers in Silent Valley NP was estimated to be 1.02 (SE 0.41) per 100 km^2 (Table 11.67). The model inferred tiger male to female sex ratio in Silent Valley NP was 0.57:0.43 (Table 11.67).

Variables	Estimates
Model space (km^2)	900.62
Camera points	103
Trap nights (effort)	2800
Unique tigers captured	7
Model	g_0 (.)σ(.) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	1.02 (0.41)
σ (SE) km	3.47 (0.3)
g_0 (SE)	0.01 (0.003)
Pmix Female (SE)	0.43 (0.18)
Pmix Male (SE)	0.57 (0.18)

Table 11.67

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Silent Valley National Park, 2018-19.

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Silent Valley National Park is not only a part of an important tiger landscape, but it also supports rich biodiversity, endemism and unique habitats. Ensuring the habitat connectivity of Silent Valley to the north with Mudumalai Tiger Reserve and Nilgiris is vital for maintaining its biodiversity values.

WAYANAD WILDLIFE SANCTUARY

INTRODUCTION

Wayanad Wildlife Sanctuary was declared a sanctuary with an area of 344 km^2 in the year 1973. The park is located in the Wayanad district between 76° 02'and 76° 27'E, 11° 35' and 11°51'N. The altitude ranges from 650 m to 1150 m above mean sea level. The Wayanad Wildlife Sanctuary has two distinct blocks of forests separated by completely human-dominated areas. The northern block of forests comprises of Tholpetty range (78 km^2), which is adjacent to Nagarahole Tiger Reserve in Karnataka. The southern block of forests comprises of Kurichiyat, Sulthan Bathery and Muthanga (KSBM) ranges, and, this block (266 km^2) is contiguous with Bandipur Tiger Reserve in Karnataka and Mudumalai Tiger Reserve in Tamil Nadu. The Sanctuary receives an average annual rainfall of about 2000 mm. The terrain is gently undulating with small hills interspersed with many swampy valleys. It is drained by several perennial and seasonal streams and rivers: Cherupuzha, Bavalipuzha, Kabini, Kannarampuzha, Kurichiatpuzha and Chedalathupuzha. Two types of forests are typically found in Wayanad: Moist Deciduous and Semi-evergreen forest. Several grassy swamps locally called vayals exist, where soil is clayey, perennially moist and supports the luxuriant growth of sedges and grasses. The forests of Malenad landscape in the Western Ghats supports large assemblages of carnivores and herbivores: tiger (*Panthera tigris*), leopard (*Panthera pardus*), Asiatic wild dog (*Cuon alpinus*) and sloth bear (*Melursus ursinus*), Asiatic elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), chital (*Axis axis*), barking deer (*Muntiacus vaginalis*), four-horned antelope (*Tetracerus quadricornis*), wild pig (*Sus scrofa*), mouse deer (*Moschiola indica*) and hanuman langur (*Semnopithecus entellus*).

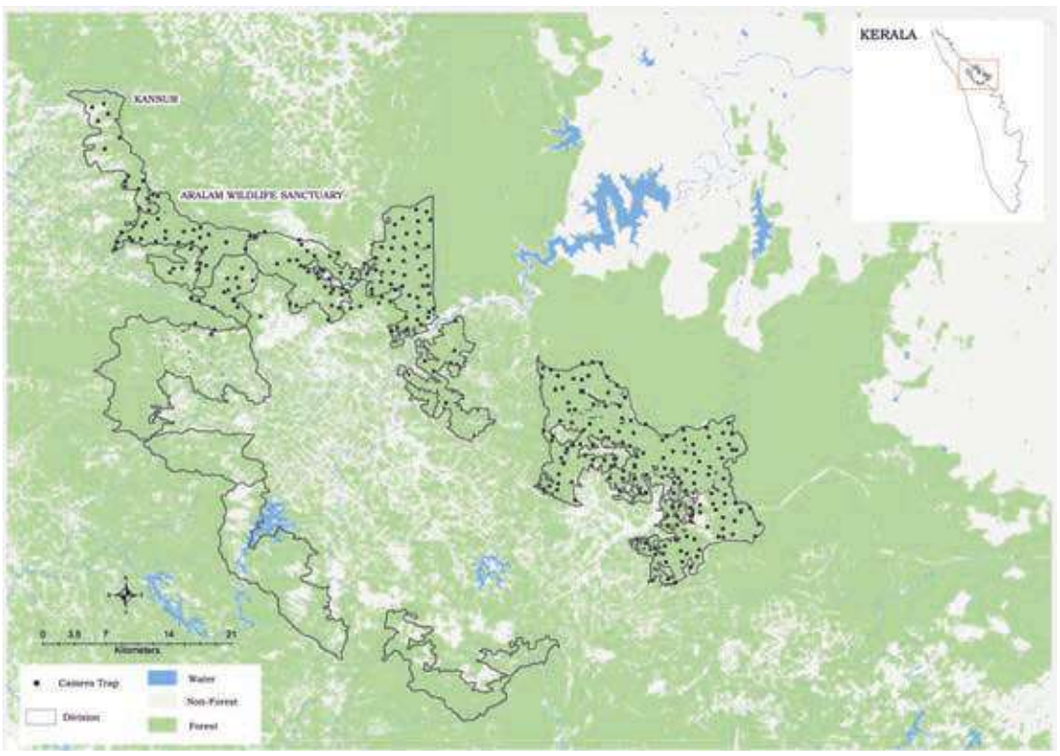


Figure 11.170
Camera trap layout in Wayanad Wildlife Sanctuary, 2018-19

RESULTS

Tiger Density Estimates

A total of 312 camera traps were deployed in Wayanad WLS yielding 1,380 tiger detections (including 29 images of cubs) from which 120 individual tigers were identified. Density of tigers in Wayanad WLS was estimated to be 9.33 (SE 0.86) per 100 km^2 (Table 11.68). The detection corrected tiger male to female sex ratio in Wayanad WLS was 0.47:0.53 (Table 11.68).

Table 11.68

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Wayanad Wildlife Sanctuary, 2018-19.

Variables	Estimates
Model space (km^2)	2016.62
Camera points	312
Trap nights (effort)	11390
Unique tigers captured	120
Model	g_0 (sex) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	9.33 (0.86)
σ Female (SE) km	1.51 (0.03)
σ Male (SE) km	2.16 (0.05)
g_0 Female (SE)	0.05 (0.003)
g0 Male (SE)	0.03 (0.002)
Pmix Female (SE)	0.53 (0.04)
Pmix Male (SE)	0.47 (0.04)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

DISCUSSION

Wayanad Wildlife Sanctuary was characterized by good prey and tiger density. The Wildlife Sanctuary has more tigers and higher density of tigers than many Tiger Reserves and should be gazetted as a tiger reserve. Together with the adjoining tiger reserves of Karnataka and Tamil Nadu this region is home to the largest tiger and elephant population in the world.

KAZIRANGA TIGER RESERVE

INTRODUCTION

Kaziranga Tiger Reserve spreads across Nagaon and Golaghat districts (26° 30' to 26° 50' N and 92° 50' to 93° 41' N) of Assam. River Brahmaputra flows on the north of Kaziranga, and the hills of Karbi-Anglong in the south constitute an ecological extension of the Tiger Reserve. However, heavy traffic on NH 37 that skirts the southern boundary of the tiger reserve often acts as a barrier to animal movement to the Karbi-Anglong hills. The rich alluvial flood plain of Brahmaputra that forms the major part of Kaziranga makes it one of the most productive terrestrial systems on the planet with a flourishing and diverse assemblage of flora and fauna making it the ideal repository for in-situ conservation of biological diversity. It is therefore recognized as a UNESCO Natural Heritage Site.

Major vegetation types of Kaziranga are wet alluvial grasslands, moist mix deciduous forests, and semi evergreen forests (Champion and Seth 1968). The grasslands cover almost 2/3rd of the tiger reserve. The main species of grasses are *Saccharum spontaneum, Saccharum munja, Imperata cylindrica, Arundo donax, Alpinia allughas, Phragmites karka,* etc. Tree species are *Bombax ceiba, Careya arborea, Albizia procera, Dillenia indica, Dillenia pentagyna, Lagerostroemia parviflora, Garcinia tinctoria* and *Syzygium* spp, amongst others.

Apart from being the largest source population of tigers (*Panthera tigris*) in Brahmaputra flood plains and North East hills, Kaziranga also harbors the single largest population of greater one horned rhinoceros (*Rhinoceros unicornis*) and wild water buffalo (*Bubalis arnee*) in the world (Technical Report, GoA). Other notable mammals of Kaziranga are sizable population of elephant (*Elephas maximus*), Eastern swamp deer (*Rucervus duvaucelli ranjitsinhi*), sambar (*Rusa unicolor*), hog deer (*Axis porcinus*), barking deer (*Muntiacus vaginalis*), hoolock gibbon (*Hoolock hoolock*), capped langur (*Trachypithecus pileatus*), leopard (*Panthera pardus*), fishing cat (*Prionailurus viverrinus*), leopard cat (*Prionailurus bengalensis*), jungle cat (*Felis chaus*), clouded leopard (*Neofelis nebulosa*), sloth bear (*Melursus ursinus*), hog badger (*Arctonyx collaris*) etc.

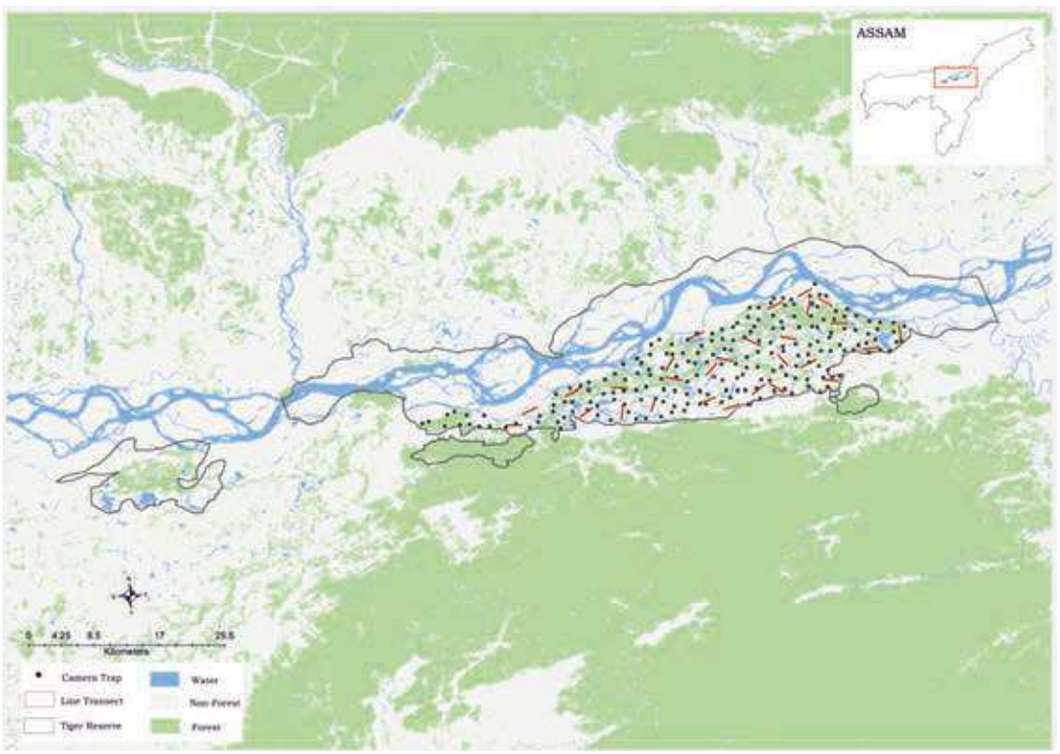


Figure 12.1
Camera trap layout in Kaziranga Tiger Reserve, 2018

RESULTS

Tiger Density Estimates

From a total of 1568 photo-captures of tigers 93 individual adult tigers were identified. The detection corrected tiger male to female sex ratio was 0.3:0.7 (Table 12.1). A total of 8 young tigers were photo-captured.

Table 12.1

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in likelihood framework for Kaziranga Tiger Reserve, 2018.

Variables	Estimates
Model space (km^2)	961.25
Camera Points	204
Trap Nights (effort)	14465
Unique tigers captured	93
Model	g_0 (sex) σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	13.06 (1.37)
σ Female (SE) km	1.36 (0.02)
σ Male (SE) km	2.14 (0.04)
g_0 Female (SE)	0.035 (0.001)
g_0 Male (SE)	0.035 (0.001)
Pmix Female (SE)	0.70 (0.05)
Pmix Male (SE)	0.30 (0.05)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ (Sigma): Spatial scale of detection function,

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

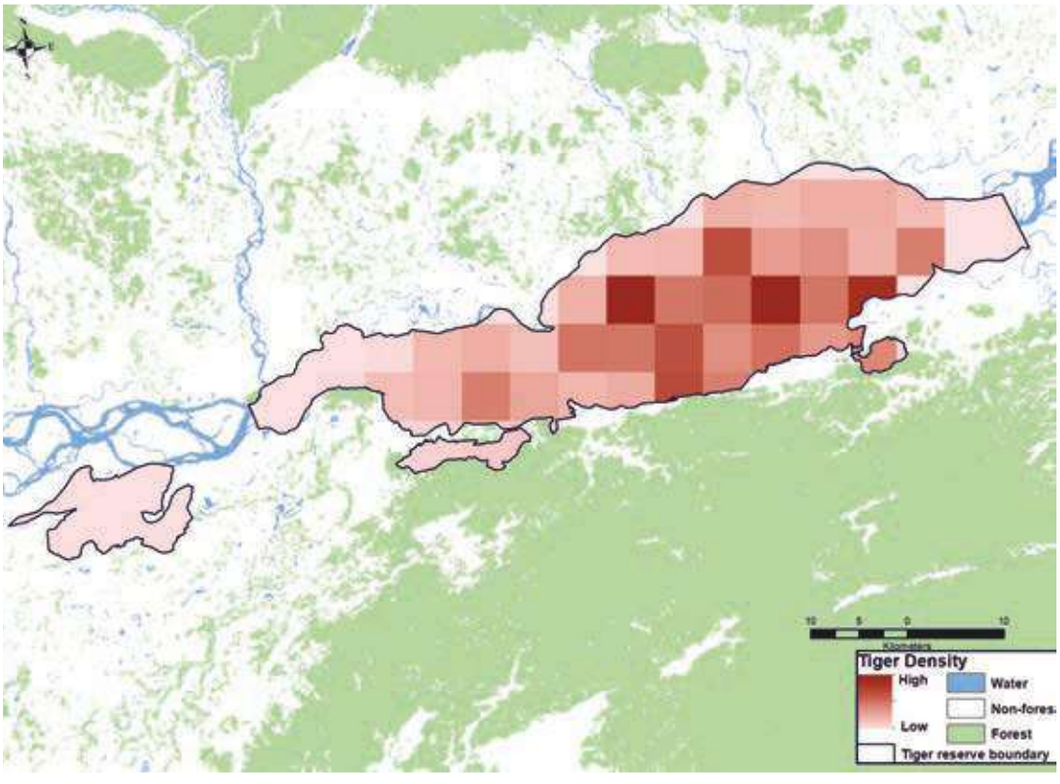


Figure 12.2

Spatial density of tigers in Kaziranga Tiger Reserve, 2018

Kaziranga Tiger Reserve has one of the highest tiger densities in the world. Within the tiger reserve, Central and Eastern ranges had the highest density of tigers.

Distribution of Major Mammalian Fauna Found in Kaziranga Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core area of Kaziranga Tiger Reserve.

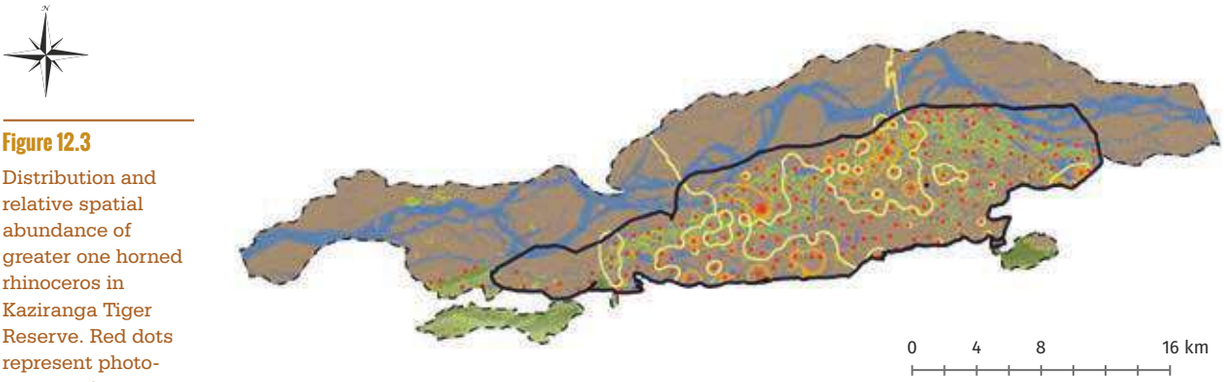


Figure 12.3

Distribution and relative spatial abundance of greater one horned rhinoceros in Kaziranga Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Greater one horned rhinoceros was distributed throughout the reserve. Capture hotspots of rhinoceros was relatively high in grasslands of the Western and the Central ranges.

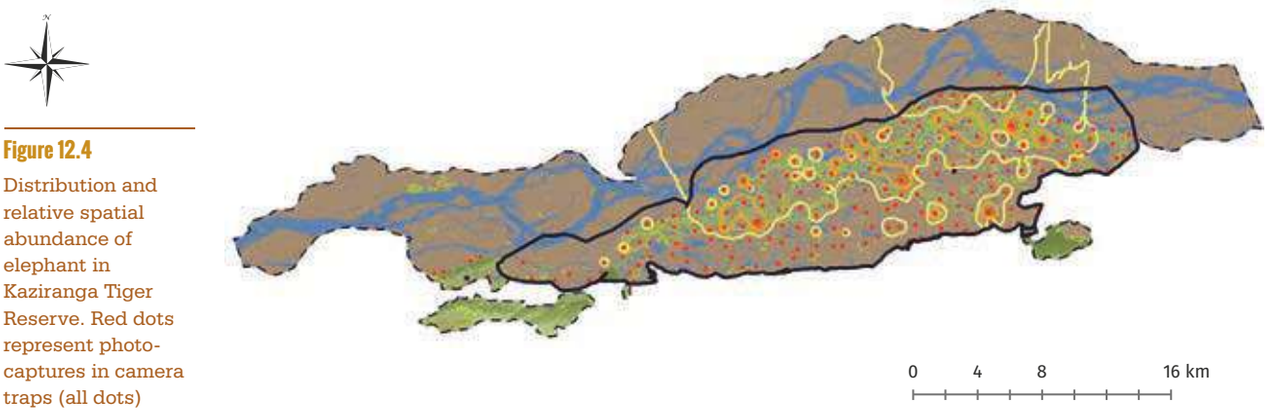
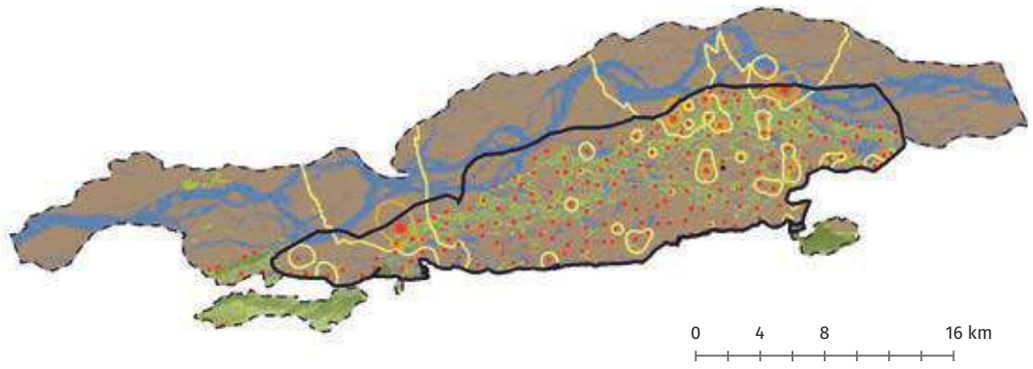


Figure 12.4

Distribution and relative spatial abundance of elephant in Kaziranga Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

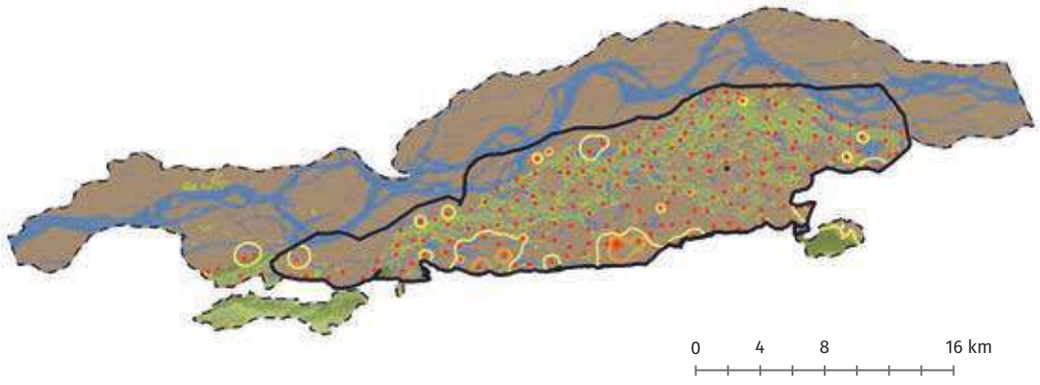
Elephant was present throughout the tiger reserve with capture hotspots relatively high in the grasslands and woodlands along the Brahmaputra river and in areas near the Karbi Anglong hills.



Hog deer was present throughout the tiger reserve with capture hotspots relatively more in grasslands and woodlands of the Western and Eastern ranges along the Brahmaputra River.

Figure 12.5

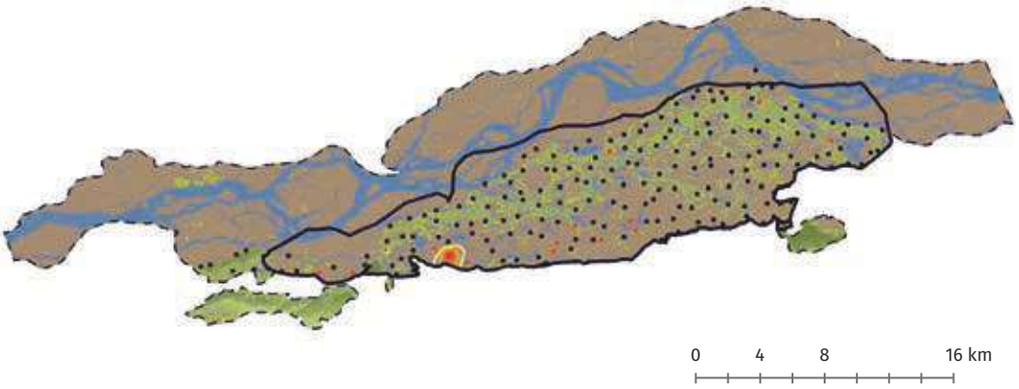
Distribution and relative spatial abundance of hog deer in Kaziranga Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-capture



Wild water buffaloes was omnipresent in the fertile floodplains of Brahmaputra river in Kaziranga. Capture hotspots of wild water buffalo was relatively more near the southern boundary of the Western and Central ranges.

Figure 12.6

Distribution and relative spatial abundance of wild water buffalo in Kaziranga Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures



Being a grassland specialist species Eastern swamp deer was restricted to specific pockets of grassland in parts of the tiger reserve. Capture hotspots were relatively more in the grasslands of the Western range.

Figure 12.7

Distribution and relative spatial abundance of Eastern swamp deer in Kaziranga Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

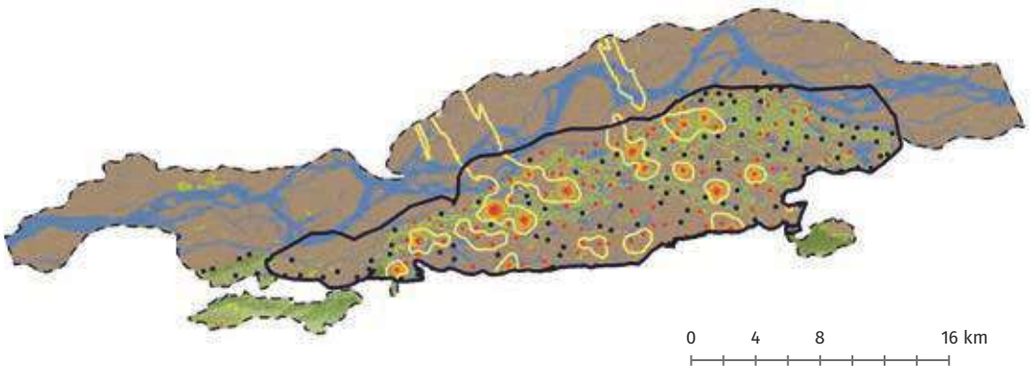


Figure 12.8

Distribution and relative spatial abundance of fishing cat in Kaziranga Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

As an inhabitant of wetland and grasslands, fishing cat was distributed throughout the tiger reserve. Kaziranga seems to be a major stronghold for the species.

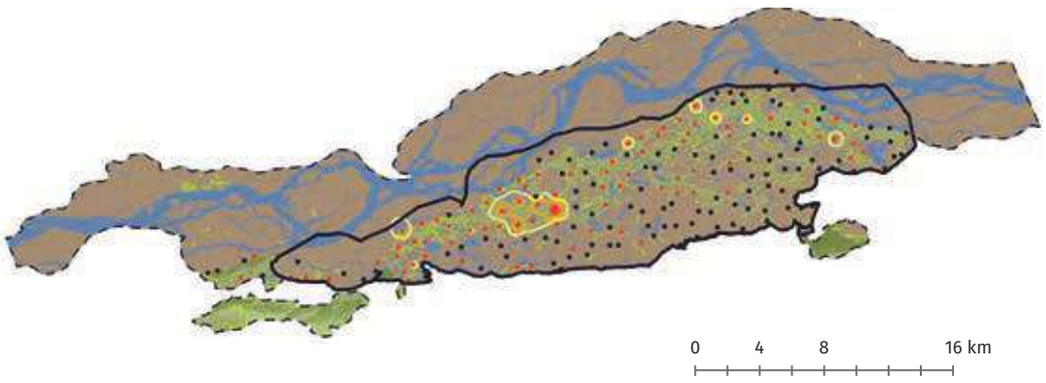


Figure 12.9

Distribution and relative spatial abundance of leopard cat in Kaziranga Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Leopard cat was distributed throughout the tiger reserve in the grasslands and woodlands along the water bodies and Brahmaputra. Capture hotspots of leopard cat were relatively more in the Western and Central ranges.

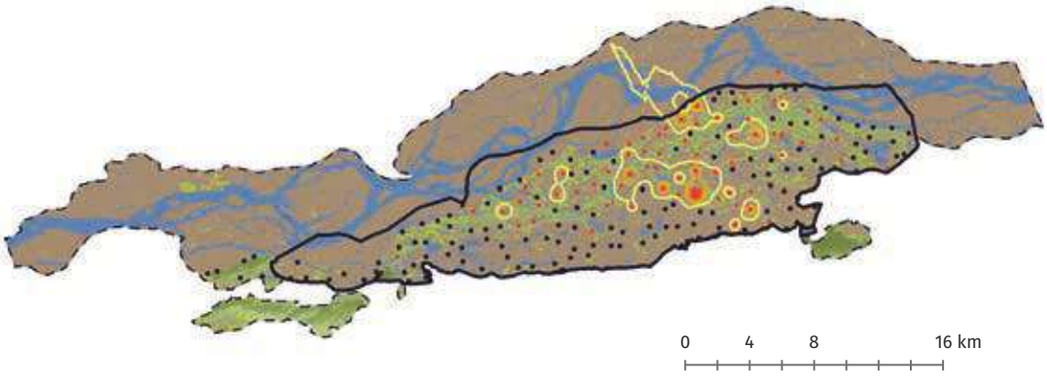
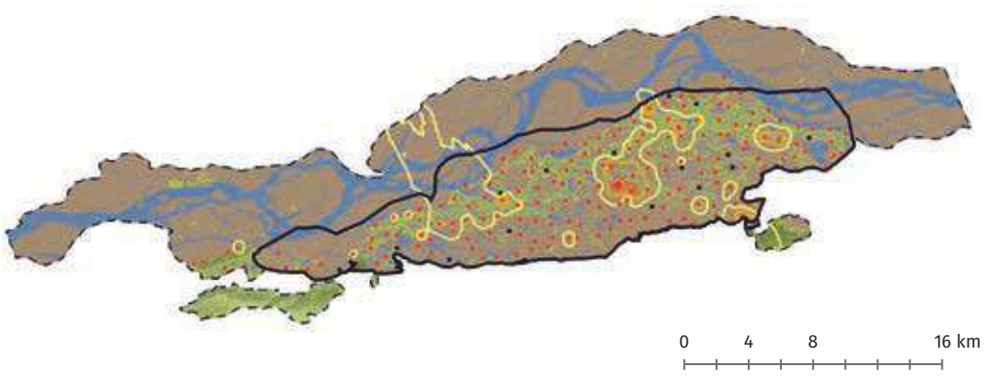


Figure 12.10

Distribution and relative spatial abundance of sloth bear in Kaziranga Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Sloth bears were distributed across the grasslands and woodlands of the Central and Eastern ranges.



Hog badgers were distributed across the grasslands and woodlands of all the ranges.

Figure 12.11

Distribution, relative spatial abundance of hog badger in Kaziranga Tiger Reserve. Red dots represent photo-captures in camera traps while contour line depict intensity of photo-captures

Relative Abundance of all Photocaptured Species in Kaziranga Tiger Reserve

Hog deer was the most common species in Kaziranga Tiger Reserve to get photo-captured followed by rhinoceros, which took 1 and 2 trap nights respectively to get a single capture (Table 12.2). Binturong was the rarest species to get photo captured (14465 trap nights required to get single capture).

DISCUSSION

The floodplains of Brahmaputra in Kaziranga is highly productive and supports the largest source population of tigers in Brahmaputra flood plain and North East hills landscape.

Table 12.2

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Kaziranga Tiger Reserve, 2018

Species	Number of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	5.12	20
Binturong	0.01	14465
Black naped hare	0.05	2066
Capped langur	0.08	1315
Clouded leopard	0.03	2893
Common palm civet	2.84	35
Domestic cat	0.88	113
Domestic dog	0.63	159
Elephant	31.68	3
Fishing cat	1.23	81
Golden jackal	0.06	1808
Himalayan crestless porcupine	6.53	15
Hog badger	13.36	7
Hog deer	161.75	1
Indian grey mongoose	0.03	2893
Jungle cat	2.56	39
Large Indian civet	3.68	27
Leopard	0.21	482
Leopard cat	1.89	53
Livestock	5.23	19
Masked palm civet	0.01	7233
Monitor lizard	0.08	1315
Red jungle fowl	8.48	12
Rhesus macaque	17.87	6
Rhinoceros	52.78	2
Sambar	21.18	5
Sloth bear	0.77	129
Small Indian civet	8.25	12
Smooth coated otter	0.41	241
Swamp deer	0.26	381
Tiger	11.35	9
Wild pig	24.42	4
Wild water buffalo	27.81	4

NAGAON WILDLIFE DIVISION

INTRODUCTION

Nagaon Wildlife Division acts as a notified buffer area of Kaziranga Tiger Reserve and comprises of two contiguous wildlife sanctuaries namely Laokhowa and Burachhapori. The wildlife division is spread across Nagaon and Sonitpur districts (26°28' to 26°33' N and 92°35' to 92°47' E) of Assam. The spatial extent of Laokhowa and Burachhapori Wildlife Sanctuaries are 70.11 km^2 and 44.06 km^2 respectively. Together these two sanctuaries act as refuges and corridors for several species to move from Kaziranga Tiger Reserve to the protected areas situated in the northern banks of Brahmaputra River through numerous river islands. The sanctuaries are also recognized as an IBA (Rahmani et al. 2016).

The primary vegetation of the sanctuaries is Tropical moist deciduous, Tropical secondary shrub, Tropical Grassland and Freshwater swamp (Champion and Seth 1968). Dominant tree species of the sanctuaries are *Albizia procera, Acacia catechu, Bombax ceiba, Dillenia pentagyna, Trivia nudiflora, and Ziziphus jujuba* with grass species like *Imperata cylindrica, Sachharum spontaneum, Phragmitis karka, Vetiveria zizanioides,* and *Arundo donax* (Ojha and Saikia 2014). Important mammalian fauna found in the sanctuaries are tiger (*Panthera tigris*), leopard (*Panthera pardus*), greater one horned rhinoceros (*Rhinoceros unicornis*), elephant *(Elephas maximus*), leopard cat (*Prionailurus bengalensis*), fishing cat (*Prionailurus viverrinus*), jungle cat (*Felis chaus*), sambar (*Rusa unicolor*), wild boar (*Sus scrofa*), and hog deer (*Axis porcinus*), amongst others.

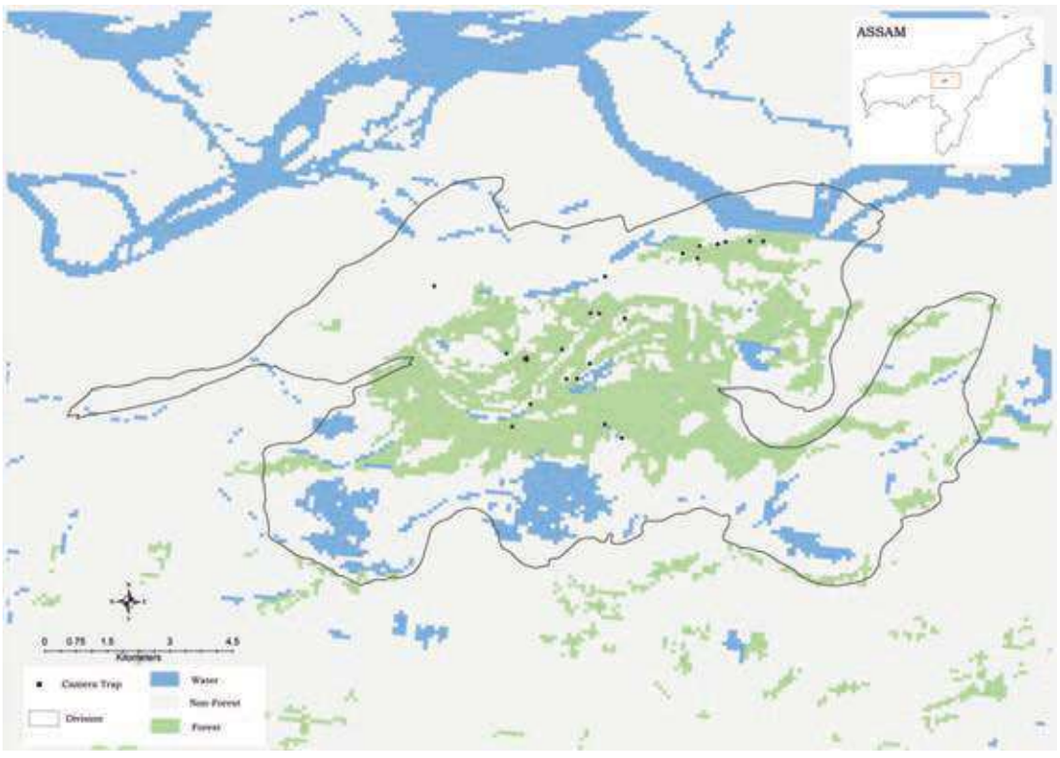


Figure 12.12
Camera trap layout in Nagaon Wildlife Division, 2018

RESULTS

Camera Trap Results

For the first time camera trapping was carried out in these sanctuaries. An adult tigress was photo-captured during the sampling period (Table 12.3).

Table 12.3
Sampling details and number of tigers photo-captured in Nagaon Wildlife Division, 2018

Sampling details	Counts
Camera points	25
Trap-nights (effort)	787
Unique tigers captured	1

ORANG TIGER RESERVE

INTRODUCTION

Orang Tiger Reserve is the 49th tiger reserve of India and declared as tiger reserve in the year of 2016. Orang Tiger Reserve comes under the jurisdiction of Mangaldoi Wildlife Division and the reserve is located in Darrang and Sonitpur districts of Assam. The reserve has an area of 492.46 km^2 (projecttiger.nic.in), comprising of 79.28 km^2 of core and 413.18 km^2 of buffer area. The geographical extent of the reserve is between 92°16' to 92°27' E longitude and 26°29' to 26°40' N latitude. River Brahmaputra forms the southern boundary of the reserve. Tributaries Dhansiri and Pachnoi (Hazarika and Saikia 2010) divide the alluvial terrace of the park into two halves, i.e. lower Orang and upper Orang.

Orang is composed of mainly four different types of vegetation (Champion and Seth 1968) viz. Eastern Himalaya's moist-deciduous forests, eastern seasonal swamp-forest, Khair-Sisso forests and eastern wet-alluvial grasslands (Deka and Saikia 2015). The vegetation of Northern Bank is unique and comprises of short and tall grasslands dotted with natural and cultural woodland and water bodies. There are 12 wetlands and 26 man made water bodies in the reservoirs (Talukdar and Sharma 1995). Orang is home to greater one horned rhinoceros (Dutta and Kakati 2019), along with other mammalian species like, elephant (*Elephas maximus*), hog deer (*Axis porcinus*), wild pig (*Sus scrofa*), fishing cat (*Prionailurus viverrinus*), jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*), golden jackal (*Canis aureus*), smooth coated otter (*Lutrogale perspicillata*), common palm civet (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*), amongst others.. Other than the varied assemblage of mammalian fauna Orang Tiger Reserve is also considered as one of the three outstanding Important Bird and Biodiversity Areas of Assam (IBAs) (BirdLife International 2003) and is home to an excellent assemblage of herpetofauna.

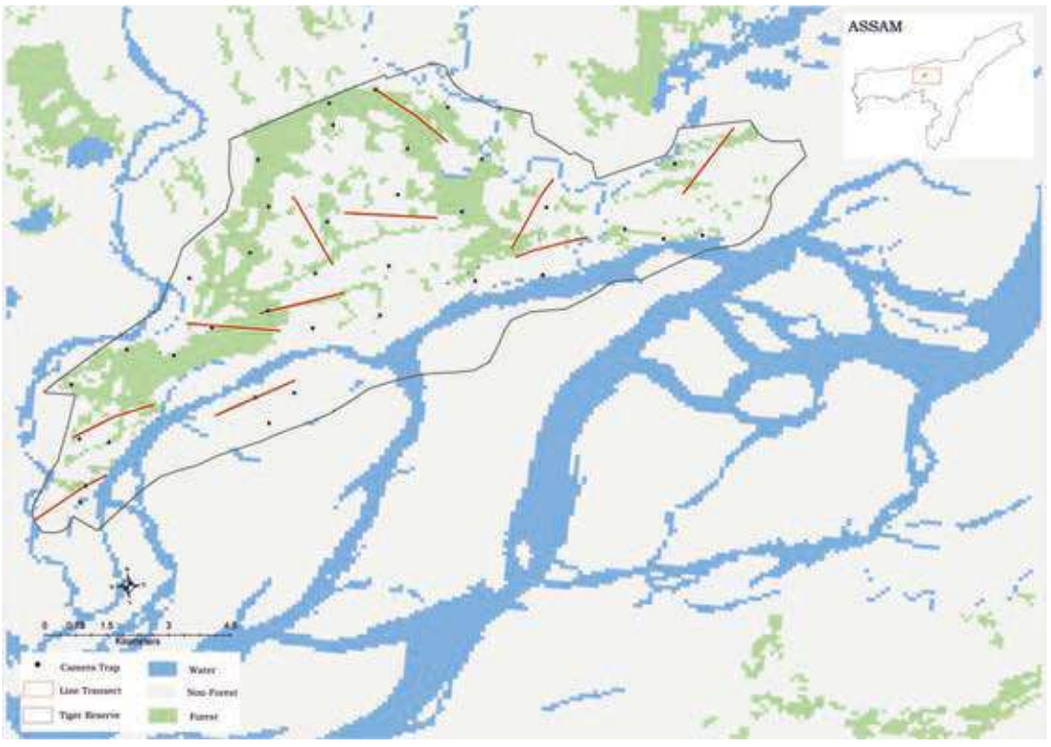


Figure 12.13
Camera trap and line transect layout in Orang Tiger Reserve, 2018

RESULTS

Tiger Density Estimates

From a total of 176 photo-captures of tigers,16 individual tigers were identified. Photo-captures of 3 young tigers were recorded (Table 12.4).

Table 12.4

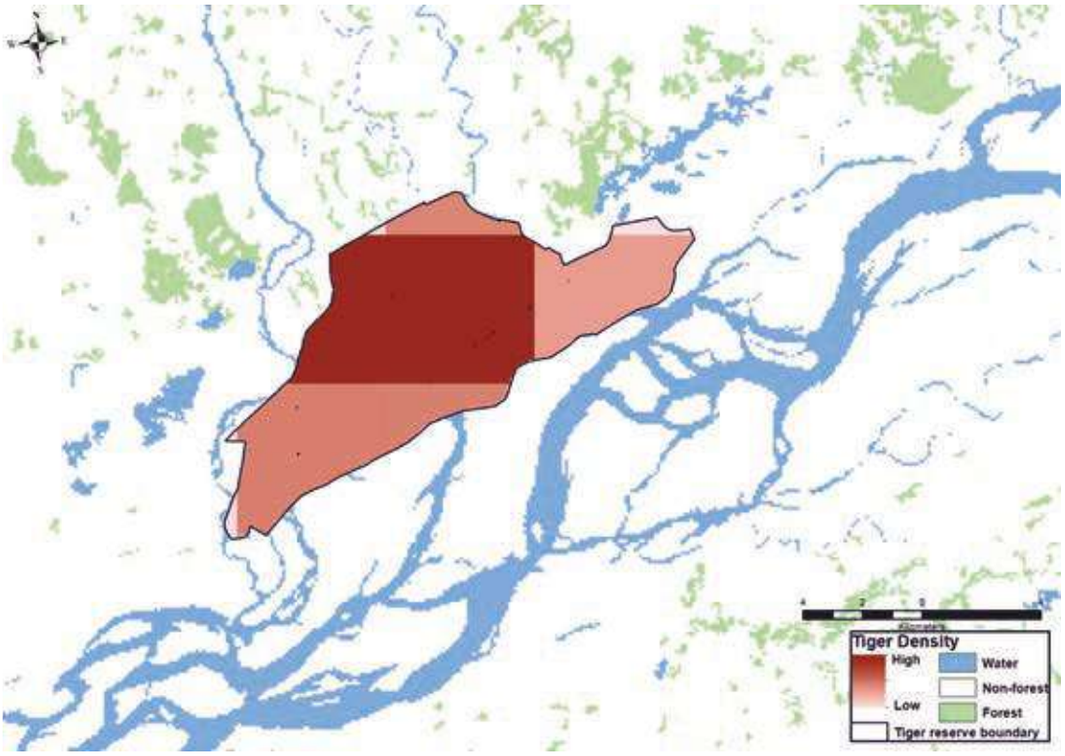
Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Orang Tiger Reserve, 2018.

Variables	Estimates
Model space (km^2)	180.13
Camera points	36
Trap nights (effort)	1437
Unique tigers captured	16
Model	$g_0(.)\sigma(.)$
$\hat{D}$ SECR (per 100 km^2)	10.62 (2.74)
σ (SE) km	2.06 (0.12)
g_0 (SE)	0.05 (0.005)

SE: Standard error
$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture
σ(Sigma): Spatial scale of detection function,
g_0: Magnitude (intercept) of detection function

Figure 12.14

Spatial density of tigers in Orang Tiger Reserve, 2018



Other than Kaziranga, Orang Tiger Reserve has high tiger densities in the Brahmaputra floodplains.

Prey Density Estimates

A total of 11 transect with 3 temporal replicates were sampled in Orang Tiger Reserve which amounted to an effort of 54.8 km. Hog deer was found to be the most abundant ungulate with a density of 59.7 (SE 18.6) per km^2 (Table 12.5). However, there were very few observations of wild pig, wild buffalo and elephant. Hence, abundance estimation could not be assessed for those species.

Table 12.5

Model statistics and parameter estimates of line transect (n=33, Total effort 54.8 km) based distance sampling for prey species in Orang Tiger Reserve, 2018

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group sq.km (SE)	Individual density/ sq.km (SE)
Hog deer	32.825 (4.75)	42	6.57 (1.04)	0.24 (0.03)	0.77(0.17)	11.68(3.06)	59.7(18.6)
Wild pig	NA	7	NA	NA	0.13 (0.04)	NA	NA

Distribution of Major Mammalian Fauna Found in Orang Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species captures rates.

One horned rhinoceros was photo captured in almost every camera trap deployed in Orang Tiger Reserve, which suggests that they were present throughout the reserve. Capture hotspots of rhinoceros were relatively higher in the grasslands in the middle of the reserve.

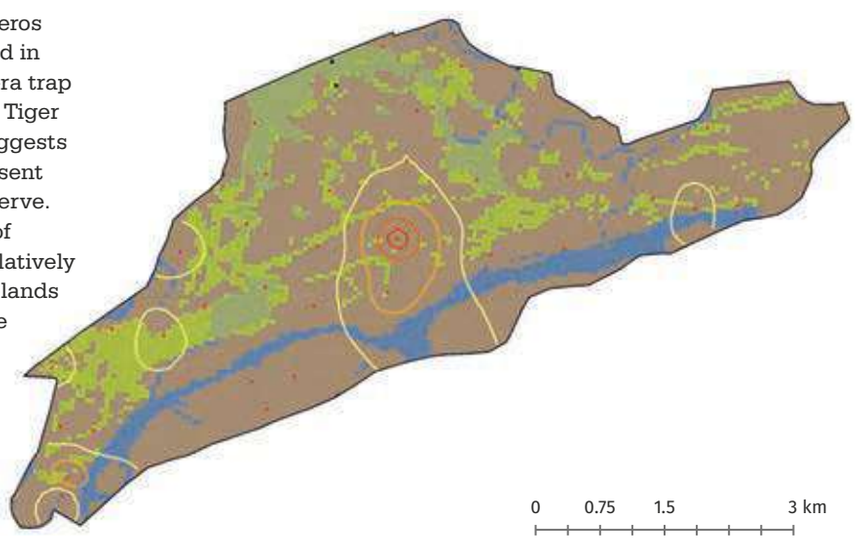


Figure 12.15

Distribution and relative spatial abundance of one horned rhinoceros in Orang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Being a grassland specialist species, hog deer was present almost throughout the reserve. Capture hotspots of hog deer were higher in the grasslands near water bodies and rivers.

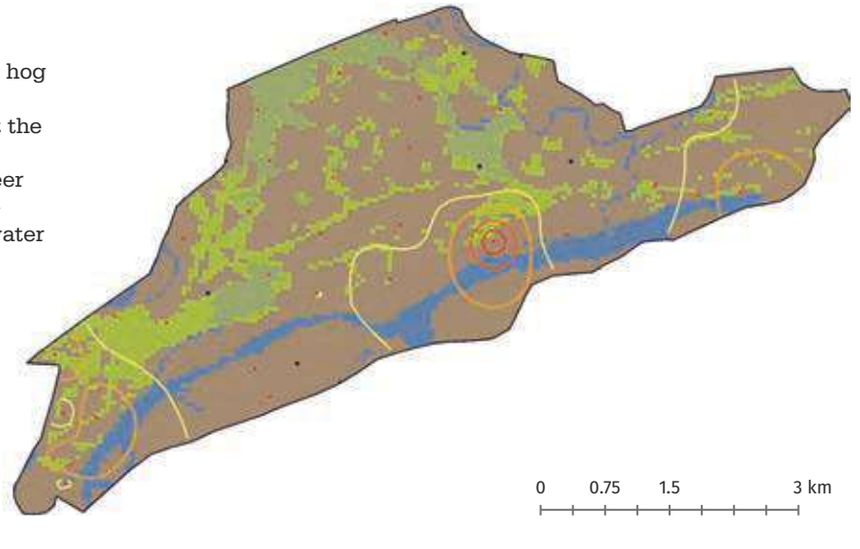


Figure 12.16

Distribution and relative spatial abundance of hog deer in Orang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

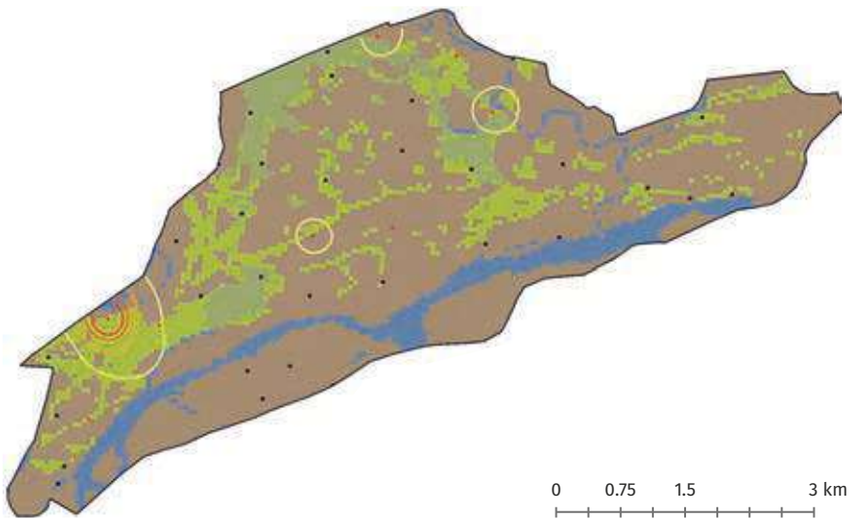


Figure 12.17

Distribution and relative spatial abundance of leopard cat in Orang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Capture hotspots of leopard cat was relatively more near western and northern boundary of the reserve on the ecotone habitats between grasslands and forests.

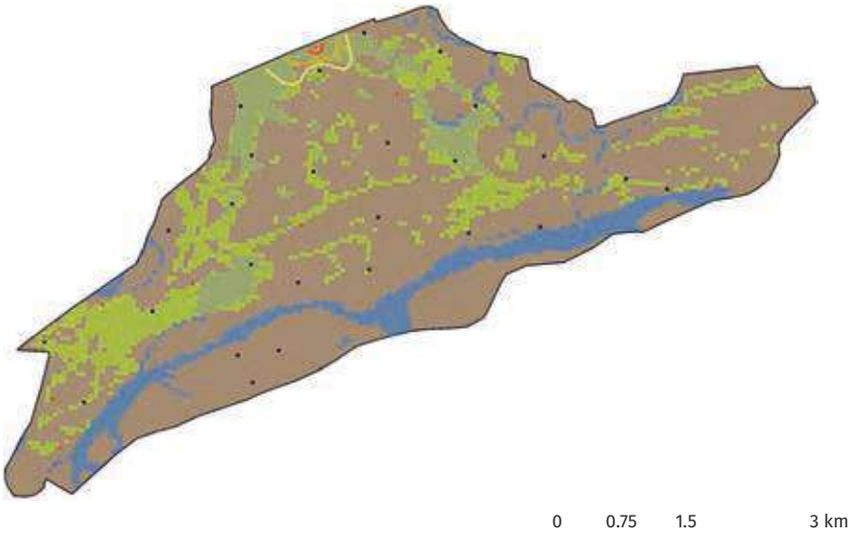


Figure 12.18

Distribution and relative spatial abundance of jungle cat in Orang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Photo captures of jungle cat were few but spread across the tiger reserve with capture hotspots were more in woodlands near the northern boundary.

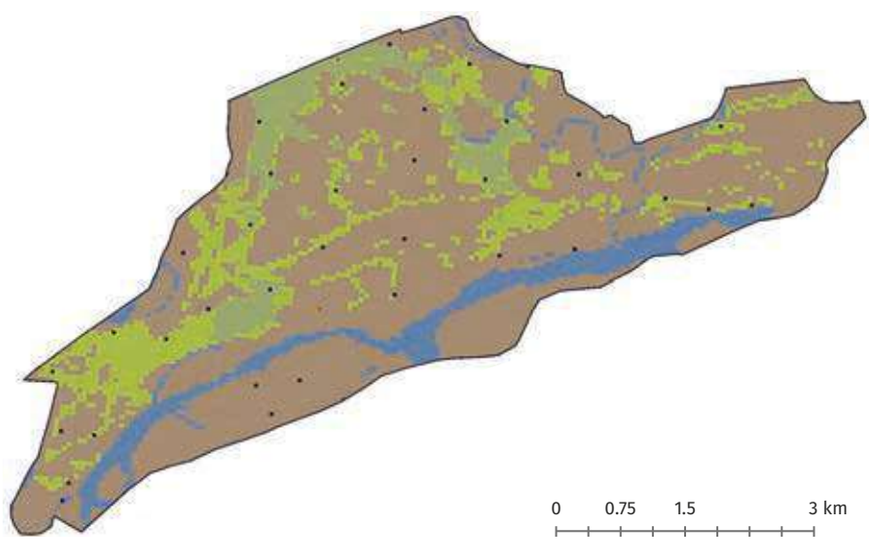


Figure 12.19

Distribution and relative spatial abundance of fishing cat in Orang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Surprisingly there were very few photo captures of fishing cat. Fishing cats was photo captured in grassland as well as woodlands.

There were very few photo-captures of golden jackal. Golden jackal were mostly photo-captured in woodlands.

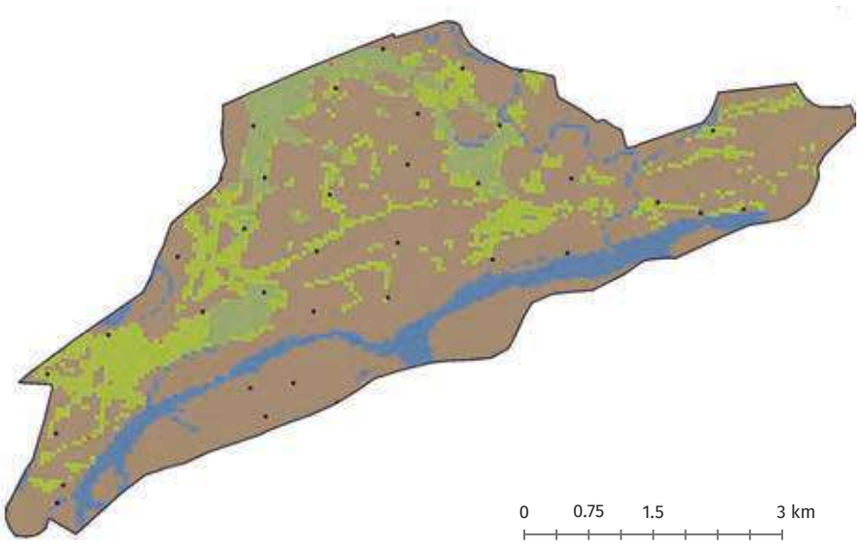


Figure 12.20
Distribution and relative spatial abundance of golden jackal in Orang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Relative Abundance of all Photocaptured Species in Orang Tiger Reserve

Hog deer was the most common species to get photo-captured in Orang Tiger to get a single capture (Table 12.6) followed by rhinoceros.

DISCUSSION

Despite having a small inviolate protected area, the highly productive grasslands of Orang Tiger Reserve supports high density of tigers and therefore of great importance of tiger and wildlife conservation.

Table 12.6
Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Orang Tiger Reserve, 2018

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Black naped hare	0.70	144
Common palm civet	0.77	131
Domestic dog	0.49	205
Fishing cat	0.14	719
Golden jackal	0.42	240
Himalayan crestless porcupine	2.16	46
Hog deer	58.25	2
Indian grey mongoose	8.42	12
Jungle cat	2.64	38
Leopard cat	1.39	72
Livestock	5.78	17
Monitor lizard	0.07	1437
Rhesus macaque	2.71	37
Rhinoceros	31.38	3
Small Indian civet	14.89	7
Smooth coated otter	0.28	359
Tiger	14.82	7
Wild pig	12.04	8

MANAS TIGER RESERVE

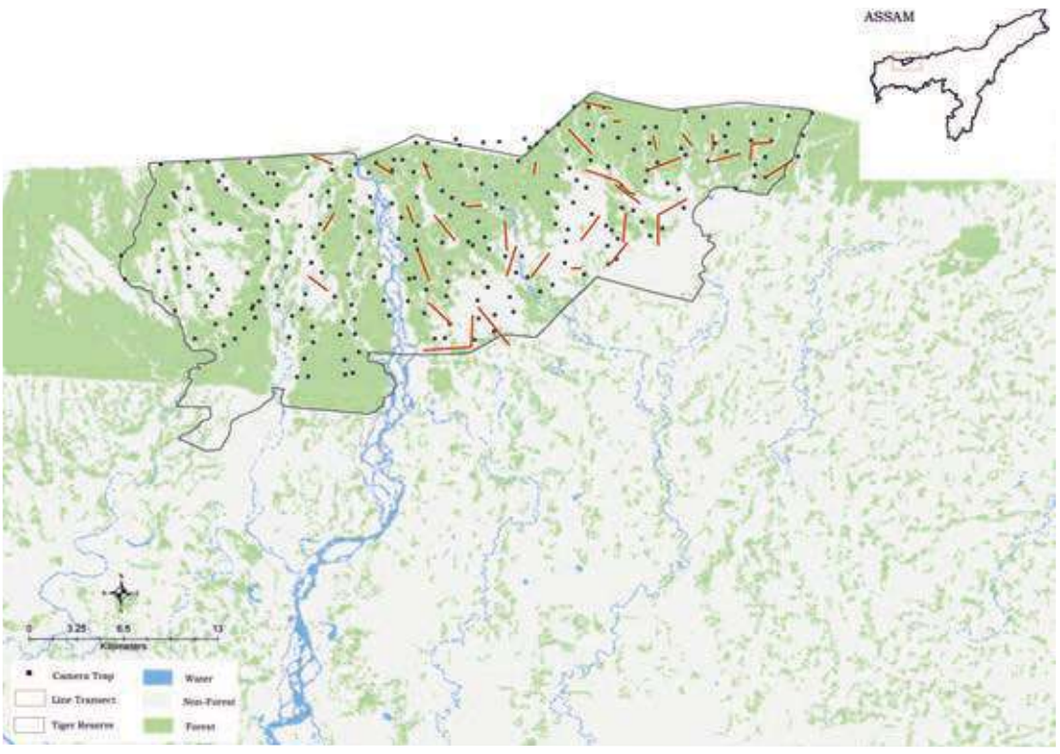
INTRODUCTION

Earlier known as North Kamrup Wildlife Sanctuary, Manas is one of the first nine tiger reserves, which were gazetted after the initiation of the "Project Tiger" in 1973. The tiger reserve spans across Baksa, Chirang and Udalguri districts (between 26°35' to 26°50' N and 90°45' to 91°15' E) of the Bodoland Territorial Area Districts (BTAD) of Assam. It has an area of 2837.1 km^2 of which 526.22 km^2 is designated as core area. River Manas and its tributaries Beki and Hakua in the north, Sankosh river in the west and Dhansiri river in the east, demarcate Manas. Manas is also a UNESCO natural world heritage site and part of Ripu-Chirang Elephant Reserve. Manas Tiger Reserve is contiguous with Royal Manas National Park in Bhutan. It is situated in the eastern Himalayan biodiversity hotspot and harbors a rich assemblage of avifauna and has significant population of some globally threatened species and thereby has been recognized as an "Important Bird Area" (Rahmani et al. 2016).

Manas has broadly three major types of vegetation: a) tropical semi- evergreen, b) tropical moist deciduous and c) alluvial grassland (Champion and Seth 1968). Along with several alluvial grass species, common tree species of Manas are *Dillenia pentagyna, Phyllanthus emblica, Bombax ceiba* and species of *Leea, Grewia,* and *Mussandra* (Rahmani et al. 2016). Manas is refuge for at least 22 globally threatened mammals among which elephant (*Elephas maximus*), one horned rhinoceros (*Rhinoceros unicornis*), wild water buffalo (*Bubalus arnee*), eastern swamp deer (*Rucervus duvaucelli ranjitsinhi*), tiger (*Panthera tigris*), leopard (*Panthera pardus*), and clouded leopard (*Neofelis nebulosa*) are noteworthy. Manas is also home to endemic and endangered species like pygmy hog (*Porcula salvanius*), hispid hare (*Caprologus hispidus*), golden langur (*Trachypithecus geei*) and critically endangered Bengal florican (*Houbaropsis bengalensis*).

Figure 12.21

Camera trap and line transect layout in Manas Tiger Reserve, 2018



RESULTS

Tiger Density Estimates

From a total of 342 photo-captures of tigers 28 individual adult tigers were identified. The detection corrected tiger male to female sex ratio in Manas Tiger Reserve was 0.3:0.7 (Table 12.7).

Table 12.7

Sampling details and tiger density parameter estimates using spatially explicit capture recapture analysis in a likelihood framework for Manas Tiger Reserve, 2018.

Variables	Estimates
Model space (km^2)	884.5
Camera points	240
Trap nights (effort)	11407
Unique tigers captured	28
Model	g_0 (sex)σ(sex) Pmix (sex)
$\hat{D}$ SECR (per 100 km^2)	3.3 (0.6)
σ Female (SE) km	2.66 (0.11)
σ Male (SE) km	3.89 (0.27)
g_0 Female (SE)	0.02 (0.002)
g_0 Male (SE)	0.01 (0.001)
Pmix Female (SE)	0.7 (0.08)
Pmix Male (SE)	0.3(0.08)

SE: Standard error

$\hat{D}$ SECR: Density estimate from Maximum Likelihood based spatially explicit capture recapture

σ(Sigma): Spatial scale of detection function

g_0: Magnitude (intercept) of detection function

Pmix: Detection corrected estimate of proportion of males and females

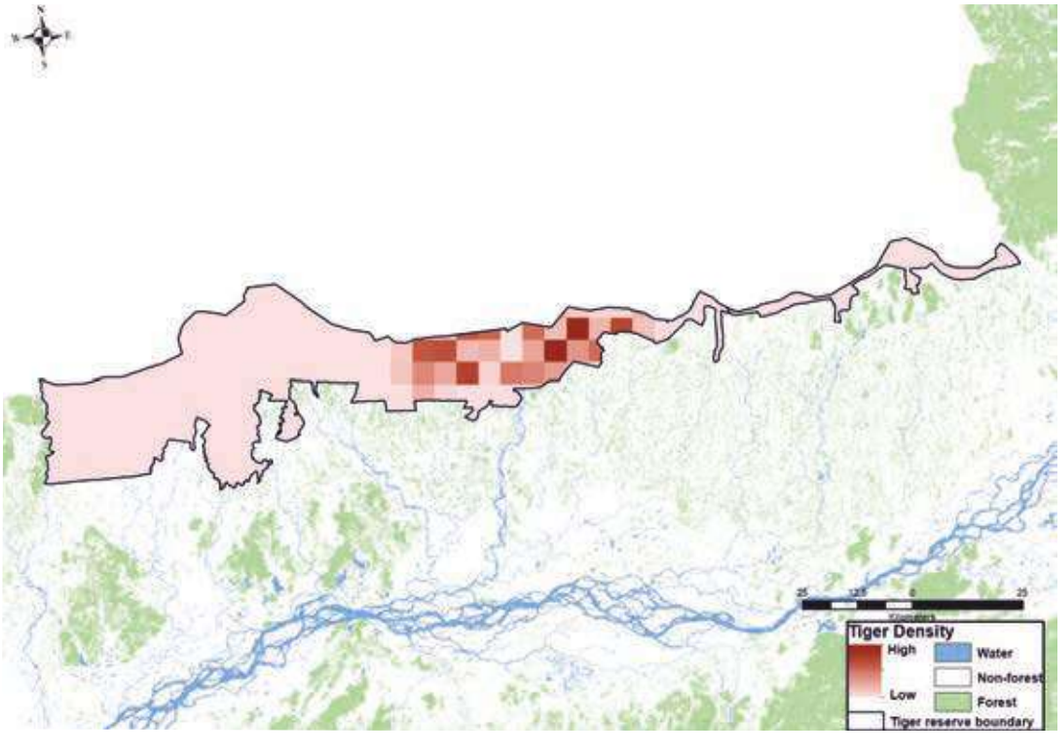


Figure 12.22

Spatial density of tigers in Manas Tiger Reserve, 2018

Eastern part of the tiger reserve had the highest density of tigers.

Prey Density Estimates

A total of 39 transects were sampled in Manas Tiger Reserve which amounted to an effort of 66.6 km. Prey species encountered on line transect were Asian elephant, hog deer, sambar and wild pig (Table 12.8). However, abundance estimates could not be assessed because of very few observations.

Table 12.8

Encounter rate estimates from line transect (n=39, Total effort 66.6 km) for prey species in Manas Tiger Reserve, 2018.

Species	# Groups detected	Encounter rate per km walk (SE)
Hog deer	9	0.14 (0.04)
Wild pig	9	0.14 (0.04)
Elephant	12	0.18 (0.05)
Sambar	12	0.18 (0.05)

Distribution of Major Mammalian Fauna Found in Manas Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species captures rates. The black outline on the map represents the core area of Manas Tiger Reserve.

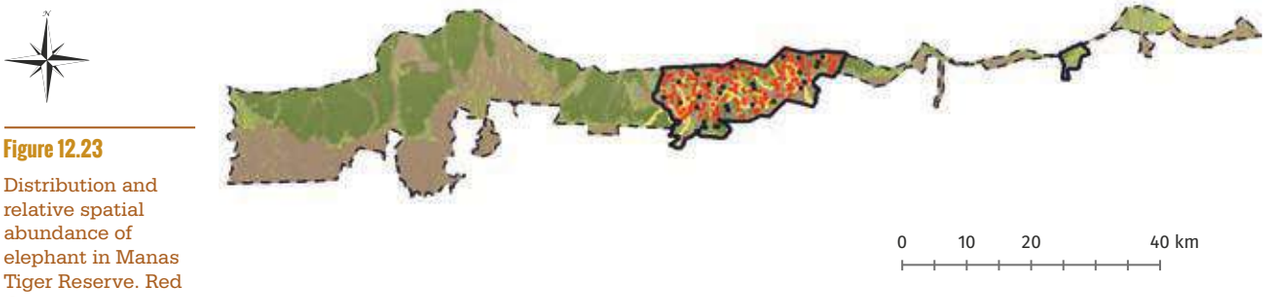


Figure 12.23

Distribution and relative spatial abundance of elephant in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Elephants were present throughout the tiger reserve. Capture hotspots of elephants were in grasslands adjacent to the woodlands.

Figure 12.24

Distribution and relative spatial abundance of one horned rhinoceros in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Rhinos were poached out during the civil unrest from Manas and the current population has been reintroduced. Rhinos seem to have established and are spreading across the tiger reserve. There were capture hotspots of rhinos in the grasslands of Bansbari range near the southern boundary of the tiger reserve. The Tiger Reserve can support a much larger population of rhinos and would benefit from additional supplementation from Pobitara, Kaziranga, and northern West Bengal rhino populations so as to bring in good genetic diversity.

Manas Tiger Reserve holds a small population of Eastern swamp deer. Being a grassland specialist species, Eastern swamp deer was photo captured in alluvial grasslands. The population had relatively higher photo-captures in the grasslands near the southern boundary.

Figure 12.25

Distribution and relative spatial abundance of Eastern swamp deer in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Hog deer was distributed across the tiger reserve. Capture hotspots of hog deer were in pockets of grasslands of the Panbari range.

Figure 12.26

Distribution and relative spatial abundance of hog deer in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Gaur was present throughout the tiger reserve. Being a browser, capture hotspots of gaur were in woodlands near the northern boundary.

Figure 12.27

Distribution, relative spatial abundance of gaur in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Figure 12.28

Distribution and relative spatial abundance of hispid hare in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Hispid hare is an endangered lagomorph and Manas Tiger Reserve is one of the last existing natural habitat. As this species prefers flat, well-drained savannah, they are distributed in pockets of grassland across the tiger reserve. Capture hotspots of hispid hare were in grasslands near the southern boundary of the reserve.

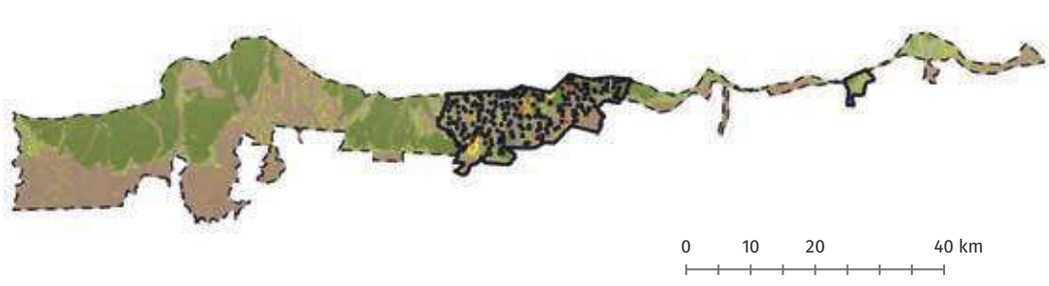


Figure 12.29

Distribution and relative spatial abundance of clouded leopard in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Clouded leopard were present in all the three ranges across the tiger reserve. Capture hotspots of clouded leopard were in moderately hilly to wooded flat terrain.

Figure 12.30

Distribution and relative spatial abundance of leopard cat in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Leopard cat was photo captured throughout the tiger reserve. Capture hotspots of leopard cat were in woodlands adjacent to grasslands and waterbodies.

There were very few photo-captures of marbled cat in Manas Tiger Reserve. Marbled cat was present in hilly terrain near the northern boundary.

Figure 12.31

Distribution and relative spatial abundance of marbled cat in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Jungle cat was distributed throughout the tiger reserve with capture hotspots higher in flat woodlands adjacent to open grasslands.

Figure 12.32

Distribution, relative spatial abundance of jungle cat in Manas Tiger Reserve. Red dots represent photo-captures in camera traps while contour line depict intensity of photo-captures

Dhole was present across the tiger reserve. Capture hotspots of dhole were in woodlands near the northern boundary.

Figure 12.33

Distribution, relative spatial abundance of dhole in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

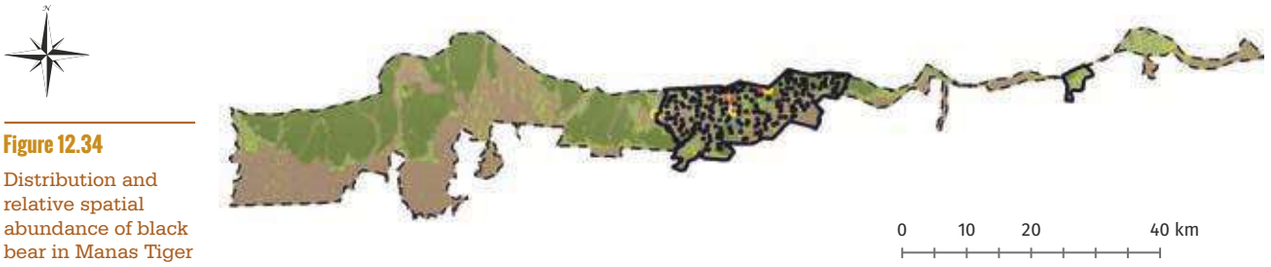


Figure 12.34

Distribution and relative spatial abundance of black bear in Manas Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Black bear was photo captured in Panbari and Bansbari range of the tiger reserve. Capture hotspots of black bear were in woodlands.

Table 12.9

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Manas Tiger Reserve, 2018

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Asiatic brush-tailed porcupine	0.06	1630
Barking deer	8.24	12
Black naped hare	1.30	77
Capped langur	0.10	1037
Chital	0.03	3802
Clouded leopard	0.09	1141
Common palm civet	1.16	86
Crab eating mongoose	0.45	224
Dhole	0.78	128
Domestic dog	0.11	877
Elephant	19.81	5
Gaur	9.57	10
Golden jackal	0.02	5704
Himalayan black bear	0.09	1141
Himalayan crestless porcupine	3.60	28
Hispid hare	0.29	346
Hog deer	6.01	17
Indian grey mongoose	0.12	815
Jungle cat	0.28	356
Large Indian civet	1.35	74
Leopard	3.69	27
Leopard cat	1.77	56
Livestock	3.09	32
Marbled cat	0.01	11407
Monitor lizard	0.02	5704
Peafowl	6.30	16
Red jungle fowl	1.43	70
Rhesus macaque	0.94	107

Relative Abundance of all Photocaptured Species in Manas Tiger Reserve

Sambar was the most common species among all the species photo-captured in Manas Tiger Reserve followed by elephant (Table 12.9). Marbled cat was the rarest species to get photo-captured.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Rhinoceros	1.51	66
Sambar	31.97	3
Small Indian civet	3.61	28
Smooth coated otter	0.05	1901
Swamp deer	0.13	760
Tiger	3.33	30
Wild pig	10.08	10
Wild water buffalo	5.49	18
Yellow throated marten	0.17	600

DISCUSSION

Manas Tiger Reserve is contiguous with Royal Manas National Park in Bhutan and a medium density tiger reserve. The Reserve is a biodiversity hotspot with its varied and mosaic habitats, after the insurgency when Manas and its fauna suffered significant losses, the Tiger Reserve is on its way to recovery and requires continuous protection as well as local community support. Transboundary cooperation with Bhutan in monitoring, intelligence sharing, and joint patrolling will enhance the biodiversity values of the region.

NAMERI TIGER RESERVE

INTRODUCTION

Nameri Tiger Reserve, geographically located in the Sonitpur district of Assam (between 26^0 48'to 27^0 03' N and 92^0 38' to 93^0 05' E) spans over an area of 464 km^2 of which 320 km^2 is designated as core area. Situated at the northern bank of Brahmaputra this tiger reserve spans across varied habitats and therefore holds a rich diversity of flora and fauna and is of conservation significance. In the north, Nameri is contiguous with Pakke Tiger Reserve of Arunachal Pradesh. Nameri is criscrossed by the river JiaBhoroli and its tributaries Nameri, Dikorai, Digi, Dinai, Doigrung etc. Jia Bhoroli demarcates the western boundary of the core and Bordikorai demarcates the eastern boundary.

The vegetation type of Nameri is primarily forest and woodlands. Narrow strips of open grasslands can be found along the river banks and dry river beds. Four major types of vegetation (Champion and Seth 1968) can be found in Nameri a) eastern alluvial secondary semi-evergreen forest, b) low alluvial savannah woodland, c) eastern Dillenia swamp forest and d) wet bamboo forest with areas of cane brakes.

Contiguity with neighbouring forests and inaccessibility due to rivers has allowed the wildlife in Nameri to survive. Other than important mammalian and avian fauna, Nameri is a refuge for the state bird of Assam, the white winged duck (*Asarcornis scutalata*). Carnivore guild of Nameri comprises of tiger (*Panthera tigris*), leopard (*Panthera pardus*), clouded leopard (*Neofelis nebulosa*), sloth bear (*Melursus ursinus*), himalayan black bear (*Ursus thibatanus*), dhole (*Cuon alpinus*), and yellow throated marten (*Martes flavigula*), amongst others. The herbivore guild includes elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), hog deer (*Axis porcinus*), barking deer (*Muntiacus vaginalis*), wild pig (*Sus scrofa*) amongst others.

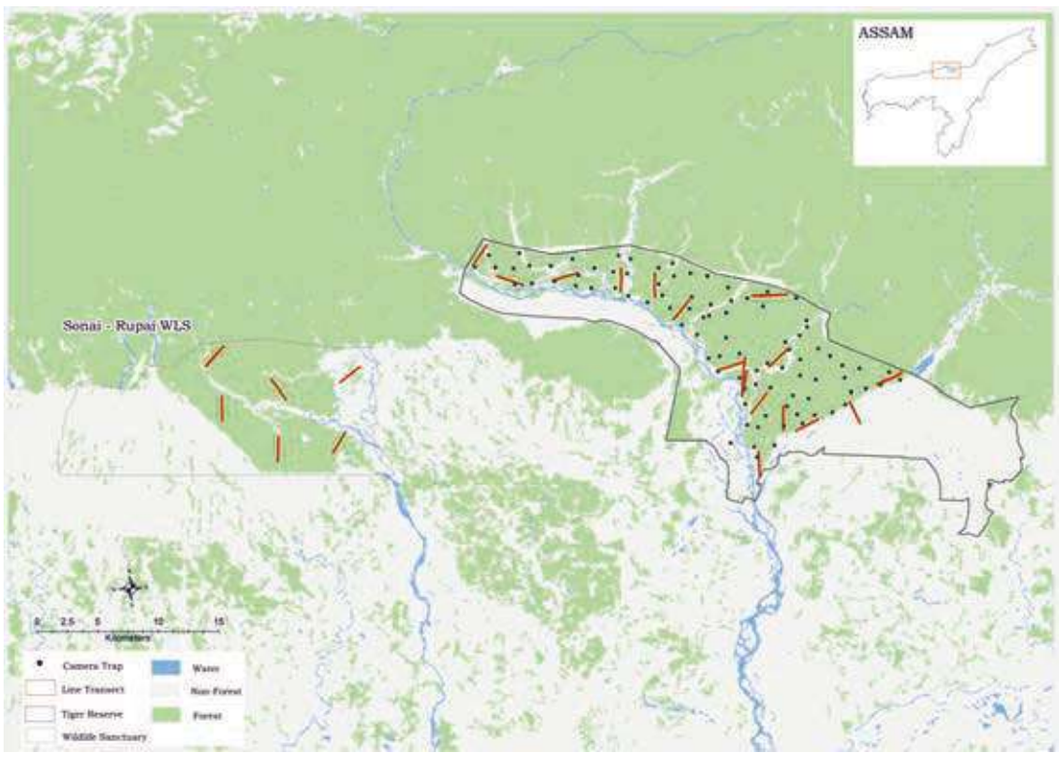


Figure 12.35
Camera trap and line transect layout in Nameri Tiger Reserve, 2018

RESULTS

Camera Trap Results

From a total of 39 photo-captures of tigers 3 adult tigers were identified (Table 12.10). These three tigers were also photo-captured in Pakke Tiger Reserve. Due to the small sample size, density parameters for tigers in Nameri Tiger Reserve could not be assessed using spatially explicit capture recapture analysis. The male to female ratio in Nameri Tiger Reserve is 2:1.

Prey Density Estimates

A total of 22 transects with a cumulative effort of 117 km were sampled in Nameri Tiger Reserve. Species observed on transects were barking deer, sambar, elephant, wild pig and gaur. Sambar was found to be the most abundant ungulate (Table 12.11). There were very few observations of Barking deer, Wild pig and Gaur and hence population abundance could not be assessed.

Sampling details	Counts
Camera points	91
Trap nights (effort)	2572
Unique tigers captured	3

Table 12.10
Sampling details for Nameri Tiger Reserve, 2018.

Table 12.11
Model statistics and parameter estimates of line transect (n=22, Total effort 117 km) based distance sampling for prey species in Nameri Tiger Reserve, 2018

Species	Effective strip width (SE)	# Groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Sambar	28.95 (5.73)	17	1.14 (0.19)	0.49 (0.1)	0.15 (0.03)	2.51 (0.71)	3.54 (1.11)
Wild pig	NA	13	NA	NA	0.11 (0.03)	NA	NA
Barking deer	NA	12	NA	NA	0.10 (0.03)	NA	
Elephant	NA	22	NA	NA	0.19 (0.03)	NA	NA
Gaur	NA	07	NA	NA	0.06 (0.02)	NA	NA

Distribution of Major Mammalian Fauna Found in Nameri Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species captures rates. The black outline on the map represents the core area of Nameri Tiger Reserve.

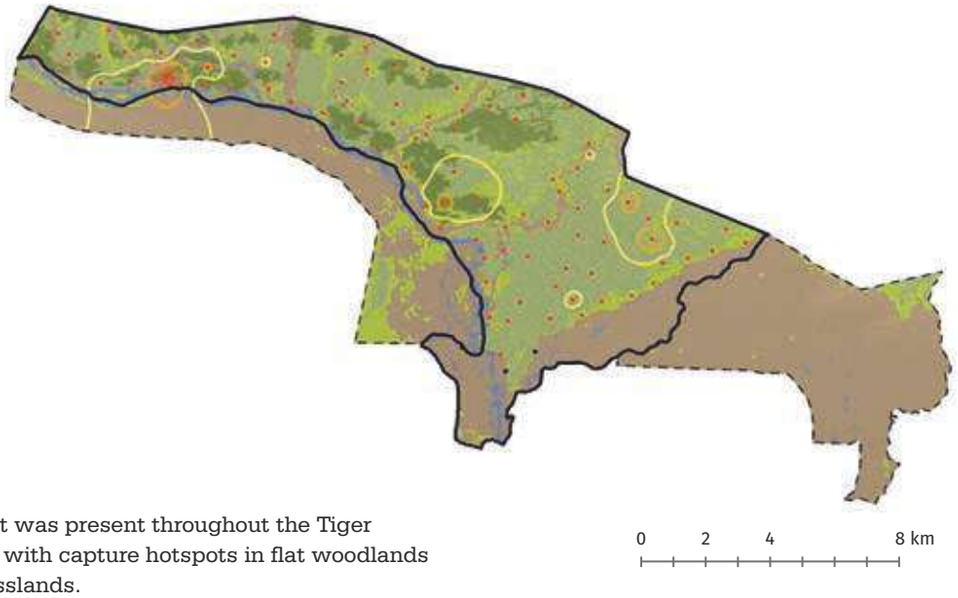


Figure 12.36
Distribution and relative spatial abundance of elephant in Nameri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Elephant was present throughout the Tiger Reserve with capture hotspots in flat woodlands and grasslands.

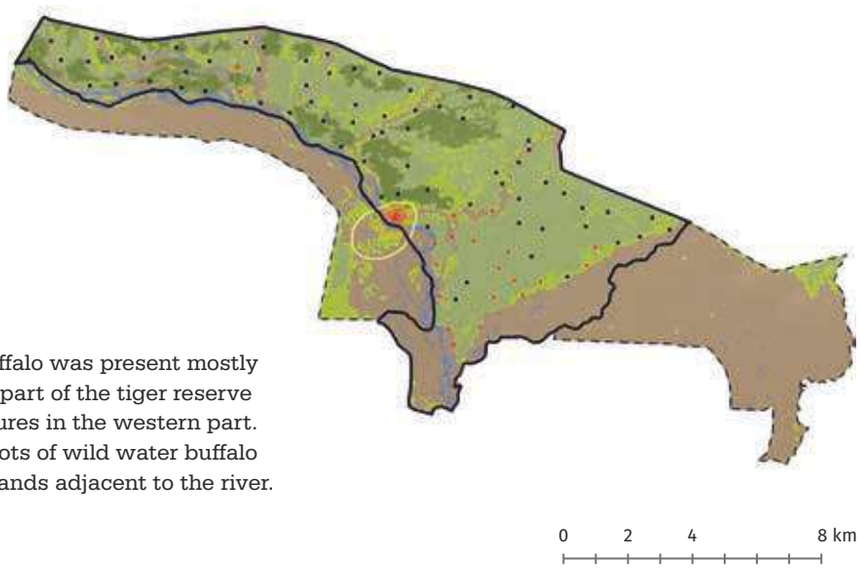


Figure 12.37

Distribution and relative spatial abundance of wild water buffalo in Nameri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Wild water buffalo was present mostly in the eastern part of the tiger reserve with few captures in the western part. Capture hotspots of wild water buffalo were in grasslands adjacent to the river.

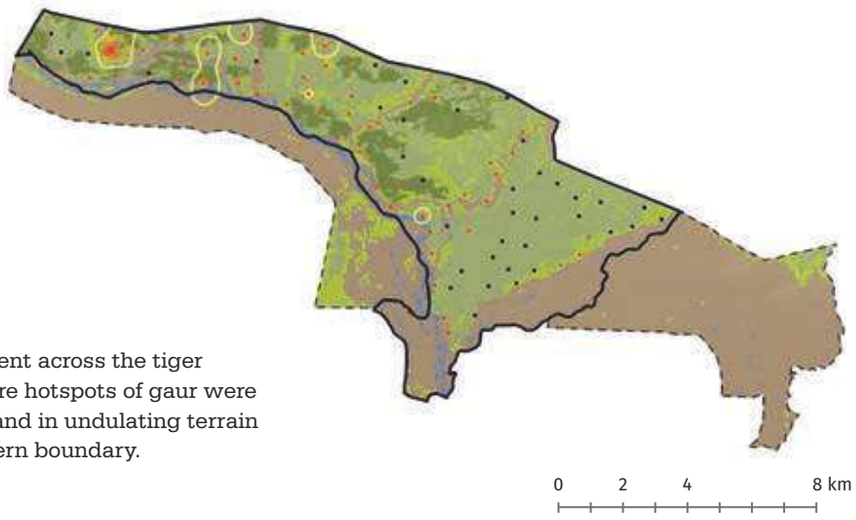


Figure 12.38

Distribution and relative spatial abundance of gaur in Nameri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Gaur was present across the tiger reserve. Capture hotspots of gaur were in woodlands and in undulating terrain near the northern boundary.

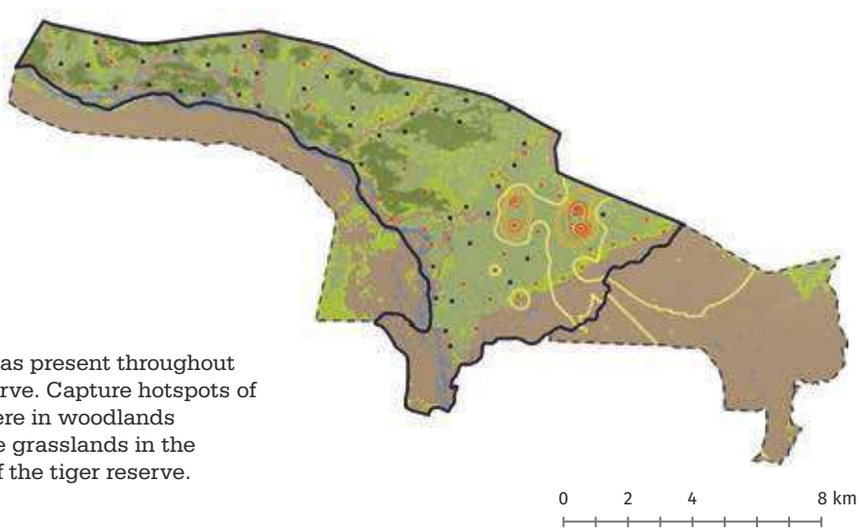
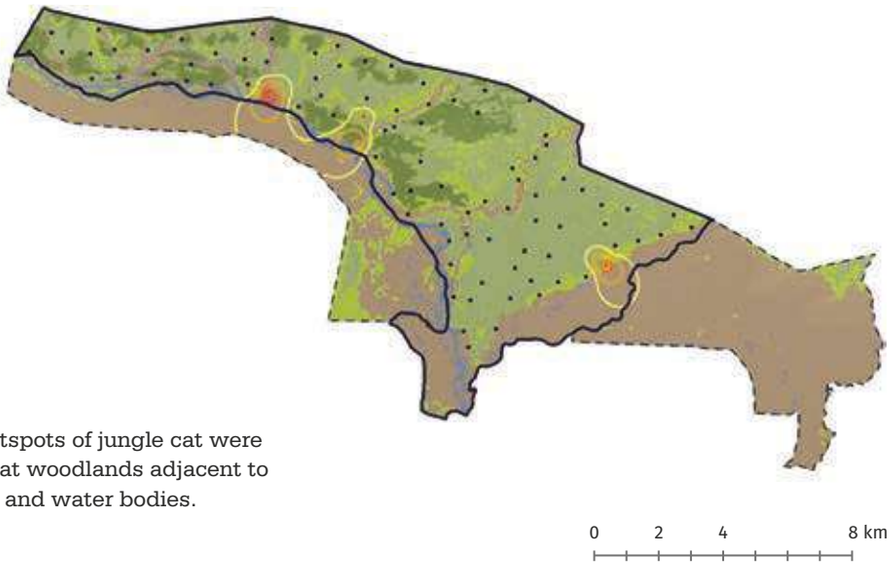


Figure 12.39

Distribution and relative spatial abundance of leopard cat in Nameri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

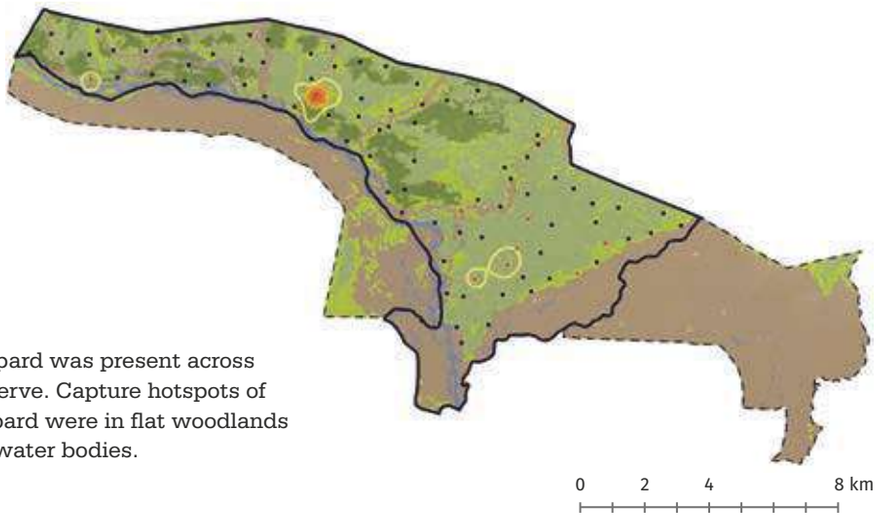
Leopard cat was present throughout the Tiger Reserve. Capture hotspots of leopard cat were in woodlands adjacent to the grasslands in the eastern part of the tiger reserve.



Capture hotspots of jungle cat were mostly in flat woodlands adjacent to grasslands and water bodies.

Figure 12.40

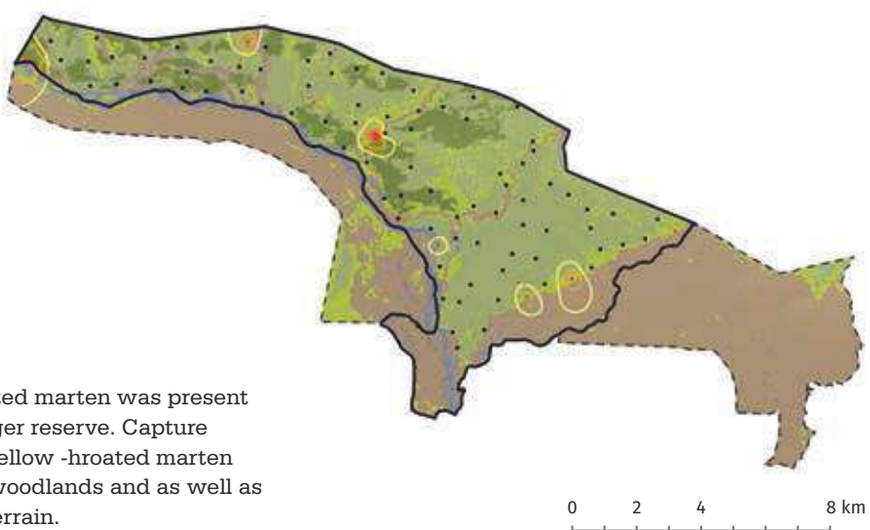
Distribution and relative spatial abundance of jungle cat in Nameri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures



Clouded leopard was present across the tiger reserve. Capture hotspots of clouded leopard were in flat woodlands adjacent to water bodies.

Figure 12.41

Distribution and relative spatial abundance of clouded leopard in Nameri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures



Yellow-throated marten was present across the tiger reserve. Capture hotspots of yellow -hroated marten were in flat woodlands and as well as undulating terrain.

Figure 12.42

Distribution and relative spatial abundance of yellow throated marten in Nameri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

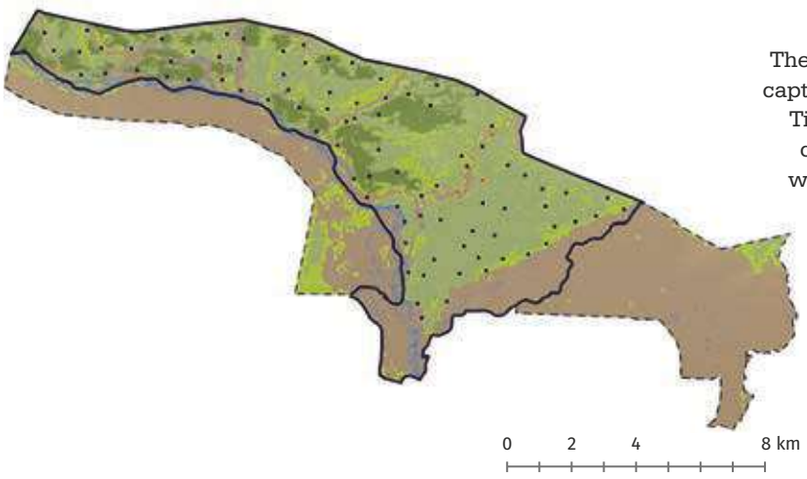


Figure 12.43
Distribution and relative spatial abundance of dhole in Nameri Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

There were very few photo captures of dhole in Nameri Tiger Reserve. The photo captures were mostly in woodlands bordering the grassland.

Table 12.12
Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Nameri Tiger Reserve, 2018

Species	Number of photos per 100 trap nights	Number of trap nights required to get single capture
Asiatic brush-tailed porcupine	0.08	1286
Barking deer	9.53	10
Black naped hare	1.75	57
Clouded leopard	0.82	122
Common palm civet	1.36	73
Crab eating mongoose	0.27	367
Dhole	0.12	857
Domestic cat	2.99	33
Elephant	32.31	3
Gaur	6.45	15
Himalayan black bear	0.04	2572
Himalayan crestless porcupine	7.62	13
Hog deer	11.00	9
Indian grey mongoose	0.08	1286
Jungle cat	0.43	234
Large Indian civet	14.70	7
Leopard	0.43	234
Leopard cat	4.74	21
Livestock	7.15	14
Marbled cat	0.08	1286
Red jungle fowl	2.49	40
Rhesus macaque	4.67	21
Sambar	16.95	6
Small Indian civet	5.21	19
Smooth coated otter	0.04	2572
Tiger	0.19	514
Wild pig	4.35	23
Wild water buffalo	2.29	44
Yellow throated marten	0.35	286

Relative Abundance of all Photocaptured Species in Nameri Tiger Reserve

Several common and threatened mammalian species were photo-captured during the sampling period in Nameri Tiger Reserve. Elephant was the most common species photo-captured (Table 12.12) followed by Sambar in the Tiger Reserve. Black bear and Smooth coated otter were the least photo captured species.

DISCUSSION

Nameri Tiger Reserve was recognized as a low tiger density area. Nameri Tiger Reserve shares tigers with Pakke Tiger Reserve in Arunachal Pradesh. This region (Nameri- Pakke-Eaglenest WLS) need to be managed for their biodiversity values and not just for tiger density. Support from local communities is an essential ingredient for successful conservation in this landscape more than any other component.

PAKKE TIGER RESERVE

INTRODUCTION

Earlier named as Pakhui Wildlife Sanctuary, Pakke Tiger Reserve (1198.45 km^2) is located in the East Kameng (between 92°36' to 93°09' E and 26°54' and 27°16' N) district of Arunachal Pradesh. Lying in the foothills of Eastern Himalaya, Pakke Tiger Reserve harbors rich faunal and floral diversity. The reserve is bordered on the north and west by Bhoroli river and Eagle Nest Wildlife Sanctuary, on the east by Pakke River and on the south by Nameri Tiger Reserve of Assam. The terrain is mountainous and rugged with narrow valleys and sloping plains. The Chittagong hills are considered to be the limits of both the Bengal tiger (*P. t. tigris*) and Indo-Chinese tiger (*P. t. corbetti*) and is likely a zone of mixing between the two subspecies (Kolipakam et al. 2019).

Vegetation of Pakke Tiger Reserve is primarily tropical semi evergreen (Champion and Seth 1968). Vegetation of the reserve is very dense and has diverse woody lianas and climbers (Datta 1998). Habitat type is typically layered i.e. tropical semi evergreen on the lower plains, tropical evergreen in mid elevation and sub-tropical broadleaved forests on the higher reaches (Datta 1998). Dominant species are *Tetrameles nudiflora, Altingia excelsia, Terminalia myriocarpa, Mesua ferrea, Dysoxylum* spp, etc. Due to its location in Oriental and Indo-Malayan realm, Pakke has a rich faunal assemblage. Mammalian species of Pakke Tiger Reserve includes tiger (*Panthera tigris*), leopard (*Panthera pardus*), clouded leopard (*Neofelis nebulosa*), dhole (*Cuon alpinus*), marbled cat (*Pardofelis marmorata*), leopard cat (*Prionailurus bengalensis*), golden jackal (*Canis aureus*), himalayan black bear (*Ursus thibatanus*), binturong (*Arctictis binturong*), elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), hog deer (*Axis porcinus*), serow (*Capricornis thar*), Assamese macaque (*Macaca assamensis*) among others.

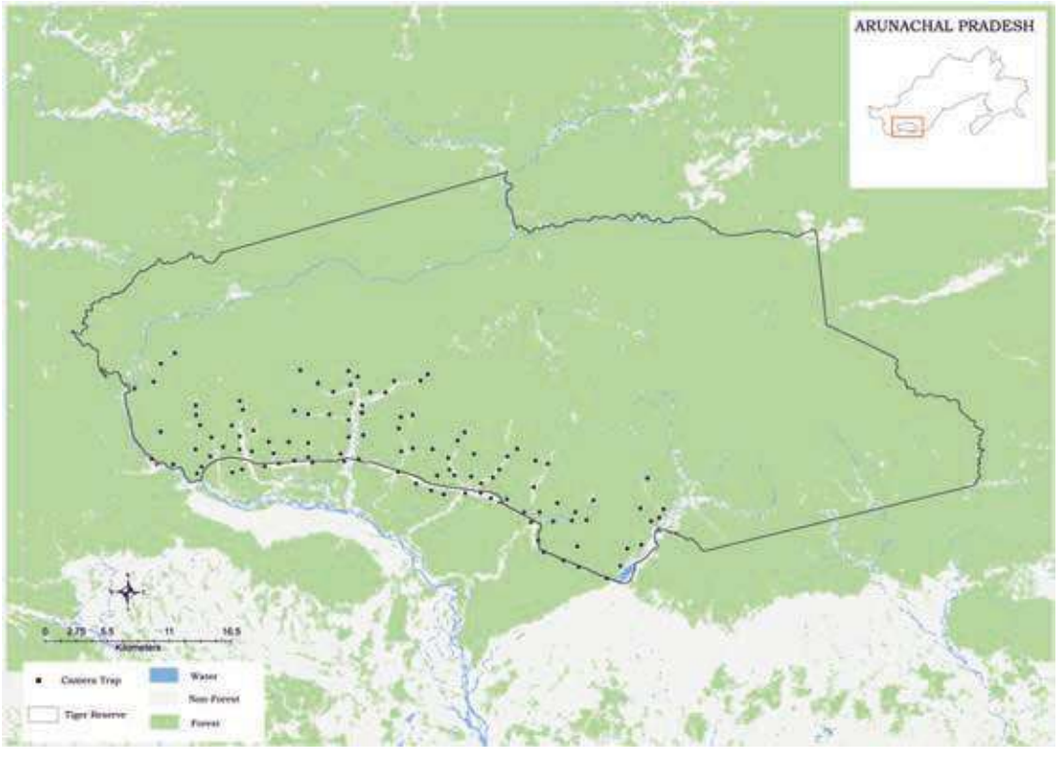


Figure 12.44
Camera trap layout in Pakke Tiger Reserve, 2018

RESULTS

Camera Trap Results

From a total of 32 photo-captures of tigers 3 adult tigers were identified (Table 12.13). These tigers were also photo-captured in Nameri Tiger Reserve. Due to the small sample size, tiger density could not be estimated by model-based inference for Pakke Tiger Reserve.

Table 12.13
Sampling details for Pakke Tiger Reserve, 2018.

Sampling details	Counts
Camera points	111
Trap nights (effort)	3561
Unique tigers captured	3

Distribution of Major Mammalian Fauna Found in Pakke Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species capture rates. The black outline on the map represents the core of Pakke Tiger Reserve.

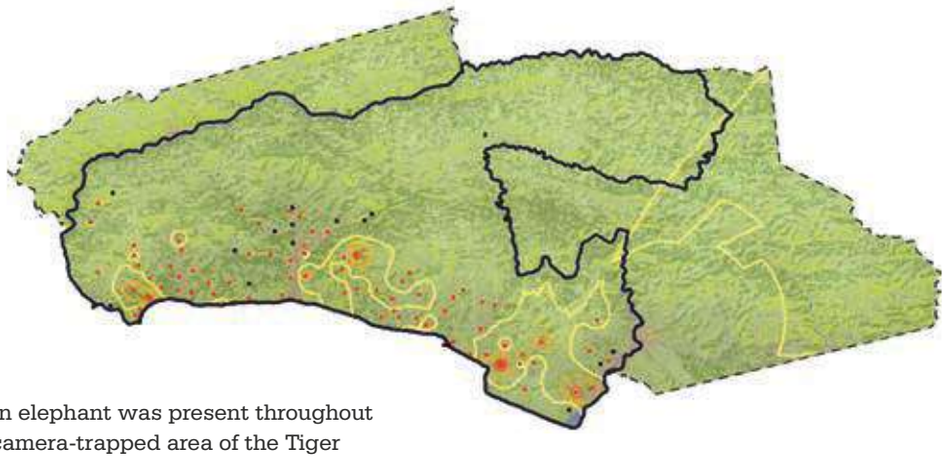


Figure 12.45
Distribution and relative spatial abundance of elephant in Pakke Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Asian elephant was present throughout the camera-trapped area of the Tiger Reserve. Capture hotspots of elephants were in woodlands and grassland valleys and in flatter terrain.

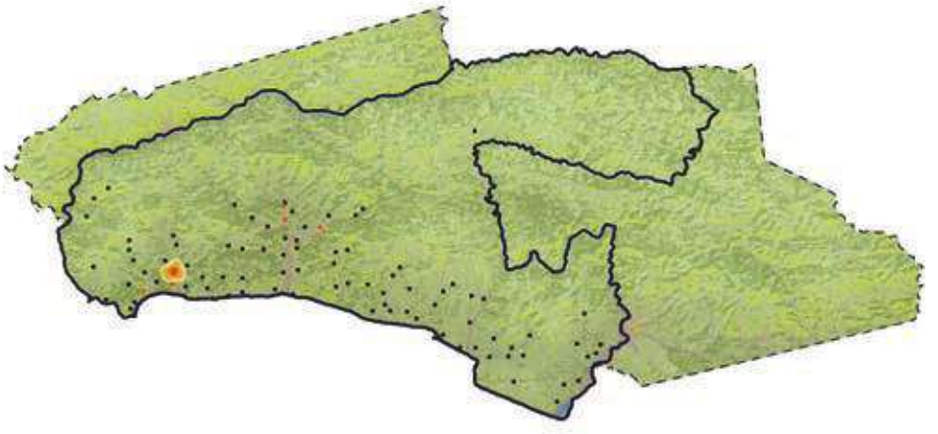
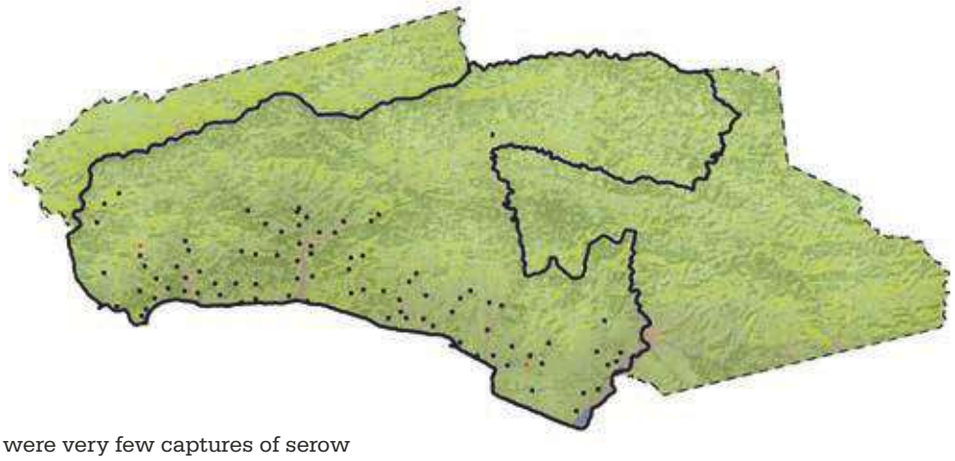


Figure 12.46
Distribution and relative spatial abundance of hog deer in Pakke Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

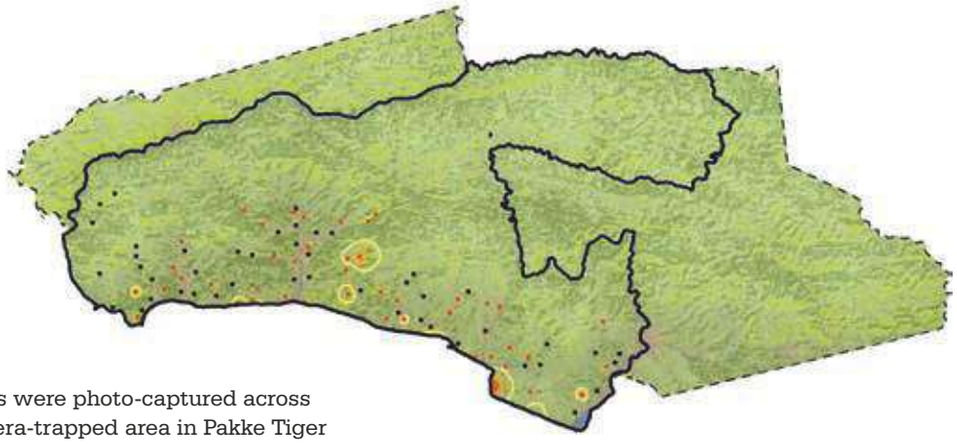
Hog deer is a flood plain grassland specialist species and capture hotspots were in grasslands adjoining the rivers and valleys.



There were very few captures of serow in Pakke Tiger Reserve. The captures were mostly in valley habitats.

Figure 12.47

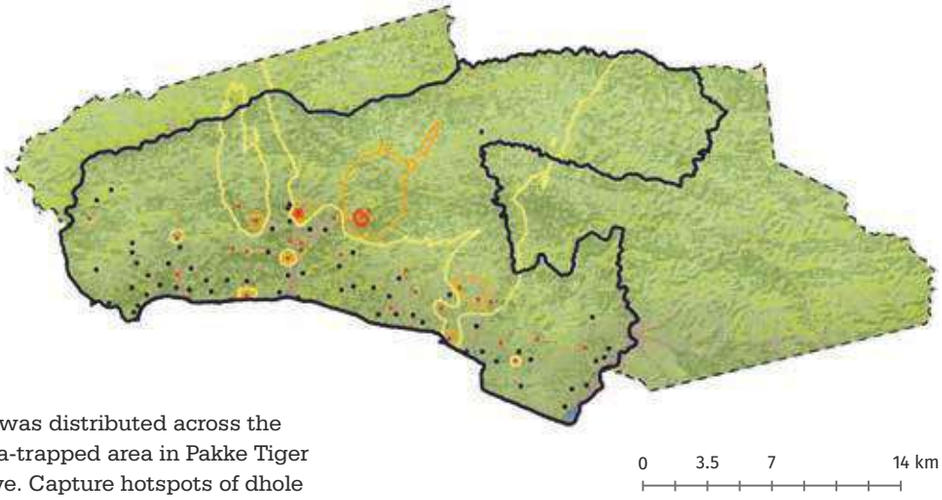
Distribution and relative spatial abundance of serow in Pakke Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures



Leopards were photo-captured across the camera-trapped area in Pakke Tiger Reserve. Capture hotspots of leopard were in woodlands in moderately undulating terrain.

Figure 12.48

Distribution and relative spatial abundance of leopard in Pakke Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures



Dhole was distributed across the camera-trapped area in Pakke Tiger Reserve. Capture hotspots of dhole were in woodlands and grasslands along the valleys.

Figure 12.49

Distribution and relative spatial abundance of dhole in Pakke Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

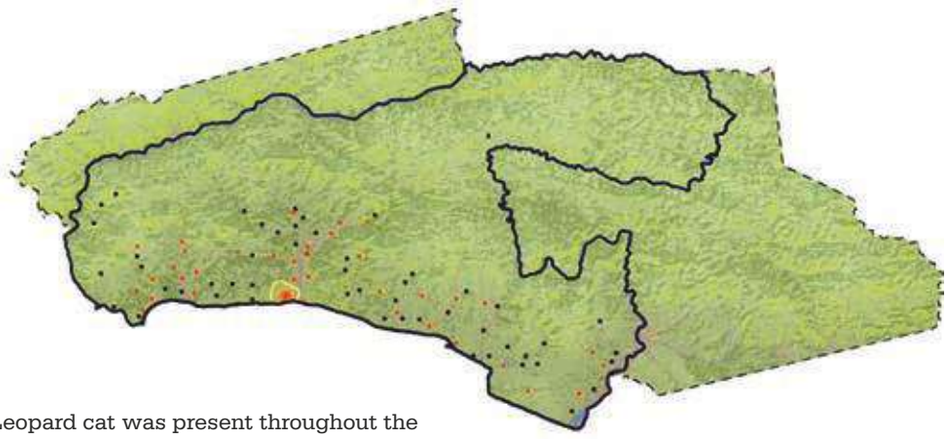


Figure 12.50

Distribution and relative spatial abundance of leopard cat in Pakke Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Leopard cat was present throughout the camera-trapped area in Pakke Tiger Reserve with capture hotspots in grassland adjacent to river.

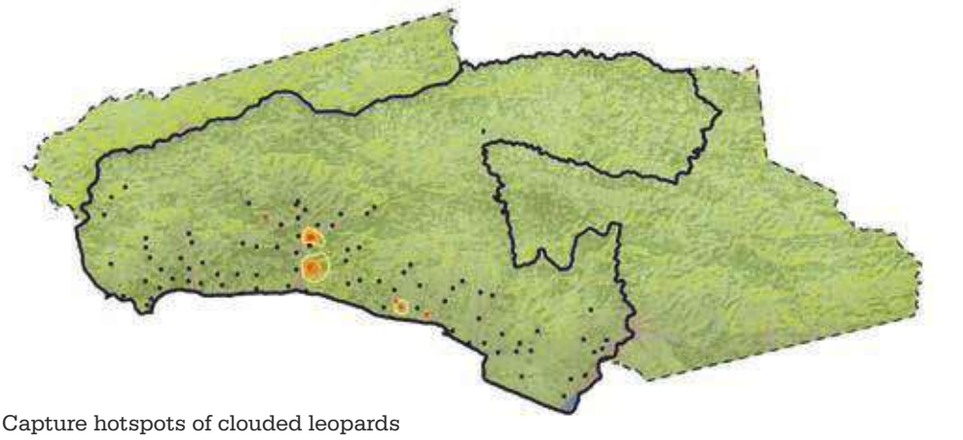


Figure 12.51

Distribution and relative spatial abundance of clouded leopard in Pakke Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Capture hotspots of clouded leopards were in woodlands adjacent to the rivers.

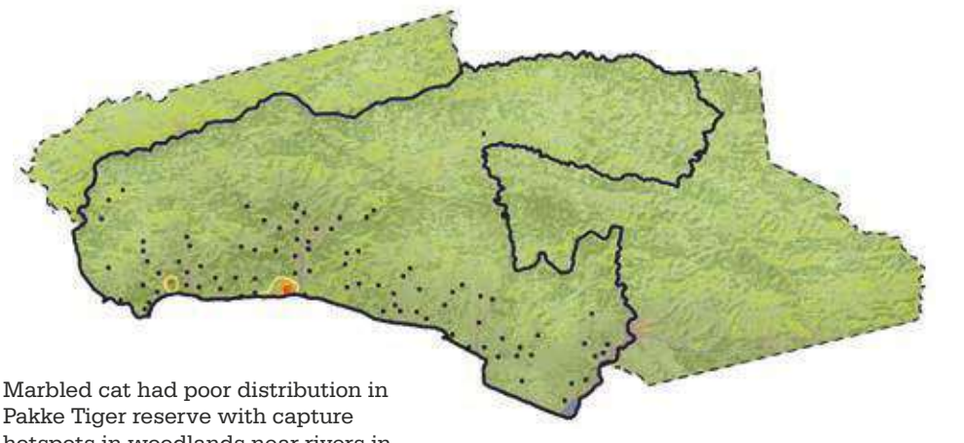
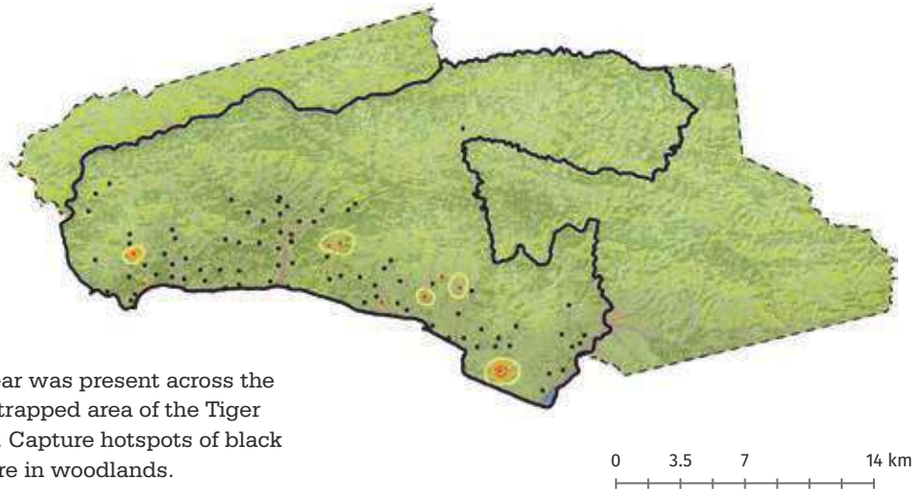


Figure 12.52

Distribution and relative spatial abundance of marbled cat in Pakke Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Marbled cat had poor distribution in Pakke Tiger reserve with capture hotspots in woodlands near rivers in the camera-trapped area of Pakke Tiger Reserve.



Black bear was present across the camera-trapped area of the Tiger Reserve. Capture hotspots of black bear were in woodlands.

Figure 12.53
Distribution and relative spatial abundance of black bear in Pakke Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Relative Abundance of all Photocaptured Species in Pakke Tiger Reserve

Several mammalian species including some rare and endemic species were photo captured during the sampling period in Pakke Tiger Reserve. Sambar and Asian elephant were the most common species (Table 12.14). Binturong was the rarest species to get photo-captured.

DISCUSSION

Pakke Tiger Reserve is also a low tiger density area and shares tiger with Nameri. Pakke-Eaglenest-Nameri complex is vital for conserving the rich biodiversity of this ecosystem and should be managed as a conservation landscape.

Table 12.14
Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Pakke Tiger Reserve, 2018

Species	Number of photos per 100 trap nights	Number of trap nights required to get single capture
Asiatic brush-tailed porcupine	0.08	1187
Barking deer	21.40	5
Binturong	0.06	1781
Capped langur	0.14	712
Clouded leopard	0.37	274
Common palm civet	2.36	42
Crab eating mongoose	0.42	237
Dhole	1.57	64
Domestic cat	0.67	148
Elephant	32.35	3
Gaur	14.69	7
Himalayan black bear	0.39	254
Himalayan crestless porcupine	5.84	17
Hog deer	0.87	115
Large Indian civet	11.46	9
Leopard	3.37	30
Leopard cat	4.13	24
Marbled cat	0.37	274
Masked palm civet	0.11	890
Monitor lizard	0.06	1781
Red jungle fowl	6.80	15
Rhesus macaque	0.84	119
Sambar	69.36	1
Serow	0.08	1187
Small Indian civet	2.70	37
Smooth coated otter	0.08	1187
Tiger	0.98	102
Wild pig	3.43	29
Yellow throated marten	0.34	297

NAMDAPHA TIGER RESERVE

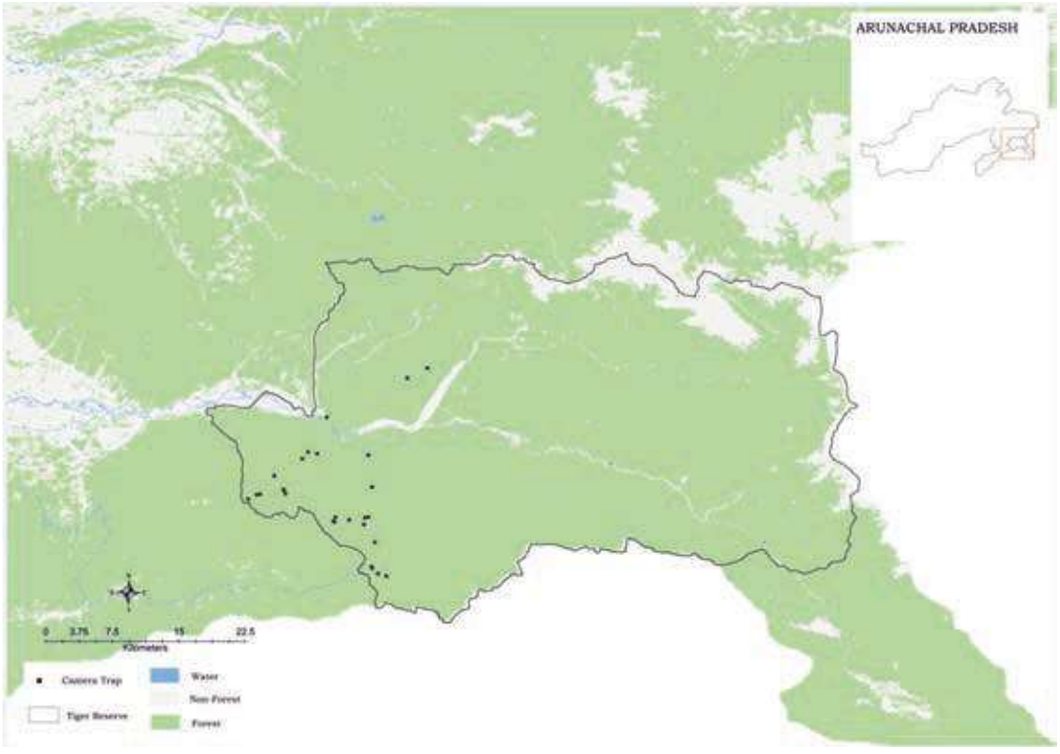
INTRODUCTION

Situated in the Changlang district (between 27°23' to 27°39' N and 96°15' to 96°58' E) of Arunachal Pradesh, Namdapha Tiger Reserve spreads over an area of 2052.82 km^2 of which 1807.82 km^2 area is designated as core habitat. The terrain is undulating hilly with elevation ranging from 200m to 4571m msl. Nestled in the eastern Himalaya, this reserve is situated at the junction of Palearctic and Indo-Malayan realm (Rodgers and Panwar 1988) and identified as a global biodiversity hotspot (Myers et al. 2000). Namdapha is also the northernmost low land tropical rainforest and harbours extensive dipterocarp forests (Proctor et al.1998).

Habitat types are diverse along the elevation gradient from sub-tropical broadleaved rainforests at lower elevations to subtropical pine and temperate broadleaved forest at mid-elevations and alpine meadows at the higher elevations (Datta et al. 2008). This variation in habitats support a diverse array of fauna. Important mammalian species of Namdapha Tiger Reserve are tiger (*Panthera tigris*), leopard (*Panthera pardus*), clouded leopard (*Neofelis nebulosa*), Asiatic golden cat (*Catopuma temminckii*), marbled cat (*Pardofelis marmorata*), leopard cat (*Prionailurus bengalensis*), dhole (*Cuon alpinus*), Himalayan black bear (*Ursus thibatanus*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), serow (*Capricornis thar*), red goral (*Nemorhaedus baileyi*), Arunachal macaque (*Macaca munzala*), hoolock gibbon (*Hoolock hoolock*), amongst others.

Figure 12.54

Camera trap layout in Namdapha Tiger Reserve, 2018



RESULTS

Camera Trap Results

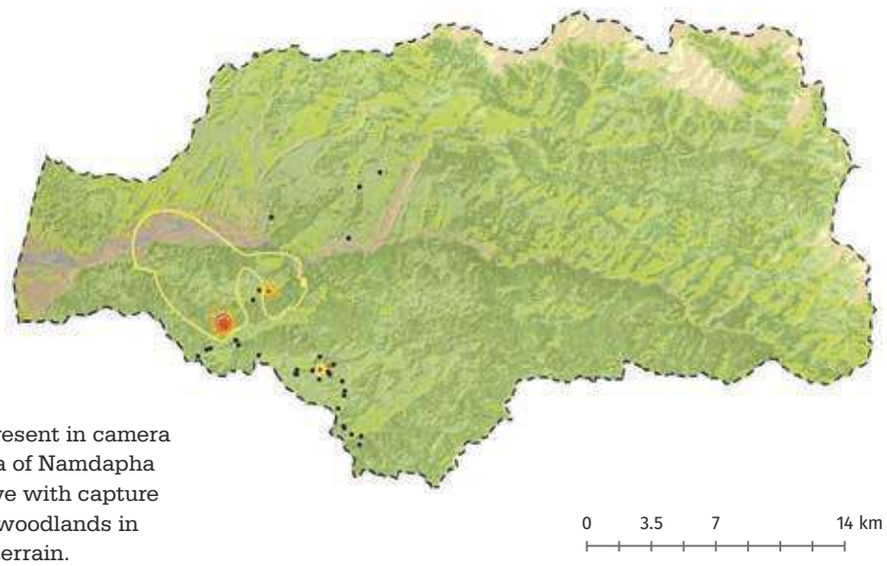
Opportunistic camera-trapping was done for the All India Tiger Monitoring exercise in Namdapha Tiger Reserve (Table 12.15) by the Forest Department. However, no tiger images were obtained during the sampling period.

Sampling details	Counts
Camera points	36
Trap nights (effort)	1725

Table 12.15
Sampling details for Namdapha Tiger Reserve, 2018.

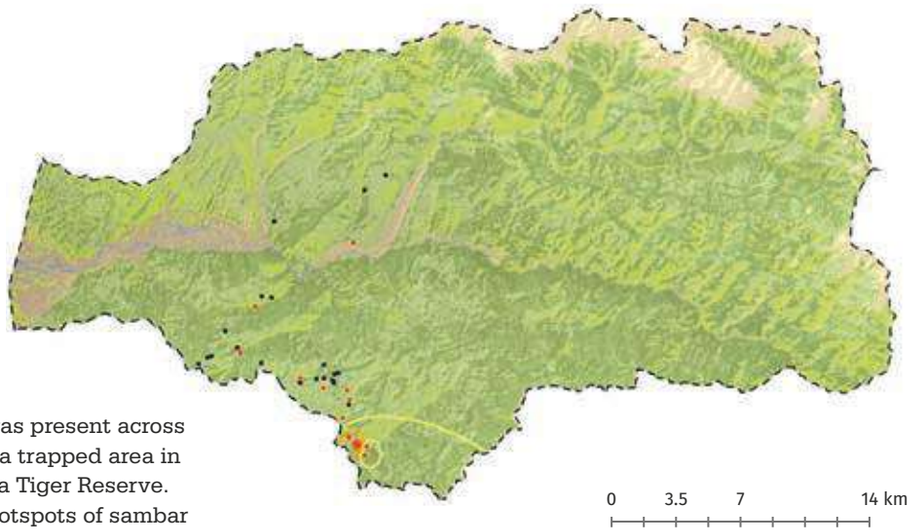
Distribution of Major Mammalian Fauna Found in Namdapha Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species captures rates.



Gaur was present in camera trapped area of Namdapha Tiger Reserve with capture hotspots in woodlands in undulating terrain.

Figure 12.55
Distribution and relative spatial abundance of gaur in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures



Sambar was present across the camera trapped area in Namdapha Tiger Reserve. Capture hotspots of sambar were in woodlands in moderately hilly terrain.

Figure 12.56
Distribution and relative spatial abundance of sambar in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

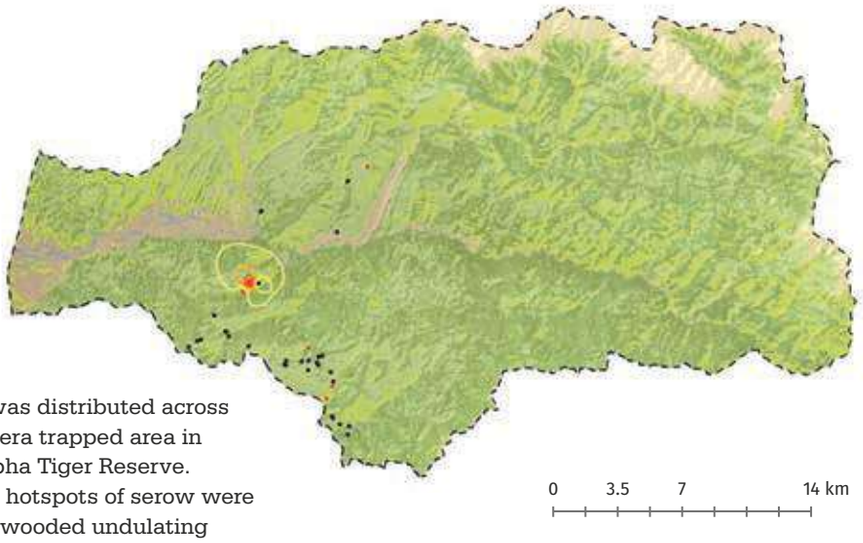


Figure 12.57

Distribution and relative spatial abundance of serow in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Serow was distributed across the camera trapped area in Namdapha Tiger Reserve. Capture hotspots of serow were were in wooded undulating terrain.

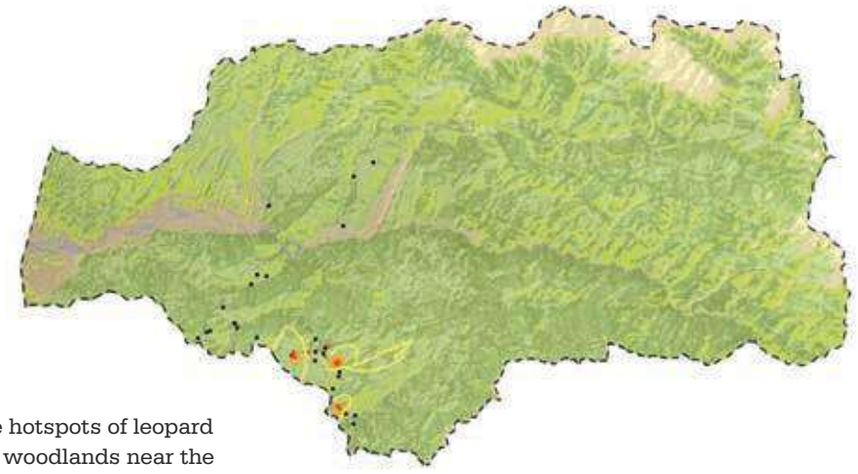


Figure 12.58

Distribution and relative spatial abundance of leopard in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Capture hotspots of leopard were in woodlands near the southern boundary.

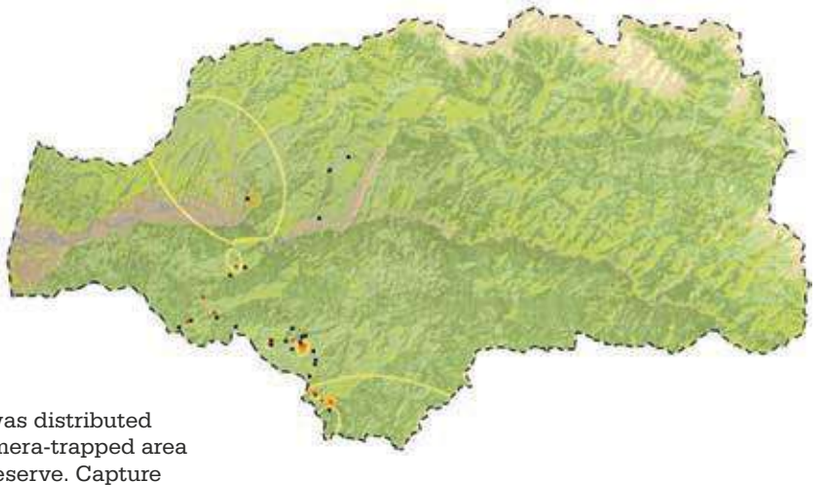
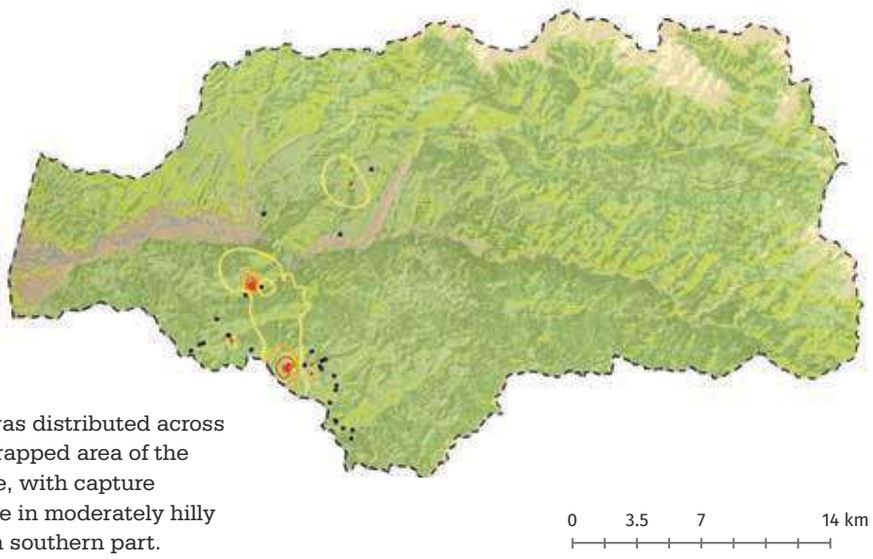


Figure 12.59

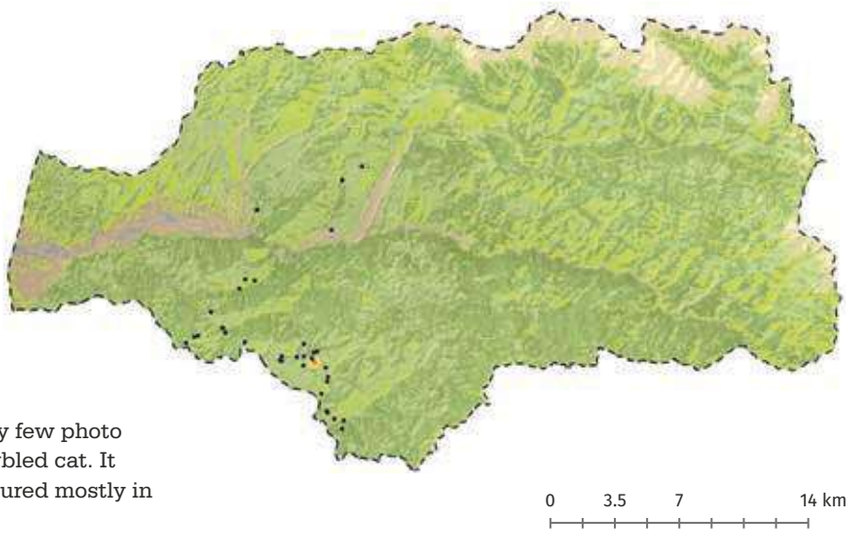
Distribution and relative spatial abundance of leopard cat in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Leopard cat was distributed across the camera-trapped area of the Tiger Reserve. Capture hotspots of leopard cat were in moderately hilly woodlands.



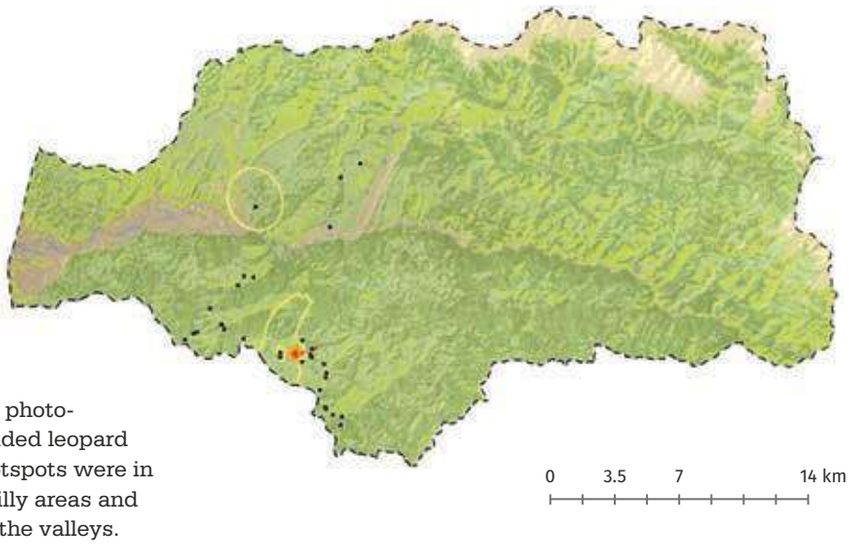
Golden cat was distributed across the camera-trapped area of the Tiger Reserve, with capture hotspots were in moderately hilly woodlands in southern part.

Figure 12.60
Distribution and relative spatial abundance of golden cat in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures



There were very few photo captures of marbled cat. It was photo captured mostly in hilly woodland.

Figure 12.61
Distribution and relative spatial abundance of marbled cat in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures



There were few photo-captures of clouded leopard with capture hotspots were in woodlands in hilly areas and as well as near the valleys.

Figure 12.62
Distribution and relative spatial abundance of clouded leopard in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

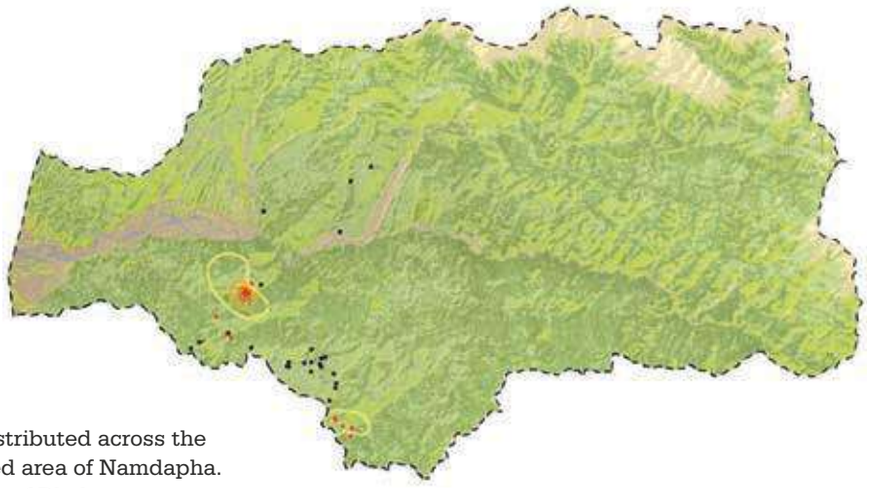


Figure 12.63

Distribution and relative spatial abundance of dhole in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Dhole were distributed across the camera trapped area of Namdapha. Photo captures of Dhole were more near the southern boundary in the undulating woodlands of the tiger reserve.

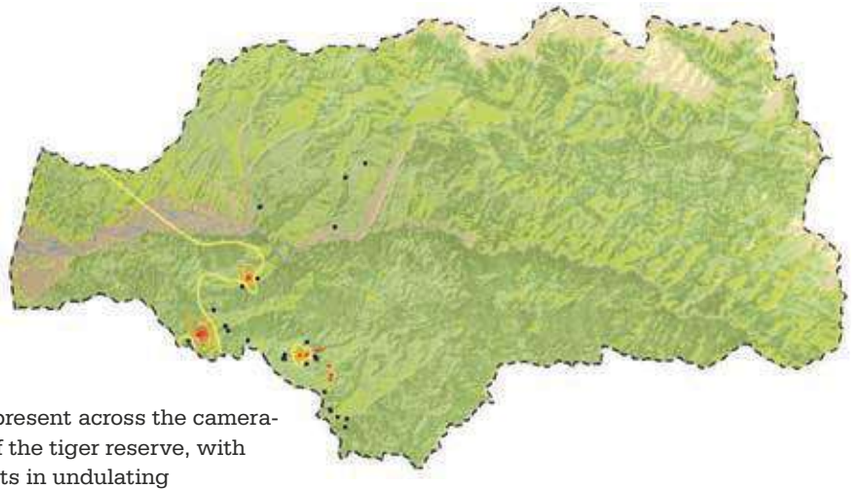


Figure 12.64

Distribution and relative spatial abundance of Sun bear in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Sun bear was present across the camera-trapped area of the tiger reserve, with capture hotspots in undulating woodlands and as well as valleys.

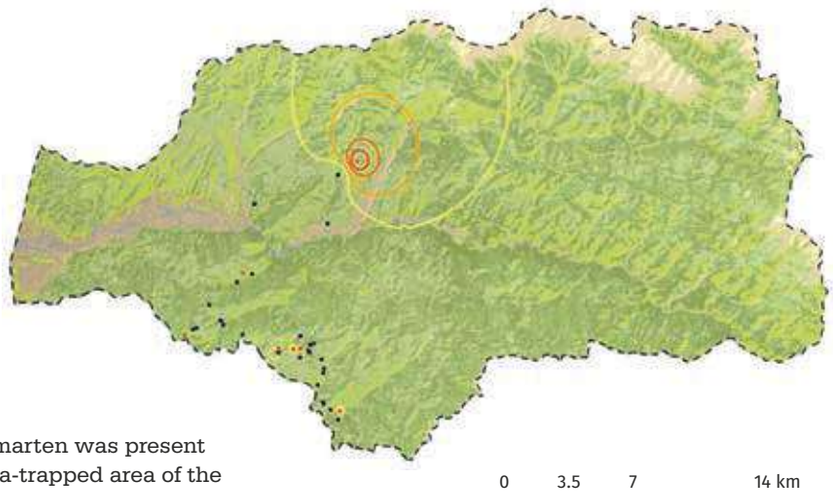


Figure 12.65

Distribution and relative spatial abundance of yellow throated marten in Namdapha Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Yellow throated marten was present across the camera-trapped area of the tiger reserve. Capture hotspots of yellow throated marten were in valleys.

Relative Abundance of all Photocaptured Species in Namdapha Tiger Reserve

25 mammal species were photo-captured during the sampling session in Namdapha Tiger Reserve, some of which are endemic to Indo-Malayan realm. Barking deer was the most common species followed by Sambar. Hog badger, spotted linsang, marbled cat and masked palm civet were the rarest species to get photo-captured.

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Asiatic brush-tailed porcupine	0.35	288
Assamese macaque	0.52	192
Barking deer	10.55	9
Clouded leopard	0.35	288
Common palm civet	2.14	47
Crab eating mongoose	0.17	575
Dhole	2.96	34
Gaur	0.35	288
Golden cat	0.70	144
Himalayan crestless porcupine	2.49	40
Hog badger	0.06	1725
Large Indian civet	1.39	72
Leopard	0.64	157
Leopard cat	1.10	91
Malayan sun bear	0.93	108
Marbled cat	0.12	863
Masked palm civet	0.12	863
Sambar	4.17	24
Serow	0.41	246
Small Indian civet	0.23	431
Smooth coated otter	0.06	1725
Spotted linsang	0.12	863
Stump tailed macaque	0.93	108
Wild pig	2.43	41
Yellow throated marten	1.51	66

Table 12.16
Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Namdapha Tiger Reserve, 2018

DISCUSSION

Although no tiger images were obtained from camera trap, but presence of tigers was confirmed by DNA profiling of carnivore scats collected during Phase I exercise.

Namdapha Tiger Reserve is a confluence zone between the two tiger subspecies which have a unique genetic structure and are a priority for conservation. Most wildlife use the productive valley habitats and care needs to be taken to safe guard these prime habitats from developmental activities as they are often used for development of roads and for agriculture.

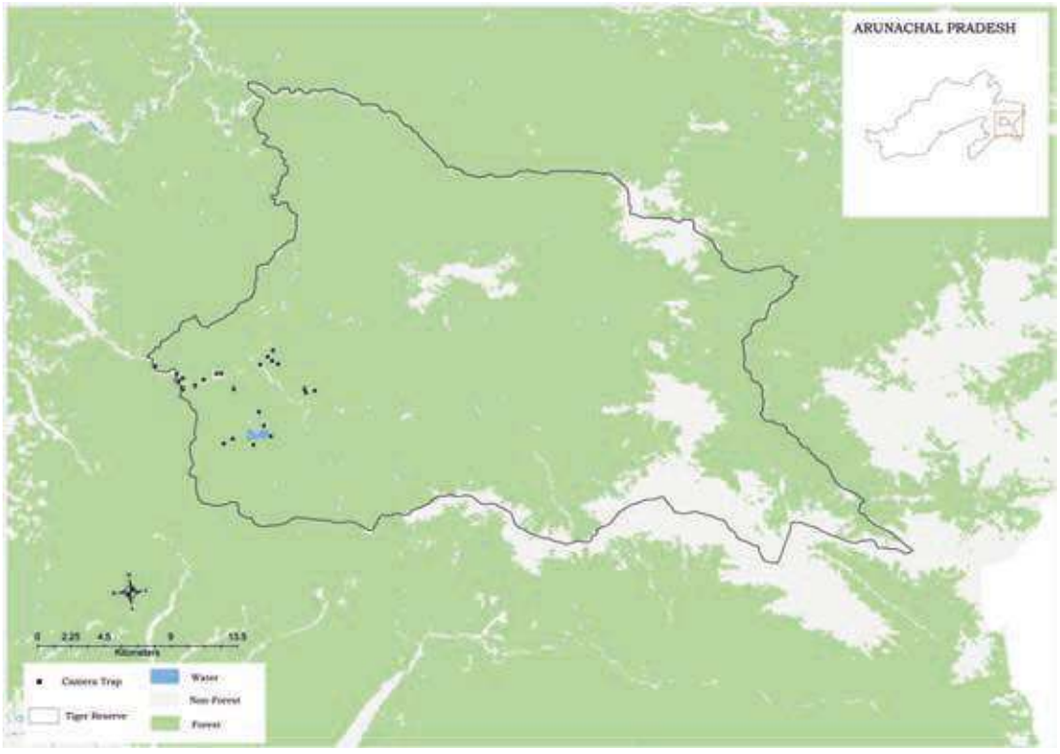
KAMLANG TIGER RESERVE

INTRODUCTION

Earlier known as Kamlang Wildlife Sanctuary, Kamlang is the youngest i.e. 50th Tiger Reserve of the country. Geographically located in the south-eastern part of Lohit district (between 27°39' to 28° N and 96°26' to 96°55'E), Kamlang Tiger Reserve spreads over 783 km² of which 671 km² area is designated as core habitat. The reserve is named after the Kamlang river which flows through the reserve and eventually joins Lohit river. In the north, Kamlang is demarcated by Lang River, while the international boundary with Myanmar in the east and Namdapha Tiger Reserve in the south delineates its southern extent. Dapha Bhum peak in the south west of the reserve separates it from Nampdapha Tiger Reserve. Due to the elevation gradient, the habitat types are diverse. The vegetation types comprising of wet evergreen tropical forests in the foothills and sub-tropical and temaperate in higher reaches (Rao and Chowlu 2006). Common tree species are *Canarium resiniferum, Terminalia chebula, Gmelina arborea, Amora wallichi* etc. Kamlang harbours rich primate diversity which comprises hoolock gibbon (*Hoolock hoolock*), capped langur (*Trachypithecus pileatus*), Assamese macaque (*Macaca assamensis*), stump tailed macaque (*Macaca arctoides*) (Choudhury 1996). Other than arboreal primate species, Kamlang has rich faunal assemblage, which includes tiger (*Panthera tigris*), leopard (*Panthera pardus*), clouded leopard (*Neofelis nebulosa*), Asiatic golden cat (*Catopuma temminckii*), leopard cat (*Prionailurus bengalensis*), marbled cat (*Pardofelis marmorata*), black bear (*Ursus thibatanus*), large Indian civet (*Viverra zibetha*), masked palm civet (*Paguma larvata*), sambar (*Rusa unicolor*), barking deer (*Munticus vaginalis*), serow (*Capricornis thar*).

Figure 12.66

Camera trap layout in Kamlang Tiger Reserve, 2018



RESULTS

Camera Trap Results

After the declaration as a Tiger Reserve, this was the first time that camera trap exercise was conducted by the Forest Department. However, no tiger images were obtained during the sampling period (Table 12.17). Camera trapping was done in the south-western part of the Tiger Reserve.

Sampling details	Counts
Camera points	25
Trap nights (effort)	573

Table 12.17
Sampling details for Kamlang Tiger Reserve, 2018.

Distribution of Major Mammalian Fauna Found in Kamlang Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species captures rates.

Gaur was present in the camera trapped area of Kamlang Tiger Reserve with capture hotspots in woodlands and near the Glou lake.

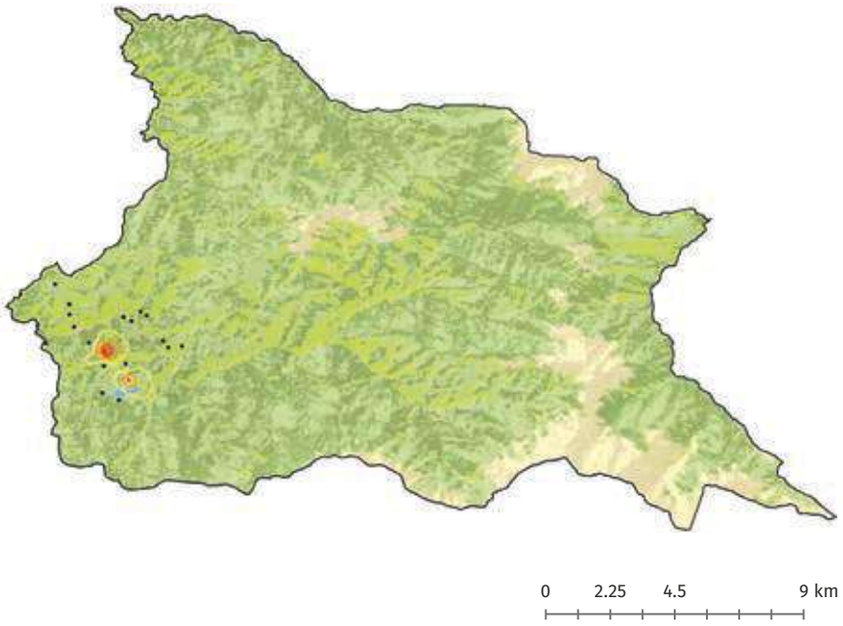


Figure 12.67
Distribution and relative spatial abundance of gaur in Kamlang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Serow was present across the camera trapped area in Kamlang Tiger Reserve with capture hotspots in woodlands near the northern boundary.

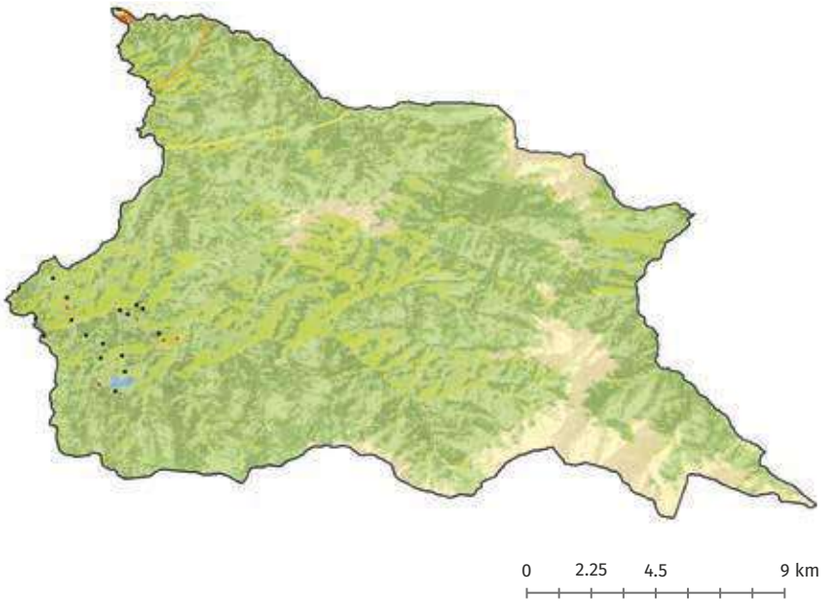


Figure 12.68
Distribution and relative spatial abundance of serow in Kamlang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

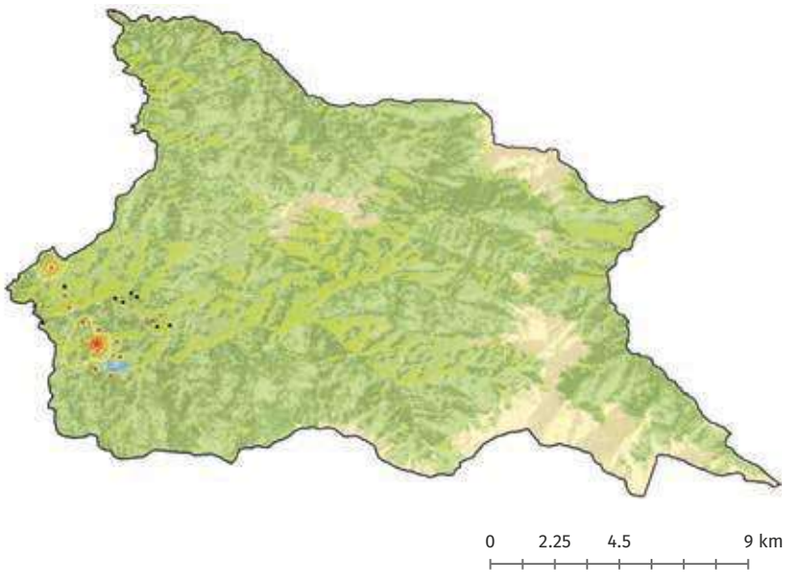


Figure 12.69

Distribution and relative spatial abundance of stump-tailed macaque in Kamlang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Photo captures of stump-tailed macaque were in woodlands across the camera trapped area.

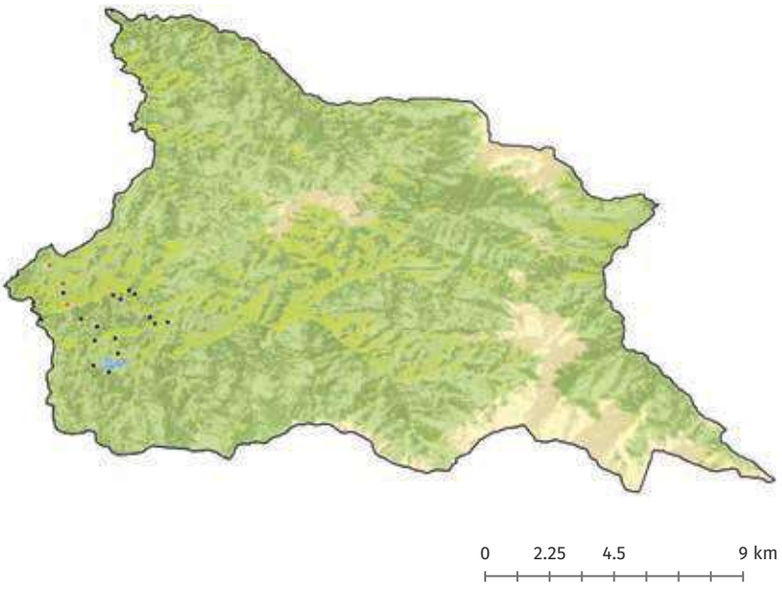


Figure 12.70

Distribution and relative spatial abundance of clouded leopard in Kamlang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

There were fewer photo captures of clouded leopard in the camera trapped area in Kamlang Tiger Reserve.

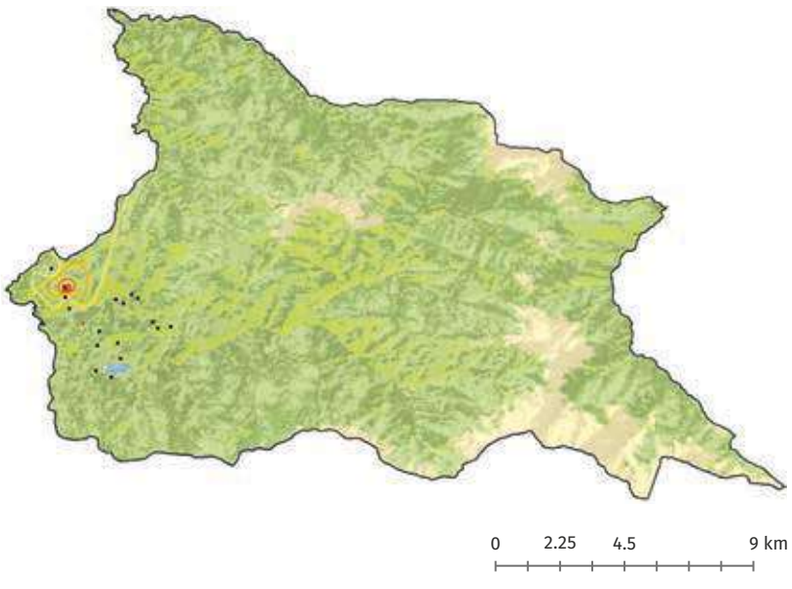


Figure 12.71

Distribution and relative spatial abundance of golden cat in Kamlang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Capture hotspot of golden cat was from woodlands adjacent to the southwestern boundary of Kamlang Tiger Reserve.

Marbled cat had a larger distribution in Kamlang Tiger Reserve with captures across the camera trapped area.

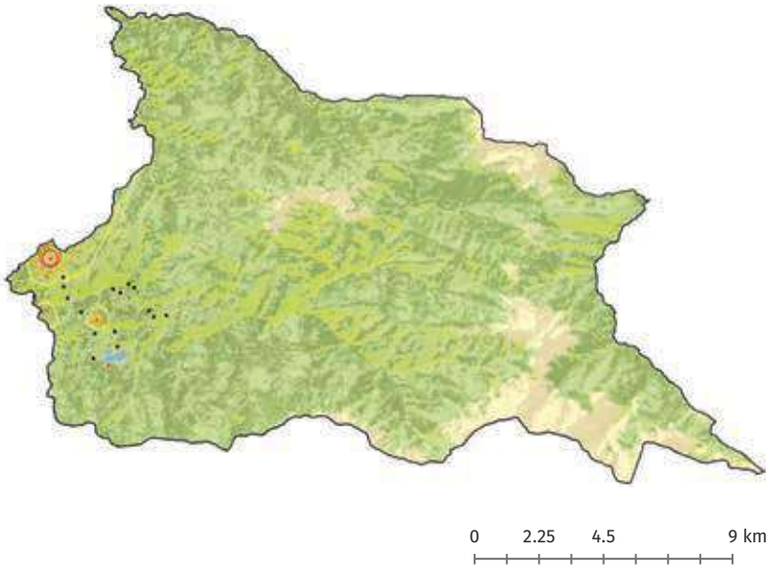


Figure 12.72

Distribution and relative spatial abundance of marbled cat in Kamlang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Leopard cat was present across the camera trapped area of Kamlang Tiger Reserve. Capture hotspots of leopard cat were in undulating woodlands.

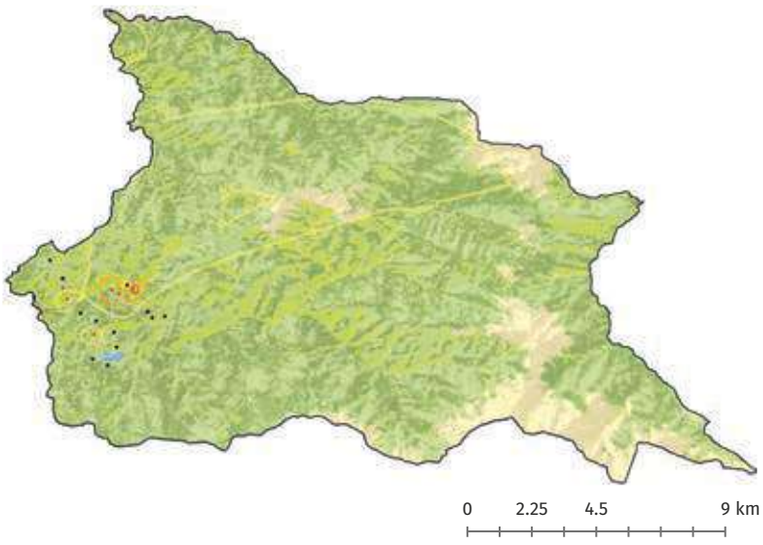


Figure 12.73

Distribution and relative spatial abundance of leopard cat in Kamlang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Black bear were photo-captured primarily from the central part of the sampled area.

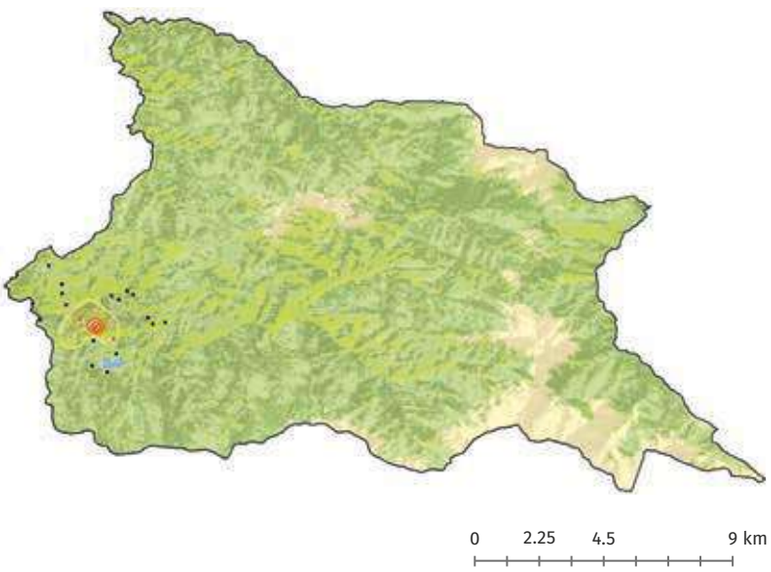


Figure 12.74

Distribution and relative spatial abundance of black bear in Kamlang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

There are very few photo captures of Golden jackal in Kamlang Tiger Reserve with captures only from the woodlands.

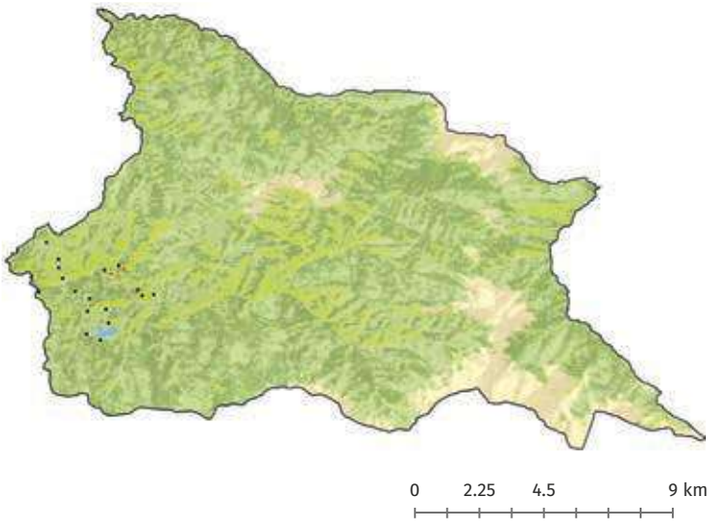


Figure 12.75

Distribution and relative spatial abundance of golden jackal in Kamlang Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Table 12.12

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Kamlang Tiger Reserve, 2018

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Asiatic brush-tailed porcupine	1.75	57
Assamese macaque	0.17	573
Barking deer	3.14	32
Chinese pangolin	0.17	573
Clouded leopard	0.17	573
Common palm civet	0.17	573
Domestic dog	0.17	573
Gaur	0.87	115
Golden cat	0.70	143
Golden jackal	0.70	143
Himalayan black bear	0.52	191
Himalayan crestless porcupine	0.17	573
Leopard cat	2.44	41
Malayan sun bear	0.17	573
Marbled cat	0.87	115
Masked palm civet	0.35	287
Mithun	4.54	22
Serow	0.52	191
Small Indian civet	0.17	573
Smooth coated otter	0.52	191
Spotted linsang	0.35	287
Stump tailed macaque	8.55	12
Wild pig	0.70	143
Yellow throated marten	2.62	38

Relative Abundance of all Photocaptured Species in Kamlang Tiger Reserve

Stump tailed macaque was the most common species (Table 12.12) followed by mithun and barking deer. Chinese pangolin, clouded leopard were among the rarest to get photo captured.

DISCUSSION

Tiger presence in Kamlang Tiger Reserve was confirmed by DNA profiling of the scat samples collected during Phase I. Kamlang and Namdapha Tiger Reserves form a large unit of forested area, and is important for in-situ conservation of tiger and other threatened species.

DIBANG WILDLIFE SANCTUARY

INTRODUCTION

Dibang Wildlife Sanctuary, situated in Upper Dibang Valley District (between 28°38' to 29°27'N and 95°17' and 96°38' E) in the most north-eastern corner of the country, spans over 4149 km^2 area (Gopi et al. 2014) and holds utmost importance for in-situ conservation of the high-altitude tigers with the help of the local community people. The sanctuary is bounded by the international boundary with Tibet Autonomous Council, People's Republic of China in the north, east and west. The sanctuary is crisscrossed by several rivers and rivulets, which are the tributaries of the Brahmaputra in later phase. The sanctuary is nestled in the Eastern Himalaya Biodiversity hotspot.

Vegetation of sanctuary is mostly Temperate broad-leaved forest, Temperate conifer forest to Sub-alpine and Alpine scrub. Dominant tree species are *Phyllostachys bambusoides, Arunadinaria spp, Michelia spp, Quercus spp, Pinus wallichiana* amongst many others. Due to the adverse climate and terrain, Dibang Wildlife Sanctuary has been poorly surveyed (Rahmani et al. 2016). Other than tigers (Panthera tigris), the sanctuary harbours several endemic and globally threatened mammalian and avian species. The protected area is home to takin (*Budorcas taxicolor*), serow (*Capricornis thar*), goral (*Naemorhodus goral*), barking deer (*Muntiacus vaginalis*), Asiatic golden cat (*Catopuma temminickii*), marbled cat (*Pardofelis marmorata*), leopard cat (*Prionailurus bengalensis*) etc.

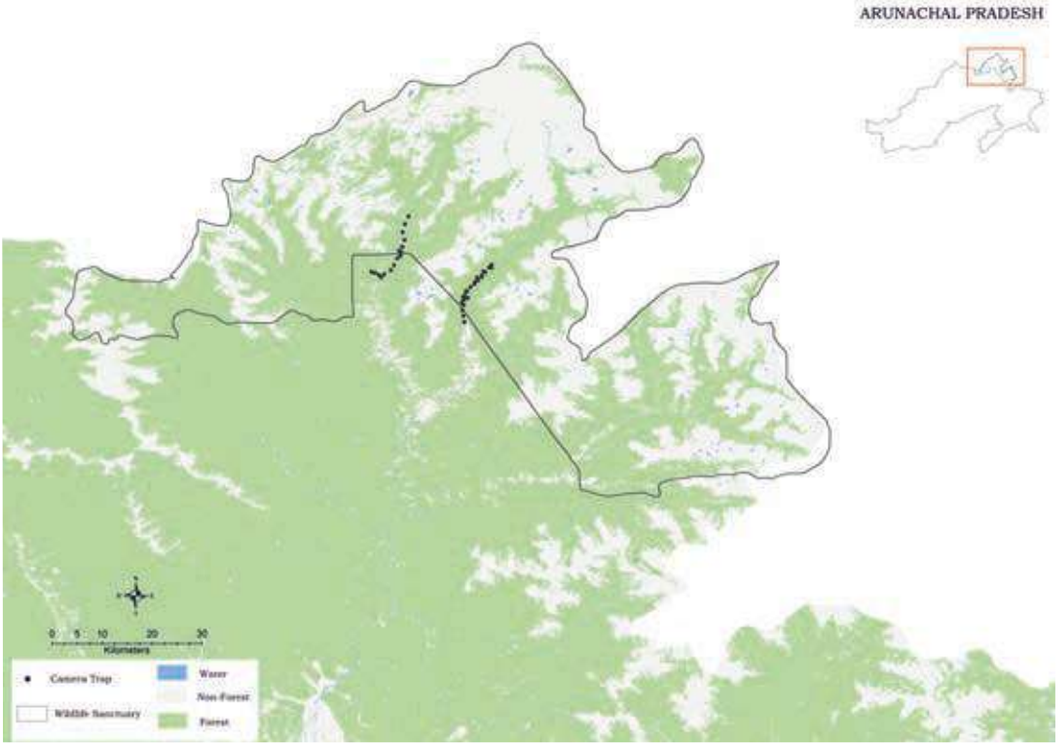


Figure 12.76
Camera trap layout in Dibang Wildlife Sanctuary, 2018

RESULTS

Camera Trap Results

A rapid field survey was carried out in 2014 during All India Tiger Estimation Exercise in Dibang Wildlife Sanctuary for tiger and prey (Gopi et al. 2014), where an adult individual tiger was photo-captured. Two adult individual tigers were photo-captured during the sampling session in 2018.

Table 12.18
Sampling details in Dibang Wildlife Sanctuary, 2018

Sampling details	Counts
Camera points	46
Trap-nights (effort)	1527
Unique tigers captured	2

DISCUSSION

Dibang Wildlife Sanctuary holds unique importance for in-situ conservation of this unique and genetically diverse lineage of tigers as the local aboriginal community consider tiger as their elder brother (Aiyadurai 2016). Though, this sanctuary supports a sizeable population of tigers (Adhikarimayum and Gopi 2018), compared to other Tiger Reserves of the state, a thorough sampling of the sanctuary and discussions with the aboriginal community are required before commencing any further legal notification.

BUXA TIGER RESERVE

INTRODUCTION

Buxa Tiger Reserve, spanning over 757.9 km^2 (between 23°30' to 23°50' N and 89°25' to 89°55' E), is situated in the Alipurduar district of West Bengal. Being located in the productive floodplains and foothills of the Eastern Himalayas known as Bengal Dooars, Buxa is an important biodiversity repository. International border with Bhutan forms the northern boundary and the eastern boundary is bounded by Sankosh River, while the southern and western boundaries are demarcated by mosaic of tea estates, human habitation and National Highway 31C. Several rivers namely Jainti, Rydak, Bala, Dima and some others intersect the Tiger Reserve.

Vegetation of Buxa Tiger Reserve is primarily Moist Tropical Forest and further sub divided into eight sub-types (Champion and Seth 1968) i.e. Sal forest, Moist Mixed/Dry Mixed Forest, Wet Mixed Forest, Semi-evergreen Forest, Evergreen Forest, Hill Forest, Savannah Forest and Riverine Forest. Dominant tree species are *Shorea robusta, Albizzia lebbeck, Dalbergia sissoo, Acacia catechu, Careya arborea, Dillenia pentagyna,* and *Butea monosperma*. Carnivore guild of Buxa Tiger Reserve comprises of leopard (*Panthera pardus*), leopard cat (*Prionailurus bengalensis*), Asiatic golden cat (*Catopuma temminckii*), jungle cat (*Felis chaus*), dhole (*Cuon alpinus*), common palm civet (*Paradoxurus hermaphroditus*) amongst others. Major herbivores are elephant (*Elephas maximus*), gaur (*Bos gaurus*), chital (*Axis axis*), sambar (*Rusa unicolor*), wild boar (*Sus scrofa*), hog deer (*Axis porcinus*) and serow (*Capricornis thar*).

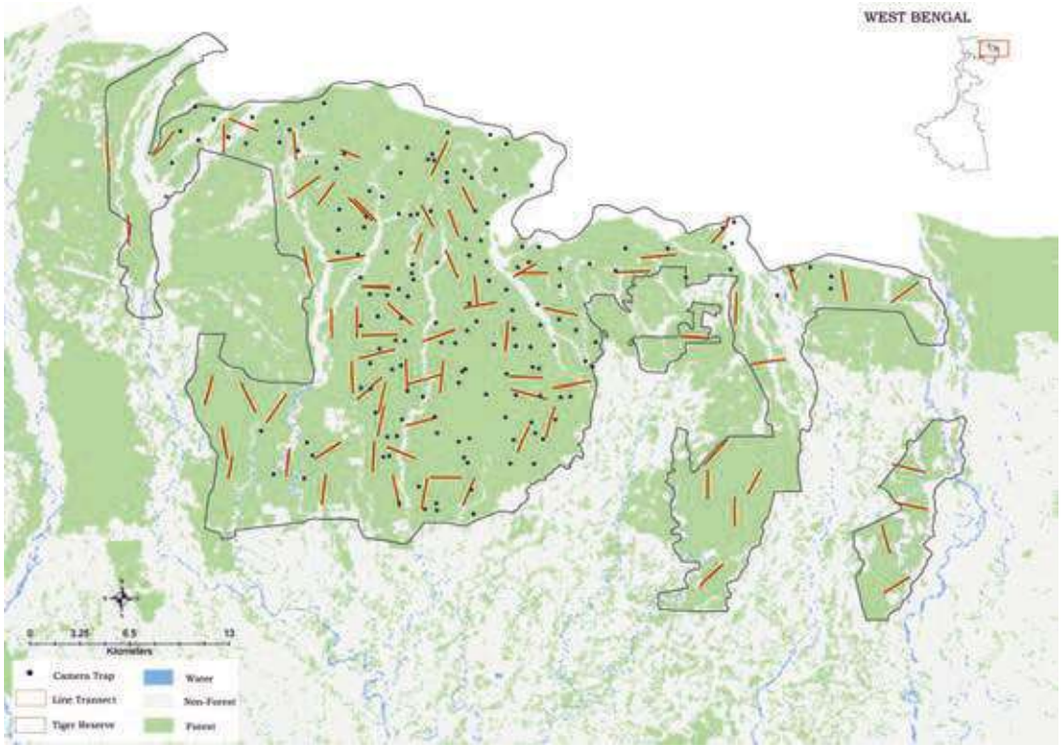


Figure 12.77
Camera trap and transect layout in Buxa Tiger Reserve, 2018

RESULTS

Camera Trap Results

Camera trapping was done by the Forest Department. However, no tiger images were obtained during the sampling period (Table 12.19).

Sampling details	Counts
Camera points	161
Trap nights (effort)	4176

Table 12.19
Sampling details for Buxa Tiger Reserve, 2018

Prey Density Estimates

A total of 97 transects were sampled in Buxa Tiger Reserve. The cumulative effort of the transects was 185.52 km. Species seen on transects were chital, wild pig, barking deer, sambar, elephant and gaur (Table 12.20). Due to very few observations, abundance estimates for sambar, elephant and gaur could not be obtained using distance sampling.

Table 12.20

Model statistics and parameter estimates of line transect (n=97, Total effort 185.52 km) based distance sampling for prey species in Buxa Tiger Reserve, 2018

Species	Effective strip width (SE)	#groups detected	Mean group size (SE)	Detection probability (SE)	Encounter rate (SE)	Group density/ sq.km (SE)	Individual density/ sq.km (SE)
Chital	38.03 (7.2)	17	4.76 (1.01)	0.41 (0.08)	0.09 (0.02)	1.2 (0.39)	5.74 (2.23)
Barking deer	23.55 (2.72)	47	1.19 (0.07)	0.47 (0.05)	0.25 (0.03)	5.38 (0.93)	6.41 (1.16)
Wild pig	26.86 (5.67)	16	2.23 (0.37)	0.54 (0.11)	0.09 (0.01)	1.61 (0.5)	3.68 (1.26)
Sambar	NA	4	NA	NA	0.02 (0.01)	NA	NA
Elephant	NA	5	NA	NA	0.03 (0.01)	NA	NA
Gaur	NA	6	NA	NA	0.03 (0.01)	NA	NA

Distribution of Major Mammalian Fauna Found in Buxa Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species captures rates. The black outline on the map represents the core area of Buxa Tiger Reserve.

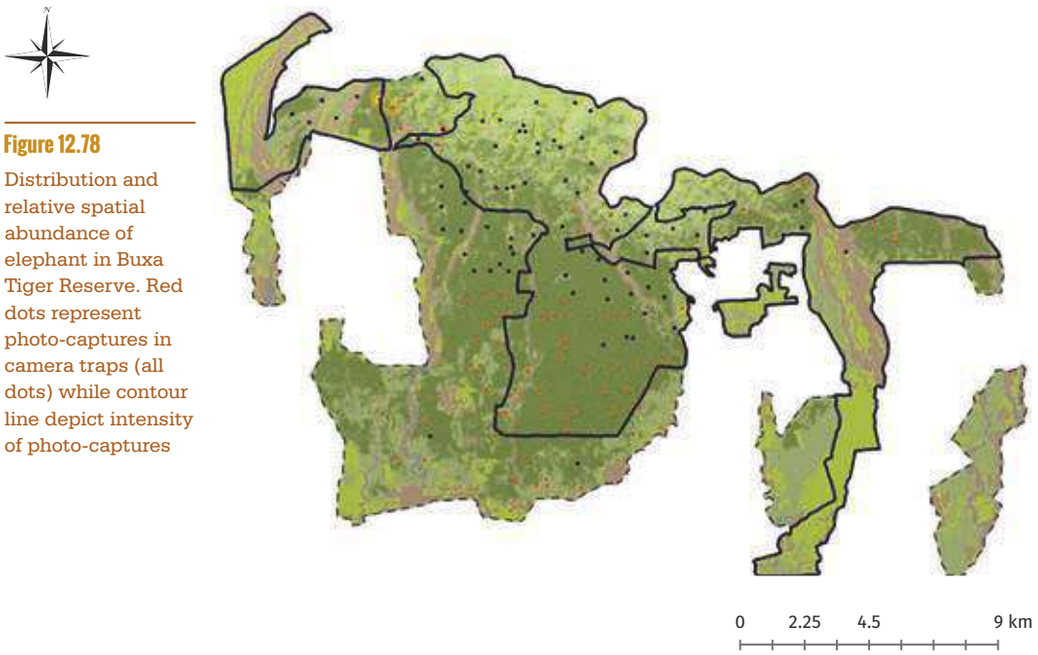


Figure 12.78

Distribution and relative spatial abundance of elephant in Buxa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Elephants was photo captured throughout the tiger reserve except in the hilly regions and in the buffer region of western part.

Photo captures of gaur were mostly in central and eastern part of the tiger reserve. Capture hotspots of gaur were high in the moderately hilly terrain near the international boundary with Bhutan in the eastern corridor habitat.

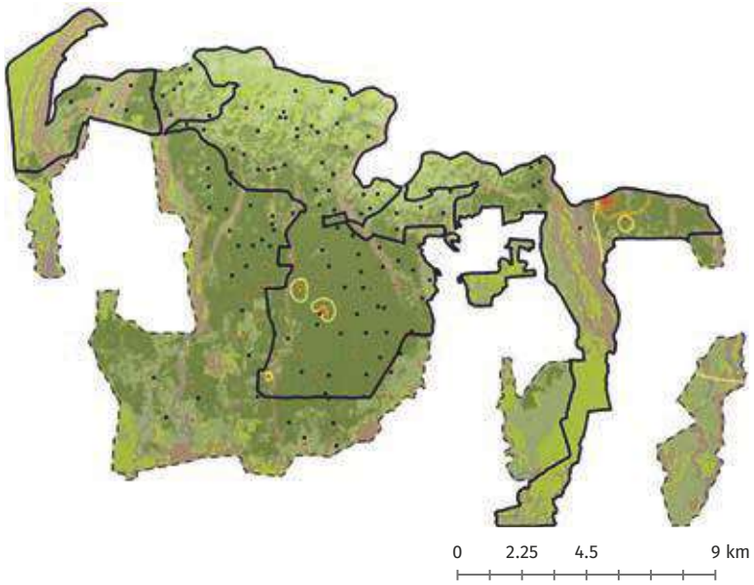


Figure 12.79

Distribution and relative spatial abundance of gaur in Buxa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

As a grassland specialist species, hog deer was present in pockets of grassland in the Tiger Reserve. Capture hotspots of hog deer were in grasslands adjacent to river in Hamiltonganj and Pana range.

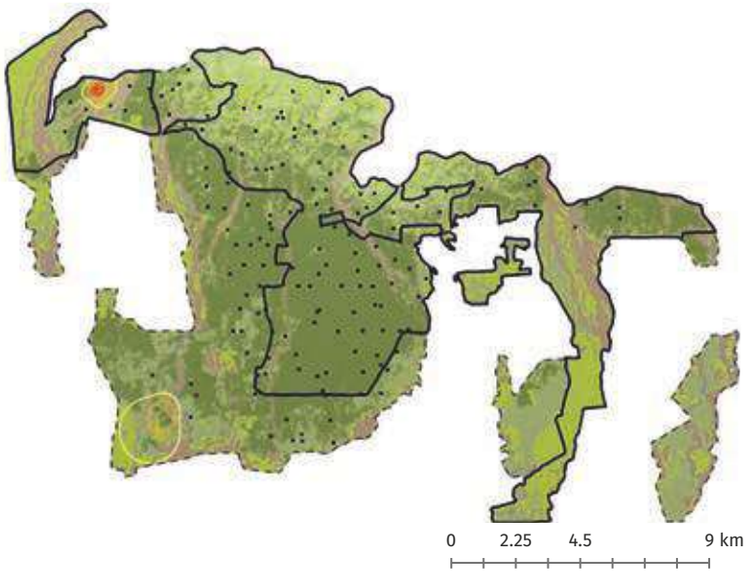


Figure 12.80

Distribution and relative spatial abundance of hog deer in Buxa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Leopard was distributed throughout the tiger reserve except in the hilly areas near to Bhutan. Capture hotspots of leopard were in woodlands in flat terrain in central and western part of the reserve.

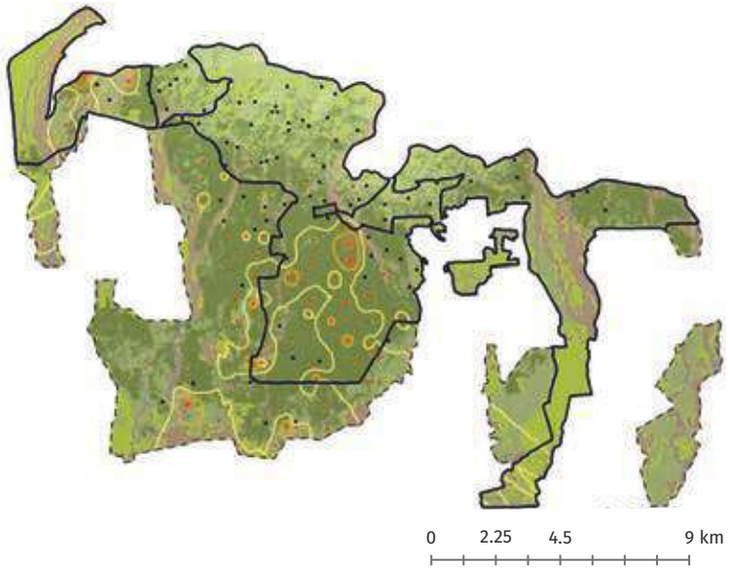


Figure 12.81

Distribution and relative spatial abundance of leopard in Buxa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

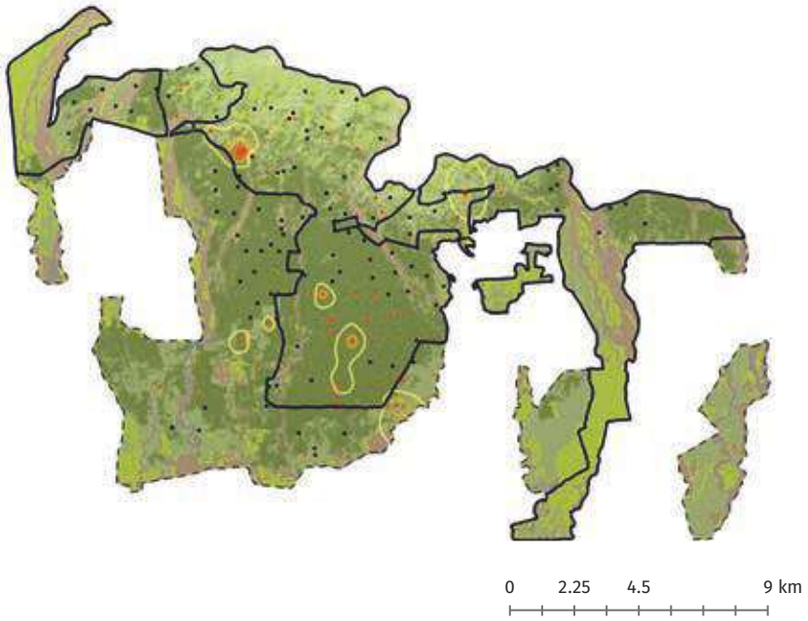


Figure 12.82

Distribution and relative spatial abundance of leopard cat in Buxa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Leopard cat was distributed across the Tiger Reserve. Capture hotspots of leopard cat were in woodlands and grasslands adjacent to rivers.

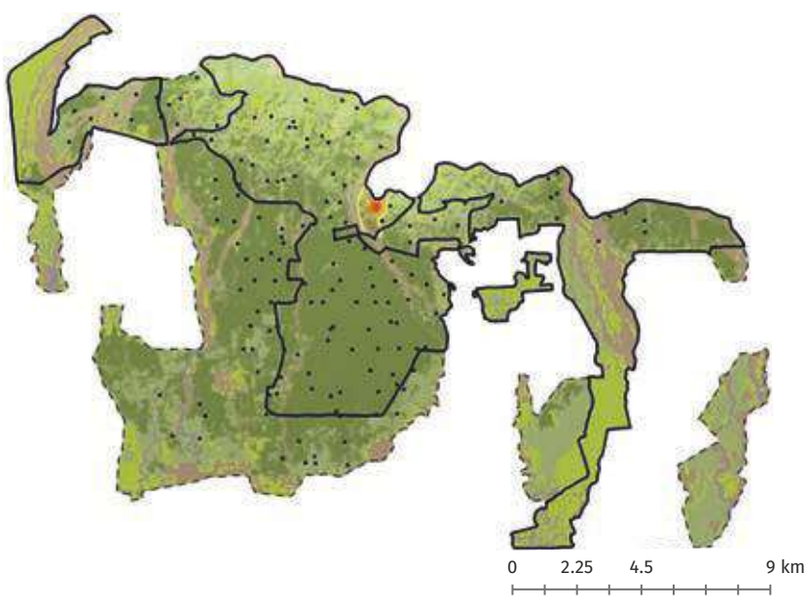


Figure 12.83

Distribution and relative spatial abundance of dhole in Buxa Tiger Reserve. Red dots represent photo-captures in camera traps while contour line depict intensity of photo-captures

Dhole photo captures were limited mostly to the hilly terrain adjacent to river in Jainti range of Buxa Tiger Reserve.

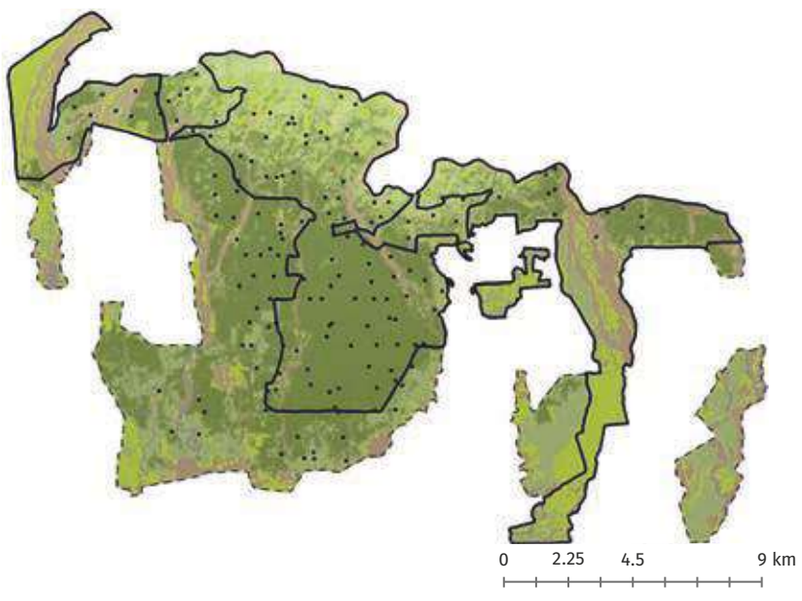


Figure 12.84

Distribution and relative spatial abundance of clouded leopard in Buxa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

The few clouded leopard photo-captures were from woodlands in hilly terrain in Buxaduar range of the tiger reserve.

Jungle cat photo-captures was sporadic but from across the tiger reserve. Capture hotspots of jungle cat were in woodland and open grasslands near rivers.

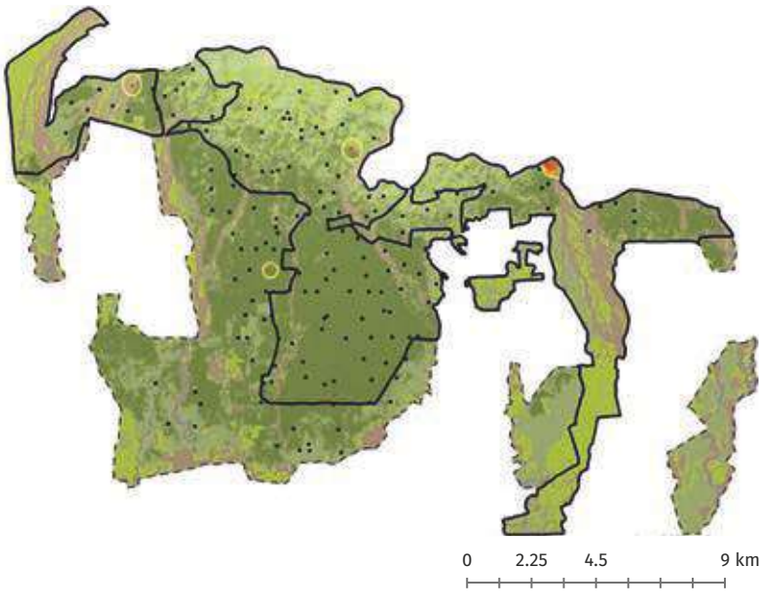


Figure 12.85
Distribution and relative spatial abundance of jungle cat in Buxa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Marbled cat distribution was limited to the woodlands near the river in Jainti range.

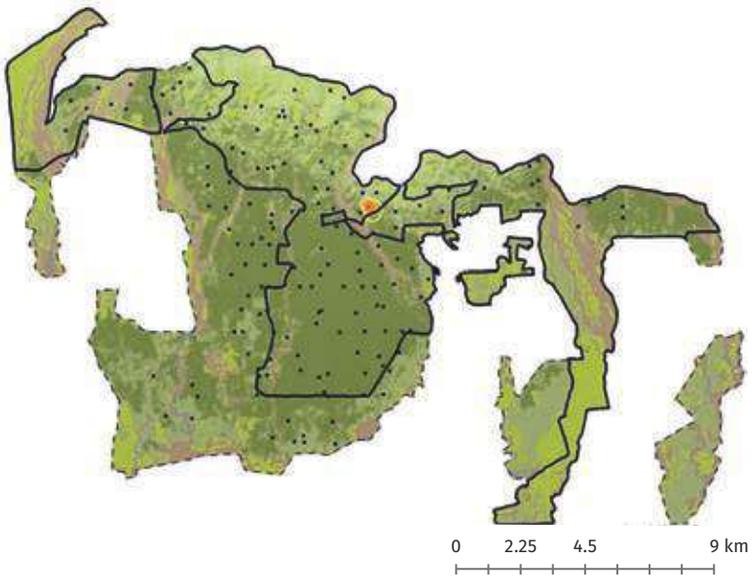


Figure 12.86
Distribution, relative spatial abundance of marbled cat in Buxa Tiger Reserve. Red dots represent photo-captures in camera traps while contour line depict intensity of photo-captures

Yellow throated marten was distributed across the Tiger Reserve with capture hotspots were in woodlands in hilly terrain of Jainti and Buxaduar range.

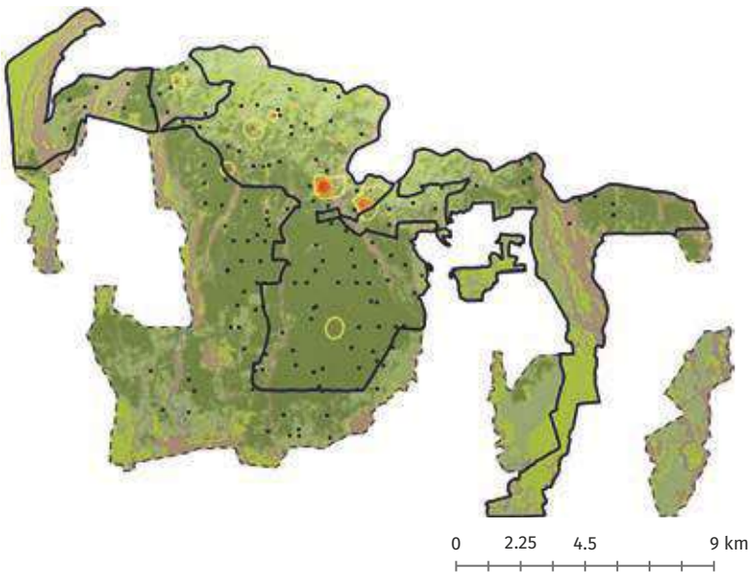


Figure 12.87
Distribution and relative spatial abundance of yellow throated marten in Buxa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Table 12.21

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in Buxa Tiger Reserve, 2018

Species	No. of photos per 100 trap nights	No. of trap nights required to get single capture
Barking deer	14.56	7
Black naped hare	1.05	95
Chital	6.66	15
Clouded leopard	0.02	4176
Common palm civet	3.42	29
Crab eating mongoose	3.50	29
Dhole	0.17	597
Domestic dogs	6.73	15
Elephant	15.28	7
Gaur	5.08	20
Golden cat	0.07	1392
Golden jackal	0.10	1044
Goral	0.10	1044
Himalayan crestless porcupine	0.93	107
Hog deer	0.07	1392
Indian grey mongoose	0.38	261
Jungle cat	0.26	380
Large Indian civet	3.74	27
Leopard	9.91	10
Leopard cat	4.00	25
Livestock	38.17	3
Marbled cat	0.05	2088
Masked palm civet	0.48	209
Monitor lizard	0.19	522
Peafowl	11.25	9
Red jungle fowl	8.64	12
Rhesus macaque	6.90	15
Sambar	15.25	7
Serow	0.12	835
Small Indian civet	1.63	61
Wild pig	9.12	11
Yellow throated marten	0.29	348

Relative Abundance of all Photocaptured Species in Buxa Tiger Reserve

Diverse array of mammalian and avian species were photo captured during the sampling period in Buxa Tiger Reserve. Elephant and sambar were the most common species (Table 12.21). Clouded leopard was the rarest photo captured species.

DISCUSSION

The RAI index suggests that compared to other areas the density of all wildlife were low and a matter of concern. Since reintroduction/supplementation of tigers is being considered for this Tiger Reserve, this should only be done after tiger prey density recovers to over 25 individuals per km^2. Major investments are required for protection, reduction of human impacts especially livestock grazing and address alternative livelihoods for local communities.

GORUMARA NATIONAL PARK

INTRODUCTION

Gorumara National Park is geographically located in the Jalpaiguri district (between 26°43' to 26°47' N and 88°47' to 88°52' E) and spread over an area of 79.85 km^2. Gorumara National Park is crisscrossed by Murti, Indong and Garati rivers and their rivulets. These three rivers ultimately meet with the Jaldhaka river in the eastern side of the Park. Situated in the foothills of Eastern Himalaya, Gorumara harbors rich biodiversity and is recognized as IBA (Rahmani et al. 2016). Due to its location in the Dooars and the flood plain, the vegetation type can be classified into Tropical moist deciduous, Tropical dry deciduous and Semi-evergreen forest (Champion and Seth 1968). Important tree species of Gorumara are *Shorea robusta, Lagerstroemia parviflora, Albizia procera, Terminalia arjuna, Terminalia bellirica, Bombax ceiba, Acacia catechu*, etc. The diverse habitat types of Gorumara is home to a rich mammalian assemblage, which includes greater one horned rhinoceros (*Rhinoceros unicornis*), elephant (*Elephas maximus*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*), chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), wild pig (*Sus scrofa*), among others.

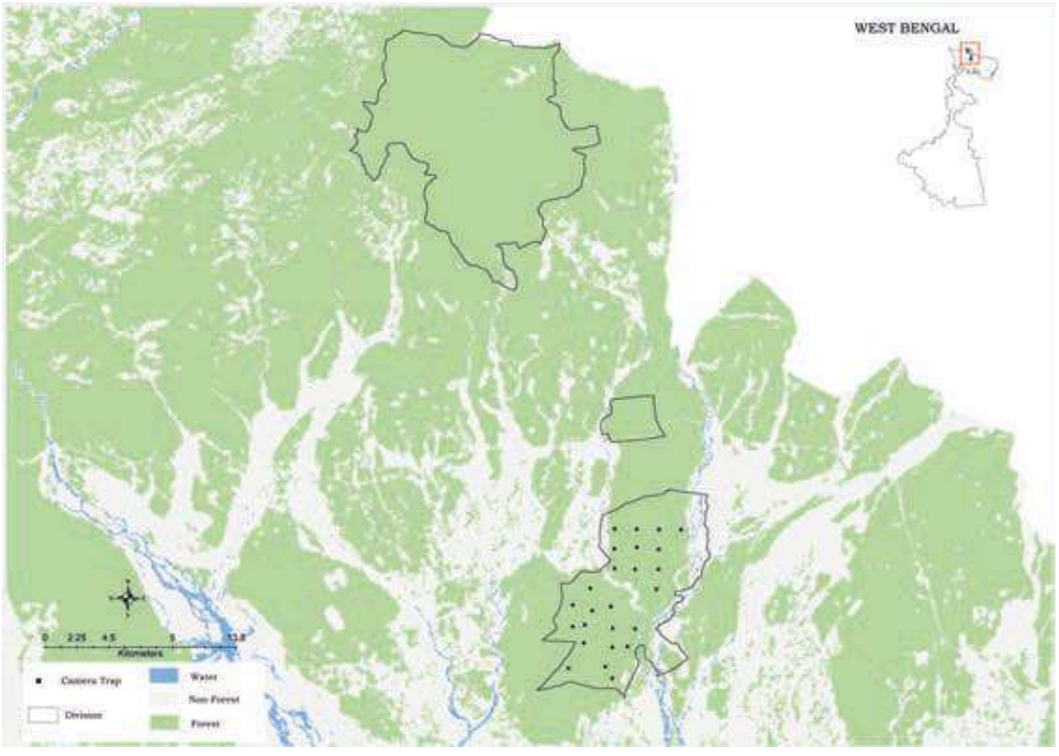


Figure 12.88
Camera trap layout in Gorumara National Park, 2018

RESULTS

Camera Trap Results

Camera trapping was carried out in Gorumara National Park for the first time by the Forest Department. However, no tiger image was obtained during the sampling period (Table 12.22).

Sampling details	Counts
Camera points	25
Trap-nights (effort)	576

Table 12.22
Sampling details in Gorumara National Park, 2018

JALDAPARA WILDLIFE SANCTUARY

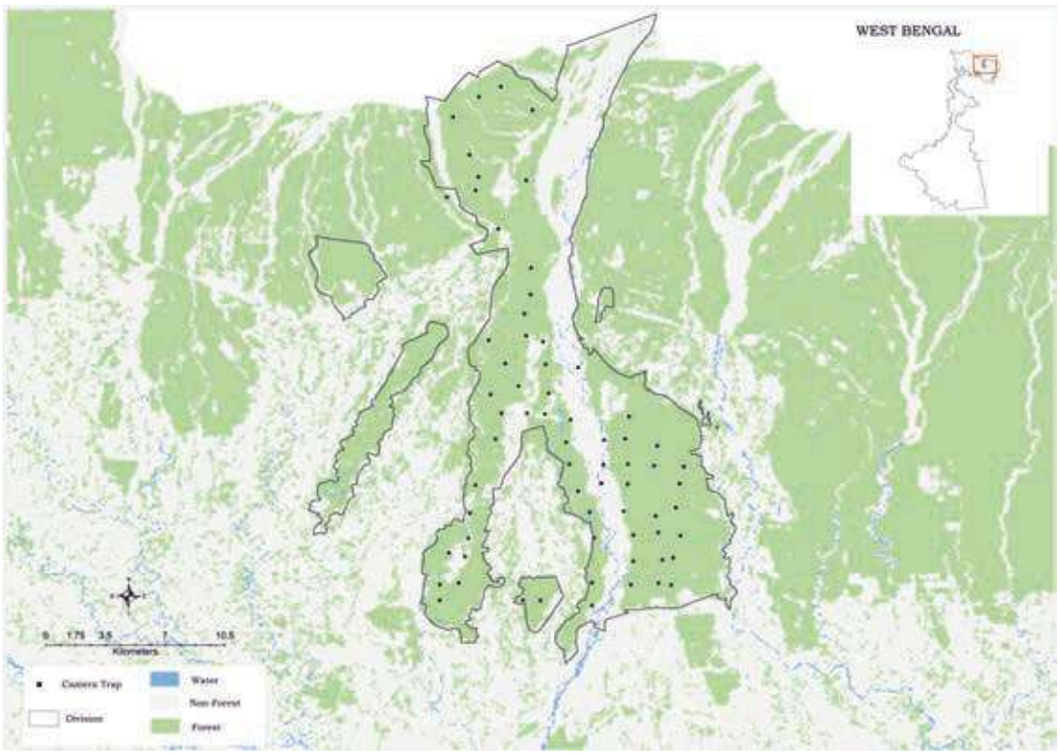
INTRODUCTION

Jaldapara Wildlife Sanctuary is situated in the Jalpaiguri district (26°30' to 26°50' N and 89°12' and 89°24' E) and spanned across 216.5 km^2. The river Torsa and many other rivulets intersect the wildlife sanctuary. The fertile flood plains support tall grasslands and diverse vegetation in the sanctuary. Jaldapara supports a sizeable population of greater one horned rhinoceros and thus holds a great importance for in-situ conservation of this perissodactyl in the state of West Bengal. Jaldapara Wildlife Sanctuary is also recognized as an IBA (Rahmani et al. 2016).

Vegetation types of the sanctuary includes mostly deciduous forest, which is further sub-divided into Tropical moist deciduous, tropical dry deciduous, tropical dry evergreen and tropical grassland (Rahmani et al.2016). Important tree species are *Shorea robusta, Albizia lebbek, Acacia catechu, Bombax ceiba, Dalbergia sissoo*, etc. Jaldapara harbours a large faunal assemblage, which comprises greater one horned rhinoceros (*Rhinoceros unicornis*), elephant (*Elephas maximus*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*), chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), wild pig (*Sus scrofa*) etc.

Figure 12.89

Camera trap layout in Jaldapara Wildlife Sanctuary, 2018



RESULTS

Camera Trap Results

Camera trapping was carried out in Jaldapara Wildlife Sanctuary for the first time by the Forest Department. However, no tiger image was obtained during the sampling period (Table 12.23).

Table 12.23

Sampling details in Jaldapara Wildlife Sanctuary, 2018

Sampling details	Counts
Camera points	65
Trap-nights (effort)	1404

INTANKI NATIONAL PARK

INTRODUCTION

Intanki National park is the only national park in Nagaland and is located in Peren district (25°18' to 25°43'N and 93°15' and 93°43'E) (PA network WII ENVIS). This park spreads over an area of 202.02 km^2. Dhansiri river on the north separates the national park from the Dhansiri Reserve Forest of Karbi Anglong Autonomous Council (Assam). Many rivers namely Monglu, Intanki, Doilung and several rivulets traverse the national park and join Dhansiri river at later stage. Major vegetation type of Intanki can be classified into tropical semi-evergreen, tropical dry deciduous and tropical moist deciduous forests (Champion and Seth 1968). Important tree species are *Sterospermum chelonoides, Pterospermum acerifolium, Terminalia myriocarpa, Phoebe goalparensis, Cedrella toona, Bombax ceiba, Gmelina arborea, Dillenia indica* etc. (Management Plan). Intanki lies in the "Indo-Burma Biodiversity Hotspot" recognized as an IBA (Rahmani et al 2016). Faunal assemblage of Intanki includes elephant (*Elephas maximus*), gaur (*Bos gaurus*), wild pig (*Sus scrofa*), sambar (*Rusa unicolor*), serow (*Capricornis thar*), goral (*Naemorhedus goral*), hoolock gibbon (*Hoolock hoolock*), rhesus macaque (*Macaca mulatta*), stump-tailed macaque (*Macaca arctoides*), Bengal slow loris (*Nycticebus bengalensis*), leopard (*Panthera pardus*), clouded leopard (*Neofelis nebulosa*), Asiatic golden cat (*Catopuma temminckii*), marbled cat (*Pardofelis marmorata*), dhole (*Cuon alpinus*), Himalayan black bear (*Ursus thibatanus*), large Indian civet (*Viverra zibetha*), common palm civet (*Paradoxurus hermaphroditus*), yellow-throated marten (*Martes flavigula*) etc.

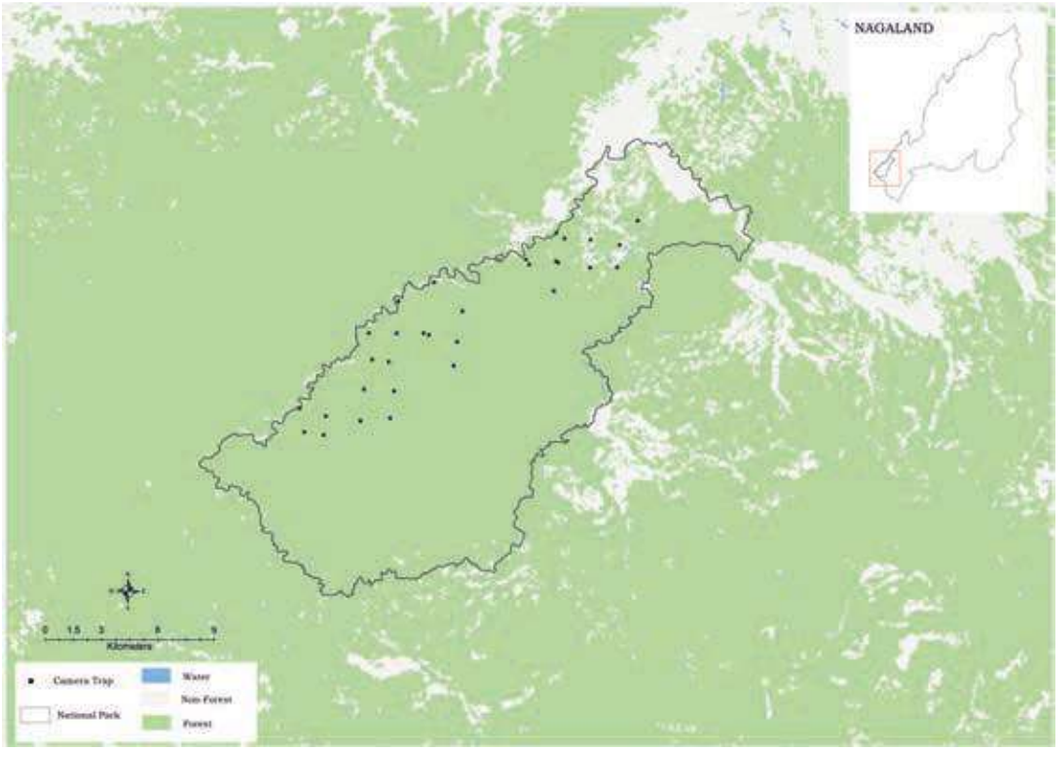


Figure 12.90
Camera trap layout in Intanki National Park, 2018

RESULTS

Camera Trap Results

Camera trapping was done in the western and north-eastern part of the national park. However, no tiger images were obtained during the sampling period (Table 12.24).

Sampling details	Counts
camera points	25
Trap-nights (effort)	1188

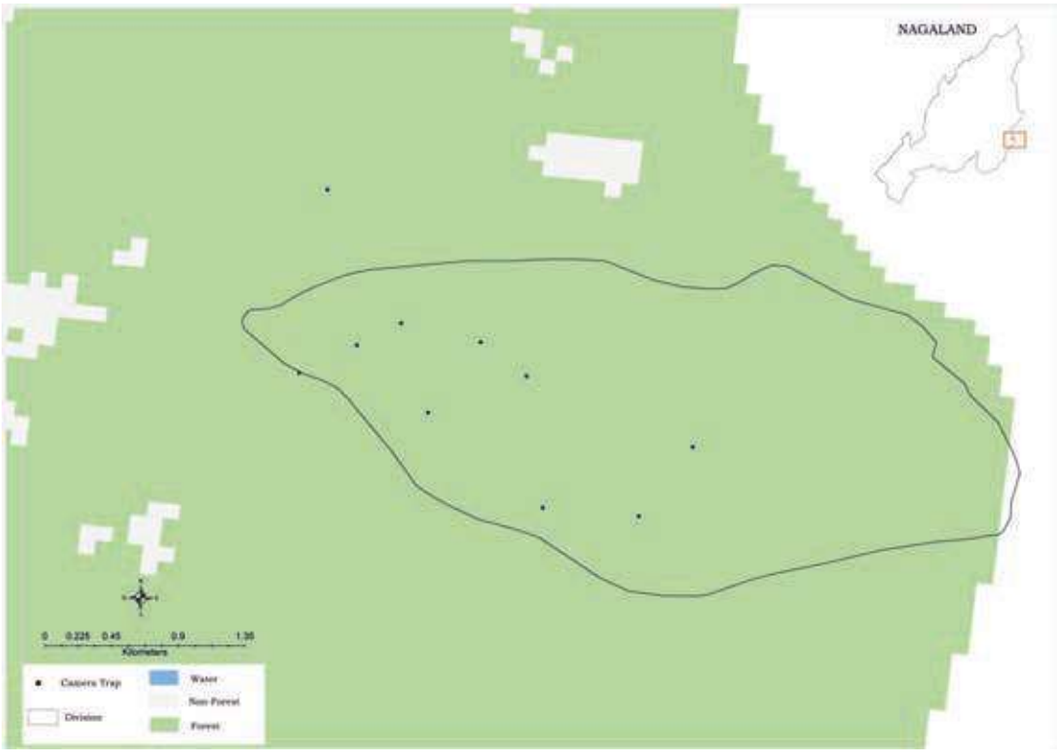
Table 12.24
Sampling details in Intanki National Park, 2018

FAKIM WILDLIFE SANCTUARY

INTRODUCTION

Fakim Wildlife Sanctuary is geographically located in Kiphire district (25°48' to 25°47' N and 94°59' and 95°02' E) and spreads over an area of 6.41 km^2. The wildlife sanctuary is situated on the slopes of Saramati mountain amidst community forest villages. Due to its location on the slopes of mountain ranges, terrain of the sanctuary is rugged and undulating. Vegetation of the wildlife sanctuary is mainly virgin primary forest of temperate broadleaf and subalpine forest types (Champion and Seth 1968) and can be classified into Naga hills wet temperate, Assam subtropical pine and East Himalayan subalpine forests (Management Plan, Fakim Wildlife Sanctuary). Important tree species are *Magnolia sp., Michelia sp., Quercus sp., Alnus nepalensis, Betula alnoides, Acer oblongum* etc. The sanctuary was constituted with the aim to protect the Blyth's tragopan (*Tragopan blythii*). Fakim and adjacent areas are rich in avifauna and identified as an IBA (Rahmani et al. 2016). Mammalian fauna of Fakim comprise of some endemic species such as leaf deer (*Muntiacus putaoensis*), goral (*Naemorhedus goral*), stump-tailed macaque (*Macaca arctoides*), Malayan sun bear (*Helarctos malayanus*), spotted linsang (*Prionodon pardicolor*), yellow-throated marten (*Martes flavigula*) etc.

Figure 12.91
Camera trap layout in Fakim Wildlife Sanctuary, 2018



RESULTS

Camera Trap Results

Camera trapping was carried out for the first time in Fakim Wildlife Sanctuary. However, no tiger images were obtained during the sampling period (Table 12.25)

Table 12.25
Sampling details in Fakim Wildlife Sanctuary, 2018

Sampling details	Counts
Camera points	10
Trap-nights (effort)	350

DAMPA TIGER RESERVE

INTRODUCTION

Dampa Tiger Reserve is located in Mamit district (23°20' to 23°47'N, 92°15' to 92°30'E) of Mizoram and spreads over an area of 988 km^2, of which 500 km^2 is designated as critical core habitat (Tiger Conservation Plan, Dampa Tiger Reserve). The reserve is geographically located in the Lushai hills and contiguous with the Chittagong Hill Tract regions of Bangladesh to the west. Rivers like Teirei, Keisalam, Seling, Saza etc. and several small perennial rivulets traverse the reserve (Rahmani et al. 2016). Dampa is situated in "Indo-Burma Biodiversity Hotspot" (Mittermeier et al. 2004) and recognized as an IBA (Rahmani et al. 2016).

Vegetation of Dampa mainly comprises of moist deciduous forest, tropical wet evergreen forest, tropical semi-evergreen forest and tropical grassland at higher altitudes (Rahmani et al. 2016). Important tree species of Dampa are *Michelia champaca, Mesua ferrea, Terminalia bellirica, Terminalia myriocarpa, Dipterocarpus turbinatus, Adina cordifolia, Syzygium cuminii, Dillenia indica, Gmelina arborea* etc. (Devi et al. 2011). Parts of the core area of the reserve had been used for shifting cultivation or 'jhum' in the past; these are now dominated by bamboo brakes (Devi et al. 2011)). Situated in the eastern Himalayas, Dampa is home to several mammalian species such as dhole (Singh et al. 2019), clouded leopard, Asiatic golden cat (*Catopuma temminckii*), marbled cat (*Pardofelis marmorata*), leopard cat (*Prionailurus bengalensis*), Himalayan black bear (*Ursus thibatanus*), Malayan sun bear (*Helarctos malayanus*), elephant (*Elephas maximus*), gaur (*Bos gaurus*), sambar (*Rusa unicolor*), red serow (*Capricornis rubidus*), barking deer (*Muntiacus vaginalis*), wild pig (*Sus scrofa*), Himalayan crestless porcupine (*Hystrix brachyura*), Asiatic brush-tailed porcupine (*Atherurus macrourus*), etc. (Singh and Macdonald, 2017).

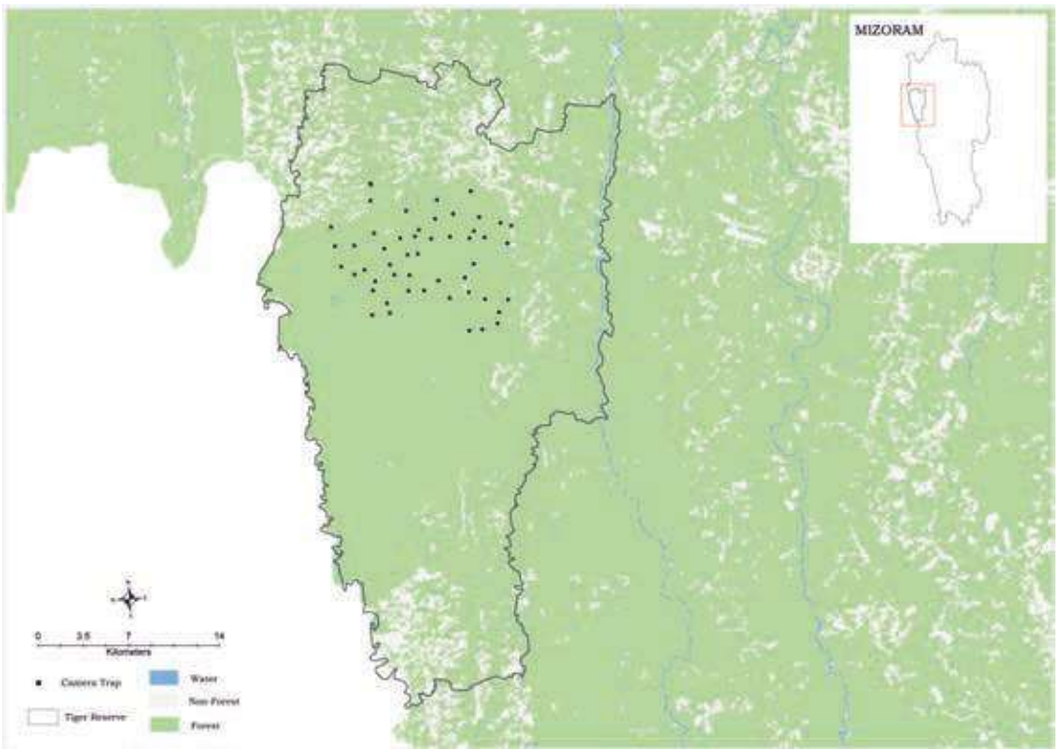


Figure 12.92
Camera trap layout in Dampa Tiger Reserve, 2019

RESULTS

Camera Trap Results

Camera trapping was conducted in a block-based approach in the north and north-eastern part of Dampa Tiger Reserve. However, no tiger images were obtained during the sampling period (Table 12.26).

Table 12.26
Sampling details for Dampa Tiger Reserve, 2019

Sampling details	Counts
Camera points	51 (Single-sided)
Trap nights (effort)	615

Spatial Occupancy Maps of Major Mammalian Species in Dampa Tiger Reserve

Herein, we use indirect and direct signs of major mammalian species obtained from Polygon Search Method to depict species' spatial distribution and occupancy. The black outline on the map represents the core area.

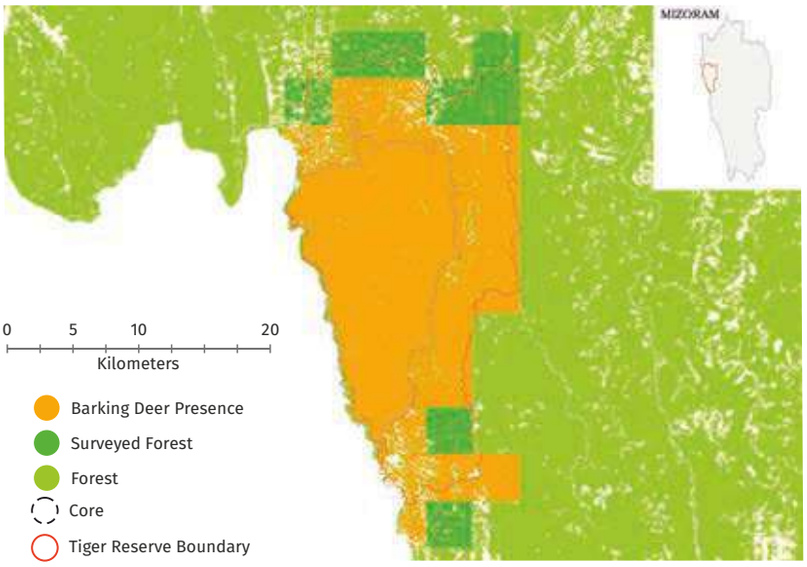


Figure 12.93
Spatial occupancy of barking deer in Dampa Tiger Reserve

Except for the few forested patches in the buffer area, barking deer was spatially distributed across the tiger reserve.

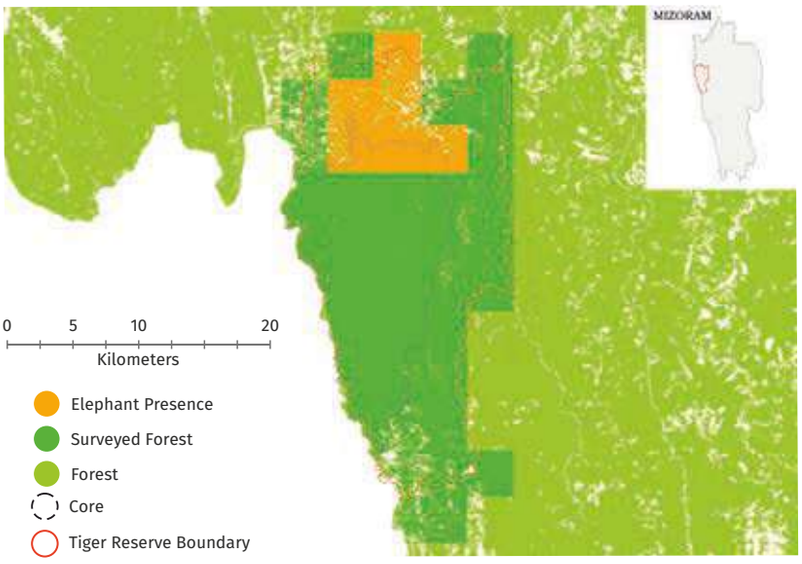


Figure 12.94
Spatial occupancy of elephant in Dampa Tiger Reserve

Spatial distribution of elephant was restricted to the northern part of the tiger reserve in moderately undulating terrain.

Gaur was spatially distributed across the core habitat of tiger reserve in moderately dense forest in moderately undulating terrain.

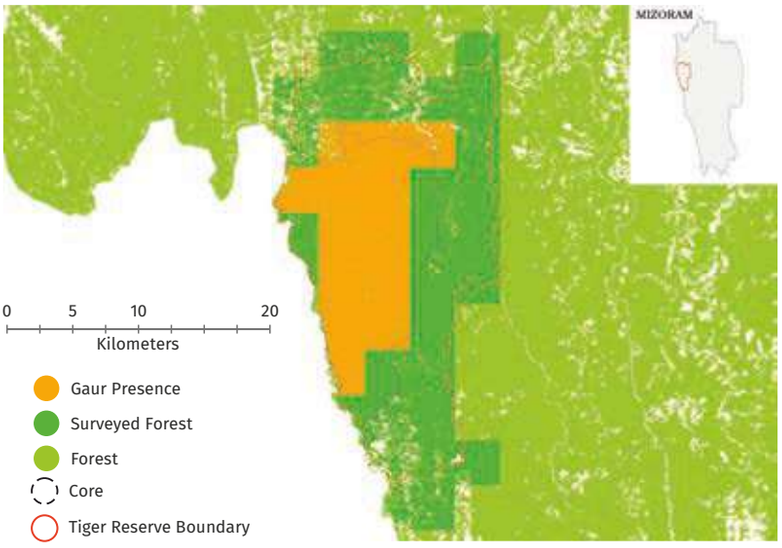


Figure 12.95
Spatial occupancy of gaur in Dampa Tiger Reserve

Except few forested patches in northern and southern part of buffer region, sambar was spatially distributed across the tiger reserve.

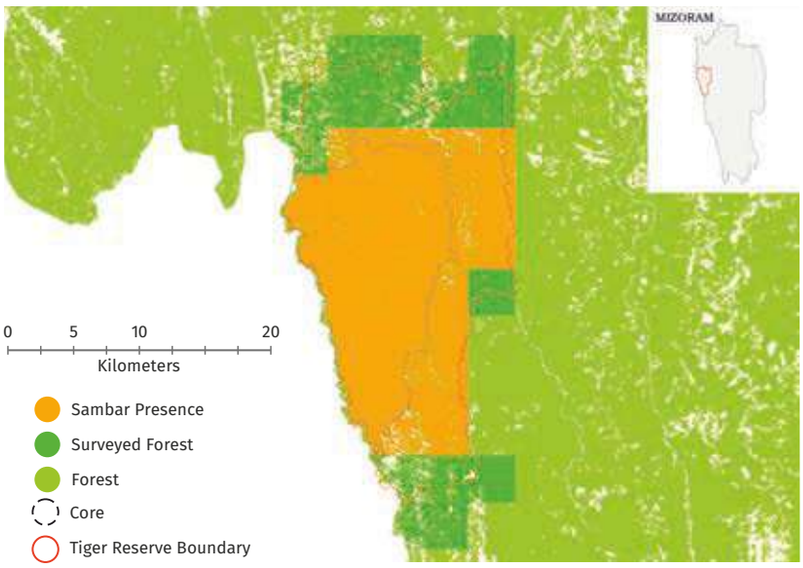


Figure 12.96
Spatial occupancy of sambar in Dampa Tiger Reserve

Spatial distribution of serow in Dampa Tiger Reserve was patchy and mostly in dense forest in undulating terrain.

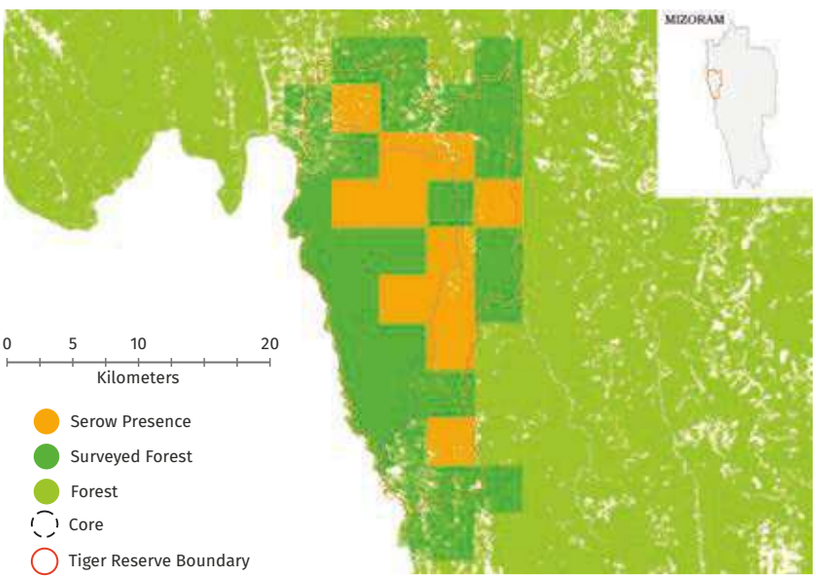


Figure 12.97
Spatial occupancy of serow in Dampa Tiger Reserve

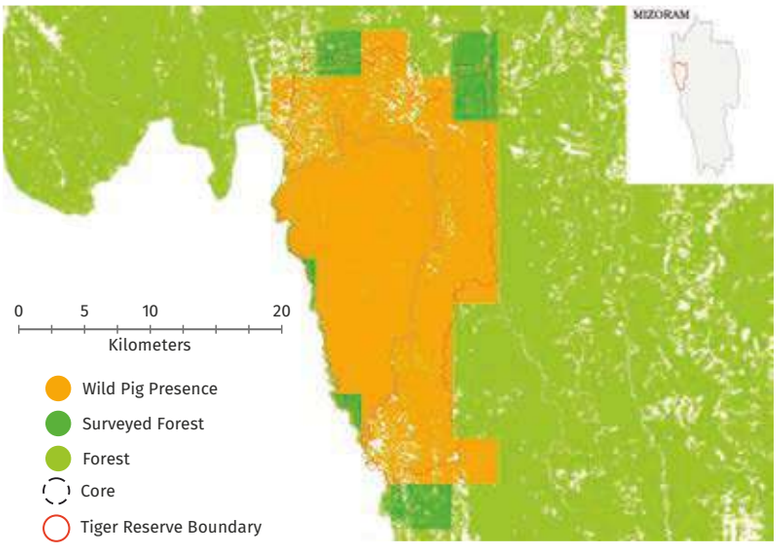


Figure 12.98
Spatial distribution of wild pig in Dampa Tiger Reserve

Wild pig was the most widely distributed mammalian species in Dampa Tiger Reserve with presence in almost every forest types and terrain types

Figure 12.99
Spatial distribution of bear in Dampa Tiger Reserve

There are two species of bear found in Dampa Tiger Reserve, Malayan sun bear and Himalayan black beer. Signs of bear species were clubbed to get the spatial distribution of bear species. Bear was spatially distributed in moderate to high density forest of core habitat. Spatial distribution of bear was mostly restricted in core habitat.

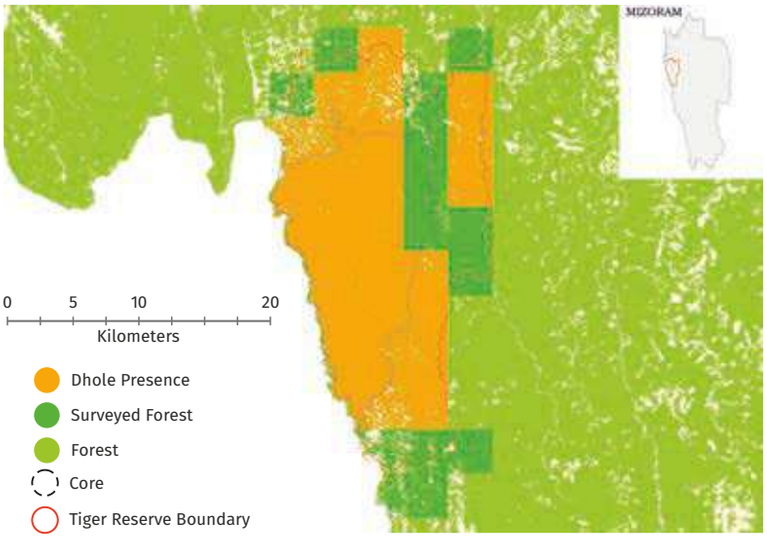


Figure 12.100
Spatial distribution of dhole in Dampa Tiger Reserve

Except few forested patches of core and buffer area, dhole was spatially distributed across the tiger reserve.

Leopard was spatially distributed in the south western and eastern part of the tiger reserve and mostly in the moderately dense forest type.

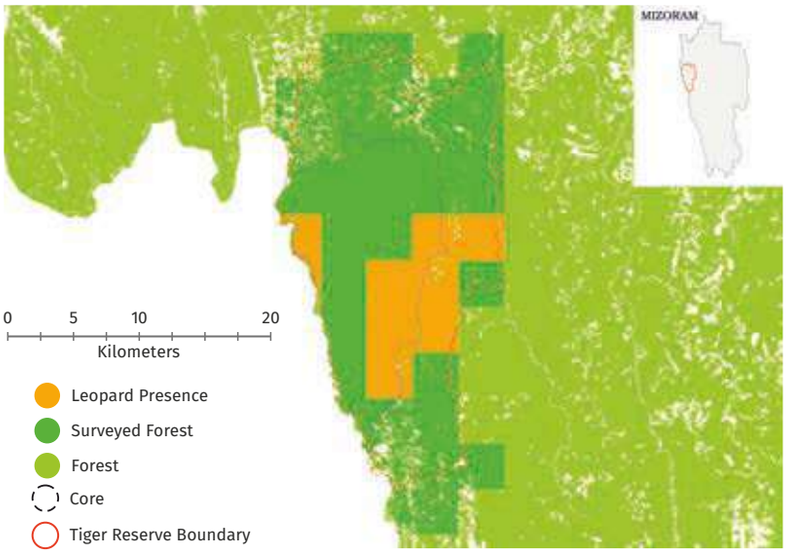


Figure 12.101

Spatial distribution of leopard in Dampa Tiger Reserve

Distribution of Major Mammalian Fauna Found in Dampa Tiger Reserve

Herein, we use photo-captures from camera traps to depict species' spatial distribution and intensity of habitat use. The following maps depict camera trap layout and species captures rates. The black outline on the map represents the core area of Dampa Tiger Reserve.

Sambar was photo-captured across the camera-trapped area in Dampa Tiger Reserve. Capture hotspots of sambar were in undulating terrain and moderately dense forest.

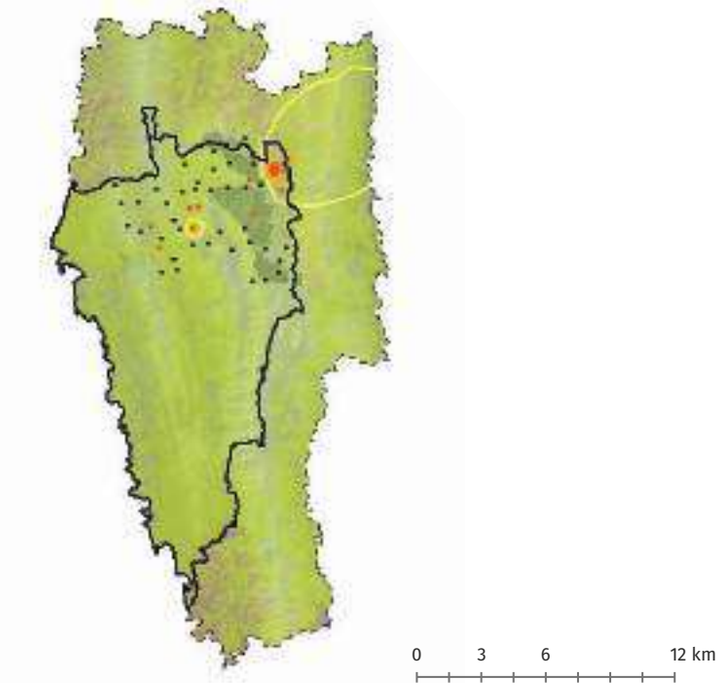


Figure 12.102

Distribution and relative spatial abundance of sambar in Dampa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

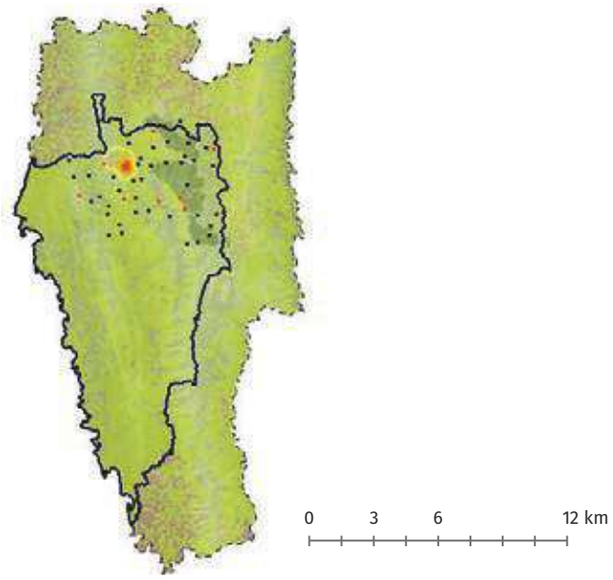


Figure 12.103

Distribution and relative spatial abundance of barking deer in Dampa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Capture hotspots of barking deer were in moderately dense habitat in undulating terrain in camera-trapped area of Dampa Tiger Reserve.

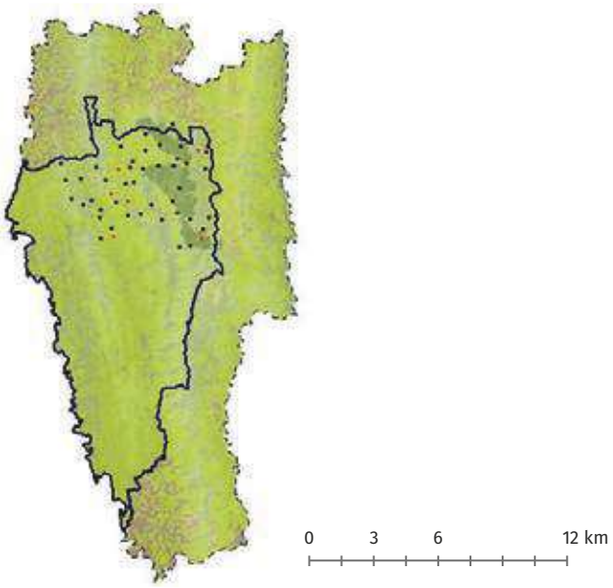


Figure 12.104

Distribution and relative spatial abundance of wild pig in Dampa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Wild pig was photo-captured in both moderately dense and dense forest of camera-trapped area of Dampa Tiger Reserve.

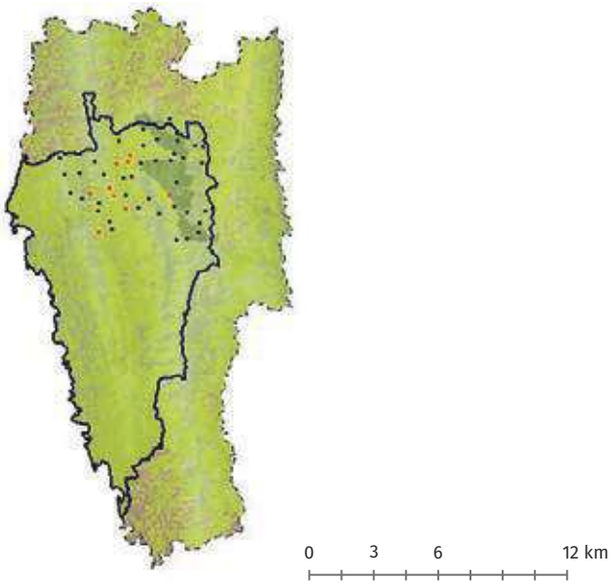


Figure 12.105

Distribution and relative spatial abundance of clouded leopard in Dampa Tiger Reserve. Red dots represent photo-captures in camera traps (all dots) while contour line depict intensity of photo-captures

Photo-captures of clouded leopard were mostly in valleys and moderately undulating terrain in camera-trapped area of Dampa Tiger Reserve.

Relative Abundance of all Photocaptured Species in Dampa Tiger Reserve

A large variety of mammalian species were photo-captured during the sampling period which include some rare and endemic species such as the Malayan sun bear and ferret badger. Sambar and common palm civet are the most common species to get single photo-capture. Binturong and marbled cat were least photo-captured species during the sampling period.

Table 12.27

Details of all photo-captured species and their relative abundance (relative abundance index (RAI)) in DampaTiger Reserve, 2019

Species	Number of photos per 100 trap nights	Trap nights required to get single capture
Barking deer	2.6	38
Binturong	0.16	625
Brush-tailed porcupine	0.98	102
Clouded leopard	1.63	61
Common Palm civet	3.74	27
Crab-eating mongoose	2.93	34
Dhole	0.98	102
Ferret badger	0.65	154
Golden cat	0.33	303
Himalayan crestless porcupine	0.33	303
Hog badger	1.14	88
Large Indian civet	2.93	34
Leopard cat	0.49	204
Malayan sun bear	0.65	154
Marbled cat	0.16	625
Pig-tailed macaque	0.49	204
Sambar	4.72	21
Serow	0.49	204
Wild pig	1.14	88
Yellow-throated marten	0.49	204

DISCUSSION

Although, no tiger images were obtained during the sampling session but Dampa Tiger Reserve is one of the important cross boundary tiger reserve which is important for tiger and other wildlife conservation by providing connectivity to other protected and forested area. It may be possible to reintroduce tigers in this landscape from the only source in the North-Eastern Hills and Brahmaputra Landscape i.e. Kaziranga Tiger Reserve. However, a proper protection regime and control of insurgency is required before bringing back tigers is to be considered.

13

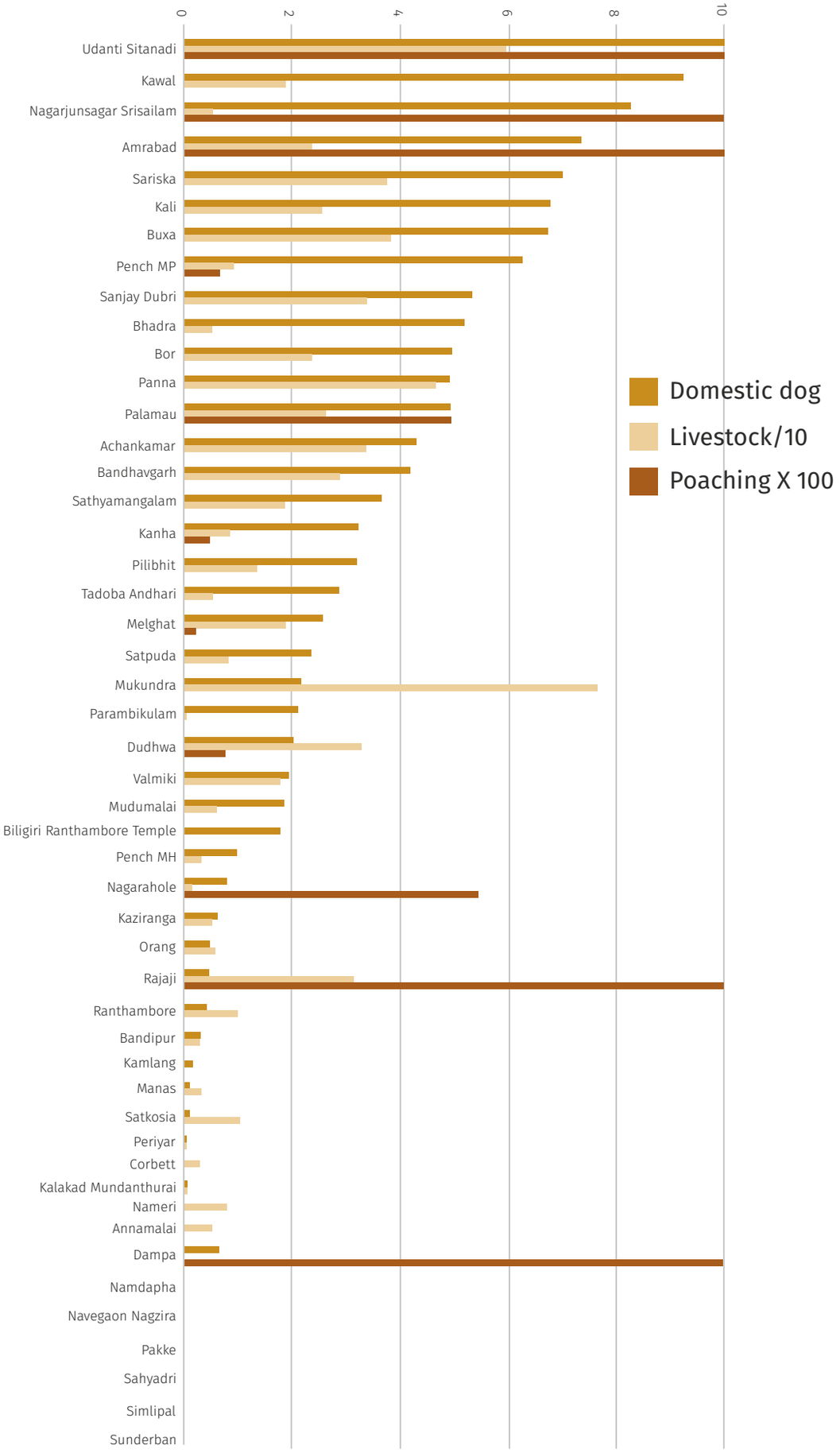
CONSERVATION IMPLICATIONS

Human Impacts

The magnitude of anthropogenic disturbances within Tiger Reserves and tiger occupied areas were assessed using Relative Abundance Index (RAI) obtained through camera trap images of livestock, free ranging domestic dogs, wild animals with snares, poachers with arms or poached carcasses. Livestock grazing was high in Mukundara, Udanti-Sitanadi, Panna, Buxa, Sariska, Sanjay-Dubri, Achanakmar, Dudhwa and Rajaji Tiger Reserves. While free ranging dogs abounded in Udanti-Sitanadi, Kawal, NSTR, Amrabad, Sariska and Kali Tiger Reserves (Fig.13.1). RAI for poaching incidences were recorded for Udanti-Sitanadi, Palamau, Srisailam (NSTR), Rajaji, Dampa, Nagarhole, Amdarbad, Dudhwa, Kanha, Pench-MP, and Melghat Tiger Reserves. Snared tiger photos were obtained from Nagarhole TR, Wayanad WLS, Tipeshwar WLS, Terai East Division, Kanha TR, and Dudhwa TR. Snared wildlife was also detected from Pench-MP TR, Rajaji TR, Dampa TR, South Panna Division, Amrabad TR, Udanti-Sitanadi TR, and Melghat TR. Armed poachers were detected in Palamau TR, Amrabad TR and Udanti Sitanadi TR. Decline and lack of improvement in the status of Udanti-Sitanadi, Achanakmar, Amrabad, Palamu, NSTR and Dampa Tiger Reserves can be correlated with a high disturbance regime and poaching. Incentivized voluntary relocation of tribal communities from the core of NSTR and Amrabad TRs should be a priority. Udanti-Sitanadi was on top of the list of Tiger Reserves for the disturbance indices, and major investments are required in protection especially since the Tiger Reserve has commenced on conservation breeding of the highly endangered swamp buffalo (*Bubalus arnee*). Feral dogs were detected in most tiger reserves (Fig. 13.1). Dogs are a threat to both ungulates (which they hunt) and to carnivores, since they carry infectious diseases like rabies, parvovirus, and distemper. From amongst tiger reserves that had good spatial camera trap coverage, human impacts were recorded to be low (good protection) for Sundarban, Orang, Kalakad Mundanthurai, Periyar, Corbett, Manas, Kaziranga and Bandipur Tiger Reserves.

Figure 13.1

Human impacts recorded through camera trap images (RAI) in tiger reserves. Livestock presence, feral dogs and poaching evidences are depicted. The RAI for livestock is divided by a factor of 10 and poaching multiplied by a factor of 100 to scale them in the same figure.



Camera trap photos of feral dogs and evidence of poaching (snares, hunting, foot traps) in various tiger reserves used to compute various RAI's of human impacts.

Tiger Reserve Status in Terms of Tigers and their Prey

Fig 13.2 provides a comparative account of tiger status within the tiger reserves. Tiger reserves shown in brown are at or nearing carrying capacity and are performing well in terms of tiger conservation. In these reserves additional inputs directed to enhance tiger numbers is not essential, mere continuation of protection and reduction of human impacts would suffice. Tiger reserves shown in yellow are still below carrying capacity and with continued investments in conservation efforts, prey density, tiger numbers and density are likely to increase here. Tiger reserves shown in red require interventions in the form of enhanced protection and investments in restoring prey and habitat. Highest prey densities were recorded for Corbett, Rajaji, Pench-MP and Bandipur TR's (Fig. 13.3). Prey densities were not sampled for Kaziranga where they are likely to be eqully high. Tiger Reserves like Dampa and western Rajaji have reasonable prey and tiger reintroduction/supplementation can be done here, provided protection regime is in place. In Buxa and Satkosia Tiger Reserves, protection needs to be enhanced as well as prey populations need to build up before reintroduction/ supplementation can be considered. Tiger status of Udanti-Sitanadi, Achanakmar, Palamau, Kawal, and Amrabad would benefit substantially with enhanced protection and better law and order situation. Regular patrols with M-STrIPES implementation, use of wireless, and proper equipment/gear, and weapons for guards would boost the morale and increase the show of strength in these Tiger Reserves. Tiger Reserves of the North East are plagued with prey depletion due to the practice of bush meat consumption and substantial investment is required to wean the forest dwelling communities from this practice for this genetically unique tiger populations to build up. Incentive driven persuasion of forest local communities to declare Dibang WLS as a Tiger Reserve would be a major initiative for tiger conservation in this landscape.

Figure 13.2

Tiger density (per 100 km^2) estimated in Tiger Reserves of India using Spatially Explicit Capture-Recapture. Reserves shown in red require restorative investments.

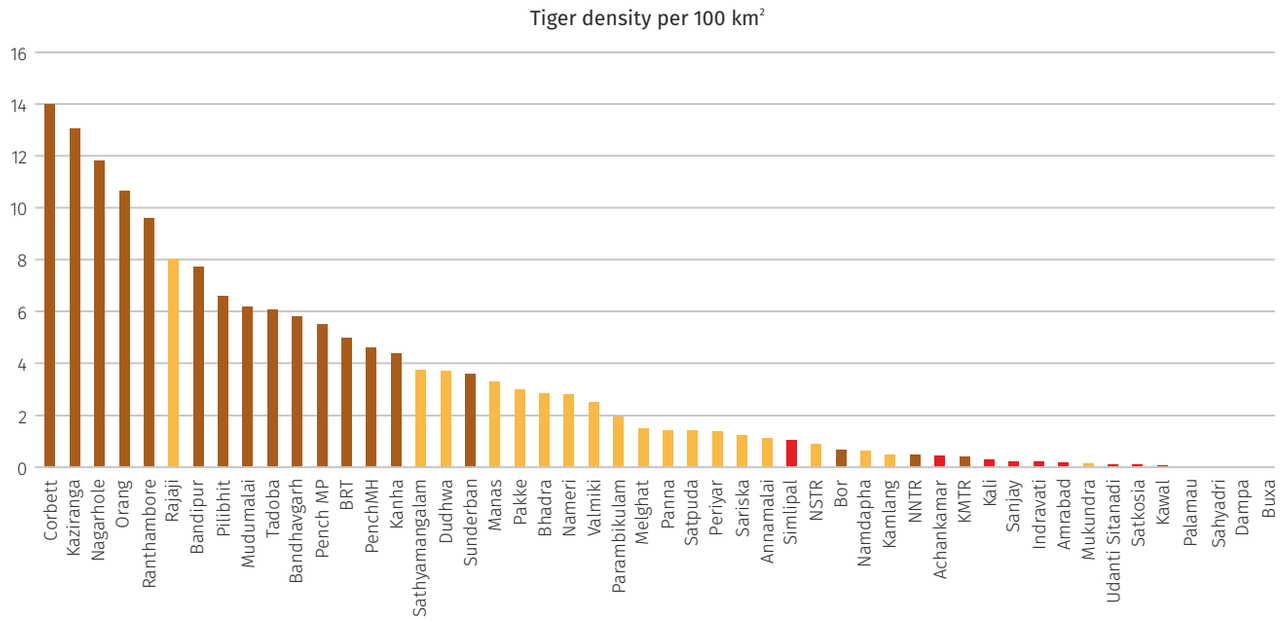
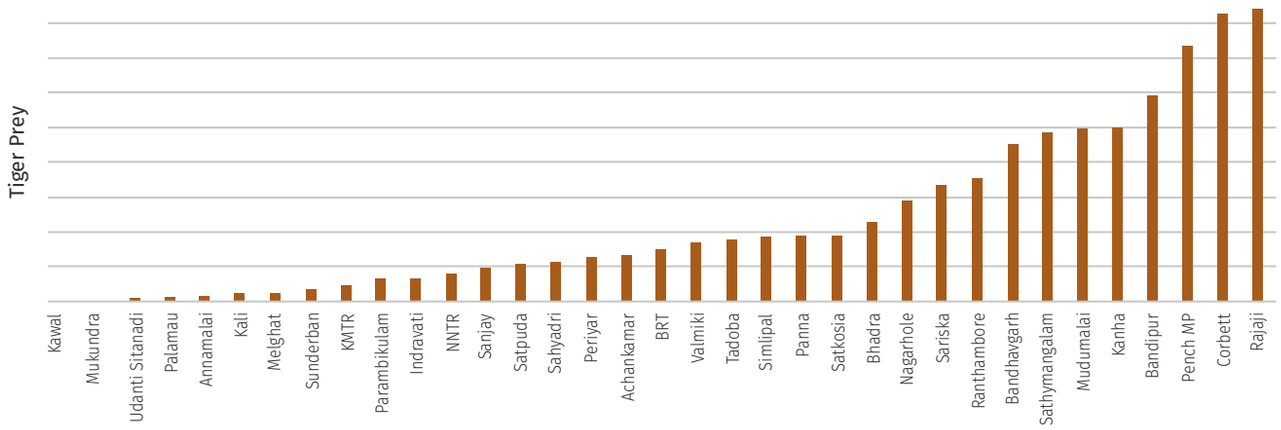


Figure 13.3

Prey (combined chital, sambar, gaur, hog deer and barasingha) densities in tiger reserves that were sampled with foot transect based distance sampling.



Conservation Investment Priority

Standards for tiger conservation should transcend beyond just increasing tiger numbers. We need to conserve the entire genepool of extant tiger populations to retain the species ecological and evolutionary potential (Kolipakam et al. 2019). To ensure this, we first need to identify tiger populations that are genetically diverse and divergent (Petit et al. 1998), subsequently, consider the vulnerability of such populations to extinction, so as to prioritise conservation investments. We develop a conservation priority index as follows:

First, the contribution of a population's genetic diversity and divergence to the total genepool of all tiger populations is calculated (Kolipakam et al 2019). To convert negative values of diversity and divergence to a positive scale, we added the difference between the maximum and minimum values to every observation (C.Div &C.Dvg). Populations that are genetically divergent as well as diverse should be given greater importance for conservation. We therefore, computed a composite genetic score (CGS - Equation 1) by using diversity value (c.Div) as an exponent to the populations' divergence (c.Dvg) score.

We convert this to a natural log scale for scaling its contribution for rating conservation priority.

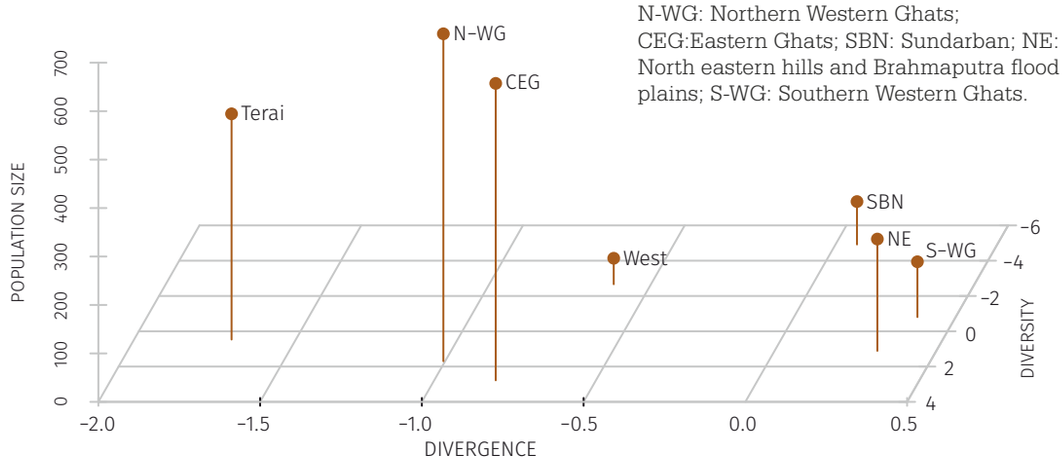
$CGS = \ln(1 + (C.Dvg)^{(C.Div)})$ - Equation (1)

Where, CGS = composite genetic score, C.Dvg = scaled divergence and C.Div = scaled diversity.

We used the inverse natural log of population size (P) to index a populations vulnerability to extinction (V - Equation 2) :

$V = 1/\ln(P)$ - Equation (2)

Each index was then scaled by taking the proportion contribution of each value to the index. Proportionating the index values ensures that each of the indices contribute equally to the final score of conservation priority. These proportionate indices were then added, i.e., The proportionate vulnerability (p.V) of a population was added to its proportionate CGS score (p.CGS) to evaluate its priority within India for conservation investments.



N-WG: Northern Western Ghats; CEG:Eastern Ghats; SBN: Sundarban; NE: North eastern hills and Brahmaputra flood plains; S-WG: Southern Western Ghats.

Figure 13.4

Three important criteria for prioritizing populations for conservation: genetic diversity, genetic divergence and population vulnerability (size, from Kolipakam et al. 2019).

Table 13.1

Conservation priority ranking based on contribution of population to overall genetic diversity, divergence and population status. Vul = Vulnerability, CGS = composite genetic score, p.CGS = Proportionate CGS score and p.Vul = proportionate vulnerability.

Population	Size	Corrected Diversity (C. Div)	Corrected Divergence (C. Dvg)	CGS	Vul =1/ (ln(popsize)	p.CGS	p.Vul	Priority
NE-hills	29	8.55	2.70	8.493	0.297	0.262	0.184	0.446
S-WG	101	7.20	2.59	6.853	0.217	0.212	0.134	0.346
NE-plains	190	7.29	2.46	6.564	0.191	0.203	0.118	0.321
WI	69	5.33	1.59	2.553	0.236	0.079	0.146	0.225
SBN	88	3.08	2.28	2.614	0.223	0.081	0.138	0.219
CEG	869	10.58	1.39	3.514	0.148	0.108	0.092	0.200
N-WG	877	9.32	1.19	1.802	0.148	0.056	0.091	0.147
Terai	646	7.88	0.49	0.004	0.155	0.000	0.096	0.096

N-WG: Northern Western Ghats; CEG:Eastern Ghats; SBN: Sundarban; NE: North eastern hills and Brahmaputra flood plains; S-WG: Southern Western Ghats; WI- Western India (Ranthambore & Sariska).

Camera trap photograph of golden phenotype of tiger coat color from Kaziranga Tiger Reserve.

The results (Table 13.1 & Fig 13.4, 13.5) show that the tigers from North Eastern Hill tiger populations gets the highest rating for conservation. This seems most relevant as these tigers are likely to share their genepool with the most critically endangered subspecies, i.e., *Panthera tigris corbetti*, that exists in Myanmar. Therefore, conservation investments for Namdahpa TR, Kamlang TR and for making Dibang WLS a tiger reserve are of paramount priority. The other priority populations were those of Southern Western Ghats and North-Eastern Plains. The landscape of Karbi-Anglong that connects the only source population (Kaziranga TR) in the NE-Plains to the southern tiger habitats of Intanki and Dampa TR is of conservation priority and needs major investments.

Cameratrap photograph of Pseudomelanistic phenotype of tiger coat color from Similipal Tiger Reserve.

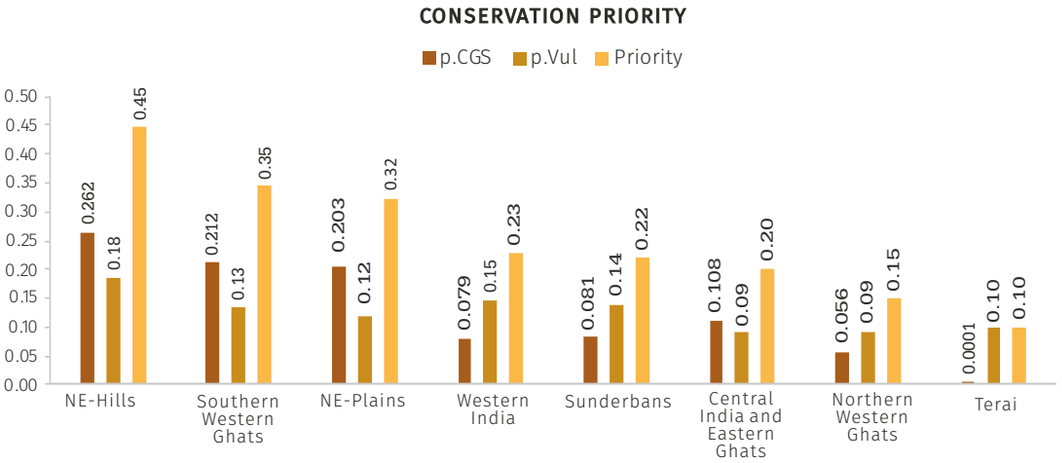


Figure 13.5

Conservation priority computed based on population vulnerability, genetic diversity and distinctiveness for tiger populations in India.

PCGS- index for population genetic diversity and divergence; p.Vul - Vulnerability of a population to extinction based on population size.

Prey Based Carrying Capacity for Tigers

We used data from areas where SECR based tiger density was obtained contemporaneously with line transect based DISTANCE sampling for prey density estimates between 2010 to 2019 for this analysis. We considered major prey for tigers to be constituted by chital, sambar, hog deer, barasingha, and gaur. We added densities (individuals per km^2) of these tiger prey species and regressed them against SECR tiger density (tigers per 100 km^2). A total of 45 spatial and temporal replicates were used to estimate the relation of tiger density to prey density. A simple linear regression explained the relationship adequately (R^2 = 85; P<0.001; PRESS R^2=0.83, Fig 13.6) and was estimated to be :

Tiger Density (per 100km^2) = (-0.377±0.36) + (0.143±0.01) X (Tiger Prey Density per km^2)

Figure 13.6 provides a graphical representation of estimating tiger density from prey density along with 95% confidence intervals. In the tall grass Terai and Shivalik hills habitat, highest tiger densities have been achieved. In these habitats tiger densities at carrying capacity can be between 10 to 16 tigers per 100 km^2. Upper limits of tiger densities in the dry deciduous forests of central India were between 6 to 10 tigers per 100 km^2. North-Central Western Ghats recorded highest tiger densities between 7-11 tigers per 100 km^2. Southern Western Ghats consistently recorded lower tiger densities with upper limits around 2-3 tigers per 100 km^2. Sundarban seems to be at carrying capacity at around 4 tigers per 100 km^2. Sundarban landscape is not included in the above computation, since tiger diet is likely very different compared to the rest of India. The hills of the North East had extremely low tiger densities (<1 per 100 km^2). We believe that the habitat specific upper limits of tiger densities are the natural carrying capacities of these habitats in different landscapes except for North Eastern Hill's where tiger densities were likely depressed by depletion of their prey because of bushmeat consumption. Tiger Reserve managers should not strive to increase tiger densities beyond the upper limits of the landscapes by artificial management practices of habitat manipulation or prey augmentation. Tiger densities beyond natural carrying capacities are likely to be detrimental to other co-predators (Kumar et al. 2019) and prey populations. To harness the umbrella effect of tigers for biodiversity conservation, it is more beneficial to increase areas occupied by tigers compared to increasing tiger density beyond those mentioned above. The above relationship with prey will allow managers to grossly assess how their tiger populations are faring and what kind of managerial inputs may be desirable for achieving the objectives of tiger reserves i.e. biodiversity conservation.

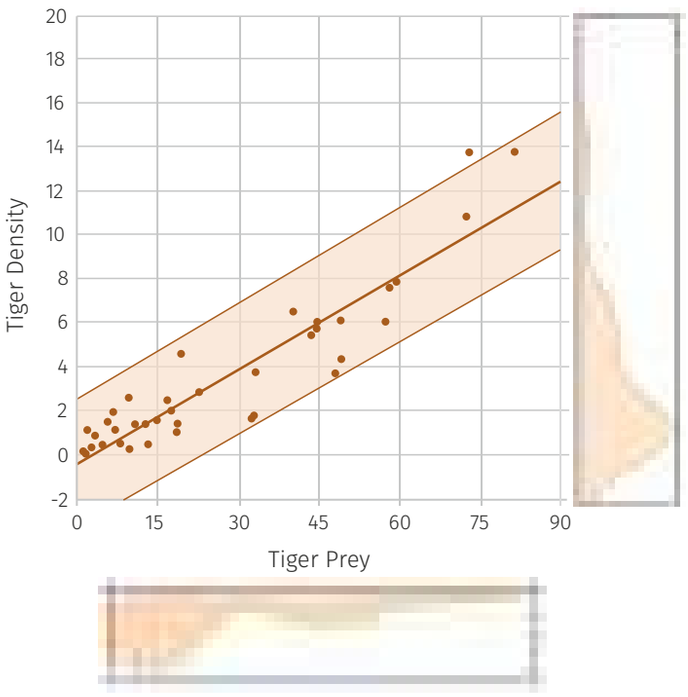


Figure 13.6

Relation between tiger prey density (per km^2) and tiger density (per 100 km^2) obtained from 45 sites from across India that were simultaneously sampled by SECR and DISTANCE sampling. Tiger reserves and Protected Areas should have tiger populations within the confidence bands to be considered optimal and in balance with their prey.

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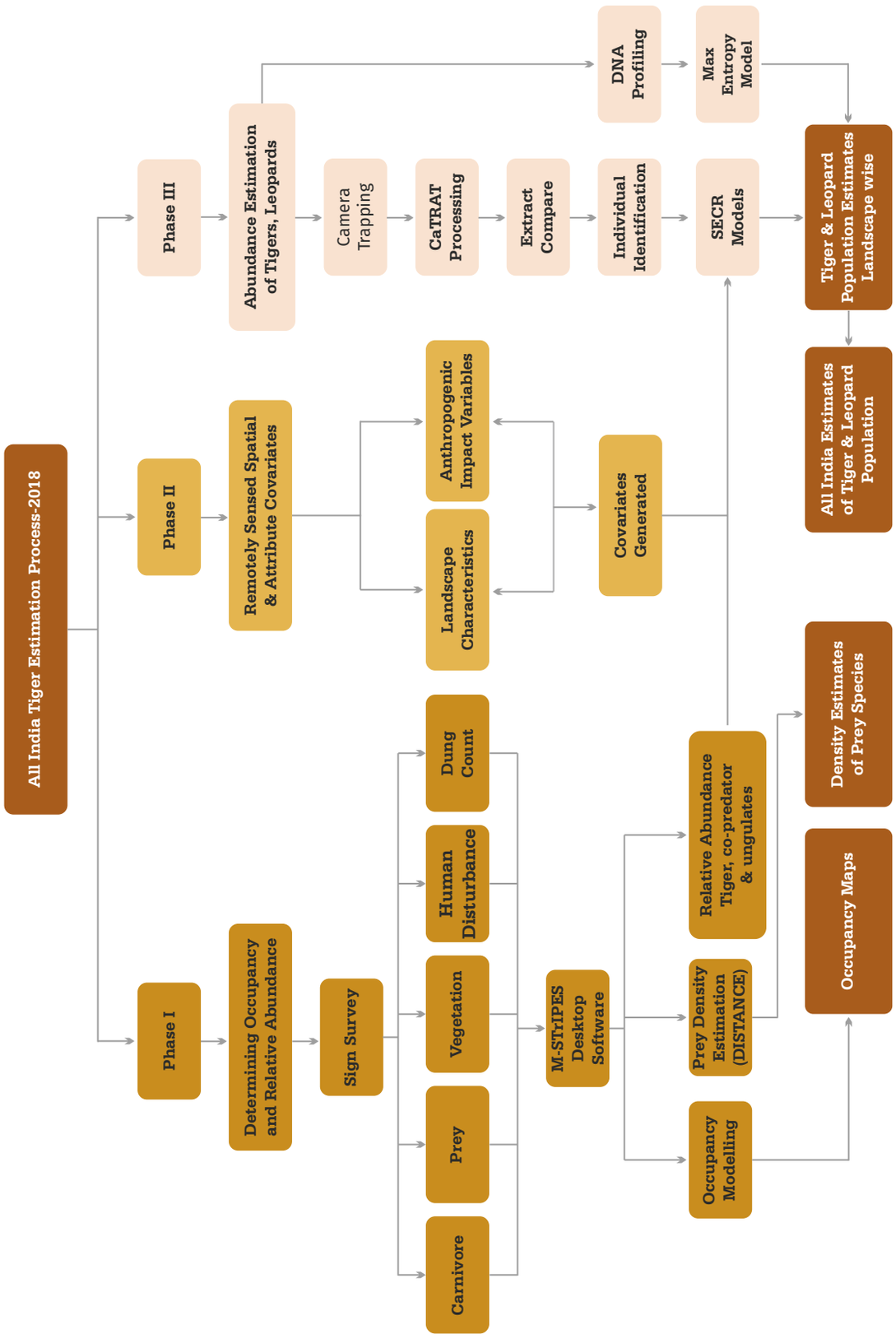
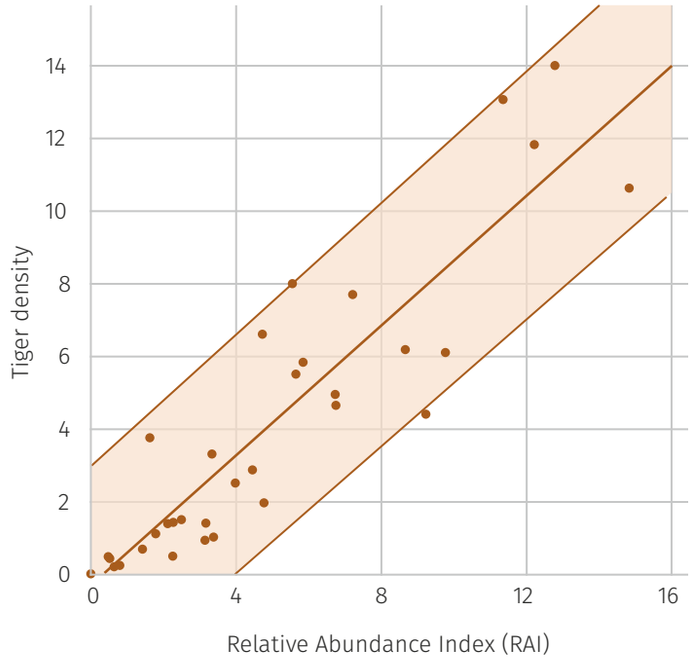
APPENDIX #1

Framework of all India Tiger Estimation Exercise 2018



Relevance of Relative Abundance Index (RAI) to surrogate actual abundance



Often the use of RAI is criticized as an uncalibrated index since it does not account for detection probability and that may not surrogate abundance. In the case of tigers where we had both SECR density estimates (100 km^2) as well as RAI (100 x Independent capture events / trap nights), we show that RAI was highly correlated with tiger density **(r = 0.91, P<0.001)**. The linear equation was :

Tiger Density = 0.89 (SE 0.07) RAI - 0.2997 (SE 0.4)

This high correlation suggests that RAI could be used as a surrogate for species that do not have absolute density estimates. At the least RAI can be used as an index to monitor trends so as to alert managers in case there are sudden drops in RAI values of certain species.

APPENDIX #2

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APPENDIX# 3

List of Training of Trainers Workshops

Date of Workshop	Venue of the Workshop	Participating States	Approximate number of personnel trained
December 05 - 07, 2017	Pench Tiger Reserve, Maharashtra	Maharashtra	80
December 05 - 07, 2017	Mudumalai Tiger Reserve, Tamil Nadu	Andhra Pradesh, Goa, Karnataka, Kerala, Tamil Nadu, Telangana	110
December 19 - 21, 2017	Kanha Tiger Reserve, Madhya Pradesh	Chhattisgarh, Jharkhand, Madhya Pradesh, Odhisa, Rajasthan	100
December 19 - 21, 2017	Kaziranga Tiger Reserve, Assam	Special Camera Trap ToT for North Eastern states	80
December 25 - 28, 2017	Valmiki Tiger Reserve, Bihar	Bihar, Uttar Pradesh, Uttarakhand, Nepal	100
January 05 - 08, 2018	Kaziranga Tiger Reserve, Assam	West Bengal (North), Gujarat, Assam, Mizoram, Manipur, Nagaland, Arunachal Pradesh, Bhutan	115
January 15 - 17, 2018	Sundarban Tiger Reserve, West Bengal	Staff of Sundarbans of India and Bangladesh	50

APPENDIX# 4

M. Hayward & Y. Jhala using MSTrIPES to document tiger sign

© Y. Jhala

© A. Sadhu

C. Carbone & J. Bump examining tiger scrape

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Deriving a population estimate for any rare and elusive species is a challenging task, but to do so for dozens of tiger populations across the entire sub-continent of India is immense. The numbers alone are phenomenal – 44,000 field staff, 600,000 person-days, 523,000 km of walked transects, 318,000 habitat surveys, 26,800 camera trap locations across an area of 381,000 km² yielding 35 million photographs of India's wildlife including 76,523 photos of tigers. Yet these efforts would be redundant without using robust methods to analyse them. There has been criticism historically about the methods used in previous tiger censuses, however I believe this is the most robust estimate of tigers possible with detectability and observer error clearly accounted for as well as possible, and I can think of no improvements based on the logistical constraints of our current technological and analytic capabilities. Hence, I am confident that the latest estimate of tigers across India is valid and robust, and represents a clear and impressive increase in population size since the previous estimate.

India in general, and the project team in particular, should be lauded for their efforts and investment in determining and securing the status of such a globally important and iconic species. This project warrants expansion and should be implemented on a suite of iconic species around the world. I wholeheartedly commend you for your wonderful efforts.

Yours sincerely

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Dr. Chris Carbone

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During a recent visit to India between June 25th and July 4th, 2019, I was able to take part in discussions and meetings at the Wildlife Institute of India (WII), the National Tiger Conservation Authority (NTCA), and Pench and Kanha National Parks. I was given the opportunity to witness the processes involved in India's effort to assess its tiger populations, which complimented an earlier visit in 2006. I took part in a number of in-depth discussions with a range of people from senior officials to forest beat guards. I commend WII and the Government of India for conducting the all-India tiger surveys. These represent a programme which is unprecedented in scale, rigour and intensity. As far as I am aware, this is the largest centrally coordinated survey of its kind in the world and represents an immense achievement providing invaluable information on the status of not only tigers, but a wide range of coexisting mammals in tiger habitats. The methodology used balances the need to vary survey effort from core tiger habitat to wider marginal areas. This programme combines, GIS analyses and the latest spatially-explicit methodologies in cameratrapping along with wider-scale but lower intensity secondary sign surveys outside of tiger core areas making such a large-scale survey achievable. There have also been impressive improvements since the original survey in 2006 due, in part, to general technological advances (e.g. camera-traps, mobile phones and GPS etc.), but also due to the efforts of WII and partners to develop software tools to automate the data recording and processing, including the use of M-STrIPES (phone app for all types of in field data entry) and data analysis (Extract Compare (tiger ID) and CATRAT (species ID)). These advances are critical to the process as they increase the speed and accuracy of data processing. The current report is immense in scale and intensity covering over 380,000 km2 and actually recording ~80% of the total tiger population directly in the photo record of ~ 75,000 tiger photos. I don't doubt that this represents an extremely robust and reliable estimate of the tiger population across the survey area. Tigers are a vital part of India's national heritage and recent reported increases are welcome news! It is essential therefore that tiger core areas and key habitat corridors continue to be maintained and protected against threats of development. In addition, it is important that working conditions of forest guards and other staff, which represent the front-line of India's tiger protection strategy, are reviewed to maintain motivation and effectiveness and to insure the future protection of tigers in the wild.

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During my June 25th – July 4th visit to India, the Wildlife Institute of India provided an in depth and comprehensive showcase of the methods and process to determine 'Status of Tigers, Co-predators, & Prey in India 2019.' India's effort to estimate its tiger population is unprecedented globally and commendable in scale and scientific sophistication. The methods and process to determine the status of tigers in India in 2018 is scientifically defensible; surveys are aligned with advancements in animal abundance methods and use defensible statistical tools available within the constraints of national-scale assessment and resources. Inclusion of both indices and camera-trap approaches makes pragmatic sense and such joint analyses strengthens the overall assessment. Those responsible for leading tiger estimation in India wholly embrace that the scientific process of peer review and publication in high-quality journals should guide the choice of appropriate methods for monitoring tigers and their prey. Sensitivity analyses would add to the robustness of the process and help address warranted and unwarranted critiques, thereby building confidence in the assessment. The voluntary village relocation program is a major step towards providing tigers needed space, but care should be taken to ensure that villages are truly returned to wildlife habitat and not used for administrative expansion. Investment in the well-being and working conditions of forest guards is an investment in the front line of tiger conservation in India. To the extent that impacts to tiger corridors are minimized the healthy future of tigers is maximized.

Dr. Joseph K. Bump

APPENDIX# 5

Contribution is based on work done for field sampling, data analysis, supervision and writing up; there is no order in the contributor list; the data presented belongs to the NTCA, WII, and State Forest Departments as per the respective MoU's.

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Chapter 8: Sundarban Landscape

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APPENDIX# 6

Camera-trap Photographs of Tigers found during the Field Survey conducted for 'Status of Tiger Habitats in High-Altitude Ecosystems in India'

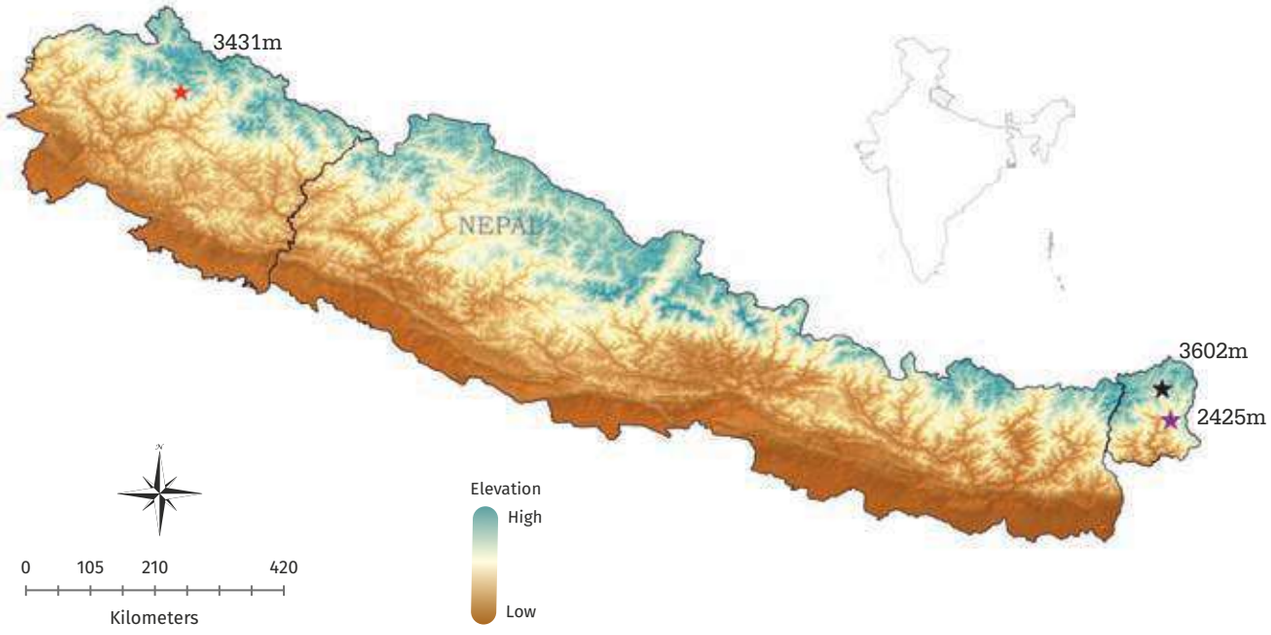


Figure 1

Camera-trap photograph of the Tiger from Kedarnath Musk Deer Sanctuary.

Figure 2

Camera-trap photograph of the Tiger near Talam, Lachen Range, North Sikkim Territorial Division.

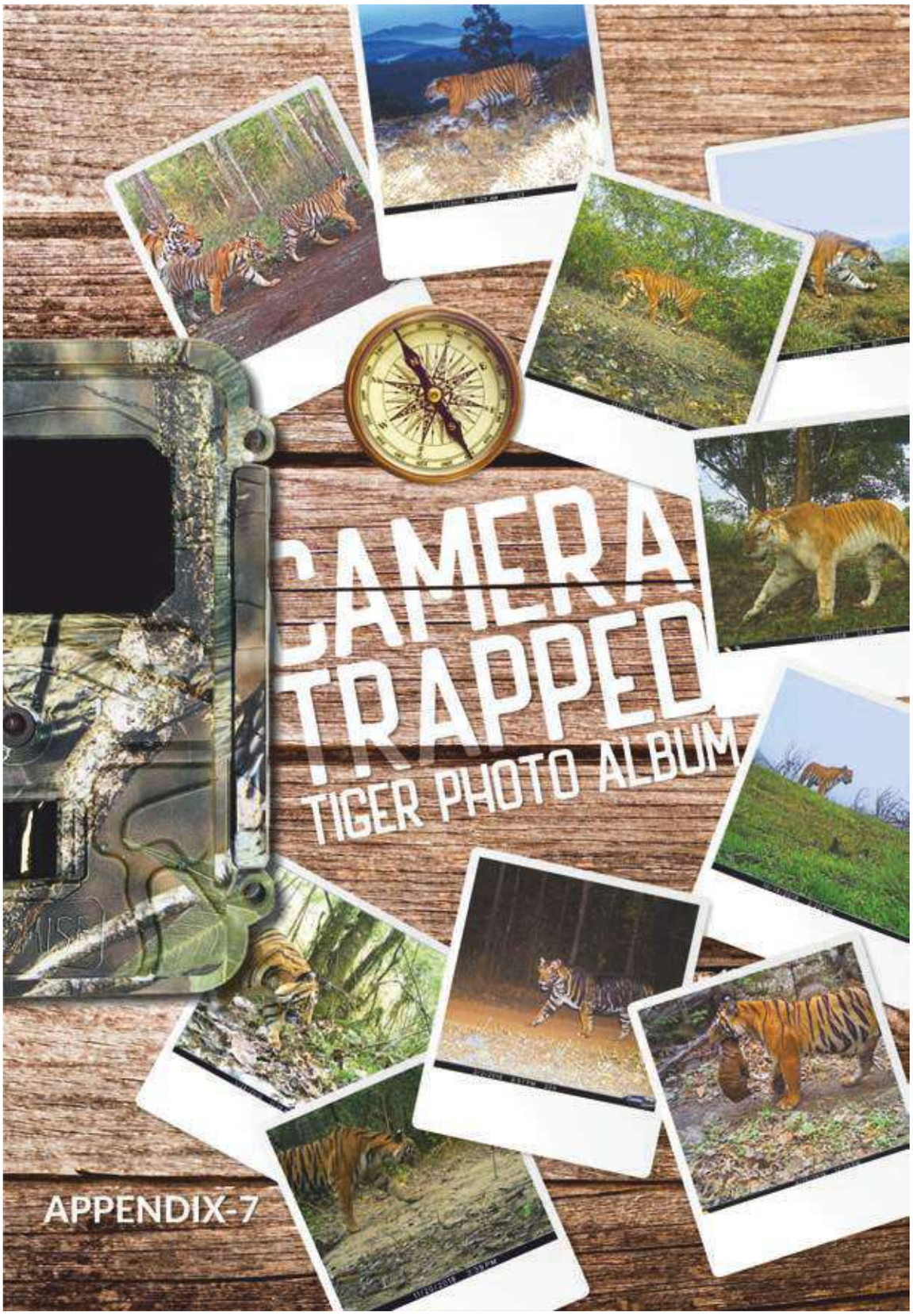
Figure 3

Camera-trap photograph of the Tiger in Naga Forest Block, Mangan Range, North Sikkim Territorial Division.

NTCA Nodal officer
Nisahnt Verma

APPENDIX# 7

CAMERA-TRAPPED TIGER PHOTO ALBUM



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NOTES

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Nature Protects if She is Protected

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